IB Diploma Programme

Chuyên luyện thi IELTS/SAT → AP / IB / A-levels

8020 ENGLISH

IB Diploma Programme Geography

Giáo trình luyện thi chuyên sâu

Song ngữ Anh–Việt

8020 ENGLISH

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Lời mở đầu · Foreword

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This book is part of the 8020 English international exam-prep series: complete English theory with Vietnamese explanations, worked examples, illustrations and fully-solved practice, aligned to the official framework.

Thành tích 8020 English

9.0 IELTS cao nhất	**1570** SAT cao nhất
5/5 AP — điểm tuyệt đối	**90/100** IB Diploma
100% GV $\geq$ 8.0 IELTS / 1500 SAT	**CMU** Tiến sĩ ĐH #1 Hoa Kỳ về CS

Đội ngũ tiêu biểu: Thầy Châu Cát Tường (Academic Head, ThS Western Sydney, top 1% IELTS 8.5) · TS Nguyễn Anh Huy (Carnegie Mellon, cựu kỹ sư Amazon) · TS Nguyễn Phước Trường (Toán, ĐH Klagenfurt) · cùng đội ngũ giảng viên SAT 1500–1600, IELTS 8.0–8.5.

Kết quả học viên — điểm thi thật: IELTS 8.0–9.0 · SAT 1550 / 1570 / 1590 · AP 5/5 (Calculus BC, Microeconomics) · IB 90/100 (Economics) · Duolingo 110 · PTE 90 · TOEFL 120. **Bảng vàng SAT:** Khánh Đăng 1510 · Thảo Nguyên 1520 · Tâm Anh 1530.

"Cuối cùng đã đậu vào trường top như mong muốn." — Phan Thị Thanh Hằng, IELTS Overall 8.5.

Cách dùng sách hiệu quả: mỗi Unit gồm (1) **Lý thuyết trọng tâm** tiếng Anh kèm **giải thích tiếng Việt**; (2) **Ví dụ mẫu** có lời giải; (3) **Hệ thống bài tập** kèm **lời giải chi tiết**. Hãy tự làm bài trước khi xem lời giải để đạt hiệu quả tối đa.

THÀNH TÍCH THỰC TẾ · 8020 ENGLISH

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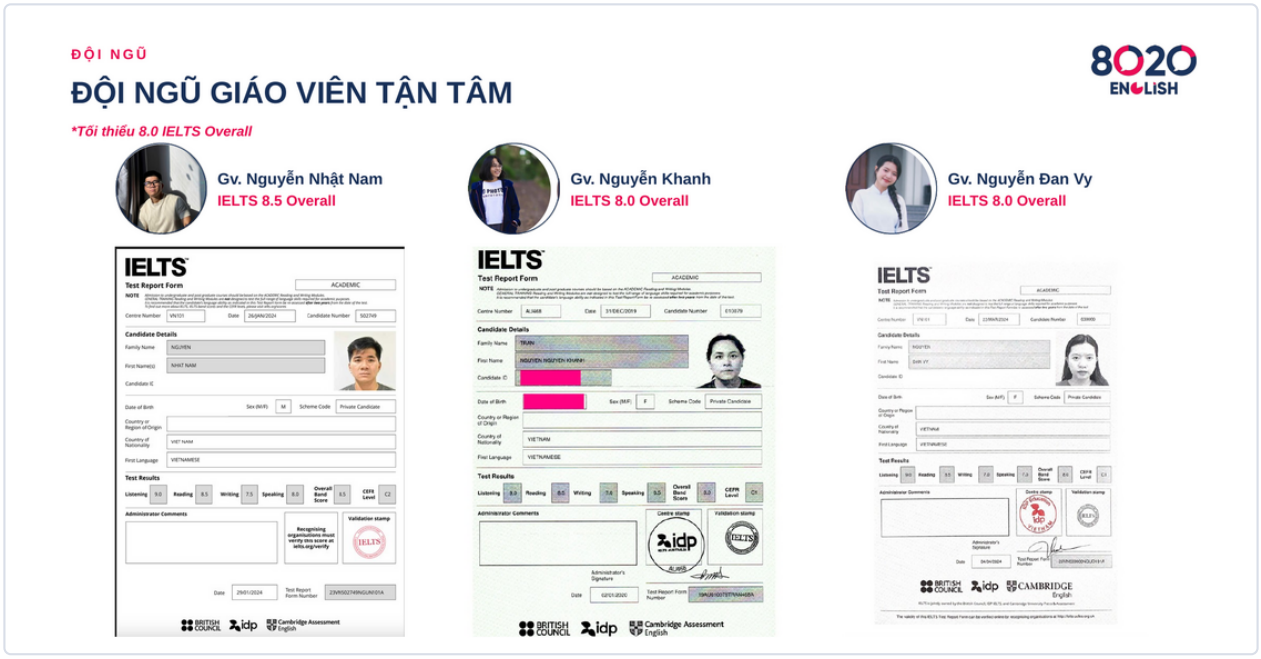

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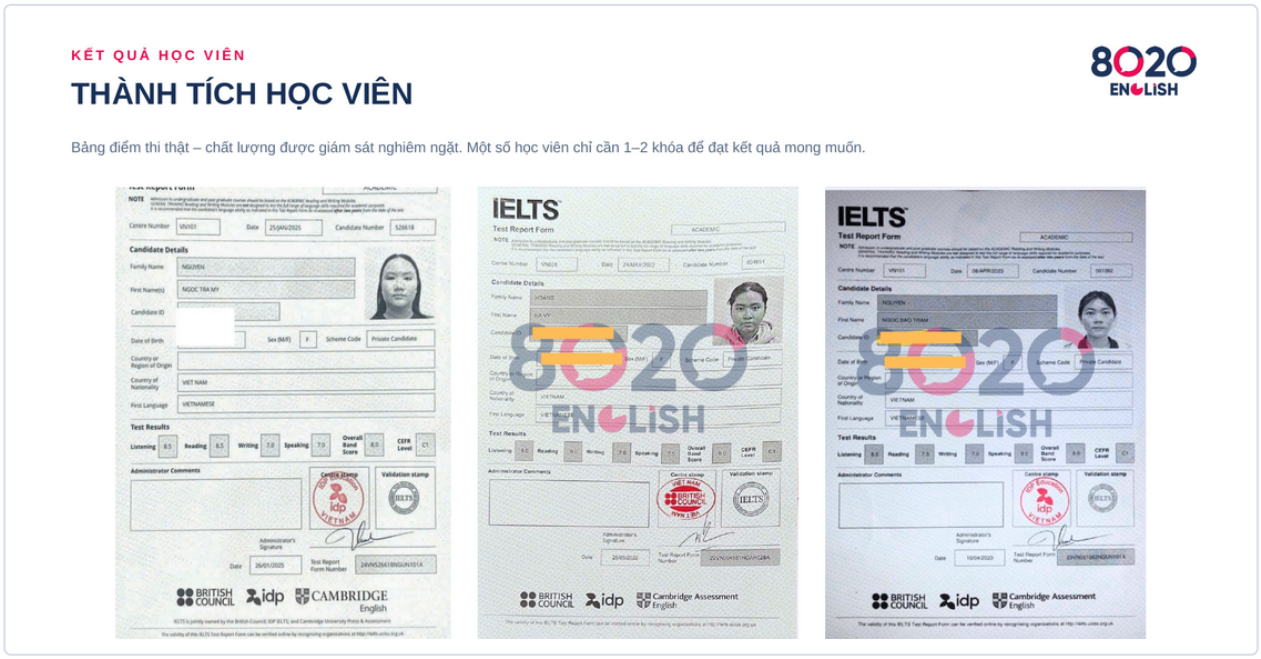

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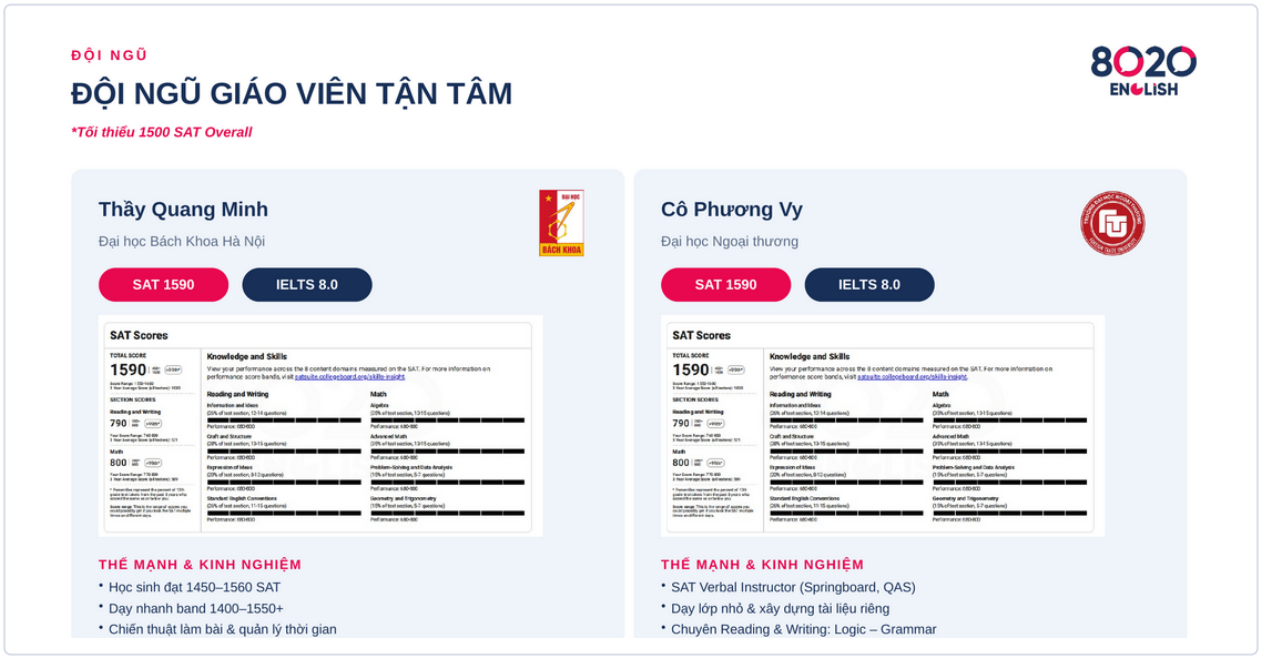
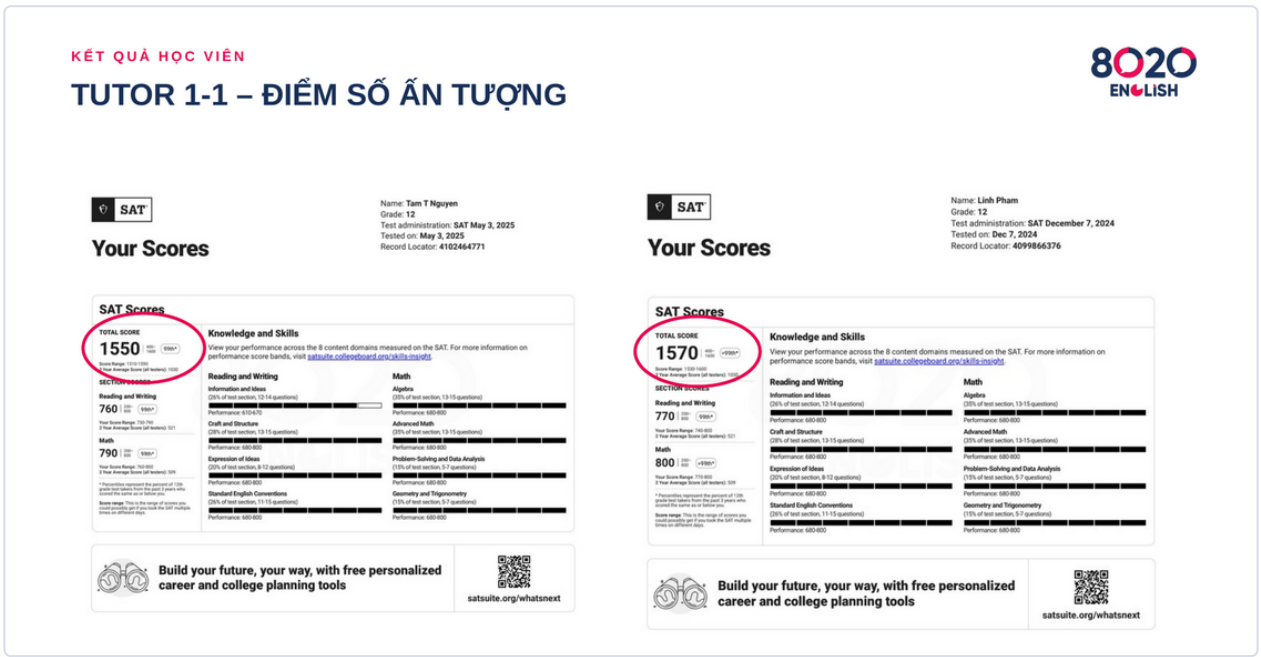
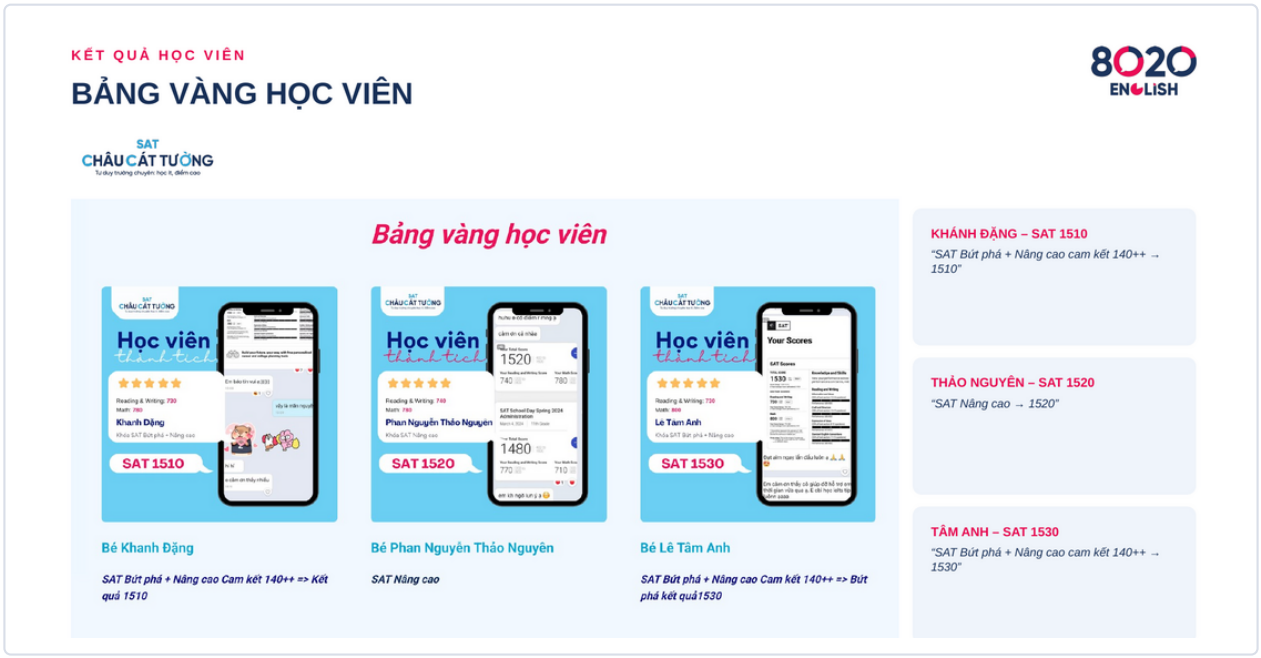


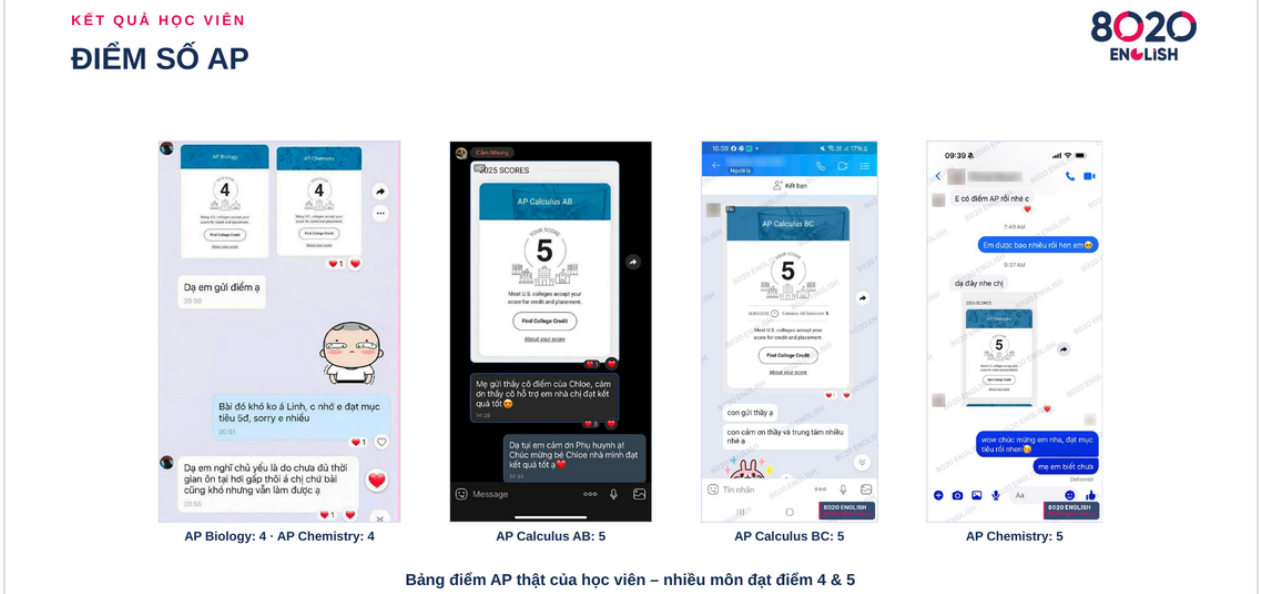
Giảng viên 8020 — SAT 1590 (ĐH Bách Khoa Hà Nội & ĐH Ngoại thương)



Học viên 8020 — SAT 1550 & 1570 (College Board)



Bảng vàng SAT — Học viên đạt 1510 · 1520 · 1530



Điểm AP thật — Calculus AB/BC 5/5 · Biology & Chemistry 4–5 (College Board)

Mục lục · Contents

Changing Population

Mục tiêu Unit: Mô tả và giải thích sự phân bố và mật độ dân số toàn cầu cùng các yếu tố tự nhiên và nhân văn chi phối; tính toán và diễn giải các chỉ số dân số (mật độ, tỉ suất sinh/tử thô, tỉ suất tăng tự nhiên, tổng tỉ suất sinh, tỉ số phụ thuộc, thời gian tăng gấp đôi); phân tích mô hình Chuyển đổi Dân số (DTM) qua năm giai đoạn và đọc tháp dân số; giải thích quán tính dân số (population momentum), già hoá dân số và hệ quả kinh tế–xã hội; phân loại và phân tích di cư, đặc biệt là di cư cưỡng bức; và đánh giá vai trò của bình đẳng giới trong biến đổi dân số cùng các chính sách dân số.

1.1 Population Distribution and Density

1.1.1 Distribution, density and the physical–human controls

Population distribution describes *where* people live across the surface of the Earth — the spatial pattern of settlement — while **population density** measures *how many* people occupy a given area. The world's population is extraordinarily unevenly distributed: roughly half of humanity lives on only about 5% of the land area, while vast tracts of desert, high mountain, tropical rainforest and polar land are almost empty. Geographers describe these extremes with two paired terms: areas of concentrated settlement are **densely populated**, and near-empty regions are **sparsely populated**.

Arithmetic (crude) population density is the simplest measure:

$$\text{Arithmetic density} = \frac{\text{total population}}{\text{total land area}} \quad (\text{persons per km}^2)$$

It treats all land as equally usable, which is its main weakness. **Physiological density** refines it by dividing population by the area of *arable* (cultivable) land, giving a better sense of the pressure population places on food-producing land. **Agricultural density** divides the number of farmers by arable land, indicating how efficient or labour-intensive the farming system is.

The controls on distribution fall into two groups. **Physical factors** that *attract* settlement include: fertile alluvial soils (river deltas and floodplains such as the Ganges, Nile and Mekong); reliable water supply; temperate or warm-humid climate; low, flat, well-drained relief; and accessible coasts or navigable rivers. **Physical factors** that *repel* settlement include aridity, extreme cold, very high altitude (thin air, steep slopes, thin soils), dense tropical forest with leached soils and disease, and tectonic or flood hazard. **Human factors** increasingly override the physical: economic opportunity (industry, services, ports, mineral wealth), historical and colonial legacies, transport networks, political stability and government policy all pull population toward cities and productive regions.

VN **GIẢI THÍCH TIẾNG VIỆT**

Phân bố dân số cho biết con người sống *ở đâu*; **mật độ dân số** cho biết *bao nhiêu* người trên một đơn vị diện tích. Mật độ số học (crude) = dân số ÷ tổng diện tích; mật độ sinh lí (physiological) = dân số ÷ diện tích đất canh tác — phản ánh sức ép lên đất trồng trọt tốt hơn. Các **yếu tố tự nhiên** như đất phù sa màu mỡ, nguồn nước, khí hậu ôn hoà, địa hình thấp phẳng, ven biển thu hút dân cư; còn khô hạn, giá lạnh, độ cao lớn, rừng rậm xích đạo lại đẩy dân cư đi. Ngày nay các **yếu tố nhân văn** (việc làm, công nghiệp, giao thông, chính sách, ổn định chính trị) ngày càng quyết định phân bố dân số mạnh hơn yếu tố tự nhiên.

Ví dụ mẫu · Arithmetic versus physiological density

Country X has a population of 164 million, a total land area of $148\,000$ km^2, of which only 59% is arable. Compute its arithmetic and physiological densities, and interpret the difference.

Arithmetic density $= \dfrac{164\,000\,000}{148\,000} = 1108$ persons/km^2.

Arable area $= 0.59 \times 148\,000 = 87\,320$ km^2.

Physiological density $= \dfrac{164\,000\,000}{87\,320} = 1878$ persons/km^2.

Interpretation: the physiological density (1878) is far higher than the arithmetic figure (1108) because a large share of the land cannot be farmed. The gap of about 770 persons/km^2 signals intense pressure on the cultivable land — every km^2 of farmland must feed nearly 1900 people, indicating heavy dependence on high-yield agriculture and/or food imports. (These figures approximate Bangladesh.)

1.1.2 Global patterns and megacities

At the global scale four great clusters of dense population stand out: **East Asia** (eastern China, Japan, the Korean peninsula), **South Asia** (the Indo-Gangetic plain), **Europe**, and **North-eastern North America**. Each combines fertile land, long agricultural history and, more recently, intense urban-industrial development. Superimposed on this is rapid **urbanisation**: for the first time in history more than half the world lives in towns and cities (about 57% by the mid-2020s), and the share is rising fastest in Africa and Asia.

A **megacity** is conventionally defined as a metropolitan area with a population of at least **10 million**. The number of megacities has grown from three in 1975 to more than thirty today, with the largest — Tokyo, Delhi, Shanghai, São Paulo, Mexico City, Dhaka, Cairo — each exceeding 20 million. Megacities generate economies of scale and agglomeration (shared infrastructure, deep labour markets, innovation) but also concentrate problems: housing shortages and informal settlements (slums), congestion, air and water pollution, and vulnerability to hazards. A **world city** (or global city, e.g. London, New York, Tokyo, Singapore) is defined less by sheer size than by its command of global finance, corporate headquarters, and flows of capital and information.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốn cụm dân cư đông đúc nhất thế giới là Đông Á, Nam Á, châu Âu và đông bắc Bắc Mỹ. **Siêu đô thị (megacity)** là vùng đô thị có từ **10 triệu** dân trở lên; hiện có hơn 30 siêu đô thị, tập trung ngày càng nhiều ở châu Á và châu Phi. Siêu đô thị mang lại lợi thế *tích tụ* (agglomeration: hạ tầng dùng chung, thị trường lao động lớn, đổi mới sáng tạo) nhưng cũng đi kèm khu ổ chuột, tắc nghẽn, ô nhiễm và rủi ro thiên tai. **Thành phố toàn cầu (world city)** được định nghĩa bởi vai trò chi phối tài chính và dòng vốn/thông tin toàn cầu chứ không chỉ bởi quy mô dân số.

1.2 Measuring Population Change

1.2.1 The vital rates and natural increase

Population change in any area is the balance of births, deaths and migration. Demographers standardise births and deaths as rates *per thousand* population so that places of different size can be compared.

$$\text{Crude Birth Rate (CBR)} = \frac{\text{live births in a year}}{\text{total population}} \times 1000$$

$$\text{Crude Death Rate (CDR)} = \frac{\text{deaths in a year}}{\text{total population}} \times 1000$$

$$\text{Rate of Natural Increase (RNI)} = \frac{\text{CBR} - \text{CDR}}{10}\ \%\ \text{per year}$$

The **rate of natural increase** excludes migration; the full change also adds **net migration** (immigration minus emigration). The word "crude" warns that these rates ignore the *age and sex structure* of the population — a country with many old people will have a high CDR even if its health care is excellent, simply because it has many people at ages when death is more likely.

Two age-standardised fertility measures are essential. The **Total Fertility Rate (TFR)** is the average number of children a woman would bear over her lifetime if she experienced the current age-specific fertility rates. A TFR of about **2.1** in a low-mortality society is the **replacement level** — just enough for each generation to replace itself (slightly above 2 to allow for children who die before reproducing and for the slight surplus of male births). The **Infant Mortality Rate (IMR)** — deaths of children under one year per 1000 live births — is one of the most sensitive indicators of a country's overall development, because infant survival depends on clean water, nutrition, maternal health and basic medical care.

Ví dụ mẫu · Natural increase and doubling time

A country records $760\,000$ live births and $290\,000$ deaths in a year within a population of 38.0 million. (a) Compute CBR, CDR and RNI. (b) Estimate the doubling time using the "rule of 70".

(a) $\text{CBR} = \dfrac{760\,000}{38\,000\,000} \times 1000 = 20.0$ per 1000. $\quad \text{CDR} = \dfrac{290\,000}{38\,000\,000} \times 1000 = 7.6$ per 1000.

$\text{RNI} = \dfrac{20.0 - 7.6}{10} = \dfrac{12.4}{10} = 1.24\%$ per year.

(b) The rule of 70 states that a quantity growing at $r\%$ per year doubles in approximately $70/r$ years:

$$\text{Doubling time} \approx \frac{70}{1.24} \approx 56 \text{ years}.$$

So, ignoring migration and assuming the rate holds, the population would double in roughly 56 years.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tỉ suất sinh thô (CBR) và **tử thô (CDR)** tính trên mỗi 1000 dân. **Tỉ suất tăng tự nhiên (RNI, %)** $= (\text{CBR} - \text{CDR})/10$, chưa tính di cư. **Tổng tỉ suất sinh (TFR)** là số con trung bình một phụ nữ sinh trong đời; mức **thay thế** ≈ 2.1. **Tỉ suất tử vong trẻ sơ sinh (IMR)** rất nhạy với trình độ phát triển. "Rule of 70": thời gian tăng gấp đôi $\approx 70/r$ với r là % tăng mỗi năm. Nhớ chữ "thô/crude": các tỉ suất này bỏ qua cấu trúc tuổi–giới, nên nước già hoá có CDR cao dù y tế tốt.

1.2.2 Dependency and the demographic dividend

The **age dependency ratio** compares the economically "dependent" population to the "working-age" population:

$$\text{Dependency ratio} = \frac{(\text{population } 0\text{–}14) + (\text{population } 65+)}{\text{population } 15\text{–}64} \times 100$$

It can be split into a **youth (child) dependency ratio** (the 0–14 group) and an **old-age dependency ratio** (the 65+ group). A high ratio means each worker must support many non-workers through taxes and family income.

When falling fertility temporarily produces a large working-age population relative to dependants, a country can enjoy a **demographic dividend** — a window of faster economic growth, *provided* the extra workers can find productive employment. The window closes as that large cohort ages into retirement, converting a youth-dependency burden into an old-age-dependency burden.

Ví divu mẫu · Computing the dependency ratio

A population is structured as follows: 0–14: 8.4 million; 15–64: 34.0 million; $65+$: 7.6 million. Compute the total, youth and old-age dependency ratios and interpret.

Total $= \dfrac{8.4 + 7.6}{34.0} \times 100 = \dfrac{16.0}{34.0} \times 100 = 47.1.$

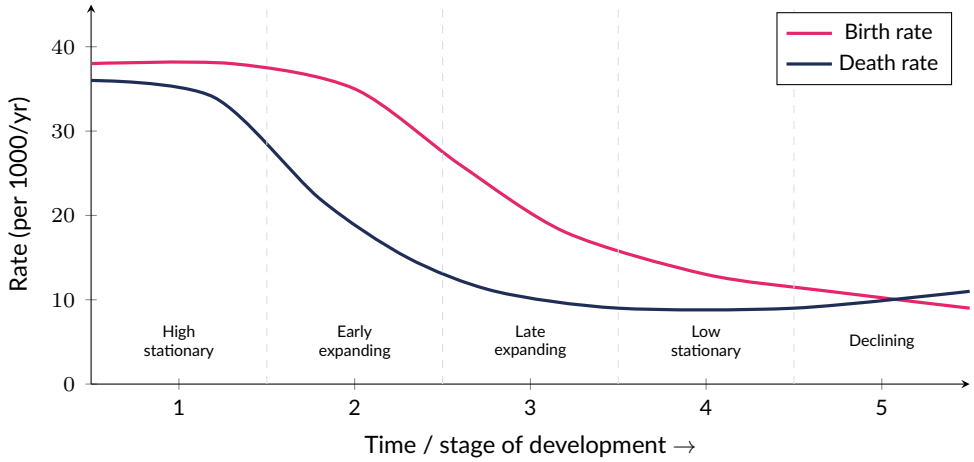
Youth $= \dfrac{8.4}{34.0} \times 100 = 24.7.$ **Old-age** $= \dfrac{7.6}{34.0} \times 100 = 22.4.$

Interpretation: about 47 dependants per 100 workers — a relatively low, favourable ratio. But youth and old-age dependency are almost equal, showing a population part-way through ageing: the future burden will shift decisively toward the elderly as the large working cohort retires and the small youth cohort cannot fully replace it.

1.3 The Demographic Transition Model

1.3.1 The five stages

The **Demographic Transition Model (DTM)** is a generalised model describing how birth and death rates — and therefore natural increase and total population — change as a society develops from a pre-industrial to a post-industrial economy. It is based on the historical experience of north-west Europe but is applied, with caution, worldwide.



The five-stage Demographic Transition Model. The gap between the birth and death curves is the rate of natural increase; the total population (not shown) rises fastest where the gap is widest (stages 2–3) and may fall in stage 5 where deaths exceed births.

The five stages of the DTM

- **Stage 1 — High stationary:** high, fluctuating CBR (∼35–40) and CDR (∼35); disease, famine and war keep death rates high; population is high but stable. No country is now fully in stage 1.
- **Stage 2 — Early expanding:** CDR falls sharply (better food supply, clean water, sanitation, basic medicine) while CBR stays high; the widening gap gives *rapid* population growth. Many of the poorest countries and rapidly developing economies are here.
- **Stage 3 — Late expanding:** CBR now falls (contraception, female education, urbanisation, lower infant mortality, changing family economics) while CDR is low; growth continues but slows.
- **Stage 4 — Low stationary:** both rates are low (∼9–13); population is high and roughly stable; typical of most high-income countries.
- **Stage 5 — Declining (natural decrease):** CBR falls below CDR; population ages and may shrink without immigration (e.g. Japan, Italy, Germany).

VN **GIẢI THÍCH TIẾNG VIỆT**

Mô hình chuyển đổi dân số (DTM) mô tả sự thay đổi CBR và CDR khi xã hội phát triển. **Giai đoạn 1**: sinh cao–tử cao, dân số ổn định. **Giai đoạn 2**: tử giảm mạnh (nước sạch, vệ sinh, y tế cơ bản) trong khi sinh còn cao ⇒ dân số bùng nổ. **Giai đoạn 3**: sinh bắt đầu giảm (tránh thai, giáo dục nữ giới, đô thị hoá) ⇒ tăng chậm lại. **Giai đoạn 4**: sinh–tử đều thấp, dân số cao ổn định. **Giai đoạn 5**: sinh < tử, dân số già và có thể giảm (Nhật, Ý, Đức). Khoảng cách giữa hai đường sinh–tử chính là tỉ suất tăng tự nhiên.

1.3.2 Strengths, limits and the epidemiological transition

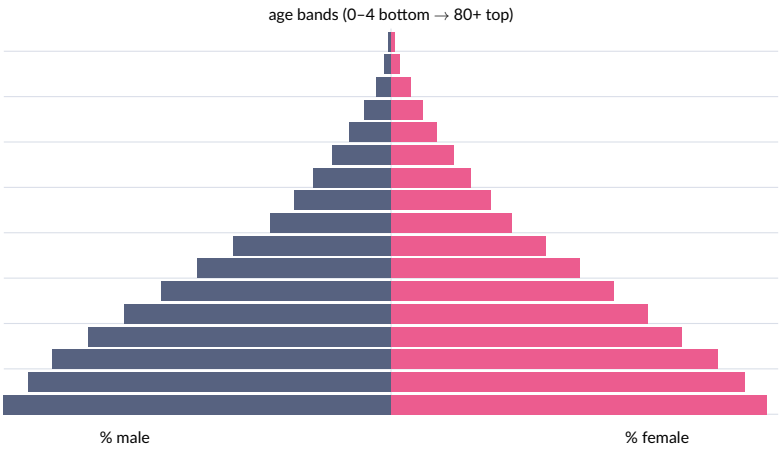
The DTM is valuable because it links demographic change to development, allows comparison and prediction, and highlights the crucial role of falling death rates in triggering growth. Its **limitations** are important: it is *Eurocentric* (death rates in many developing countries fell far faster, imported by external medicine and aid, than the internal economic change that lowered European rates); it does not build in **migration**; it originally had no stage 5; and it assumes falling birth rates inevitably follow, which cultural or religious factors can delay. Running alongside it, the **epidemiological transition** describes the shift in the leading causes of death from infectious and parasitic diseases (dominant in stages 1–2) toward chronic, degenerative and "lifestyle" diseases such as heart disease and cancer (dominant in stages 4–5).

(!) Lỗi thường gặp: Nhiều học sinh nhầm rằng "dân số giảm ở giai đoạn 5 nghĩa là tử suất tăng vọt". Thực ra ở giai đoạn 5, tử suất chỉ *nhích lên nhẹ* do dân số già (nhiều người ở tuổi có nguy cơ tử vong cao); nguyên nhân chính khiến dân số giảm là **tỉ suất sinh rơi xuống dưới mức thay thế**, không phải do y tế xấu đi.

1.4 Population Structure, Momentum and Ageing

1.4.1 Reading population pyramids

A **population pyramid** (age–sex pyramid) is a pair of back-to-back horizontal bar charts showing the percentage (or number) of the population in each five-year age band, males on the left and females on the right. Its shape reveals a country's stage in the DTM and its demographic future.



An *expansive* (wide-based) pyramid typical of a stage-2 country: a broad base of young children, rapidly narrowing upward, indicates high fertility and high youth dependency. A *constrictive* pyramid narrows at the base (low fertility, ageing); a *stationary* pyramid has near-vertical sides (stage 4).

VN **GIẢI THÍCH TIẾNG VIỆT**

Tháp dân số là biểu đồ hai cột đối xứng theo nhóm tuổi 5 năm, nam bên trái, nữ bên phải. *Tháp đáy rộng* (expansive): sinh suất cao, dân số trẻ (giai đoạn 2). *Tháp thắt đáy* (constrictive): sinh suất thấp, dân số già (giai đoạn 5). *Tháp thẳng đứng* (stationary): sinh–tử thấp, ổn định (giai đoạn 4). Vết "lõm/lồi" trên tháp phản ánh sự kiện lịch sử (chiến tranh, bùng nổ sinh, di cư).

1.4.2 Population momentum

Population momentum is the tendency of a population to keep growing (or shrinking) for decades after fertility has reached replacement level, because of the age structure inherited from the past. A country that has recently had high fertility has an exceptionally large cohort of children and young adults; even if every couple now has only two children, the sheer number of women entering their childbearing years means the total number of births — and hence the population — keeps rising until that bulge ages through. Momentum is why the world population will continue to grow to perhaps 10.3 billion around the 2080s even though global average fertility is already close to replacement.

Ví dụ mẫu · Why fertility at 2.1 does not stop growth immediately

Country Y reaches a TFR of exactly 2.1 this year, but 32% of its people are under 15 while only 5% are over 65. Explain, using momentum, why its population will keep growing for decades.

Reasoning: the very large under-15 group (32%) will move into the 15–49 childbearing ages over the next 10–35 years. Even at replacement fertility, this greatly enlarged number of *potential mothers* will produce more total births each year than the small elderly group (5%) produces deaths. Births therefore exceed deaths — natural increase stays positive — until the youthful bulge has aged into the older, higher-mortality bands, which takes roughly 40–60 years. Growth is "locked in" by the inherited age structure, not by current family size.

1.4.3 Ageing populations: causes and consequences

An **ageing population** is one in which the median age is rising and the proportion aged 65 and over is increasing. Its causes are the twin successes of development: **rising life expectancy** (people surviving to old age) and **falling fertility** (fewer young people entering at the base). The **consequences** are far-reaching. Economically, the old-age dependency ratio rises, shrinking the tax base while increasing spending on pensions, health care and social care; labour shortages can slow growth. Socially,

demand grows for elderly care, adapted housing and age-friendly services, and family structures shift as fewer working-age adults support more elderly relatives (the "sandwich generation"). Governments respond by raising the retirement age, encouraging higher fertility (pro-natalist policies), promoting immigration of workers, and raising productivity through automation.

VN **GIẢI THÍCH TIẾNG VIỆT**

Dân số già hoá do tuổi thọ tăng và sinh suất giảm. Hệ quả: tỉ số phụ thuộc người già tăng, sức ép lên quỹ hưu trí, y tế và chăm sóc dài hạn; thiếu hụt lao động; thay đổi cấu trúc gia đình. Đối phó: nâng tuổi nghỉ hưu, chính sách khuyến sinh (pro-natalist), thu hút lao động nhập cư, tự động hoá để tăng năng suất. Già hoá vừa là *thành tựu* của phát triển vừa là *thách thức* tài khoá lâu dài.

1.5 Migration and Forced Displacement

1.5.1 Types, causes and impacts of migration

Migration is the movement of people across a boundary to establish a new permanent or semi-permanent residence. It is classified by direction (internal vs. international), duration (permanent, temporary, seasonal), and cause (**voluntary**, chiefly economic, vs. **forced**). Ernst Ravenstein's "laws of migration" and later models describe it in terms of **push factors** at the origin (unemployment, poverty, conflict, hazard, persecution, land degradation) and **pull factors** at the destination (jobs, higher wages, safety, services, family ties), moderated by **intervening obstacles** (distance, cost, borders, laws).

Migration reshapes both origin and destination. **Origins** may lose working-age adults and skills (a "brain drain") but gain **remittances** — money sent home by migrants, which for some countries exceeds foreign aid and direct investment combined and is a major development resource. **Destinations** gain labour, skills, youth and cultural diversity, helping to offset ageing, but may face pressure on housing and services and social tension. Selective migration also distorts the age–sex structure at both ends: origins are left with more elderly and children, destinations gain a bulge of young adults (often male in labour-migration corridors).

VN **GIẢI THÍCH TIẾNG VIỆT**

Di cư được phân loại theo hướng (nội địa/quốc tế), thời gian và nguyên nhân (*tự nguyện* chủ yếu vì kinh tế vs. *cưỡng bức*). Mô hình **đẩy–kéo**: yếu tố *đẩy* tại nơi đi (thất nghiệp, nghèo, xung đột, thiên tai) và yếu tố *kéo* tại nơi đến (việc làm, lương cao, an toàn), cùng *trở ngại trung gian* (khoảng cách, chi phí, biên giới, luật). Nơi đi có thể "chảy máu chất xám" nhưng nhận **kiều hối (remittances)**; nơi đến được bổ sung lao động trẻ nhưng chịu sức ép nhà ở, dịch vụ và có thể căng thẳng xã hội.

1.5.2 Forced migration: refugees and internally displaced people

Forced migration occurs when people have no realistic choice but to leave. International law distinguishes several categories. A **refugee** (1951 Refugee Convention) is someone outside their country of nationality who cannot return owing to a well-founded fear of persecution on grounds of race, religion, nationality, political opinion or membership of a social group; refugees have specific legal protections including **non-refoulement** (they must not be returned to danger). An **asylum seeker** is a person who has applied for refugee status and is awaiting a decision. An **internally displaced person (IDP)** has been forced to flee but remains *within* their own country and so falls outside the Refugee Convention. By the mid-2020s more than 120 million people were forcibly displaced worldwide — the highest total on record — driven by conflict (Syria, Ukraine, Sudan), persecution, and increasingly by disaster and climate stress.

Environmental and climate-driven displacement is rising: sudden-onset hazards (floods, cyclones) and slow-onset stresses (drought, desertification, sea-level rise, salinisation) drive people from their

homes. The term **"climate refugee"** is widely used but has no formal legal status, since the Refugee Convention does not cover those fleeing environmental change — a growing gap in international protection.

Ví dụ mẫu · Classifying displaced people

A family flees fighting in their home region. (a) They move to a camp 200 km away but stay inside their own country. (b) A cousin crosses an international border and lodges a claim for protection, now awaiting a decision. (c) A neighbour, already granted protected status abroad because of a well-founded fear of persecution, cannot be returned home. Classify each.

(a) Internally displaced person (IDP) — forced to move but still within the national territory; not covered by the Refugee Convention.
(b) Asylum seeker — has applied for refugee status and awaits a decision.
(c) Refugee — recognised status; protected by *non-refoulement*, so cannot be sent back to danger.

1.6 Gender, Policy and Population Change

1.6.1 Gender and demographic change

The status of women is one of the strongest determinants of demographic change. **Female education** lowers fertility powerfully: educated women marry later, are more likely to use contraception, have greater economic opportunities and lower infant mortality, and choose smaller families. Improving **gender equality** — in education, employment, property rights and political voice — is therefore both a development goal in itself and a key driver of the fertility decline that carries countries through the DTM. Conversely, strong **son preference** in some societies, combined with small-family norms and prenatal sex selection, has produced skewed **sex ratios at birth** (well above the natural $\sim$105 boys per 100 girls in parts of Asia), creating long-term "missing women" and marriage-market imbalances.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bình đẳng giới là động lực mạnh của biến đổi dân số. **Giáo dục nữ giới** làm giảm sinh suất: phụ nữ kết hôn muộn hơn, dùng biện pháp tránh thai nhiều hơn, có cơ hội kinh tế và tỉ lệ tử vong trẻ thấp hơn, chọn gia đình ít con. Ngược lại, tâm lí "trọng nam" cộng với chuẩn mực ít con và lựa chọn giới tính trước sinh làm **tỉ số giới tính khi sinh** lệch cao (vượt mức tự nhiên ≈ 105 bé trai/100 bé gái), gây mất cân bằng giới lâu dài.

1.6.2 Population policies

Governments intervene through **anti-natalist** policies (to slow growth: family planning, contraception access, incentives for small families, and in the extreme China's One-Child Policy of 1979–2015) and **pro-natalist** policies (to raise fertility in ageing societies: cash "baby bonuses", generous parental leave, subsidised childcare, tax breaks — as in France, Singapore, Hungary and, since 2016, China's shift to two- and then three-child policies). Evidence suggests coercive anti-natalism produces sharp but socially costly declines (skewed sex ratios, an ageing "4-2-1" family structure), while pro-natalist incentives have only modest effects unless they substantially reduce the real cost of combining work and parenthood.

Ví dụ mẫu · Evaluating a pro-natalist policy

An ageing country with TFR $= 1.3$ introduces a "baby bonus" and 12 months of paid parental leave. Outline why fertility may still not reach replacement.

Answer: the decision to have children responds to the *full* lifetime cost — housing, education,

childcare and, crucially, the career and income women lose (the "motherhood penalty"). A one-off bonus is small relative to these costs, and short leave does not remove the long-run conflict between employment and childrearing. Fertility tends to rise meaningfully only where policy makes it genuinely affordable and career-compatible to raise several children (high-quality subsidised childcare, gender-equal division of unpaid work, secure housing). Cultural norms and high urban living costs further blunt the effect, so many such policies lift TFR only modestly (e.g. from 1.3 to perhaps 1.5).

(!) Lỗi thường gặp: Đừng viết "chính sách một con khiến dân số Trung Quốc giảm ngay". Trên thực tế dân số vẫn *tăng* nhiều thập kỉ sau 1979 do **quán tính dân số**; hệ quả rõ nhất là cấu trúc tuổi bị bóp méo (già hoá nhanh, tỉ số giới tính lệch) chứ không phải sụt giảm tức thời.

1.7 Practice Problems

Bài tập luyện tập

1. Which measure best reflects the pressure of population on food-producing land?

(A) Arithmetic density
(B) Physiological density
(C) Agricultural density
(D) Crude density

Lời giải chi tiết

(B). Physiological density divides total population by the area of *arable* land, so it directly captures how many people depend on each unit of cultivable land. Arithmetic/crude density (A, D) treat all land as usable and understate pressure where much land is desert or mountain; agricultural density (C) measures farming intensity (farmers per arable area), not overall food pressure.

Bài tập luyện tập

2. A city of 12.5 million on 1900 km^2: (a) state whether it qualifies as a megacity; (b) compute its density.

Lời giải chi tiết

(a) Yes — its population exceeds the 10-million megacity threshold. **(b)** Density $= 12\,500\,000/1900 = 6579$ persons/km^2, an extremely high urban density implying heavy demand on housing, transport and services.

Bài tập luyện tập

3. A country has CBR $= 32$, CDR $= 8$. (a) Find RNI. (b) Estimate doubling time. (c) Name the most likely DTM stage.

Lời giải chi tiết

(a) RNI $= (32-8)/10 = 2.4\%$/yr. **(b)** Doubling time $\approx 70/2.4 \approx 29$ years. **(c)** High birth rate with a much lower, falling death rate and rapid growth is characteristic of **Stage 2 (early expanding)**,

or early Stage 3 if the birth rate has just begun to fall.

Bài tập luyện tập

4. Explain why a wealthy country with excellent healthcare can still record a higher crude death rate than a poor country.

Lời giải chi tiết

The CDR is "crude" because it ignores **age structure**. A wealthy, ageing country (e.g. Japan) has a very large proportion of elderly people, who have naturally higher mortality; so many deaths occur simply because so many people are old, pushing CDR up (to ∼11–12). A poor country in Stage 2 has a *youthful* structure — most people are in low-mortality age bands — so its CDR can be lower (∼7–8) despite worse healthcare. Age-standardised mortality rates would reverse the picture.

Bài tập luyện tập

5. Population by age: 0–14: 6.0m; 15–64: 20.0m; $65+$: 4.0m. Compute total, youth and old-age dependency ratios.

Lời giải chi tiết

Total $= (6.0 + 4.0)/20.0 \times 100 = 50.0$. Youth $= 6.0/20.0 \times 100 = 30.0$. Old-age $= 4.0/20.0 \times 100 = 20.0$. Interpretation: 50 dependants per 100 workers, with youth dependency still exceeding old-age dependency — a population early in its ageing process.

Bài tập luyện tập

6. Which factor most powerfully drives the fall in the birth rate during DTM Stage 3?

(A) Improved sanitation
(B) Female education and contraception
(C) Falling death rate alone
(D) Rising life expectancy

Lời giải chi tiết

(B). Stage 3's defining change is the *birth* rate falling, driven above all by female education, women's employment and access to contraception, reinforced by urbanisation and lower infant mortality (parents no longer need many children to ensure some survive). Sanitation and life expectancy (A, D) mainly lowered the *death* rate in Stage 2; (C) confuses cause and effect.

Bài tập luyện tập

7. Define population momentum and explain why it means global population will keep rising despite falling fertility.

Lời giải chi tiết

Population momentum is continued population growth after fertility reaches replacement level, caused by an inherited youthful age structure. Because decades of higher fertility have produced very large cohorts of children and young adults, an unusually large number of women

are now, or soon will be, of childbearing age. Even at a TFR of $\sim$2.1, this many mothers produce more total annual births than the (currently small) elderly population produces deaths, so natural increase stays positive until the youthful bulge ages through — roughly 40–60 years. Hence world population is projected to keep rising to about 10.3 billion around the 2080s.

Bài tập luyện tập

8. Distinguish clearly between a refugee, an asylum seeker and an internally displaced person.

Lời giải chi tiết

A **refugee** has crossed an international border and been recognised as having a well-founded fear of persecution (1951 Convention), gaining legal protection including non-refoulement. An **asylum seeker** has crossed a border and *applied* for refugee status but is still awaiting a decision. An **internally displaced person (IDP)** has been forced from home but remains *inside* their own country, and so is not covered by the Refugee Convention, relying instead on their own (often the persecuting) government for protection.

Bài tập luyện tập

9. A migrant corridor sees young adult males move from country A to country B for work. Describe two effects on the age–sex structure of *each* country.

Lời giải chi tiết

Origin A: loss of young adult males creates a "bite" in the 20–40 male bars of its pyramid, leaving a relatively higher proportion of women, children and the elderly; the dependency ratio rises and the sex ratio becomes female-skewed. **Destination B:** gains a bulge of young adult males, lowering its median age, boosting the working-age share and dependency position, and producing a male-skewed sex ratio in those age bands. Remittances flow back to A, while B gains labour that can offset ageing.

Bài tập luyện tập

10. State two strengths and two limitations of the Demographic Transition Model.

Lời giải chi tiết

Strengths: (i) it links demographic change to development and allows comparison and broad prediction; (ii) it highlights the key role of the falling death rate in triggering rapid growth. **Limitations:** (i) it is Eurocentric — many developing countries' death rates fell far faster (imported medicine/aid) than internal development, and birth rates have not always followed as the model predicts; (ii) it omits **migration** and originally had no Stage 5 to describe natural decrease and ageing.

Bài tập luyện tập

11. A country records 1.2 million births, 0.9 million deaths, $250\,000$ immigrants and $180\,000$ emigrants in a population of 60 million. Find (a) natural increase, (b) net migration, (c) overall population change and (d) the overall growth rate (%).

Lời giải chi tiết

(a) Natural increase $= 1\,200\,000 - 900\,000 = 300\,000$. **(b)** Net migration $= 250\,000 - 180\,000 = +70\,000$. **(c)** Total change $= 300\,000 + 70\,000 = 370\,000$. **(d)** Growth rate $= 370\,000/60\,000\,000 \times 100 = 0.62\%$/yr. Migration adds nearly a fifth of the total change here, illustrating why the RNI alone understates change in migration-affected countries.

Bài tập luyện tập

12. Explain why the "rule of 70" gives only an approximate doubling time.

Lời giải chi tiết

The rule derives from continuous exponential growth: doubling time $t = \ln 2/r \approx 0.693/r$; multiplying by 100 gives $\approx 69.3/r\% \approx 70/r$. It is approximate because (i) 70 rounds 69.3; (ii) real growth is not perfectly exponential — birth, death and migration rates change over time; and (iii) it assumes the current rate is held constant, which rarely happens over the many decades a doubling takes.

Bài tập luyện tập

13. Which of the following best explains a skewed sex ratio at birth of 118 boys per 100 girls?

(A) Higher natural male birth probability

(B) Son preference plus prenatal sex selection

(C) Higher female infant mortality only

(D) Male-dominated immigration

Lời giải chi tiết

(B). The natural sex ratio at birth is about 105 (A explains only that baseline, not 118). A ratio as high as 118 reflects cultural **son preference** combined with small-family norms and **prenatal sex selection** (sex-selective abortion). Female infant mortality (C) affects the ratio *after* birth, not the ratio *at* birth; immigration (D) does not change births.

Bài tập luyện tập

14. Evaluate the likely long-term demographic consequences of China's former One-Child Policy.

Lời giải chi tiết

The policy (1979–2015) accelerated the fall in fertility well below replacement, but because of momentum the population kept growing for decades. Its enduring consequences are structural: (i) **rapid ageing** and a rising old-age dependency ratio, with a shrinking workforce; (ii) a distorted **sex ratio at birth** (peaking near 118) from son preference and sex selection, leaving a surplus of young men; (iii) the "**4-2-1**" family, in which one child may support two parents and four grandparents; and (iv) below-replacement fertility that pro-natalist reversals (two- then three-child policies) have so far failed to lift substantially. The case shows that coercive anti-natalism can change numbers quickly but leaves long-lasting structural imbalances.

Bài tập luyện tập

15. Country Z: total area $= 300\,000$ km^2; population $= 25$ million; 40% of land arable; 4 million people are farmers. Compute arithmetic, physiological and agricultural densities.

Lời giải chi tiết

Arable area $= 0.40 \times 300\,000 = 120\,000$ km^2. **Arithmetic** $= 25\,000\,000/300\,000 = 83$ /km^2. **Physiological** $= 25\,000\,000/120\,000 = 208$ /km^2. **Agricultural** $= 4\,000\,000/120\,000 = 33$ farmers/km^2. The moderate agricultural density relative to physiological density suggests a fairly productive, not purely subsistence, farming system.

Bài tập luyện tập

16. Explain two reasons remittances can be a more reliable development resource for an origin country than foreign aid.

Lời giải chi tiết

(i) Remittances flow **directly to households**, so they immediately raise consumption, health, education and small-business investment without being lost to bureaucracy or conditions attached to aid. (ii) They are relatively **stable and even counter-cyclical** — migrants often send *more* home when their families face hardship (e.g. after a disaster or downturn), whereas aid and investment can be volatile or politically conditional. A limitation is dependency and the loss of the migrants themselves (brain drain).

Bài tập luyện tập

17. A pyramid has a very narrow base, bulging middle-age bars and a wide top. State the DTM stage and two implications.

Lời giải chi tiết

This is a **constrictive** pyramid typical of **Stage 5** (natural decrease/ageing). Implications: (i) a rising old-age dependency ratio will strain pensions, healthcare and social care while the tax base shrinks; (ii) a future labour shortage may require raising the retirement age, pro-natalist policy or immigration to sustain the workforce.

Bài tập luyện tập

18. "Improving female education is the single most effective population policy." Discuss.

Lời giải chi tiết

Support: female education consistently lowers fertility toward or below replacement by delaying marriage, expanding women's economic options, improving contraceptive use and cutting infant mortality (so parents need fewer births to ensure survivors). It is non-coercive, has wide development co-benefits (health, income, gender equality) and helps countries move through Stages 3–4. **Qualification:** its effect is gradual, not immediate, and works best alongside contraceptive access, healthcare and employment for women; in already low-fertility societies the priority reverses toward pro-natalist and pro-immigration measures. **Judgement:** for high-fertility, developing countries it is arguably the most cost-effective and rights-respecting lever,

but "single most effective" overstates a factor that depends on complementary policies.

Bài tập luyện tập

19. Distinguish between the epidemiological transition and the demographic transition.

Lời giải chi tiết

The **demographic transition** describes changes in *rates* — the fall of death and then birth rates and the resulting population growth. The **epidemiological transition** describes changes in the *causes* of death — a shift from infectious and parasitic diseases and famine (dominant in DTM Stages 1–2) toward chronic, degenerative and lifestyle diseases such as heart disease, stroke and cancer (dominant in Stages 4–5). They run in parallel: controlling infectious disease is a major reason the death rate falls in Stage 2.

Bài tập luyện tập

20. A country's TFR falls from 5.0 to 2.5 over 25 years. Give three plausible causes and one likely consequence for its pyramid shape.

Lời giải chi tiết

Causes: rising female education and employment; wider access to contraception and family planning; urbanisation raising the cost of children and lowering their economic value; falling infant mortality reducing "insurance" births. **Consequence:** the pyramid's base narrows relative to the middle — the population begins moving from an expansive toward a stationary shape, and youth dependency falls, potentially opening a demographic dividend if jobs are available.

Bài tập luyện tập

21. Explain why the term "climate refugee" is problematic in international law.

Lời giải chi tiết

The 1951 Refugee Convention defines a refugee narrowly as someone fleeing **persecution** on specific grounds (race, religion, nationality, political opinion, social group). People displaced by environmental change — drought, sea-level rise, cyclones — do not meet this definition, and most such movement is *internal* (making them IDPs, not refugees). So "climate refugee", though widely used, confers no legal status or protection, exposing a governance gap as environmental displacement grows.

Bài tập luyện tập

22. A demographic dividend requires more than a large working-age population. Explain.

Lời giải chi tiết

A falling dependency ratio only *enables* faster growth; it does not guarantee it. The dividend is realised only if the enlarged working-age cohort is **productively employed** — which requires investment in education and skills, job creation, sound governance, savings and infrastructure, and openness to trade. Without jobs, a youth bulge can instead produce unemployment, underemployment and instability. The dividend is also a *window*: it closes as the cohort ages into

retirement, so countries must build wealth and institutions before it does.

Bài tập luyện tập

23. Two regions have equal arithmetic density but very different physiological density. What does this tell you?

Lời giải chi tiết

Equal arithmetic density but differing physiological density means the two regions differ in the *share of land that is arable*. The region with the *higher* physiological density has less cultivable land (more desert, mountain or built-up area), so its population presses harder on each unit of farmland and is more dependent on intensive agriculture or food imports. It shows why arithmetic density alone can mislead when comparing resource pressure.

Bài tập luyện tập

24. Outline how a natural hazard can act as both a push factor and a driver of forced migration, using an example.

Lời giải chi tiết

A sudden-onset hazard such as a major flood or cyclone (e.g. in Bangladesh's delta) destroys homes, farmland and livelihoods, acting as a strong **push factor**. Where the damage is severe and recovery impossible, movement becomes **forced**: people flee with no realistic choice, often becoming internally displaced. Slow-onset stresses (salinisation, sea-level rise) compound this by degrading land permanently, converting temporary displacement into permanent migration — yet such people lack refugee status, highlighting the protection gap for environmentally displaced populations.

Bài tập luyện tập

25. A country with TFR $= 1.2$ debates raising the retirement age versus increasing immigration to address ageing. Evaluate.

Lời giải chi tiết

Raising the retirement age keeps experienced workers contributing taxes and delays pension costs, and adjusts automatically to longer lifespans; but it is politically unpopular, may not suit physically demanding jobs, and does nothing for the shrinking base of young workers. **Increasing immigration** of working-age people directly enlarges the labour force and tax base and can lower the median age quickly; but it may face public resistance, requires integration, and only postpones ageing since migrants themselves grow old. **Judgement:** neither alone solves below-replacement fertility; most ageing societies combine a higher retirement age, targeted immigration, productivity gains (automation) and pro-natalist support, since each addresses a different part of the problem.

IB DIPLOMA PROGRAMME • Unit 2

Global Climate — Vulnerability and Resilience

Mục tiêu Unit: Giải thích cấu trúc khí quyển và cân bằng bức xạ Trái Đất (hằng số mặt trời, suất phản chiếu albedo, hiệu ứng nhà kính tự nhiên và tăng cường); phân tích nguyên nhân của biến đổi khí hậu do con người (khí nhà kính, các nguồn phát thải, khái niệm forcing bức xạ) và các bằng chứng quan sát; đánh giá các tác động vật lí và nhân văn (nhiệt độ, băng tan, mực nước biển, thời tiết cực đoan, hệ sinh thái); giải thích vì sao mức độ dễ tổn thương (vulnerability) và khả năng chống chịu (resilience) khác nhau giữa các nhóm và quốc gia; và so sánh các chiến lược thích ứng (adaptation) với giảm nhẹ (mitigation) cùng bối cảnh địa chính trị của quản trị khí hậu.

2.1 The Atmospheric System and Energy Balance

2.1.1 Structure and composition of the atmosphere

The atmosphere is a thin envelope of gases held to the Earth by gravity, organised into layers by their temperature profile. The lowest layer, the **troposphere** (surface to ∼12 km), contains about 75% of atmospheric mass and virtually all weather and water vapour; temperature falls with height at an average **environmental lapse rate** of about $6.5\,^{\circ}$C per km. Above it the **stratosphere** (to ∼50 km) contains the **ozone layer**, where temperature *rises* with height because ozone absorbs ultraviolet radiation. Dry air is ∼78% nitrogen and ∼21% oxygen; the climatically active constituents — water vapour, carbon dioxide, methane and others — are minor by volume but control the planet's energy balance.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khí quyển gồm nhiều tầng phân theo nhiệt độ. **Tầng đối lưu (troposphere)** chứa $\approx 75\%$ khối lượng và toàn bộ thời tiết; nhiệt độ giảm theo độ cao ($\approx 6.5\,^{\circ}$C/km). **Tầng bình lưu (stratosphere)** chứa tầng ozone, nhiệt độ *tăng* theo độ cao do ozone hấp thụ tia cực tím. Không khí khô chủ yếu là nitơ ($\approx 78\%$) và oxy ($\approx 21\%$), nhưng các khí "vết" như hơi nước, CO_2, CH_4 mới là yếu tố điều khiển cân bằng năng lượng của khí hậu.

2.1.2 The Earth's radiation budget

The Earth's climate is powered by incoming **shortwave** solar radiation and cooled by outgoing **longwave** (infrared) radiation. Averaged over the globe and a year, incoming energy at the top of the atmosphere is about 340 W m^{-2} (a quarter of the **solar constant**, ∼1361 W m^{-2}, because a disc of area πr^2 intercepts sunlight but a sphere of area $4\pi r^2$ radiates). Of this, roughly 30% is reflected straight back to space — this reflected fraction is the planetary **albedo**. Bright surfaces (fresh snow, ice, cloud tops, desert) have high albedo; dark surfaces (ocean, forest, bare soil) have low albedo and absorb more energy.

Albedo is the fraction of incident shortwave radiation reflected by a surface, from 0 (perfect absorber) to 1 (perfect reflector). Fresh snow ≈ 0.8–0.9; thick cloud ≈ 0.6–0.9; desert sand ≈ 0.4; grassland ≈ 0.25; ocean ≈ 0.06 (for a high sun). Because ice has high albedo and open ocean low albedo, melting ice lowers albedo, absorbs more energy and drives further melting — the **ice–albedo positive feedback**.

For a stable climate, absorbed shortwave energy must be balanced by emitted longwave energy at the top of the atmosphere. The natural **greenhouse effect** explains why the surface is far warmer than this balance alone predicts.

Ví dụ mẫu · Effective temperature and the greenhouse effect

Estimate the Earth's "effective" emitting temperature and compare it with the observed surface mean of ∼15 °C. Take $S = 1361$ W m^{-2}, albedo $\alpha = 0.30$, Stefan–Boltzmann constant $\sigma = 5.67 \times 10^{-8}$ W m^{-2}K^{-4}.

Energy balance: absorbed = emitted $\Rightarrow \dfrac{S}{4}(1-\alpha) = \sigma T^4$.

$$T = \left[\frac{S(1-\alpha)}{4\sigma}\right]^{1/4} = \left[\frac{1361(0.70)}{4(5.67\times10^{-8})}\right]^{1/4} = \left[\frac{952.7}{2.268\times10^{-7}}\right]^{1/4}.$$

$$T = \left[4.201\times10^{9}\right]^{1/4} \approx 255\ \text{K} = -18\,^{\circ}\text{C}.$$

The effective temperature is about -18 °C, yet the actual surface averages $+15$ °C. The ∼33 °C difference is the **natural greenhouse effect**: greenhouse gases absorb outgoing longwave radiation and re-emit part of it back to the surface, warming it. Without it, Earth would be frozen.

VN **GIẢI THÍCH TIẾNG VIỆT**

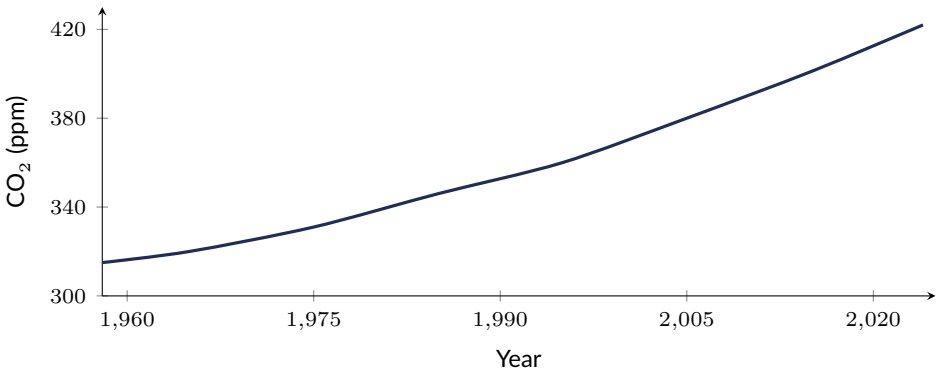
Năng lượng vào ≈ 340 W m^{-2} (bằng $1/4$ hằng số mặt trời do đĩa chặn nắng nhưng hình cầu bức xạ). Khoảng 30% bị phản xạ (đó là **albedo**). Nếu chỉ cân bằng bức xạ, nhiệt độ "hiệu dụng" của Trái Đất là $\approx -18\,^{\circ}$C, nhưng thực tế bề mặt $\approx +15\,^{\circ}$C. Chênh lệch $\approx 33\,^{\circ}$C là **hiệu ứng nhà kính tự nhiên**: khí nhà kính hấp thụ bức xạ hồng ngoại đi ra rồi phát ngược một phần về bề mặt. Băng tan làm giảm albedo ⇒ hấp thụ nhiều hơn ⇒ tan thêm: đó là **phản hồi dương băng–albedo**.

2.2 The Enhanced Greenhouse Effect and Human Causes

2.2.1 Greenhouse gases and radiative forcing

The **natural greenhouse effect** keeps Earth habitable; the problem is the **enhanced (anthropogenic) greenhouse effect**, in which human emissions increase greenhouse-gas concentrations and trap additional heat. The principal long-lived greenhouse gases are **carbon dioxide** (CO_2, from burning fossil fuels, cement making and deforestation), **methane** (CH_4, from livestock, rice paddies, landfills and fossil-fuel leaks — far more potent per molecule but shorter-lived), **nitrous oxide** (N_2O, from fertilisers) and industrial **halocarbons**. Water vapour is the strongest greenhouse gas but acts as a *feedback* (a warmer atmosphere holds more of it) rather than a direct human forcing.

Radiative forcing measures, in W m^{-2}, the change a factor imposes on the Earth's energy balance relative to pre-industrial (1750): a positive forcing warms, a negative forcing (e.g. reflective aerosols) cools. The concept of **global warming potential (GWP)** expresses a gas's total warming over a chosen period (usually 100 years) relative to CO_2: methane's 100-year GWP is roughly 28–30, nitrous oxide's about 270, meaning small amounts have a large effect. Atmospheric CO_2 has risen from ∼280 ppm in 1750 to over 420 ppm today, tracked continuously since 1958 by the **Keeling curve**.



The Keeling curve: the steady rise of atmospheric CO_2 measured at Mauna Loa (annual mean, small seasonal wiggle omitted). Concentration has climbed from ∼315 ppm in 1958 to over 420 ppm, closely tracking cumulative fossil-fuel emissions.

VN **GIẢI THÍCH TIẾNG VIỆT**

Hiệu ứng nhà kính tăng cường do con người phát thải: CO_2 (đốt nhiên liệu hoá thạch, xi măng, phá rừng), CH_4 (chăn nuôi, lúa nước, bãi rác, rò rỉ khí), N_2O (phân bón), halocarbon. **Radiative forcing** (W m^{-2}) đo mức tác động lên cân bằng năng lượng so với thời tiền công nghiệp (1750). **GWP** so sánh khả năng làm nóng của một khí với CO_2 trong 100 năm ($CH_4 \approx 28$–30; $N_2O \approx 270$). CO_2 đã tăng từ ≈ 280 ppm (1750) lên > 420 ppm, thể hiện qua **đường Keeling**.

2.2.2 Evidence and attribution

Multiple independent lines of evidence show the climate is warming and that recent warming is human-caused: instrumental records show global mean surface temperature about 1.1–$1.3\,^{\circ}$C above pre-industrial; ice cores link temperature to CO_2 over 800 000 years and show today's concentrations are unprecedented; Arctic sea-ice extent, glacier mass and the Greenland/Antarctic ice sheets are declining; sea level is rising (∼3.7 mm/yr and accelerating); and the pattern of warming (troposphere warming while the stratosphere cools) is the "fingerprint" expected from greenhouse forcing rather than a brighter Sun. **Attribution science** uses climate models run with and without human emissions to show that observed warming cannot be reproduced by natural factors (solar, volcanic) alone.

Ví dụ mẫu · Interpreting GWP

A dairy operation emits 500 tonnes of methane per year. Express this as "CO_2-equivalent" using a 100-year GWP of 28, and comment.

$CO_2e = 500$ t $CH_4 \times 28 = 14\,000$ tonnes CO_2-equivalent per year.

Comment: although only 500 tonnes of methane by mass, its warming effect over a century equals that of 14 000 tonnes of CO_2. Because methane is also short-lived (∼12 years in the atmosphere), cutting methane emissions delivers relatively rapid climate benefit — a key reason livestock, landfill and fossil-fuel-leak methane are priority mitigation targets.

2.3 Impacts of Climate Change

2.3.1 Physical impacts

Warming drives a cascade of physical changes: rising **global mean temperature** with more frequent and intense heatwaves; **cryosphere loss** (shrinking glaciers, Arctic sea ice, ice sheets and permafrost); **sea-level rise** from both *thermal expansion* of warming seawater and *added meltwater* from land ice; intensification of the **hydrological cycle** (heavier downpours and flooding in some regions, deeper drought in others); **ocean warming and acidification** (as the ocean absorbs CO_2, forming carbonic

acid and lowering pH, harming shell-forming organisms and coral); and shifts in the frequency or intensity of some extreme events, including more energetic tropical cyclones. Positive feedbacks — ice–albedo, permafrost methane release, reduced ocean CO_2 uptake — risk pushing parts of the system past **tipping points** of irreversible change.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tác động vật lí: nhiệt độ tăng và sóng nhiệt gay gắt hơn; băng tan (sông băng, băng biển Bắc Cực, tảng băng, băng vĩnh cửu); **nước biển dâng** do *giãn nở nhiệt* của nước biển ấm và nước băng tan trên lục địa; chu trình nước mạnh lên (mưa lớn/lũ nơi này, hạn hán sâu nơi khác); đại dương ấm và **acid hoá** (hấp thụ CO_2 tạo acid carbonic, hạ pH, hại san hô và loài tạo vỏ). Các **phản hồi dương** có thể đẩy hệ khí hậu vượt **điểm tới hạn (tipping point)** không thể đảo ngược.

2.3.2 Human impacts and disparities in vulnerability

The human impacts are unevenly distributed: threats to **food security** (shifting growing zones, drought, heat stress on crops and livestock), **water security**, **health** (heat mortality, expanding ranges of vector-borne diseases such as malaria and dengue), **coastal and small-island livelihoods**, and **displacement**. Crucially, the people least responsible for emissions are often the most exposed. **Vulnerability** depends on three elements: *exposure* (how much a place experiences the hazard), *sensitivity* (how much harm that exposure causes), and *adaptive capacity* (the ability to cope and adjust). Low-income countries, small island developing states (SIDS), and marginalised groups (the poor, women, the elderly, indigenous peoples) typically have high exposure and sensitivity but low adaptive capacity — a profound climate **injustice**, since high-income countries have produced the bulk of historic emissions.

$$\text{Risk} = f(\text{Hazard} \times \text{Exposure} \times \text{Vulnerability}), \qquad \text{Vulnerability} \propto \frac{\text{Sensitivity}}{\text{Adaptive capacity}}$$

Two places facing the same physical hazard can experience very different *risk* because their exposure, sensitivity and adaptive capacity differ. Reducing vulnerability — through wealth, education, infrastructure, insurance and governance — reduces risk even if the hazard itself is unchanged.

Ví dụ mẫu · Why two coastlines face different risk

A wealthy delta city and a poor delta community both face 0.5 m of sea-level rise this century. Explain why their *risk* differs despite identical hazard.

Exposure may be similar (both low-lying), but **sensitivity** and **adaptive capacity** differ sharply. The wealthy city can fund sea walls, storm-surge barriers, pumping, managed realignment, insurance and early-warning systems, lowering both sensitivity and consequences. The poor community, with limited finance, weak infrastructure and livelihoods tied directly to the land (farming, fishing), has high sensitivity and low adaptive capacity, so the same physical change causes far greater loss of life, property and livelihood. Risk is therefore a social as much as a physical outcome — the basis of the argument for climate justice and adaptation finance.

2.4 Responding to Climate Change

2.4.1 Mitigation

Mitigation means reducing the *causes* of climate change — cutting greenhouse-gas emissions or enhancing sinks that remove CO_2. Strategies include: switching from fossil fuels to **renewables** (solar, wind, hydro, geothermal) and nuclear; improving **energy efficiency**; electrifying transport and heat-

ing; **carbon pricing** (taxes or cap-and-trade emissions trading) to make polluters pay; protecting and expanding **carbon sinks** (afforestation, reforestation, restoring peatlands and wetlands, "blue carbon" in mangroves and seagrass); and **carbon capture and storage (CCS)**. Mitigation tackles the root of the problem and benefits everyone globally, but its costs fall on those who act while the benefits are shared worldwide — the classic "free-rider" problem that makes international cooperation essential.

2.4.2 Adaptation

Adaptation means adjusting to the *impacts* that can no longer be avoided — reducing vulnerability and building **resilience**, the capacity of a system to absorb disturbance and recover. Examples: **sea defences** and managed retreat for coasts; **drought-resistant and heat-tolerant crops** and changed planting calendars; improved **water storage and irrigation efficiency**; **early-warning systems** and cyclone shelters; heat-health action plans and urban greening; and **disaster risk reduction** more broadly. Adaptation delivers local, near-term benefits and is essential for the most vulnerable, but it treats symptoms not causes, can be costly, and has limits — some losses (submerged islands, lost species) cannot be adapted away, which is why **"loss and damage"** has become central to climate negotiations.

Ví dụ mẫu · Classifying responses

Classify each as mitigation (M) or adaptation (A): (a) building a coastal sea wall; (b) subsidising rooftop solar panels; (c) breeding flood-tolerant rice; (d) a carbon tax; (e) planting mangroves along an eroding shore.

(a) A — reduces impact of sea-level rise/surge. **(b) M** — reduces emissions by displacing fossil electricity. **(c) A** — copes with changed flooding. **(d) M** — reduces emissions by pricing carbon. **(e) Both** — mangroves *adapt* (buffer waves, reduce erosion) *and mitigate* (store "blue carbon"), a useful example of a co-benefit "no-regret" measure.

VN **GIẢI THÍCH TIẾNG VIỆT**

Giảm nhẹ (mitigation) = tấn công *nguyên nhân*: cắt phát thải (năng lượng tái tạo, hiệu suất, điện khí hoá, định giá carbon) và tăng bể hấp thụ (trồng rừng, đất than bùn, "blue carbon"). **Thích ứng (adaptation)** = đối phó với *tác động* không tránh được, xây dựng **khả năng chống chịu (resilience)**: đê biển, giống cây chịu hạn/mặn, hệ cảnh báo sớm, hạ tầng chống thiên tai. Giảm nhẹ có lợi toàn cầu nhưng gặp vấn đề "ăn theo" (free-rider); thích ứng cho lợi ích địa phương tức thời nhưng chỉ trị "triệu chứng" và có giới hạn (mất mát không thể đảo ngược → "loss and damage").

2.4.3 The geopolitics of climate governance

Because greenhouse gases mix globally, no country can solve the problem alone, yet responsibility and capacity are unequal — the core tension of climate **geopolitics**. The principle of **"common but differentiated responsibilities"** (CBDR) recognises that industrialised nations, having emitted most historic CO_2, should lead and help finance action in poorer countries. Key milestones: the **UNFCCC** (1992); the **Kyoto Protocol** (1997), which set binding targets only for developed countries; and the **Paris Agreement** (2015), under which nearly all countries submit voluntary **Nationally Determined Contributions (NDCs)** aiming to hold warming "well below 2 °C" and pursue 1.5 °C. Disputes persist over historic responsibility, climate finance (the pledged support for developing countries), fossil-fuel phase-out, and "loss and damage" compensation for the most vulnerable states.

2.5 Practice Problems

Bài tập luyện tập

1. Why is the average solar energy at the top of the atmosphere about one quarter of the solar constant?

(A) Because 75% is reflected

(B) Because a sphere's area is $4\times$ the intercepting disc

(C) Because of the greenhouse effect

(D) Because of albedo

Lời giải chi tiết

(B). Sunlight is intercepted over a disc of area πr^2 but the energy is spread over the whole rotating sphere of area $4\pi r^2$; the ratio $\pi r^2/4\pi r^2 = 1/4$. So the global-mean insolation is $1361/4 \approx 340$ W m^{-2}. Albedo (D) then reflects $\sim$30% of *that*; it is a separate step.

Bài tập luyện tập

2. Compute the effective emitting temperature of a planet with $S = 1361$ W m^{-2} and albedo 0.15. ($\sigma = 5.67 \times 10^{-8}$.)

Lời giải chi tiết

$$T = \left[\frac{S(1-\alpha)}{4\sigma}\right]^{1/4} = \left[\frac{1361(0.85)}{4(5.67\times10^{-8})}\right]^{1/4} = \left[\frac{1156.9}{2.268\times10^{-7}}\right]^{1/4} = [5.101\times10^{9}]^{1/4} \approx 267$$

K $= -6\,^{\circ}$C. A lower albedo means more absorbed energy and a higher effective temperature than Earth's 255 K.

Bài tập luyện tập

3. Explain the ice–albedo feedback and state whether it is positive or negative.

Lời giải chi tiết

Ice and snow have high albedo ($\sim$0.8), reflecting most sunlight; open ocean and land have low albedo ($\sim$0.06–0.25), absorbing most. As warming melts ice, bright surface is replaced by dark, so more solar energy is absorbed, causing further warming and further melting. Because the change *amplifies* the original warming, it is a **positive** (reinforcing) feedback — a key reason the Arctic warms faster than the global average.

Bài tập luyện tập

4. A farm emits 200 t CH_4 and 10 t N_2O per year. Using GWP_{100} of 28 (CH_4) and 273 (N_2O), find the total CO_2e.

Lời giải chi tiết

CH_4: $200 \times 28 = 5600$ t CO_2e. N_2O: $10 \times 273 = 2730$ t CO_2e. **Total** $= 5600 + 2730 = 8330$ t CO_2-equivalent per year. Note how the 10 t of N_2O contributes almost half as much warming as the 200 t of methane, because of its very high GWP.

Bài tập luyện tập

5. Distinguish clearly between the natural and the enhanced greenhouse effect.

Lời giải chi tiết

The **natural greenhouse effect** is the warming (about $+33\,^{\circ}$C) produced by naturally occurring greenhouse gases (water vapour, CO_2, etc.), which keeps Earth habitable. The **enhanced greenhouse effect** is the *additional* warming caused by human emissions raising greenhouse-gas concentrations above pre-industrial levels, trapping more outgoing longwave radiation and driving present-day climate change. The mechanism is the same; the difference is the human increase in gas concentrations.

Bài tập luyện tập

6. Name and explain the two main contributions to sea-level rise.

Lời giải chi tiết

(i) **Thermal expansion**: as seawater warms it expands, occupying more volume even without added water — historically the largest single contributor. (ii) **Added meltwater from land ice**: melting glaciers and the Greenland and Antarctic ice sheets transfer water from land to ocean. (Melting *sea* ice does not directly raise sea level, since floating ice already displaces its own weight.) Together these produce the observed $\sim$3.7 mm/yr rise, which is accelerating.

Bài tập luyện tập

7. Using Risk $= f$(Hazard, Exposure, Vulnerability), explain why a rich and a poor country can face different climate risk from the same hazard.

Lời giải chi tiết

The hazard (e.g. a heatwave or storm) may be physically identical, but risk also depends on **exposure** (how many people/assets are in harm's way) and **vulnerability** (sensitivity $\div$ adaptive capacity). A rich country's high adaptive capacity — infrastructure, healthcare, early warning, insurance, wealth — lowers vulnerability and therefore risk. A poor country with high sensitivity (livelihoods tied to land) and low adaptive capacity suffers far greater loss from the same hazard. Risk is thus socially, not just physically, determined.

Bài tập luyện tập

8. Classify each as adaptation or mitigation: (a) reforestation; (b) building cyclone shelters; (c) emissions trading scheme; (d) desalination for drought; (e) electric buses.

Lời giải chi tiết

(a) **Mitigation** (enhances carbon sink); (b) **Adaptation** (reduces hazard impact); (c) **Mitigation** (prices/limits emissions); (d) **Adaptation** (copes with water scarcity); (e) **Mitigation** (cuts transport emissions). Reforestation can also give adaptation co-benefits (shade, flood control), but its primary climate role is mitigation.

Bài tập luyện tập

9. Explain why methane reduction gives faster climate benefit than CO_2 reduction.

Lời giải chi tiết

Methane has a very high global warming potential ($GWP_{100} \approx 28$) but a short atmospheric lifetime ($\sim$12 years), whereas CO_2 persists for centuries. Cutting methane emissions therefore lowers atmospheric methane — and its strong warming effect — within a couple of decades, delivering rapid slowing of warming. Cutting CO_2 is essential for the long term but its concentration falls only slowly. Hence methane action (from agriculture, waste, fossil-fuel leaks) is a powerful near-term "lever".

Bài tập luyện tập

10. Why does mitigation suffer from a "free-rider" problem while adaptation does not?

Lời giải chi tiết

Mitigation reduces global greenhouse-gas concentrations, so its benefits are shared by *all* countries regardless of who pays — a global public good. Each country is therefore tempted to let others bear the cost while enjoying the shared benefit (free-riding), which is why binding international cooperation is needed. Adaptation, by contrast, produces mostly *local* benefits — a sea wall or early-warning system protects the country that builds it — so the incentive to act is direct and free-riding is not a problem.

Bài tập luyện tập

11. A surface reflects 210 W m^{-2} of an incident 350 W m^{-2}. Find its albedo and classify the surface.

Lời giải chi tiết

Albedo $= 210/350 = 0.60$. A value of 0.6 is high — consistent with thick cloud or fairly fresh snow/ice. Such a bright surface absorbs only 40% of incoming shortwave radiation, so replacing it with a darker surface (open ocean, bare ground) would sharply increase absorbed energy.

Bài tập luyện tập

12. Outline the principle of "common but differentiated responsibilities" and one dispute it generates.

Lời giải chi tiết

CBDR holds that, although all countries must act on climate change, industrialised nations bear greater responsibility because they produced most historic emissions and have greater capacity, so they should lead in cutting emissions and help finance action in developing countries. **Dispute:** defining fair shares — e.g. whether rapidly growing large emitters (with high *current* but low *historic per-capita* emissions) should take on binding targets, and how much climate finance and "loss and damage" compensation rich countries owe. These disputes have repeatedly stalled negotiations.

Bài tập luyện tập

13. Which observation is a "fingerprint" that warming is greenhouse-driven rather than solar?

(A) Whole atmosphere warming evenly
(B) Troposphere warms while stratosphere cools
(C) Warming only by day
(D) Warming only in summer

Lời giải chi tiết

(B). A brighter Sun would warm the *whole* atmosphere, including the stratosphere. Greenhouse forcing instead warms the lower atmosphere (troposphere) while the stratosphere *cools*, because more outgoing infrared is trapped below. This vertical pattern is a distinctive fingerprint of greenhouse-driven warming and is exactly what is observed.

Bài tập luyện tập

14. Explain ocean acidification and one consequence.

Lời giải chi tiết

The ocean absorbs roughly a quarter of human CO_2 emissions. Dissolved CO_2 reacts with seawater to form carbonic acid, releasing hydrogen ions and lowering the ocean's pH (it has already fallen $\sim$0.1 units, a $\sim$30% rise in acidity). **Consequence:** the reduced availability of carbonate ions makes it harder for corals, shellfish and plankton to build calcium-carbonate skeletons and shells, threatening coral reefs and the marine food web on which fisheries depend.

Bài tập luyện tập

15. A small island state argues it needs "loss and damage" finance, not just adaptation aid. Explain the distinction.

Lời giải chi tiết

Adaptation funds measures to *reduce future harm* (sea walls, early warning). **Loss and damage** refers to harms that adaptation *cannot prevent* — permanent, unavoidable losses such as land submerged by sea-level rise, destroyed ecosystems, cultural heritage and lives lost. A low-lying island contributing almost nothing to emissions may face existential losses no sea wall can stop, so it argues for compensation/finance for these residual damages from the high-emitting countries responsible — a central and contested issue in climate justice.

Bài tập luyện tập

16. Why is water vapour treated as a feedback rather than a forcing?

Lời giải chi tiết

A **forcing** is an externally imposed change to the energy balance (e.g. humans adding CO_2). Humans do not directly control atmospheric water vapour; instead, warming from other forcings raises the temperature, and warmer air holds more water vapour (Clausius–Clapeyron), which then adds *further* warming. Because water vapour responds to, and amplifies, warming

caused by other factors, it acts as a powerful positive **feedback**, not an independent driver.

Bài tập luyện tập

17. Define a climate "tipping point" and give one example.

Lời giải chi tiết

A **tipping point** is a threshold beyond which a part of the climate system shifts, often abruptly and irreversibly, to a new state, driven by self-reinforcing feedbacks. Example: collapse of the Greenland or West Antarctic ice sheet, which past a certain warming would continue melting even if temperatures stabilised, committing the world to multi-metre sea-level rise. Other examples include Amazon dieback and permafrost methane release.

Bài tập luyện tập

18. Contrast the Kyoto Protocol and the Paris Agreement in their approach to targets.

Lời giải chi tiết

Kyoto (1997) set *top-down*, *binding* emission-reduction targets, but only for developed (Annex I) countries, exempting developing nations; several major emitters did not participate or withdrew. **Paris (2015)** is *bottom-up*: nearly all countries, developed and developing, submit their own **Nationally Determined Contributions (NDCs)**, which are voluntary in stringency but subject to transparency and a five-yearly "ratchet" review, aiming to hold warming well below 2 °C and pursue 1.5 °C. Paris is more inclusive but relies on voluntary ambition rather than binding caps.

Bài tập luyện tập

19. A city plants trees, paints roofs white and creates parks to fight heatwaves. Are these adaptation, mitigation, or both? Explain.

Lời giải chi tiết

Primarily **adaptation**: shade, evapotranspiration and higher albedo lower urban temperatures, reducing the "urban heat island" and heat-health risk. There are also **mitigation co-benefits** — trees sequester some carbon, and cooler buildings need less air-conditioning, cutting energy use and emissions. White roofs additionally raise albedo, slightly offsetting warming. Such "no-regret" urban greening delivers both, which is why it is popular.

Bài tập luyện tập

20. Explain why marginalised groups (the poor, women, elderly, indigenous peoples) are often more vulnerable to climate impacts.

Lời giải chi tiết

These groups tend to have higher **sensitivity** and lower **adaptive capacity**. The poor depend on climate-sensitive livelihoods (subsistence farming, fishing), live in exposed locations (floodplains, informal settlements) and lack savings or insurance. Women may have less access to land, credit, information and decision-making. The elderly are physiologically more sen-

sitive to heat and less mobile in disasters. Indigenous peoples often depend directly on local ecosystems. With fewer resources to prepare, cope and recover, the same hazard causes them greater harm — a core dimension of climate injustice.

Bài tập luyện tập

21. A country's emissions are low per capita but high in total, or high per capita but low in total. Why does this matter for climate negotiations?

Lời giải chi tiết

Different metrics assign responsibility differently. A large, populous country may have *high total* emissions (making it pivotal to global outcomes) yet *low per-capita* emissions (implying each citizen emits little and has a right to develop). A small rich country may have *low total* but *high per-capita* emissions. Negotiations clash over which is fair: total-emissions framing pressures large developing economies to cut, while per-capita and historic-cumulative framing places the burden on wealthy, early-industrialising nations. The choice of metric therefore shapes who is expected to act and pay.

Bài tập luyện tập

22. Explain one strength and one limitation of carbon pricing as mitigation.

Lời giải chi tiết

Strength: a carbon tax or emissions-trading scheme puts a price on emissions, giving every firm and consumer a market incentive to cut carbon in whatever way is cheapest, and can raise revenue for green investment or rebates — an efficient, economy-wide signal. **Limitation:** if set too low it barely changes behaviour; it can be regressive (hitting poorer households harder) unless revenues are recycled; and unilateral pricing risks "carbon leakage", where emitting industry relocates to countries without a carbon price, requiring border-adjustment measures and international coordination.

Bài tập luyện tập

23. "Adaptation is enough; we do not need mitigation." Evaluate.

Lời giải chi tiết

Against the claim: adaptation only manages *impacts* and has hard limits — some losses (submerged islands, lost species, exceeded tipping points) cannot be adapted to, and adaptation costs rise steeply as warming increases. Without mitigation the hazard keeps intensifying indefinitely, eventually overwhelming any feasible adaptation. **For a balanced view:** mitigation is essential to limit ultimate warming, while adaptation is necessary because some change is already locked in. **Judgement:** the two are complementary, not alternatives; relying on adaptation alone is unsustainable because it does nothing to stop the underlying driver.

Global Resource Consumption and Security

Mục tiêu Unit: Phân tích các xu hướng toàn cầu về tiêu thụ tài nguyên gắn với tăng trưởng dân số và tầng lớp trung lưu; tính toán và diễn giải **dấu chân sinh thái** (ecological footprint) và năng lực sinh học (biocapacity), khái niệm "ngày vượt ngưỡng" (overshoot day); phân tích **nexus nước–lương thực–năng lượng** và các đánh đổi giữa ba tài nguyên; đánh giá an ninh tài nguyên và các quan điểm về giới hạn tăng trưởng (Malthus, Boserup, Club of Rome); và trình bày các chiến lược quản lí bền vững, tái chế và **kinh tế tuần hoàn (circular economy)**, cùng chỉ số như đường Kuznets môi trường.

3.1 Global Trends in Resource Consumption

3.1.1 Drivers of rising consumption

Global demand for water, food, energy and materials is rising faster than population, driven by three linked forces: **population growth** (more people to feed, house and supply); **rising affluence** — the explosive growth of a global **middle class**, especially in Asia, who consume more meat, electricity, cars and manufactured goods per person; and **urbanisation and technological change**, which raise material and energy intensity. Because consumption per person differs enormously between rich and poor countries, a small rich population can consume more resources than a large poor one. The central question of resource geography is whether such consumption can be sustained within the Earth's biophysical limits.

The **IPAT** identity expresses environmental impact as the product of three factors:

$$I = P \times A \times T$$

where I is environmental **I**mpact, P is **P**opulation, A is **A**ffluence (consumption per person, e.g. GDP per capita), and T is **T**echnology (impact per unit of consumption). Impact can rise even if population stabilises, if affluence grows faster than technology improves; conversely cleaner technology (lower T) can offset growth in P and A.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nhu cầu tài nguyên tăng nhanh hơn dân số do ba lực: **tăng dân số**, **tăng mức sống** (tầng lớp trung lưu bùng nổ ở châu Á tiêu thụ nhiều thịt, điện, ô tô hơn) và **đô thị hoá + công nghệ**. Tiêu thụ theo đầu người chênh lệch rất lớn giữa nước giàu và nghèo. Đồng nhất thức **IPAT**: $I = P \times A \times T$ (Tác động = Dân số $\times$ Mức sống $\times$ Công nghệ) cho thấy tác động môi trường có thể tăng ngay cả khi dân số ổn định, nếu mức sống tăng nhanh hơn tiến bộ công nghệ.

3.1.2 The ecological footprint and biocapacity

The **ecological footprint** measures the area of biologically productive land and sea (expressed in *global hectares*, gha) required to supply the resources a population consumes and to absorb its waste — above all the CO_2 from fossil fuels. It is compared with **biocapacity**: the productive area actually

available. When a population's footprint exceeds its biocapacity it is in **ecological deficit** (or *overshoot*), living beyond the regenerative capacity of its territory and drawing on stocks or on other regions.

$$\text{Number of Earths required} = \frac{\text{humanity's ecological footprint}}{\text{Earth's biocapacity}}$$

Humanity's footprint is currently about 1.7 times the Earth's biocapacity — we use resources as if we had 1.7 planets. **Earth Overshoot Day** marks the date each year on which humanity's demand exceeds what the planet can regenerate in that year; the earlier the date, the deeper the overshoot.

Ví dụ mẫu · Computing an ecological footprint and overshoot

A nation of 50 million people has an average ecological footprint of 6.4 gha per person and a total national biocapacity of 180 million gha. (a) Find the total footprint. (b) State whether it is in deficit or reserve, and by how much. (c) Estimate this nation's "overshoot day".

(a) Total footprint $= 50\,000\,000 \times 6.4 = 3.2 \times 10^8 = 320$ million gha.

(b) Footprint (320 m gha) $>$ biocapacity (180 m gha), so an **ecological deficit** of $320 - 180 = 140$ million gha. The nation demands $320/180 = 1.78$ times its own biocapacity.

(c) Its biocapacity would be exhausted after a fraction $180/320 = 0.5625$ of the year. $0.5625 \times 365 \approx$ day 205, i.e. around late July — after that it draws on other regions' capacity or on natural stocks.

VN **GIẢI THÍCH TIẾNG VIỆT**

Dấu chân sinh thái (ecological footprint) = diện tích đất–biển sinh học (đơn vị *global hectare*) cần để cung cấp tài nguyên và hấp thụ chất thải (nhất là CO_2) của một dân số. **Năng lực sinh học (biocapacity)** = diện tích sinh học sẵn có. Dấu chân $>$ năng lực $\Rightarrow$ **thâm hụt sinh thái (overshoot)**. Hiện nhân loại dùng ≈ 1.7 lần năng lực Trái Đất. **Earth Overshoot Day** là ngày trong năm mà nhu cầu vượt khả năng tái tạo cả năm của Trái Đất — ngày càng sớm nghĩa là vượt ngưỡng càng sâu.

3.1.3 Views on limits: Malthus, Boserup and the Club of Rome

Whether rising consumption must end in crisis has long been debated. **Thomas Malthus** (1798) argued that population grows *geometrically* while food supply grows only *arithmetically*, so population must eventually outrun food, checked by "positive checks" (famine, disease, war) and "preventive checks" (delayed marriage). **Ester Boserup** (1965) reversed the logic: population pressure is a stimulus to **agricultural innovation** — "necessity is the mother of invention" — so people intensify farming and raise yields to feed themselves. The **Club of Rome**'s *Limits to Growth* (1972) used systems modelling to warn that unchecked growth in population, industry and pollution would overshoot planetary limits within a century. Modern **neo-Malthusians** stress finite resources and ecological limits; **cornucopians** (e.g. Simon) trust markets and technology to substitute and innovate around scarcity.

Ví dụ mẫu · Applying Malthus and Boserup

A region's population doubles over 40 years while good farmland is fixed. Predict the outcome under (a) a Malthusian and (b) a Boserupian view.

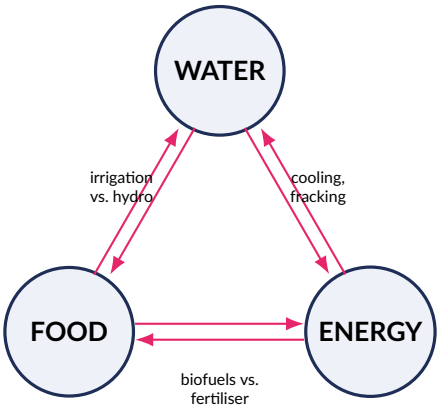
(a) Malthusian: food production cannot keep pace with geometric population growth on fixed land, so food per person falls until "positive checks" — famine, disease, higher mortality — force the population back toward the land's carrying capacity. **(b) Boserupian:** the pressure

of more mouths drives intensification — irrigation, multiple cropping, new high-yield varieties, terracing, fertilisers — raising output per hectare enough to feed the larger population. Historically both dynamics appear: many societies innovated (Boserup), but where innovation or institutions failed, Malthusian crises occurred.

3.2 The Water--Food--Energy Nexus

3.2.1 Interdependence and trade-offs

The **water–food–energy nexus** is the idea that these three resources are so deeply interdependent that a decision about one inevitably affects the others; they cannot be managed in isolation. **Water for energy:** thermal and nuclear power need water for cooling; hydropower stores and controls water; biofuels and shale gas "fracking" consume large volumes. **Energy for water:** pumping, treating, desalinating and distributing water are energy-intensive. **Water for food:** agriculture uses about 70% of all freshwater withdrawals. **Energy for food:** modern farming depends on fossil-fuel-based fertilisers, machinery, processing and transport. **Food for energy:** biofuel crops compete with food crops for land and water.



The water–food–energy nexus: each resource is both an input to, and constrained by, the other two, so managing one in isolation creates trade-offs elsewhere.

VN **GIẢI THÍCH TIẾNG VIỆT**

Nexus nước–lương thực–năng lượng: ba tài nguyên phụ thuộc lẫn nhau, không thể quản lí riêng rẽ. Nước để làm mát nhà máy điện, để tưới ($\approx 70\%$ lượng nước ngọt dùng cho nông nghiệp); năng lượng để bơm, xử lí, khử mặn nước và để sản xuất phân bón, vận hành máy móc nông nghiệp; cây nhiên liệu sinh học lại cạnh tranh đất–nước với cây lương thực. Vì thế mọi quyết định về một tài nguyên đều tạo **đánh đổi (trade-off)** cho hai tài nguyên còn lại.

Ví dụ mẫu · A nexus trade-off

A government promotes maize-based biofuel to cut oil imports and emissions. Trace the nexus consequences.

Growing more maize for fuel diverts **land** and **water** (irrigation) away from food crops, potentially raising food prices and reducing food security. It also requires **energy**-intensive fertiliser, so the net energy and emissions saving may be small. Meanwhile the extra irrigation draws on scarce water that might otherwise supply households or cooling for power stations. Thus a single "energy" policy ripples through the water and food systems — the essence of nexus thinking: apparent gains in one resource can be offset by losses in the others.

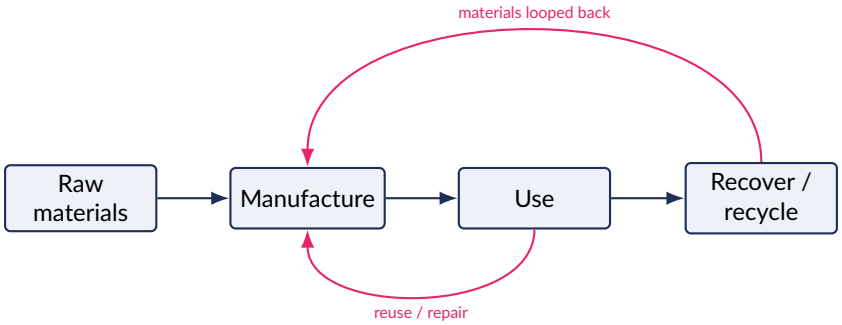
3.2.2 Resource security

Resource security is reliable, affordable access to the water, food and energy a society needs. **Water security** is threatened by scarcity, pollution and competition (including transboundary rivers). **Food security** — the FAO's four pillars are *availability*, *access*, *utilisation and stability* — is threatened by price shocks, conflict, land degradation and climate change. **Energy security** concerns reliable supply at reasonable cost, affected by import dependence, geopolitics and the transition away from fossil fuels. Insecurity in any one resource can trigger political instability, conflict over shared resources, and migration.

3.3 Resource Stewardship and the Circular Economy

3.3.1 From linear to circular

The conventional **linear economy** follows a "take–make–use–dispose" path: extract raw materials, manufacture, consume, then discard as waste. A **circular economy** redesigns this into a loop that keeps materials in use for as long as possible, following the hierarchy of the **"R"s** — *refuse*, *reduce*, *reuse*, *repair*, *refurbish*, *remanufacture*, *recycle* — so that the "waste" of one process becomes the "food" of another. The goal is to **decouple** economic activity from resource depletion and pollution.



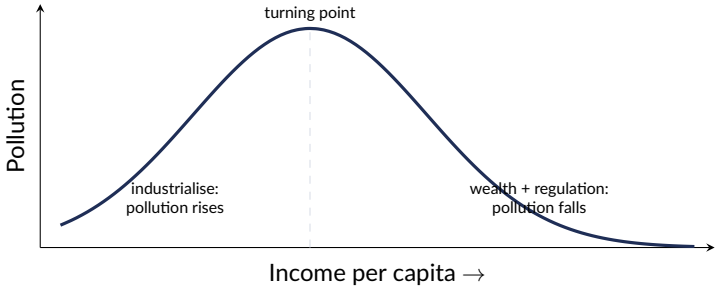
A circular economy loops products and materials back into use (reuse, repair, remanufacture, recycle) instead of discarding them, reducing demand for virgin raw materials and cutting waste.

VN **GIẢI THÍCH TIẾNG VIỆT**

Kinh tế tuyến tính: "khai thác–sản xuất–dùng–vứt bỏ". **Kinh tế tuần hoàn (circular economy)**: giữ vật liệu trong vòng sử dụng lâu nhất có thể theo thứ tự ưu tiên các chữ "R" (từ chối, giảm, tái sử dụng, sửa chữa, tân trang, tái chế), biến "chất thải" của quá trình này thành "nguyên liệu" của quá trình khác. Mục tiêu là **tách rời (decouple)** tăng trưởng kinh tế khỏi cạn kiệt tài nguyên và ô nhiễm.

3.3.2 Recycling, decoupling and the environmental Kuznets curve

Recycling reprocesses waste materials into new products, saving raw materials and energy (recycling aluminium, for example, uses about 95% less energy than making it from bauxite ore). But recycling sits low in the "R" hierarchy — *reducing* and *reusing* save more — and has limits (contamination, downcycling, collection cost, export of waste to poorer countries). The **environmental Kuznets curve (EKC)** hypothesises an inverted-U relationship between income and pollution: environmental degradation rises during early industrialisation, then falls once a country is rich enough to afford cleaner technology and demand regulation. The EKC holds for some *local* pollutants (smoke, river pollution) but is contested for *global* ones like CO_2, where rich-country "improvements" may partly reflect **outsourcing** dirty production to poorer countries.



The environmental Kuznets curve: pollution first rises then falls as income grows. It fits some local pollutants but is disputed for CO_2, partly because wealthy countries may outsource emissions-intensive production.

Ví dụ mẫu · Energy saving from recycling

A city recycles $40\,000$ tonnes of aluminium a year instead of smelting new metal. If recycling uses only 5% of the energy of primary production, and primary aluminium needs 14 MWh per tonne, estimate the annual energy saved.

Primary energy for $40\,000$ t $= 40\,000 \times 14 = 560\,000$ MWh. Recycling uses 5% of this $= 0.05 \times 560\,000 = 28\,000$ MWh. **Energy saved** $= 560\,000 - 28\,000 = 532\,000$ MWh per year (i.e. 95%). This large saving — plus avoided mining and emissions — is why aluminium is one of the most valuable materials to recycle.

(!) Lỗi thường gặp: "Tái chế là giải pháp tốt nhất cho rác thải." Thực ra tái chế đứng *thấp* trong thứ tự ưu tiên các chữ "R": **giảm (reduce)** và **tái sử dụng (reuse)** tiết kiệm tài nguyên và năng lượng nhiều hơn tái chế. Tái chế còn bị giới hạn bởi nhiễm bẩn, "downcycling" và chi phí thu gom. Ưu tiên hàng đầu luôn là *tiêu thụ ít hơn*, không phải tái chế nhiều hơn.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đường Kuznets môi trường (EKC) giả định quan hệ chữ U ngược giữa thu nhập và ô nhiễm: ô nhiễm tăng khi mới công nghiệp hoá rồi giảm khi nước đủ giàu để chi cho công nghệ sạch và luật lệ. EKC đúng với một số chất ô nhiễm *địa phương* (khói, nước thải) nhưng gây tranh cãi với chất ô nhiễm *toàn cầu* như CO_2, một phần vì nước giàu "chuyển" sản xuất bẩn sang nước nghèo (outsourcing/leakage).

3.4 Practice Problems

Bài tập luyện tập

1. In the IPAT identity, which change could reduce impact even as population and affluence rise?

(A) Higher birth rate
(B) Cleaner, more efficient technology
(C) More consumption per person
(D) Faster urbanisation

Lời giải chi tiết

(B). $I = P \times A \times T$. If technology T (impact per unit of consumption) falls fast enough — cleaner energy, greater efficiency — it can offset rising P and A, lowering total impact. The other options raise P or A (or leave T unchanged), increasing impact.

Bài tập luyện tập

2. A country has a per-capita footprint of 5.0 gha, population 80 million, biocapacity 260 million gha. Find the total footprint and state deficit or reserve.

Lời giải chi tiết

Total footprint $= 80\,000\,000 \times 5.0 = 400$ million gha. Compared with biocapacity 260 million gha, footprint exceeds capacity, so an **ecological deficit** of $400 - 260 = 140$ million gha. The country demands $400/260 = 1.54$ times its own biocapacity.

Bài tập luyện tập

3. Humanity's footprint is 1.7 Earths. Estimate Earth Overshoot Day (day of year).

Lời giải chi tiết

If demand is $1.7\times$ capacity, one year's biocapacity is used up after a fraction $1/1.7 = 0.588$ of the year. $0.588 \times 365 \approx$ day 215, i.e. around early August. After that date humanity is drawing down natural stocks faster than they regenerate.

Bài tập luyện tập

4. Contrast the Malthusian and Boserupian views of population and food.

Lời giải chi tiết

Malthus (pessimist): population grows geometrically but food only arithmetically, so population outstrips food and is checked by famine, disease and war (positive checks) or restraint (preventive checks). **Boserup** (optimist): population pressure *induces* agricultural innovation and intensification (irrigation, new crops, multiple cropping), so output rises to feed the larger population — "necessity is the mother of invention." Malthus sees a fixed ceiling; Boserup sees an adjustable one raised by human ingenuity.

Bài tập luyện tập

5. Explain the water–food–energy nexus with one concrete example of a trade-off.

Lời giải chi tiết

The nexus is the mutual dependence of the three resources, so managing one affects the others. **Example:** building a large dam for hydro-*energy* stores water and can supply irrigation for *food*, but it may deprive downstream farms and cities of *water*, flood farmland, and alter sediment supply. Thus a gain in energy security can cost water and food security downstream — resources must be planned together, not in silos.

Bài tập luyện tập

6. Roughly what share of global freshwater withdrawals is used by agriculture, and why does this matter for the nexus?

Lời giải chi tiết

About **70%.** Because agriculture dominates water use, any change in food demand (e.g. more meat, which is water-intensive) or in irrigation efficiency has huge implications for water security; and because pumping and treating that water needs energy, food, water and energy demands are tightly linked. Improving irrigation efficiency is therefore one of the highest-leverage nexus interventions.

Bài tập luyện tập

7. Rank these by the "R" hierarchy from most to least preferable: recycle, reduce, reuse. Justify.

Lời giải chi tiết

Reduce > **Reuse** > **Recycle.** *Reducing* consumption avoids the resource and energy use entirely — the greatest saving. *Reusing* keeps a product in service without reprocessing, saving most of the embodied energy. *Recycling*, while valuable, still requires collection, transport and energy to reprocess materials (and often "downcycles" to lower quality), so it saves less than the first two. Hence recycling is a last resort within the loop, not a first choice.

Bài tập luyện tập

8. A recycler processes 25 000 t of steel; recycling uses 30% of primary energy; primary steel needs 5.5 MWh/t. Find energy saved.

Lời giải chi tiết

Primary energy $= 25\,000 \times 5.5 = 137\,500$ MWh. Recycling uses $0.30 \times 137\,500 = 41\,250$ MWh. **Saved** $= 137\,500 - 41\,250 = 96\,250$ MWh (i.e. 70%). Steel is highly recyclable and magnetic (easy to separate), making recovery economically and energetically attractive.

Bài tập luyện tập

9. What does the environmental Kuznets curve predict, and why is it disputed for CO_2?

Lời giải chi tiết

The EKC predicts an inverted-U: pollution rises with income during industrialisation, then falls once countries are rich enough to afford clean technology and demand regulation. It is disputed for CO_2 because (i) global greenhouse-gas emissions have kept rising overall, and (ii) apparent falls in rich countries partly reflect **outsourcing** emissions-intensive manufacturing to poorer countries ("carbon leakage"), so consumption-based emissions have not fallen as much as territorial ones. The turning point may simply move the pollution elsewhere rather than eliminate it.

Bài tập luyện tập

10. Define ecological deficit and explain how a country can run one indefinitely.

Lời giải chi tiết

An **ecological deficit** exists when a population's ecological footprint exceeds its own biocapacity. A country can sustain it for a long time by (i) **importing** biocapacity — buying food, timber, fuel and goods embodying other regions' land and water; and (ii) **drawing down natural stocks and global commons** — e.g. emitting CO_2 into the shared atmosphere or depleting fisheries and aquifers faster than they regenerate. This is possible only because *other* regions run reserves or the global commons absorb the overshoot — it cannot continue for the planet as a whole.

Bài tập luyện tập

11. State the FAO's four pillars of food security and give one threat to each.

Lời giải chi tiết

Availability — enough food produced/imported; threatened by drought, land degradation, conflict. **Access** — ability to obtain it; threatened by poverty and high prices. **Utilisation** — nutritious use with clean water, sanitation and care; threatened by poor diets and disease. **Stability** — reliable supply over time; threatened by price shocks, conflict and climate variability. All four must hold for genuine food security; a country can produce plenty yet leave the poor food-insecure through lack of access.

Bài tập luyện tập

12. A biofuel policy raises food prices. Explain the mechanism using the nexus.

Lời giải chi tiết

Diverting crops (e.g. maize, sugarcane) or cropland to fuel reduces the land and water available for **food**, cutting food supply and pushing prices up. It also raises demand for the same crops (as both food and fuel), tightening markets further. Meanwhile fertiliser and processing consume **energy**, and irrigation consumes **water** that food or power stations also need. Thus an energy policy transmits directly into food prices through shared land, water and energy — a textbook nexus trade-off.

Bài tập luyện tập

13. Which best decouples growth from resource depletion?

(A) Exporting waste abroad
(B) A circular economy
(C) Raising per-capita consumption
(D) Faster resource extraction

Lời giải chi tiết

(B). A circular economy keeps materials in use through reuse, repair, remanufacture and recycling, so economic activity can continue while demand for virgin raw materials and waste output fall — the definition of decoupling. Exporting waste (A) just relocates the problem; (C) and (D) increase depletion.

Bài tập luyện tập

14. Evaluate whether recycling alone can solve the resource-consumption problem.

Lời giải chi tiết

Recycling helps by saving raw materials and energy, but it cannot alone solve the problem. It sits *low* in the R-hierarchy (reduce and reuse save more); it consumes energy and often "down-cycles" to lower-grade material; contamination and collection costs limit real recovery rates; and it does nothing to curb rising *demand*. If consumption keeps growing (rising P and A in IPAT), even high recycling rates leave total resource use climbing. A genuine solution requires reducing consumption, redesigning products for durability and reuse, cleaner technology and a shift to a circular economy — with recycling as one component, not the whole answer.

Bài tập luyện tập

15. A middle class of 300 million grows to 600 million, each raising meat consumption. Predict the nexus consequences.

Lời giải chi tiết

Doubling a meat-eating middle class sharply raises demand for **food** (grain to feed livestock — several kg of feed per kg of meat), for **water** (meat is highly water-intensive), and for **energy** and land (feed production, processing, refrigeration, transport), while increasing methane and deforestation. The nexus effect is amplified because meat converts crops inefficiently, so consumption of underlying resources rises far faster than the population of consumers — illustrating how rising *affluence* (the A in IPAT), not just population, drives resource pressure.

Bài tập luyện tập

16. Explain why per-capita footprint matters as much as total population for global sustainability.

Lời giải chi tiết

Global impact is population $\times$ average footprint (cf. IPAT). Because per-capita footprints differ by an order of magnitude between rich and poor countries, a relatively small high-consuming population can impose a larger total footprint than a much larger low-consuming one. Focusing only on population growth (mostly in low-footprint regions) while ignoring high per-capita consumption in wealthy regions misdiagnoses the problem: reducing over-consumption where footprints are highest is as important as slowing population growth where they are lowest.

Bài tập luyện tập

17. Give two reasons energy security is becoming more complex during the low-carbon transition.

Lời giải chi tiết

(i) Countries must maintain reliable, affordable supply while shifting from established (but polluting) fossil fuels toward variable renewables (solar, wind), which need storage, grid upgrades and backup to ensure reliability. (ii) The transition changes geopolitical dependencies — from

oil and gas exporters toward suppliers of critical minerals (lithium, cobalt, rare earths) needed for batteries and turbines — creating new import vulnerabilities and supply-chain risks. Managing security therefore now means balancing reliability, affordability, emissions and new resource dependencies simultaneously.

Bài tập luyện tập

18. A nation's footprint per person is 8 gha (world biocapacity per person is ∼1.6 gha). How many Earths if everyone lived this way?

Lời giải chi tiết

Earths required $= 8/1.6 = 5.0$. If the entire world population consumed at this per-capita rate, humanity would need the biocapacity of **five** Earths — an obviously unsustainable level, illustrating the vast inequality in resource use and why high-footprint lifestyles cannot be universalised without drastic efficiency gains.

Bài tập luyện tập

19. Explain how the concept of "decoupling" relates to sustainability, and distinguish relative from absolute decoupling.

Lời giải chi tiết

Decoupling means breaking the link between economic growth and resource use/environmental impact. **Relative decoupling**: impact grows more *slowly* than the economy (impact per unit GDP falls, but total impact still rises). **Absolute decoupling**: total impact *falls* even as the economy grows. Sustainability ultimately requires *absolute* decoupling of resource use and emissions from GDP; relative decoupling alone still increases total pressure and is insufficient. Achieving absolute decoupling is the central challenge of a circular, low-carbon economy.

Bài tập luyện tập

20. A river is shared by three countries; the upstream state builds dams. Explain the resource-security tensions.

Lời giải chi tiết

The upstream state can gain water storage, hydro-energy and irrigation, but by controlling flow it reduces the **water security** of downstream states, cutting their supply for farming (food security) and hydropower (energy security), and trapping sediment that downstream deltas need. Because no single authority governs the transboundary river, this creates a classic "upstream–downstream" conflict over a shared resource, which can escalate to diplomatic disputes or "water wars" unless resolved by treaties and cooperative basin management. It shows resource security is inherently geopolitical.

Bài tập luyện tập

21. Evaluate the claim that technology will always allow humanity to overcome resource limits.

Lời giải chi tiết

Cornucopian support: history shows repeated innovation — the Green Revolution, substitution of scarce materials, efficiency gains, renewable energy — expanding effective resource limits, echoing Boserup and Simon. **Neo-Malthusian caution:** some limits are physical and hard to substitute (freshwater, phosphorus, a stable climate, biodiversity), and technology has side-effects and time-lags; overshoot and tipping points may be crossed before solutions scale. **Judgement:** technology has repeatedly *raised* limits but has not abolished them, and it depends on the right institutions, incentives and investment; prudent policy combines innovation with reduced consumption and circular design rather than assuming technology alone will suffice.

Freshwater

Mục tiêu Unit: Sau khi hoàn thành Unit này, học sinh có thể: mô tả vòng tuần hoàn nước (hydrological cycle) toàn cầu gồm các bể chứa (đại dương, băng hà/chỏm băng, nước ngầm, hồ/sông, sinh khối, khí quyển) và các dòng chuyển (bốc hơi, thoát hơi nước, ngưng tụ, giáng thuỷ, thấm, thấm sâu, dòng chảy mặt, dòng chảy ngầm), đồng thời giải thích khái niệm thời gian lưu trú (residence time) và vì sao nó khác biệt rất lớn giữa các bể chứa; mô tả lưu vực sông (drainage basin) như một hệ thống mở ở quy mô địa phương/khu vực và áp dụng phương trình cân bằng nước lưu vực $P = Q + E \pm \Delta S$; đọc, mô tả và giải thích biểu đồ lũ (storm hydrograph) — nhánh lên, đỉnh lũ, thời gian trễ, nhánh xuống, dòng chảy cơ bản — và các yếu tố khiến lũ "nhanh, gắt" (flashy) hay "chậm, dịu" (subdued), đặc biệt vai trò của đô thị hoá; giải thích các quá trình xói mòn, vận chuyển và lắng đọng của sông, áp dụng khái niệm đường cong Hjulström để xác định sông đang xói mòn, vận chuyển hay lắng đọng trầm tích ở một vận tốc và kích cỡ hạt cho trước; mô tả và giải thích sự hình thành các dạng địa hình sông ở thượng nguồn (thung lũng chữ V, mỏm đồi xen kẽ, thác nước, hẻm vực, hố xoáy) và trung–hạ lưu (khúc uốn sông, dòng chảy xoắn ốc, hồ móng ngựa, đồng bằng ngập lũ, đê tự nhiên, châu thổ); tính chu kỳ lặp lại lũ (recurrence interval) bằng công thức Weibull và diễn giải xác suất vượt ngưỡng hàng năm; phân biệt khan hiếm nước vật lý và khan hiếm nước kinh tế; đánh giá lợi ích và chi phí của đập/hồ chứa lớn qua hai case study (đập Aswan trên sông Nile, đập Tam Hiệp trên sông Dương Tử); và giới thiệu cách tiếp cận quản lý tài nguyên nước tổng hợp (IWRM) qua case study lưu vực sông Colorado.

4.1 The Global Hydrological Cycle

4.1.1 Stores in the hydrological cycle

The **hydrological cycle** (water cycle) is the continuous global circulation of water between the oceans, atmosphere, land surface, and subsurface, driven ultimately by solar energy (which powers evaporation) and gravity (which drives all downhill and downward movement of liquid water). Like any system, the hydrological cycle can be described in terms of **stores** (reservoirs where water is held for some period of time) linked by **fluxes** (the flows/transfers that move water between stores). At the global scale the hydrological cycle behaves as a **closed system**: essentially no matter (water) is added to or lost from planet Earth as a whole (aside from trivial amounts contributed by meteorites or lost to space), even though solar energy continuously enters and heat continuously radiates out. At smaller scales — a single drainage basin, a lake, an aquifer — the same water cycle is more usefully modelled as an **open system**, since water and energy both cross the boundary of any sub-global area under study; this local/regional-scale application is developed in Section 4.2.

Khái niệm cốt lõi · Stores of the hydrological cycle

The principal global stores of water, ranked approximately from largest to smallest by volume, are: (1) **oceans** — by far the largest store, holding roughly 97% of all water on Earth (almost all of it saline); (2) **ice caps, glaciers and permanent snow** — the largest store of *fresh* water, holding roughly two-thirds of all freshwater; (3) **groundwater** — water held in the pore spaces and fractures of rock and sediment below the water table, the largest store of *liquid* freshwater; (4) **lakes and rivers** (surface freshwater) — a comparatively small store despite being the source of most water used directly by people; (5) **soil moisture** — water held in the unsaturated zone of the soil, small in volume but critical for plant growth and agriculture; (6) **biomass** — water

held within the tissues of living organisms, a very small store; and (7) the **atmosphere** — water vapour, cloud droplets and ice crystals suspended in the air, by far the *smallest* store by volume, yet the one that turns over fastest (see residence time, Section 4.1.3).

VN **GIẢI THÍCH TIẾNG VIỆT**

Vòng tuần hoàn nước gồm các **bể chứa (stores)** nối với nhau qua các **dòng chuyển (fluxes)**. Xếp theo thể tích từ lớn đến nhỏ: **đại dương** (lớn nhất, $\approx 97\%$ tổng lượng nước, hầu hết là nước mặn) → **băng hà/chỏm băng** (bể chứa nước ngọt lớn nhất, khoảng hai phần ba tổng lượng nước ngọt) → **nước ngầm** (bể chứa nước ngọt *dạng lỏng* lớn nhất) → **hồ và sông** (nhỏ dù là nguồn nước con người dùng trực tiếp nhiều nhất) → **độ ẩm đất** (nhỏ nhưng thiết yếu cho nông nghiệp) → **sinh khối** (rất nhỏ) → **khí quyển** (nhỏ nhất về thể tích nhưng luân chuyển nhanh nhất). Ở quy mô toàn cầu, vòng tuần hoàn nước được xem là **hệ kín** (trao đổi năng lượng mặt trời nhưng gần như không trao đổi vật chất với vũ trụ); ở quy mô nhỏ hơn như một lưu vực sông, nó được xem là **hệ mở**.

4.1.2 Fluxes (transfers) in the hydrological cycle

Water moves continuously between the stores listed above through a set of named fluxes. **Evaporation** is the conversion of liquid water at the surface of oceans, lakes, rivers, soil, and moist surfaces into water vapour, driven by solar (thermal) energy; **transpiration** is the closely related process by which plants draw up water through their roots and release it as vapour through pores (stomata) in their leaves as a side-effect of gas exchange for photosynthesis. Because evaporation from open/-soil surfaces and transpiration from vegetation are difficult to measure separately over a vegetated land surface, they are very often combined into a single flux, **evapotranspiration (ET)**, representing the total water vapour returned to the atmosphere from a given land area. Water vapour rising into the atmosphere cools, and **condensation** converts it back into liquid droplets or ice crystals, forming clouds and fog; when droplets/crystals grow large enough to overcome updraughts and air resistance, they fall back to the surface as **precipitation** (rain, snow, sleet, hail).

Once precipitation reaches the ground, several further fluxes route the water through the land surface and subsurface. **Infiltration** is the downward entry of surface water into the soil; water that infiltrates may then move by **percolation** — continued downward movement through the soil and underlying rock, driven by gravity, until it reaches the saturated zone and becomes groundwater. Water that cannot infiltrate quickly enough (because the soil is already saturated, frozen, compacted, or simply because rainfall intensity exceeds the soil's infiltration capacity) instead flows across the surface as **overland flow / surface (channel) runoff**, draining rapidly toward the nearest stream channel. Once water is stored underground, it moves slowly through the pore spaces of saturated rock and sediment as **groundwater flow**, following the hydraulic gradient of the water table, typically discharging very gradually into river channels, springs, or the sea.

Fluxes of the hydrological cycle: evaporation (surface water → vapour); transpiration (plant water → vapour); evapotranspiration (combined evaporation + transpiration from a vegetated surface); condensation (vapour → liquid/ice, forming clouds); precipitation (clouds → surface, as rain/snow/sleet/hail); infiltration (surface → soil); percolation (soil → groundwater, continued downward movement under gravity); surface/channel runoff (surface → river channel, the fast pathway); groundwater flow (slow lateral/downward movement of water below the water table, eventually discharging to rivers, springs or the sea).

VN **GIẢI THÍCH TIẾNG VIỆT**

Bốc hơi (evaporation): nước lỏng → hơi nước, nhờ nhiệt mặt trời. **Thoát hơi nước (transpiration)**: thực vật hút nước qua rễ rồi thải ra dạng hơi qua khí khổng ở lá. Vì khó đo riêng hai

quá trình này trên bề mặt có thực vật che phủ, người ta thường gộp thành **bốc thoát hơi nước (evapotranspiration, ET)**. **Ngưng tụ (condensation)**: hơi nước → giọt nước/tinh thể băng, tạo mây. **Giáng thuỷ (precipitation)**: mây rơi xuống mặt đất dưới dạng mưa/tuyết/mưa đá. Trên mặt đất: **thấm (infiltration)** là nước đi vào đất; **thấm sâu (percolation)** là nước tiếp tục đi xuống tới tầng nước ngầm; nước không thấm kịp chảy thành **dòng chảy mặt (overland flow/surface runoff)** nhanh chóng đổ vào sông; nước ngầm di chuyển rất chậm dưới mặt đất thành **dòng chảy ngầm (groundwater flow)**, cuối cùng đổ ra sông, suối hoặc biển.

4.1.3 Residence time

The **residence time** (or turnover time) of a store is the average length of time a molecule of water spends in that store before it is removed by an outflow. It is calculated using the same simple systems-thinking formula used for any storage-and-flow problem:

$$\tau = \frac{M}{F}$$

where M is the quantity of water held in the store and F is the rate at which water leaves that store, expressed in consistent units (so that if M is in cubic kilometres and F is in cubic kilometres per year, τ comes out in years). Residence times across the global hydrological cycle span an enormous range — from a matter of days to many thousands of years — and this range is one of the most important ideas in the whole topic, because it determines how quickly a given store can respond to (and recover from) a disturbance such as pollution, drought, or a change in extraction rate.

Approximate order-of-magnitude residence times (illustrative, not exact): atmospheric water vapour ≈ 8–10 days (the shortest of any major store, because evaporation and precipitation continuously and rapidly cycle a comparatively tiny quantity of water); river channels ≈ 2–6 months; soil moisture ≈ 1–2 months in the active root zone; lakes $\approx$ years to decades (very variable with lake size and outflow rate); shallow groundwater $\approx$ tens to hundreds of years; the ocean as a whole $\approx 3\,000$–$4\,000$ years; deep groundwater and large ice sheets (Antarctica, Greenland) $\approx$ thousands to tens of thousands of years, among the longest residence times of any water store on Earth.

VN **GIẢI THÍCH TIẾNG VIỆT**

Thời gian lưu trú (residence time) $\tau = M/F$, với M là lượng nước trong bể chứa và F là tốc độ dòng ra. Khí quyển có τ ngắn nhất (chỉ khoảng 8–10 ngày) vì bốc hơi và giáng thuỷ luân chuyển lượng hơi nước rất nhỏ một cách liên tục và nhanh chóng; ngược lại, nước ngầm sâu và các khối băng lớn (Nam Cực, Greenland) có τ lên tới hàng nghìn đến hàng chục nghìn năm. Ý nghĩa quan trọng: bể chứa có τ ngắn phản ứng gần như tức thời với thay đổi (ô nhiễm khí quyển tự làm sạch trong vài ngày), còn bể chứa có τ dài phản ứng cực kỳ chậm — một khi nước ngầm sâu hay băng hà bị ô nhiễm hoặc cạn kiệt, việc phục hồi có thể mất hàng thế kỷ, nên phòng ngừa quan trọng hơn nhiều so với khắc phục.

Ví dụ mẫu · Residence time of a deep aquifer

A deep confined aquifer holds an estimated 4.8×10^{11} m^3 of groundwater. Natural discharge to springs and rivers, plus a small amount of human extraction, removes water from the aquifer at a rate of 8.0×10^{7} m^3 per year. Calculate the residence time of water in this aquifer, and comment on the implication for an aquifer that becomes contaminated by an industrial pollutant.

Apply $\tau = M/F$:

$$\tau = \frac{4.8 \times 10^{11}\ \text{m}^3}{8.0 \times 10^{7}\ \text{m}^3\text{yr}^{-1}} = 6\,000\ \text{years}.$$

A residence time of $6\,000$ years means that, on average, water entering this aquifer today will remain there for six millennia before being naturally flushed out. If such an aquifer becomes contaminated, natural processes alone cannot be relied upon to clean it within any humanly meaningful timeframe — active remediation (if even feasible for such a large, inaccessible store) or, more realistically, permanent avoidance of contamination in the first place, is the only practical strategy. This is precisely why deep groundwater is generally treated as a effectively *non-renewable* resource on human timescales, even though it is technically part of the "renewable" hydrological cycle.

Ví dụ mẫu · Comparing residence times across stores

A river channel reach holds approximately 2.5×10^{6} m^3 of water at any moment, with water flowing through (and being replaced) at a rate of 3.0×10^{7} m^3 per year. Calculate the residence time of water in this river reach, express it in days, and compare it qualitatively with the $6\,000$-year residence time of the deep aquifer above.

$$\tau = \frac{2.5 \times 10^{6}\ \text{m}^3}{3.0 \times 10^{7}\ \text{m}^3\text{yr}^{-1}} = 0.083\ \text{years} \approx 30\ \text{days}.$$

The river's residence time (about one month) is roughly $73\,000$ times shorter than the deep aquifer's $6\,000$ years. This enormous contrast illustrates why rivers recover from short-term pollution incidents (e.g., an accidental spill) within weeks, while contamination of deep groundwater is, for practical purposes, permanent — reinforcing why groundwater protection legislation is typically far stricter than surface-water discharge standards.

VN **GIẢI THÍCH TIẾNG VIỆT**

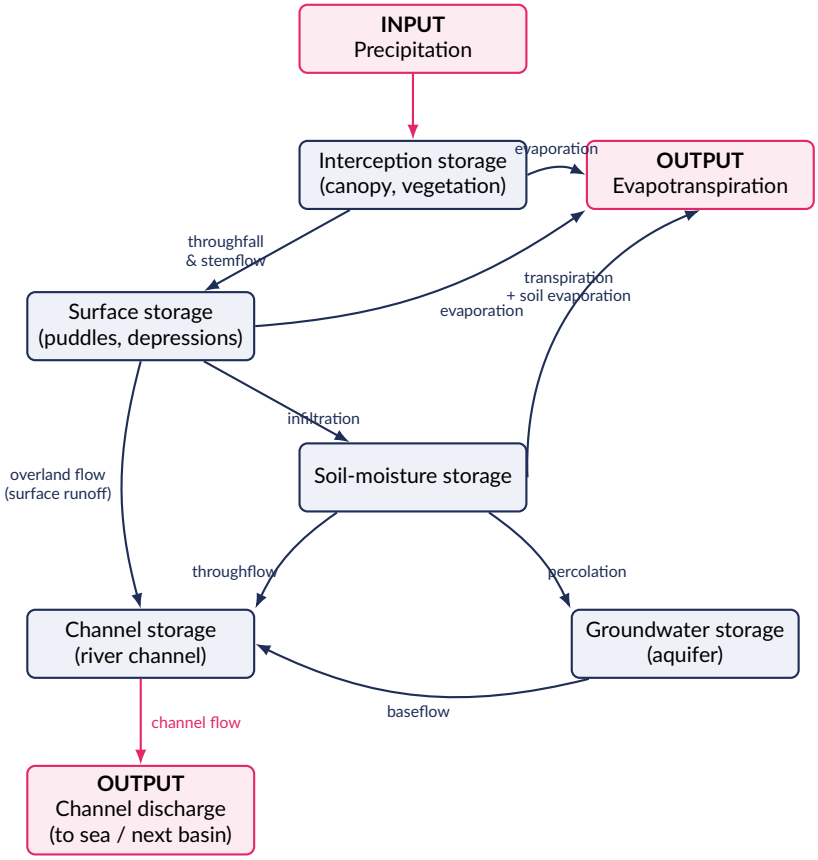
Hai ví dụ trên cho thấy độ lớn chênh lệch khổng lồ giữa thời gian lưu trú của các bể chứa khác nhau: một đoạn sông chỉ mất khoảng 1 tháng để "thay nước" hoàn toàn, trong khi một tầng nước ngầm sâu có thể mất tới $6\,000$ năm. Đây là lý do sông có thể tự phục hồi sau sự cố ô nhiễm ngắn hạn trong vài tuần, còn ô nhiễm nước ngầm sâu gần như là vĩnh viễn xét theo thang thời gian con người — và cũng là lý do luật bảo vệ nước ngầm thường nghiêm ngặt hơn nhiều so với tiêu chuẩn xả thải ra mặt nước.

4.2 The Drainage Basin as an Open System

4.2.1 Inputs, stores, flows and outputs

At the scale of a single **drainage basin** (also called a river basin, catchment, or watershed — the total area of land that drains into a particular river and its tributaries, bounded by a ridge of high land called the **watershed** or drainage divide), the hydrological cycle is best modelled as a local, **open system**: energy and matter (water) both cross the drainage basin's boundary. The single **input** to a drainage basin system is **precipitation** falling within the basin. Water is held temporarily within the basin in several distinct **stores**: **interception storage** (water held on the surfaces of vegetation — leaves, branches, stems — before it reaches the ground); **surface storage** (water held in small depressions, puddles, and surface detention before it either infiltrates or runs off); **soil-moisture storage** (water held in the unsaturated zone of the soil, available for plant uptake); **groundwater storage** (water held in the saturated zone below the water table, within permeable rock or sediment, i.e. an **aquifer**); and

channel storage (water held within the river channel itself at any given moment). Water is transferred between these stores, and ultimately out of the basin, by the fluxes already introduced in Section 4.1.2 — infiltration, percolation, overland flow, and groundwater flow — together with two additional near-channel transfers: **throughflow** (the lateral movement of infiltrated water through the soil, roughly parallel to the slope, toward the river channel) and **baseflow** (the slow, sustained contribution of groundwater to river discharge, which keeps a river flowing even during prolonged dry spells with no recent rainfall). The drainage basin system has two **outputs**: **evapotranspiration** (water returned directly to the atmosphere) and **channel discharge** (water leaving the basin as streamflow, ultimately reaching the sea, an inland lake, or a neighbouring basin).



The drainage basin as an open system: the single input (precipitation) is partitioned among five stores (interception, surface, soil-moisture, groundwater, channel) linked by transfer pathways (throughfall/stemflow, infiltration, percolation, overland flow, throughflow, baseflow), before ultimately leaving the basin through two outputs: evapotranspiration back to the atmosphere, and channel discharge downstream.

VN **GIẢI THÍCH TIẾNG VIỆT**

Lưu vực sông là một **hệ thống mở** ở quy mô địa phương: **đầu vào** duy nhất là giáng thuỷ; **bể chứa** gồm: nước đọng trên tán lá (interception), nước đọng trên bề mặt (surface storage), độ ẩm đất (soil-moisture storage), nước ngầm trong tầng chứa nước (groundwater storage/aquifer), và nước trong lòng sông (channel storage); các **dòng chuyển** nối các bể chứa gồm thấm (infiltration), thấm sâu (percolation), dòng chảy mặt (overland flow), **dòng chảy ngang trong đất (throughflow)** và **dòng chảy cơ bản từ nước ngầm (baseflow)** — baseflow chính là lý do sông vẫn còn nước chảy ngay cả khi đã lâu không mưa. **Đầu ra** gồm bốc thoát hơi nước (trả lại khí quyển) và lưu lượng dòng chảy ra khỏi lưu vực (đổ ra biển hoặc lưu vực kế cận).

4.2.2 The drainage basin water balance

Because a drainage basin is a system, the principle of conservation of mass applies directly to it: over any given time period, the total water entering the basin (precipitation) must equal the total water

leaving the basin (as evapotranspiration and channel discharge) plus or minus any net change in the amount of water held in storage within the basin. This relationship is formalised as the **drainage basin water balance equation**:

$$P = Q + E \pm \Delta S$$

where P is **precipitation** (input), Q is **channel discharge / runoff / streamflow** (output), E is **evapotranspiration** (output), and ΔS is the **net change in storage** over the period considered (positive if storages such as soil moisture, groundwater or channel/lake levels increase over the period; negative if they decrease). All four terms are conventionally expressed as an equivalent depth of water (millimetres) spread evenly over the basin's area, which allows basins of very different sizes to be compared directly. Over a long-run average (many years), ΔS tends toward zero for a basin in equilibrium, so the equation simplifies to $P \approx Q + E$; over shorter periods (a single season or year), ΔS can be substantial in either direction, e.g. positive during a wet season as soil and groundwater stores recharge, negative during a drought as those stores are progressively drawn down.

VN **GIẢI THÍCH TIẾNG VIỆT**

Phương trình cân bằng nước lưu vực: $P = Q + E \pm \Delta S$, trong đó P là giáng thuỷ (đầu vào), Q là lưu lượng dòng chảy/dòng chảy mặt (đầu ra), E là bốc thoát hơi nước (đầu ra), và ΔS là **thay đổi lượng nước lưu trữ** trong lưu vực (dương nếu bể chứa tăng, âm nếu giảm). Tất cả thường quy về đơn vị chiều sâu nước (mm) trải đều trên diện tích lưu vực để có thể so sánh các lưu vực khác kích thước. Trung bình nhiều năm, $\Delta S \approx 0$ (lưu vực ở trạng thái cân bằng), nên phương trình rút gọn thành $P \approx Q + E$; nhưng trong một mùa hoặc một năm cụ thể, ΔS có thể lệch đáng kể theo hướng dương (mùa mưa, bể chứa được bổ sung) hoặc âm (hạn hán, bể chứa bị rút cạn dần).

Ví dụ mẫu · Solving the water balance for runoff, Q

A drainage basin receives an average annual precipitation of $P = 1\,200$ mm. Evapotranspiration losses are measured at $E = 450$ mm for the year, and the basin is judged to be in long-run storage equilibrium ($\Delta S \approx 0$). Calculate the annual runoff (streamflow), Q, leaving the basin.

Rearrange the water balance equation to solve for Q: $Q = P - E - \Delta S$.

$$Q = 1\,200 - 450 - 0 = \textbf{750}\ \text{mm}.$$

Roughly 62.5% of the precipitation falling on this basin ($750/1\,200$) leaves as channel discharge, with the remaining 37.5% returned directly to the atmosphere by evapotranspiration — a plausible split for a temperate basin with moderate vegetation cover and no long-term change in storage.

Ví dụ mẫu · Solving the water balance for precipitation, P

A gauging station records an annual channel discharge of $Q = 380$ mm (expressed as an equivalent depth over the basin) and evapotranspiration of $E = 520$ mm. Over the same year, soil-moisture and groundwater surveys indicate that storage *increased* by $\Delta S = +40$ mm (a wetter-than-average year recharged the basin's stores). Calculate the total precipitation, P, that must have fallen on the basin.

Rearrange to solve for P: $P = Q + E + \Delta S$ (adding ΔS because storage increased, so this

water must be accounted for on the input side of the balance).

$$P = 380 + 520 + 40 = \textbf{940}\ \text{mm}.$$

Ví dụ mẫu · Solving the water balance for change in storage, ΔS

A drainage basin receives $P = 950$ mm of precipitation in a given year. Channel discharge for the same year is measured at $Q = 600$ mm, and evapotranspiration is estimated at $E = 300$ mm. Calculate ΔS and state, with a reason, whether the basin's water stores grew or shrank over the year.

Rearrange to solve for ΔS: $\Delta S = P - Q - E$.

$$\Delta S = 950 - 600 - 300 = +\textbf{50}\ \text{mm}.$$

Because ΔS is positive, the basin's combined stores (soil moisture, groundwater, channel/lake levels) grew by an amount equivalent to 50 mm of water depth over the year — more precipitation fell than left the basin as discharge and evapotranspiration combined, so the surplus was retained in storage (e.g. recharging the water table).

VN **GIẢI THÍCH TIẾNG VIỆT**

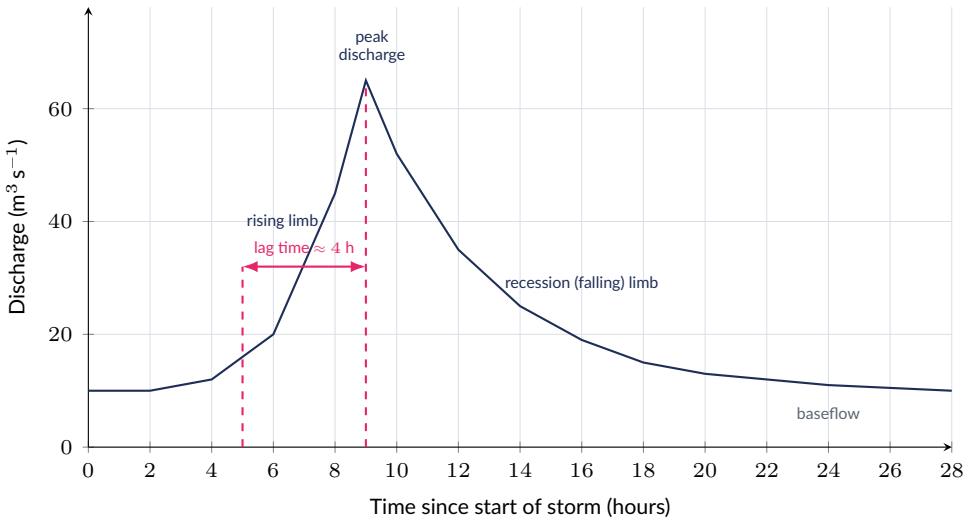
Ba ví dụ trên minh hoạ cách giải phương trình cân bằng nước cho *bất kỳ* đại lượng nào còn thiếu, miễn biết ba đại lượng còn lại: luôn viết lại phương trình gốc $P = Q + E \pm \Delta S$ rồi cô lập đại lượng cần tìm. Lưu ý dấu của ΔS: nếu bể chứa **tăng** trong kỳ, ΔS dương và phải được **cộng** vào $Q + E$ khi tính P (vì lượng nước đó đến từ giáng thuỷ nhưng chưa rời khỏi lưu vực); nếu bể chứa **giảm**, ΔS âm.

4.3 The Storm Hydrograph

4.3.1 Reading a hydrograph

A **storm hydrograph** is a graph showing how the **discharge** of a river — the volume of water passing a given point in the channel per unit time, conventionally measured in cubic metres per second (m^3s^{-1}, sometimes called "cumecs") — changes over the hours and days following a rainfall event. Storm hydrographs are the single most important diagnostic tool for describing and comparing how different drainage basins respond to the same rainfall input, and for assessing flood risk.

Key features of a storm hydrograph: baseflow is the discharge sustained by slow groundwater seepage into the channel, present continuously even without recent rainfall, and forming the hydrograph's "background" level before and long after a storm. The **rising limb** is the segment of the graph where discharge increases rapidly as storm runoff (overland flow and throughflow) reaches the channel. **Peak discharge** is the highest point reached by the hydrograph, corresponding to the moment when the maximum combined volume of storm runoff is passing the gauging station. The **lag time** is the time interval between the peak of the rainfall event (on an accompanying hyetograph, a bar chart of rainfall intensity over time) and the peak of the resulting discharge — it measures how quickly a basin translates rainfall into peak streamflow. The **recession limb** (or falling limb) is the segment after the peak where discharge gradually declines, as the fast surface and throughflow contributions are exhausted and the hydrograph gradually returns toward the baseflow level.



A storm hydrograph for a rural catchment. The antecedent rainfall event peaked at approximately hour 5; discharge rises from a baseflow of about 10 m^{3}s^{-1}, peaks at 65 m^{3}s^{-1} around hour 9 (a lag time of roughly 4 hours), then declines gradually back toward baseflow over the following day.

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Biểu đồ lũ (storm hydrograph) biểu diễn **lưu lượng dòng chảy (discharge)** của sông theo thời gian sau một trận mưa. **Dòng chảy cơ bản (baseflow)**: mức nền do nước ngầm rỉ ra liên tục. **Nhánh lên (rising limb)**: lưu lượng tăng nhanh khi nước mưa đổ về sông. **Đỉnh lũ (peak discharge)**: điểm cao nhất. **Thời gian trễ (lag time)**: khoảng thời gian giữa *đỉnh mưa* (trên biểu đồ mưa — hyetograph) và *đỉnh lũ* — đo tốc độ lưu vực chuyển mưa thành lũ. **Nhánh xuống (recession/falling limb)**: lưu lượng giảm dần trở lại mức dòng chảy cơ bản sau khi nguồn nước mưa nhanh (dòng chảy mặt, throughflow) cạn dần.

(!) Lỗi thường gặp: Đừng nhầm **thời gian trễ (lag time)** với **tổng thời gian kéo dài của trận lũ**. Lag time chỉ đo khoảng cách giữa *đỉnh mưa* và *đỉnh lũ* (ví dụ 4 giờ trong biểu đồ trên) — nó không phải là thời gian từ lúc mưa bắt đầu đến lúc lũ kết thúc, và cũng không phải thời gian nhánh xuống kéo dài (nhánh xuống thường kéo dài lâu hơn nhiều so với lag time, vì nước rút chậm hơn nhiều so với tốc độ nước dâng).

4.3.2 Flashy versus subdued hydrographs

Not every basin responds to the same rainfall event in the same way. A **"flashy" hydrograph** shows a short lag time and a high, sharply-peaked rising limb — discharge rises quickly to a large peak soon after rainfall, and typically falls away quickly afterward too — and is associated with a substantially elevated flood risk, because the basin gives little advance warning between the rainfall and the resulting peak flow. A **"subdued" hydrograph** shows a long lag time and a lower, more gently-rounded peak — rainfall is absorbed and released slowly, spreading the same total volume of runoff over a longer period and a lower maximum discharge, giving more time for warning and response and posing a lower flood risk for the same rainfall input.

Factors producing a flashy hydrograph (short lag, high peak, elevated flood risk): a **small, circular-shaped** basin (rainfall reaches the channel from all directions at similar times); **steep slopes** (rapid overland flow and throughflow); **impermeable rock/soil** (e.g. clay or bare rock, forcing overland flow rather than infiltration); **sparse vegetation cover** (little interception, so more rainfall reaches the ground directly and quickly); **high antecedent soil moisture / saturated ground** (from previous rainfall, so infiltration capacity is already used up); **intense, short-duration rainfall**; and, critically, **urbanisation** — impermeable surfaces (roads, roofs, pavement) that eliminate infiltration almost entirely, combined with efficient artificial drainage networks (storm drains, gutters, culverts) engineered to remove water from the surface as fast as possible, together sharply shorten lag time and substantially raise peak discharge for a given storm. **Factors producing a subdued hydrograph (long lag, low peak, reduced flood risk):** a **large, elongated** basin (runoff from different parts of the basin arrives at the outlet at more staggered times); **gentle slopes**; **permeable rock/soil** (e.g. sandstone, chalk, or well-structured soil, promoting infiltration and percolation over overland flow); **dense vegetation cover** (substantial interception and transpiration, delaying and reducing the volume of water reaching the channel); and **dry antecedent conditions** (spare infiltration capacity available to absorb the new rainfall).

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Lưu vực khác nhau phản ứng khác nhau với cùng một trận mưa. **Lũ "nhanh, gắt" (flashy)**: lag time ngắn, đỉnh cao và nhọn — rủi ro lũ lụt cao vì ít thời gian cảnh báo. **Lũ "chậm, dịu" (subdued)**: lag time dài, đỉnh thấp và bo tròn — rủi ro lũ lụt thấp hơn. Các yếu tố gây lũ flashy: lưu vực nhỏ/hình tròn, dốc, đá/đất không thấm nước, thực vật thưa, đất đã bão hoà nước từ trước, mưa cường độ cao trong thời gian ngắn — và đặc biệt là **đô thị hoá**: bề mặt không thấm (đường nhựa, mái nhà) và hệ thống cống rãnh hiệu quả khiến nước gần như không thấm mà chảy thẳng và nhanh ra sông, làm lag time rút ngắn mạnh và đỉnh lũ tăng cao rõ rệt — đây là lý do các lưu vực đô thị hoá nhanh đối mặt nguy cơ lũ lụt gia tăng dù lượng mưa không đổi.

Ví dụ mẫu · Reading a hydrograph and classifying a rural catchment

The table below gives discharge readings for a rural, largely forested catchment following a storm in which rainfall intensity peaked at hour 3.

Time (hours)	0	3	15	30
Discharge (m^3s^{-1})	8	9	58	14

Given that peak discharge in this record occurs at hour 15, (a) state the peak discharge and the lag time, and (b) classify the hydrograph as flashy or subdued, justifying your answer with reference to a plausible catchment characteristic.

(a) Peak discharge $= 58$ m^3s^{-1}, occurring at hour 15. Rainfall peaked at hour 3, so lag time $= 15 - 3 =$ **12** hours.

(b) A 12-hour lag time is long, and the rise from baseflow (8 m^3s^{-1}) to peak (58 m^3s^{-1}) is gradual rather than sharp — this is a **subdued** hydrograph, consistent with the catchment being described as rural and forested: dense vegetation intercepts and delays rainfall, tree roots and organic litter promote high infiltration rates, and the absence of impermeable urban surfaces or efficient artificial drainage allows water to reach the channel slowly via throughflow and groundwater rather than rapid overland flow.

Ví dụ mẫu · Comparing a rural and an urbanised catchment

The same 40 mm storm falls on two neighbouring, similarly-sized catchments on the same day: Catchment A is rural and forested; Catchment B has been extensively urbanised over the past twenty years (new roads, roofs, and a piped storm-drain network). Rainfall peaks at hour 2 in both catchments. Catchment A's discharge peaks at 35 m^{3}s^{-1} at hour 14; Catchment B's discharge peaks at 95 m^{3}s^{-1} at hour 4. (a) Calculate the lag time for each catchment. (b) Explain why the two hydrographs differ so much despite identical rainfall, and state which catchment faces the greater flood risk.

(a) Catchment A: lag time $= 14 - 2 = 12$ hours. Catchment B: lag time $= 4 - 2 =$ **2** hours.

(b) Catchment B's urbanisation has replaced permeable, vegetated surfaces with impermeable roofs and roads, essentially eliminating infiltration, while its piped drainage network transports the resulting overland flow directly and rapidly to the channel, bypassing the slower soil throughflow and groundwater pathways still active in Catchment A. This produces a far shorter lag time (2 vs. 12 hours) and a much higher, sharper peak discharge (95 vs. 35 m^{3}s^{-1}) in Catchment B for the identical rainfall input. **Catchment B (the urbanised catchment) faces the substantially greater flood risk**: not only is its peak flow nearly three times higher, but the very short lag time leaves residents and emergency services far less warning time to respond before the river peaks.

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Hai ví dụ trên cho thấy cách đọc dữ liệu bảng để xác định **đỉnh lũ**, **thời điểm đỉnh lũ**, tính **lag time** (đỉnh lũ trừ đỉnh mưa), rồi phân loại flashy/subdued dựa trên độ dài lag time và độ dốc/độ cao của đỉnh. Ví dụ so sánh lưu vực nông thôn và lưu vực đô thị hoá minh hoạ trực tiếp lý do đô thị hoá làm tăng rủi ro lũ lụt: bề mặt không thấm + cống rãnh hiệu quả rút ngắn mạnh lag time và đẩy cao đỉnh lũ dù lượng mưa giống hệt nhau.

4.4 River Channel Processes

4.4.1 Erosion, transportation and deposition

Rivers continuously reshape the landscape they flow through via three interacting groups of processes. **Erosion** processes remove and detach material from the river bed and banks: **hydraulic action** is the sheer mechanical force of moving water itself, compressing air into cracks in the bank/bed and prising material loose; **abrasion** (also called corrasion) is the wearing away of the bed and banks by the load of transported sediment (sand, pebbles) grinding, scraping and rubbing against them as they are carried along — typically the most effective erosion process in high-energy rivers; **attrition** is the process by which transported particles themselves collide with one another, progressively breaking, chipping and rounding each other into smaller, smoother fragments as they move downstream (attrition changes the character of the load rather than eroding the channel itself); and **solution** (also called corrosion) is the chemical dissolving of soluble rock (such as limestone or chalk) by slightly acidic river water.

Transportation processes then carry the eroded material downstream, with different processes suited to different particle sizes and available river energy: **traction** is the rolling and dragging of the largest, heaviest particles (boulders, large stones) along the river bed, requiring the greatest energy; **saltation** is the intermittent bouncing and hopping of medium-sized particles (typically sand-sized) along the bed, briefly lifted by turbulence before settling again; **suspension** is the carrying of fine particles (silt and clay) held up within the main body of flowing water by turbulence, without regularly touching the bed — responsible for the visibly muddy, turbid colour of many rivers, especially in flood; and **solution** also transports dissolved chemical ions invisibly within the water itself.

Deposition occurs whenever the velocity (and hence the kinetic energy) of a river falls below

the threshold required to keep a given particle size in transport — the largest, heaviest particles are dropped first as velocity declines, with progressively finer particles deposited as velocity continues to fall, producing the characteristic downstream (and lateral) sorting of sediment size seen in real river deposits.

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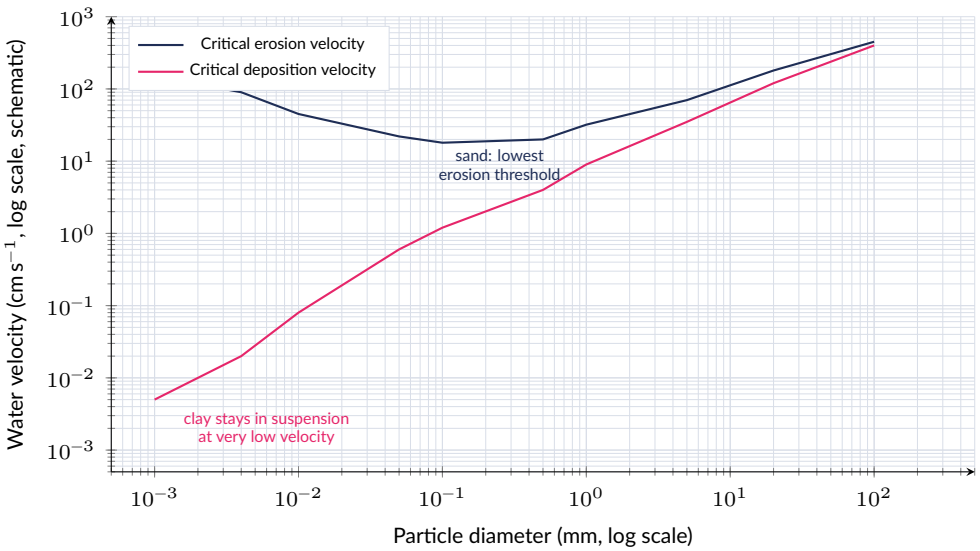
Xói mòn (erosion): **hydraulic action** (lực cơ học của dòng nước đẩy khí vào khe nứt bờ/đáy sông), **mài mòn (abrasion/corrasion)** (vật liệu mang theo cọ xát vào lòng sông — thường hiệu quả nhất), **cọ xát lẫn nhau (attrition)** (các hạt va chạm nhau làm mòn và tròn dần), **hoà tan (solution/corrosion)** (nước hơi acid hoà tan đá dễ tan như đá vôi). **Vận chuyển (transportation)**: **traction** (lăn/kéo hạt lớn nhất dọc đáy), **saltation** (hạt cỡ trung nhảy cóc), **suspension** (hạt mịn lơ lửng trong dòng chảy — khiến nước sông đục), **solution** (ion hoà tan vô hình). **Lắng đọng (deposition)** xảy ra khi vận tốc/năng lượng sông giảm xuống dưới mức cần thiết để tiếp tục vận chuyển một cỡ hạt nhất định — hạt nặng lắng trước, hạt mịn lắng sau, tạo ra sự phân loại trầm tích theo kích cỡ.

4.4.2 The Hjulström curve

The relationship between water velocity and the behaviour of a given particle size (erosion, transportation, or deposition) is classically summarised by the **Hjulström curve**, a graph of critical water velocity (vertical axis, log scale) against particle diameter (horizontal axis, log scale). For any given particle size, there is a **critical erosion velocity**: the minimum velocity required to lift and entrain a stationary particle of that size from the bed into transport. There is also a lower **critical deposition (fall/settling) velocity**: the velocity below which a particle already in transport will settle out of suspension/transport onto the bed. Crucially, these two threshold velocities are *not* the same for a given particle size, and the gap between them (the **zone of transportation**) means that once a particle has been eroded and entrained, it continues to be transported across a fairly wide range of velocities, even as the river gradually slows, until velocity finally drops below the (lower) deposition threshold.

The single most important and counter-intuitive feature of the Hjulström curve concerns very fine particles. Coarse and medium sand (≈ 0.1–1 mm) sits at the *minimum* of the erosion-velocity curve — it is the easiest particle size of all to erode, requiring only a modest velocity (order of tens of centimetres per second) to lift from the bed. Moving toward larger particles (gravel, pebbles, boulders), progressively higher velocities are needed to erode them, simply because they are heavier. But moving toward *smaller* particles (silt, and especially clay), the erosion-velocity threshold rises again, often dramatically — because fine clay particles are strongly **cohesive**: electrostatic and chemical bonding between microscopic clay platelets, and their tendency to compact into a dense, coherent mass on the bed, makes them physically difficult to prise loose, even though each individual particle is extremely light. This produces the Hjulström curve's characteristic asymmetric "U"/hook shape for the erosion threshold, and it means that, remarkably, a river may need a *higher* velocity to erode consolidated clay than it needs to erode medium sand — even though, once eroded, that same clay requires only an extremely low velocity to remain in suspension and an even lower velocity before it will finally settle back out.



A simplified, schematic Hjulström-curve-style diagram (values are illustrative, not exact). The upper curve is the critical velocity needed to *erode* a stationary particle of a given size; the lower curve is the critical velocity below which a transported particle will be *deposited*. Medium/coarse sand has the lowest erosion threshold of any particle size; clay requires a comparatively high velocity to erode (cohesion between fine particles) despite requiring only a very low velocity to remain in suspension and an even lower velocity before it finally settles.

Reading the Hjulström curve at velocity v for a particle of diameter d: if v is above the erosion-velocity threshold for d, the river is actively **eroding** that particle size from the bed (and, if already moving, continuing to transport it). If v is below the erosion threshold but above the deposition threshold for d, the river cannot newly erode stationary particles of that size, but any particle of size d already in transport remains in transport (**transportation zone**) — erosion and deposition are not simply mirror images of one another. If v is below the deposition threshold for d, particles of that size fall out of transport and are **deposited** onto the bed.

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Đường cong Hjulström biểu diễn vận tốc dòng nước cần thiết để xói mòn, vận chuyển hoặc lắng đọng một cỡ hạt nhất định. Với một hạt đường kính d ở vận tốc v: nếu v cao hơn **ngưỡng xói mòn** của d thì sông đang xói mòn (và vận chuyển) hạt đó; nếu v thấp hơn ngưỡng xói mòn nhưng vẫn cao hơn **ngưỡng lắng đọng**, hạt đã ở trong dòng chảy sẽ tiếp tục được vận chuyển dù không có hạt mới nào bị xói lên (**vùng vận chuyển**); nếu v thấp hơn ngưỡng lắng đọng, hạt sẽ lắng xuống đáy. Điểm đặc biệt: **cát trung bình** (≈ 0.1–1 mm) có ngưỡng xói mòn *thấp nhất* trong mọi cỡ hạt, trong khi **đất sét** lại cần vận tốc *cao* để xói mòn (do lực cố kết giữa các hạt sét) mặc dù chỉ cần vận tốc cực thấp để tiếp tục lơ lửng và lắng đọng.

Ví dụ mẫu · Applying the Hjulström curve (medium sand)

A river reach flows at 40 cm s^{-1} over a bed of stationary medium sand (diameter ≈ 0.5 mm), for which the schematic curve above gives a critical erosion velocity of about 20 cm s^{-1} and a critical deposition velocity of about 4 cm s^{-1}. State, with reasoning, what is happening to this sand.

Because the flow velocity (40 cm s^{-1}) exceeds the critical erosion velocity for this particle size (20 cm s^{-1}), the river has enough energy to lift stationary sand grains from the bed into transport — the sand is being **actively eroded** (and, once entrained, transported, since 40 cm s^{-1} is also well above the 4 cm s^{-1} deposition threshold).

Ví dụ mẫu · Applying the Hjulström curve as a river decelerates

As a river approaches its mouth, its velocity falls from 30 cm s^{-1} to 3 cm s^{-1} over a bed of fine sand/coarse silt (diameter ≈ 0.05 mm), for which the erosion threshold is about 22 cm s^{-1} and the deposition threshold is about 0.6 cm s^{-1}. Describe what happens to this sediment at each of the two velocities.

At 30 cm s^{-1}: this exceeds the 22 cm s^{-1} erosion threshold, so the river is actively eroding this grain size from the bed as well as transporting any that are already loose.

At 3 cm s^{-1}: this is below the 22 cm s^{-1} erosion threshold (so the river can no longer newly erode stationary grains of this size), but it is still above the 0.6 cm s^{-1} deposition threshold — so any of this sediment that is already suspended or in transport **continues to be transported** rather than immediately settling out. Only once velocity falls below 0.6 cm s^{-1} would this sediment finally be deposited. This illustrates why a river can carry a substantial sediment load well beyond the point where it could newly erode fresh material of the same size — the wide gap between the erosion and deposition thresholds (the transportation zone) delays deposition until velocity drops much further.

Ví dụ mẫu · The clay-cohesion exception

A river flows at a moderate 25 cm s^{-1} over a bed of consolidated clay (diameter ≈ 0.001 mm), for which the schematic curve gives a (high, cohesion-driven) erosion threshold of roughly 150 cm s^{-1} and an extremely low deposition threshold of roughly 0.005 cm s^{-1}. Explain what is happening to this clay bed, and why the result may seem counter-intuitive at first.

Although 25 cm s^{-1} would be more than sufficient to erode medium sand (threshold ≈ 20 cm s^{-1}), it is far *below* the much higher 150 cm s^{-1} erosion threshold required for this cohesive clay — so the consolidated clay bed is **not being eroded** at this velocity; it remains stable. This can seem counter-intuitive because clay particles are individually far smaller and lighter than sand grains, so students often assume they must be easier to erode. In fact, electrostatic/-chemical cohesion between fine clay platelets binds them together into a resistant mass, so *stationary, consolidated* clay actually requires a *higher* velocity to erode than sand does — even though, once clay particles are already suspended in the water column (e.g. stirred up during an earlier flood), they will remain in suspension and continue travelling at velocities as low as a fraction of a centimetre per second, far below what would cause sand to deposit.

(!) Lỗi thường gặp: Lỗi thường gặp: nghĩ rằng "vận tốc dòng chảy càng cao thì luôn xói mòn mạnh hơn, và hạt càng nhỏ/nhẹ thì càng dễ bị xói mòn" — điều này *sai* với đất sét (clay). Vì lực liên kết **cố kết (cohesion)** giữa các hạt sét cực nhỏ, đất sét đã lắng chặt lại thực ra cần vận tốc **cao hơn** để xói mòn so với cát trung bình (medium sand) — cát mới là cỡ hạt *dễ xói mòn nhất* trên đường cong Hjulström (đáy đường cong xói mòn), không phải sét. Tuy nhiên, một khi sét đã ở dạng lơ lửng (suspension), nó cần vận tốc *rất thấp* để tiếp tục di chuyển và lắng đọng cực chậm — hai tính chất (khó xói mòn khi cố kết, nhưng khó lắng khi đã lơ lửng) tồn tại đồng thời và thường bị đề thi khai thác để kiểm tra hiểu biết sâu, không chỉ ghi nhớ máy móc.

4.5 Fluvial Landforms

4.5.1 Upper-course landforms

In the steep, high-energy upper course of a river, vertical erosion (downcutting) dominates over lateral (sideways) erosion, producing a distinctive set of landforms. A **V-shaped valley** forms as the river cuts down into its bed while the valley sides are simultaneously weakened by weathering and

mass movement (slumping, soil creep) and washed down-slope, producing the characteristic steep-sided, V-shaped cross-profile. Where a river's valley bends around alternating projections of more resistant rock (since the river has too little lateral energy in the upper course to erode straight through these obstacles), the resulting protruding ridges are called **interlocking spurs** — viewed from within the valley, spurs from opposite sides appear to interlock like the teeth of a zip, blocking a straight-line view up or down the valley. A **waterfall** forms where a river crosses a band of resistant (hard) rock overlying softer, less resistant rock: the softer rock is eroded (by hydraulic action and abrasion) faster than the resistant cap-rock, undercutting it to form an overhang that periodically collapses under gravity, with hydraulic action continuing to scour out a deep **plunge pool** at the base; over time, repeated collapse causes the waterfall to retreat gradually upstream, leaving behind a steep-sided **gorge** (a narrow valley with near-vertical walls) marking the waterfall's former positions. **Potholes** are small, roughly circular depressions worn into the solid bedrock of a river bed, formed where pebbles and coarser sediment become trapped in a natural hollow and are swirled around by turbulent flow (a rotational form of abrasion), progressively grinding the hollow deeper and more circular.

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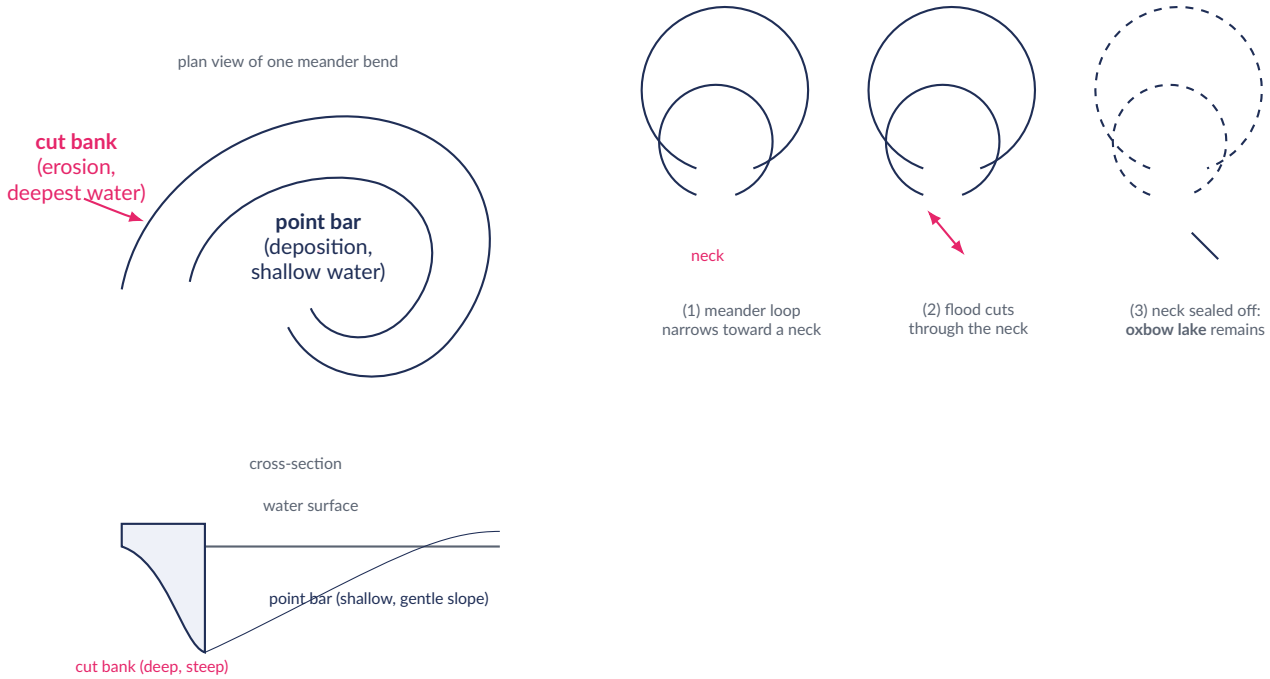
Thượng nguồn sông có năng lượng xói mòn theo chiều **thẳng đứng** (đào sâu lòng sông) mạnh hơn chiều ngang. **Thung lũng chữ V**: sông đào sâu trong khi hai bên sườn thung lũng bị phong hoá và trôi xuống, tạo hình chữ V. **Mỏm đồi xen kẽ (interlocking spurs)**: sông uốn quanh các mỏm đá cứng nhô ra xen kẽ hai bên vì chưa đủ năng lượng ngang để xói thẳng qua. **Thác nước (waterfall)**: hình thành nơi sông chảy qua lớp đá cứng nằm trên lớp đá mềm — đá mềm bị xói mòn nhanh hơn tạo hốc lõm, phần đá cứng nhô ra sập xuống theo thời gian khiến thác lùi dần về thượng nguồn, để lại **hẻm vực (gorge)** phía sau; **hố xoáy (plunge pool)** hình thành do nước xoáy mạnh tại chân thác. **Hố xoáy nhỏ trong lòng đá (potholes)**: sỏi đá bị cuốn xoáy trong một hốc nhỏ trên đáy sông, mài rộng và làm tròn hốc đó theo thời gian.

4.5.2 Middle- and lower-course landforms

Further downstream, as gradient flattens and discharge increases, lateral erosion and deposition become progressively more important relative to vertical erosion, producing a different suite of landforms. A river channel rarely stays perfectly straight for long; instead it develops sinuous bends called **meanders**. Within a meander bend, flow follows a corkscrew-like three-dimensional path called **helicoidal flow**: at the surface, the fastest-moving water is thrown toward the outer bank of the bend by centrifugal force, while a compensating undercurrent of water moves along the bed toward the inner bank. On the **outer bank** (the concave side of the bend), this concentration of fast-flowing water produces the deepest part of the channel and the greatest erosive energy, cutting a steep, actively-eroding **cut bank** (also called a river cliff). On the **inner bank** (the convex side of the bend), water is shallower and slower, so sediment carried along the bed by the helicoidal undercurrent is deposited, building up a gently-sloping accumulation of sand and gravel called a **point bar**. Over time, continued erosion of the cut bank and deposition on the point bar cause meander bends to migrate laterally and to become progressively more pronounced (more sinuous), narrowing the neck of land between adjacent bends of the same loop. Eventually, most often during a high-discharge flood event, the river breaks through this narrow neck (a **neck cutoff**), taking the new, shorter, straighter path; the abandoned meander loop is gradually sealed off from the new channel by continued deposition at both ends, leaving a crescent-shaped, still-water **oxbow lake**, which will slowly silt up and vegetate over subsequent decades.

Beyond the meander belt, a **floodplain** is the wide, flat valley floor bordering the river, built up over many years by the deposition of fine sediment during repeated flood events (when the river's discharge exceeds the capacity of its channel and spills out across the adjacent land) together with lateral meander migration progressively reworking the whole valley floor. **Levees** are raised, natural embankments running along the top of the riverbank, built up over successive floods: as floodwater spreads out of the channel, it loses velocity and energy very abruptly, so the coarsest,

heaviest sediment it carries is deposited immediately adjacent to the channel (building the levee), while progressively finer sediment is carried further out across the floodplain before settling. At a river's mouth, where it enters a standing body of water (the sea or a lake) and loses velocity abruptly, its sediment load is deposited to build a **delta** — a landform that grows as successive deposits force the river's flow to split into multiple smaller channels called **distributaries**, each depositing further sediment and gradually extending the delta outward.



Left: plan view of a single meander bend and its cross-section — the cut bank (outer, concave side) is deep with active erosion; the point bar (inner, convex side) is shallow with active deposition, driven by helicoidal (corkscrew) flow. Right: a simplified three-stage sequence of oxbow-lake formation by neck cutoff — (1) a meander loop's neck narrows progressively; (2) a flood cuts a new, straighter channel through the neck; (3) the neck is sealed by deposition and the abandoned loop survives as a crescent-shaped oxbow lake, now disconnected from the main channel (dashed).

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Khúc uốn sông (meander) hình thành do **dòng chảy xoắn ốc (helicoidal flow)**: ở bề mặt, nước chảy nhanh nhất bị đẩy về phía bờ ngoài (lõm) do lực ly tâm; dưới đáy, có một dòng chảy ngầm ngược lại đẩy về bờ trong (lồi). Bờ ngoài trở thành **cut bank** (nước sâu nhất, xói mòn mạnh nhất); bờ trong trở thành **point bar** (nước nông, lắng đọng cát/sỏi). Theo thời gian, khúc uốn di chuyển ngang và trở nên gấp khúc hơn, làm cổ đất giữa hai đoạn uốn (neck) hẹp dần; khi lũ lớn, sông cắt thẳng qua cổ đất này (**neck cutoff**), để lại khúc uốn cũ bị cô lập thành **hồ móng ngựa (oxbow lake)**. **Đồng bằng ngập lũ (floodplain)** hình thành từ trầm tích lắng đọng qua nhiều trận lũ; **đê tự nhiên (levee)** là gờ đất cao dọc bờ sông do trầm tích thô lắng ngay khi nước lũ tràn bờ và mất năng lượng đột ngột; **châu thổ (delta)** hình thành tại cửa sông khi dòng chảy mất tốc độ đột ngột khi gặp biển/hồ, buộc sông phải chia thành nhiều nhánh nhỏ (distributaries).

4.6 Flood Risk and Frequency

Predicting how often a river is likely to produce a flood of a given size is central to flood-risk management, land-use planning, and infrastructure design (e.g. deciding how high to build a flood-defence wall, or whether to permit construction on a given plot of floodplain land). The standard statistical tool used is the **recurrence interval** (also called the return period): the average number of years

expected to elapse between floods of a given magnitude or greater, estimated from a historical discharge record using the **Weibull formula**:

$$RI = \frac{n+1}{m}$$

where n is the number of years of discharge record available, and m is the **rank** of a given flood's magnitude within that record (the largest flood on record is ranked $m = 1$, the second-largest $m = 2$, and so on). The recurrence interval is then converted into an **annual exceedance probability (AEP)** — the probability that a flood of at least that magnitude will occur in any single given year — simply as $AEP = 1/RI$, usually expressed as a percentage.

Two important caveats limit how the recurrence interval should be used and interpreted. First, the method assumes **stationarity** — that the statistical properties of the flood-producing system (climate, land use, channel form) remain unchanged over time, so that the past record is a reliable guide to future probability. In reality, ongoing climate change (altering rainfall intensity and frequency) and land-use change within the basin (especially urbanisation, which increases peak discharge for a given rainfall, as discussed in Section 4.3.2) can both invalidate this assumption, meaning a recurrence interval calculated from an older historical record may substantially *underestimate* present-day flood risk. Second, a recurrence interval is a long-run statistical average, *not* a fixed countdown clock or a guarantee of even spacing: a flood with a recurrence interval of 100 years has, in any given year, exactly a $1/100 = 1\%$ chance of occurring, regardless of how recently a previous flood of that size occurred — two "100-year floods" can, in principle, occur in consecutive years, and the average interval only emerges over a very long run of many such events.

Ví dụ mẫu · Calculating a recurrence interval

A river gauging station has $n = 25$ years of discharge records. The largest flood in that record is ranked $m = 1$. Calculate its recurrence interval, and state the annual exceedance probability of a flood at least this large occurring in any given year.

$$RI = \frac{n+1}{m} = \frac{25+1}{1} = \textbf{26} \text{ years.}$$

$$AEP = \frac{1}{RI} = \frac{1}{26} \approx \textbf{3.8}\% \text{ per year.}$$

On average, a flood at least this large is expected roughly once every 26 years, equivalent to a 3.8% chance of such a flood occurring in any single year, based on this 25-year record.

Ví dụ mẫu · Recurrence interval for a lower-ranked flood

The same gauging station has a longer record of $n = 50$ years. A flood of a particular magnitude of interest is ranked the 5th-largest in that record ($m = 5$). Calculate its recurrence interval and annual exceedance probability, and explain in words what an "$RI = 10.2$ years" flood means for a homeowner deciding whether to build on nearby floodplain land.

$$RI = \frac{n+1}{m} = \frac{50+1}{5} = \frac{51}{5} = \textbf{10.2} \text{ years.}$$

$$AEP = \frac{1}{10.2} \approx \textbf{9.8}\% \text{ per year.}$$

This means a flood at least this large has, on average, about a 1-in-10 chance of occurring in *any* given year — not that exactly 10.2 years will elapse between each such flood. Over a 30-year mortgage, for example, the cumulative probability of experiencing at least one flood

of this size is therefore substantial (considerably higher than 9.8%, since the risk compounds year after year), which is why floodplain zoning and insurance underwriting rely on recurrence-interval/AEP estimates rather than on how long it has been since the last flood of that size.

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Chu kỳ lặp lại lũ (recurrence interval, RI) tính bằng công thức Weibull $RI = (n+1)/m$, với n là số năm dữ liệu và m là thứ hạng độ lớn trận lũ (lũ lớn nhất xếp hạng $m = 1$). **Xác suất vượt ngưỡng hàng năm (AEP)** $= 1/RI$. Hai lưu ý quan trọng: (1) phương pháp này giả định **tính ổn định (stationarity)** — khí hậu và cách sử dụng đất trong lưu vực không đổi theo thời gian; biến đổi khí hậu và đô thị hoá có thể khiến RI tính từ dữ liệu cũ **đánh giá thấp** rủi ro lũ hiện tại; (2) RI **không phải** là một chiếc đồng hồ đếm ngược đảm bảo — lũ "100 năm một lần" có xác suất 1% xảy ra trong *bất kỳ* năm nào, kể cả năm ngay sau khi vừa xảy ra một trận lũ tương tự.

(!) Lỗi thường gặp: Lỗi thường gặp: hiểu chu kỳ lặp lại lũ (ví dụ "lũ 100 năm") như một **lời hứa về thời điểm** — nghĩ rằng nếu vừa xảy ra một trận lũ 100 năm thì phải đợi đúng 100 năm nữa mới có trận tiếp theo. Đây là **ngộ nhận thống kê** (tương tự "gambler's fallacy"): RI chỉ là *xác suất trung bình dài hạn* (1% mỗi năm cho lũ 100 năm), không phải chu kỳ cố định — về mặt lý thuyết, hai trận lũ 100 năm hoàn toàn có thể xảy ra trong hai năm liên tiếp.

4.7 Water Scarcity Revisited

Water scarcity at the scale of a drainage basin or a country can arise from two quite different underlying causes, and distinguishing between them is essential for designing an appropriate policy response. **Physical water scarcity** exists where the total renewable freshwater resource available (from precipitation, rivers, and recharging aquifers) is genuinely insufficient to meet the demands of the population and economy relying on it — common in arid and semi-arid regions with naturally low precipitation and few large perennial rivers (parts of the Middle East and North Africa, for example), and increasingly a concern where climate change reduces reliable rainfall or where population and irrigation demand have grown to exceed a basin's natural renewable supply. **Economic water scarcity** exists where adequate water resources are physically present within a country or region, but a lack of the investment, infrastructure (reservoirs, pipelines, treatment plants, wells), institutional capacity, or governance needed to capture, store, treat and distribute that water prevents significant parts of the population from reliably accessing it — much of sub-Saharan Africa is classified as experiencing economic rather than physical water scarcity, since renewable water resources per capita are often adequate on paper, but chronic under-investment leaves large numbers of people without a reliable, safe supply.

Physical water scarcity: not enough renewable freshwater physically exists to meet demand (e.g. arid climate, over-allocated rivers, depleted aquifers). **Economic water scarcity:** enough water physically exists, but a lack of infrastructure, investment, or governance prevents people from accessing it. The policy response differs sharply: physical scarcity calls for demand management, water-use efficiency, and (where feasible) supply augmentation (desalination, transfers); economic scarcity calls for investment in storage, treatment, and distribution infrastructure, and improved governance/institutions.

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Khan hiếm nước vật lý (physical water scarcity): không đủ nước ngọt tái tạo về mặt vật lý để đáp ứng nhu cầu (khí hậu khô hạn, sông bị phân bổ quá mức, tầng nước ngầm cạn kiệt).

Khan hiếm nước kinh tế (economic water scarcity): nước vẫn tồn tại đủ về mặt vật lý, nhưng thiếu đầu tư, cơ sở hạ tầng (hồ chứa, đường ống, nhà máy xử lý) hoặc quản trị khiến người dân không tiếp cận được — đây là tình trạng phổ biến ở nhiều nơi tại châu Phi cận Sahara. Phân biệt hai loại này quan trọng vì giải pháp chính sách khác nhau: khan hiếm vật lý cần quản lý nhu cầu và tăng nguồn cung (khử mặn, chuyển nước liên lưu vực); khan hiếm kinh tế cần đầu tư hạ tầng và cải thiện quản trị.

4.8 Drainage Basin Management: Dams and Reservoirs

4.8.1 Benefits and costs of large dams

Building a large dam and reservoir across a river is one of the most direct ways that a drainage basin's natural flows and stores can be deliberately re-engineered by human management, and it typically brings a distinctive mix of substantial benefits alongside serious, often long-lasting, costs.

Khái niệm cốt lõi · Costs and benefits of large dams

Benefits: hydroelectric power (HEP) generation, providing a large, relatively low-carbon source of electricity once built; **flood control**, by holding back peak flows during storms and releasing them gradually afterward, reducing downstream flood risk; a reliable **irrigation water supply**, stored during wet periods and released during the growing season, supporting agricultural intensification; improved **navigation**, since a dam's reservoir can raise and stabilise water depth over what was previously a shallower, more variable river; and a stable municipal/industrial **water supply**. **Costs: sedimentation** — the reservoir traps virtually all of the sediment the river would naturally carry downstream, progressively reducing the reservoir's storage capacity (and, eventually, its useful lifespan) while starving the channel, floodplain and delta downstream of sediment they previously depended on for natural fertility and land-building, often leading to accelerated coastal/delta erosion; the **resettlement** of populations whose homes, farmland, and cultural/historical sites are flooded by the new reservoir, frequently with inadequate compensation or loss of livelihood; substantial **evaporative losses** from the large open-water surface of the reservoir, especially significant in hot, arid climates; and wide-ranging **downstream ecological disruption**, including blocked fish migration routes, altered water temperature and chemistry released from the dam, and the loss of the natural flood pulse that many downstream and floodplain/delta ecosystems depend on.

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Lợi ích của đập/hồ chứa lớn: phát điện thuỷ điện (HEP), kiểm soát lũ (giữ lại đỉnh lũ rồi xả dần), cung cấp nước tưới tiêu ổn định, cải thiện giao thông đường thuỷ, và cấp nước sinh hoạt/công nghiệp ổn định. **Chi phí**: **bồi lắng (sedimentation)** — hồ chứa giữ lại gần như toàn bộ trầm tích, làm giảm dần dung tích hồ và khiến hạ lưu/châu thổ mất nguồn phù sa vốn nuôi dưỡng đất đai; **tái định cư** dân cư bị ngập do lòng hồ, thường đền bù không thoả đáng; **tổn thất do bốc hơi** từ bề mặt hồ rộng lớn, đặc biệt nghiêm trọng ở vùng khí hậu khô nóng; và **xáo trộn sinh thái hạ lưu** — chặn đường di cư của cá, thay đổi nhiệt độ/hoá học nước xả ra, và mất đi nhịp lũ tự nhiên mà nhiều hệ sinh thái hạ lưu phụ thuộc vào.

4.8.2 Case study: the Aswan High Dam, Egypt

The **Aswan High Dam**, completed in **1970** on the **Nile River** in southern Egypt, created one of the world's largest artificial reservoirs, **Lake Nasser**, extending upstream into northern Sudan. Before the dam, the Nile had flooded predictably each year, depositing a fresh layer of nutrient-rich silt across the Egyptian floodplain — a natural fertilisation process that had sustained Egyptian agriculture for millennia. The dam brought major benefits: it provides substantial and reliable **hydroelectric**

power for Egypt; it ended the unpredictable extremes of the Nile's natural flood cycle, protecting riverside settlements and infrastructure from destructive floods while also providing a secure water reserve during years of low Nile flow (drought protection); and it enabled a major expansion and intensification of **irrigated agriculture**, allowing some areas to grow multiple crops per year instead of relying on the single annual flood season. However, the dam also imposed substantial costs: by trapping virtually all of the Nile's sediment load behind it in Lake Nasser, the dam **ended the annual natural flood and silt deposition** that had fertilised Egyptian farmland for thousands of years, forcing farmers to substantially increase their use of **chemical fertiliser** to replace the lost natural nutrient input (raising both farming costs and the risk of fertiliser runoff pollution); the loss of sediment reaching the Nile Delta and the eastern Mediterranean coast has also contributed to increased coastal erosion, since the delta is no longer being naturally replenished; and the creation of Lake Nasser required the resettlement of large numbers of Nubian people from land that was flooded by the new reservoir, and evaporative losses from Lake Nasser's vast surface area (in Egypt's hot, arid climate) represent a very significant ongoing loss of water from the Nile system.

4.8.3 Case study: the Three Gorges Dam, China

The **Three Gorges Dam**, built across the **Yangtze River** in central China and completed in stages between **2006 and 2012** (with the main structure finished in 2006 and the full project, including the ship-lift, completed by 2012), is the **world's largest hydropower station by installed generating capacity**. Its benefits include large-scale generation of relatively low-carbon **electricity** for China's economy, and substantial **flood control** for the densely populated middle and lower Yangtze floodplain, an area that has historically suffered some of the world's most destructive river floods. However, the project also carries major, well-documented costs: the reservoir required the **resettlement of over one million people**, along with the submergence of numerous towns, farmland, and archaeologically and culturally significant sites; ongoing concerns persist over **sedimentation** building up behind the dam (reducing reservoir capacity over time and depriving the middle/lower Yangtze and its delta of sediment); and the altered water level in the reservoir has been linked to increased **landslide risk** along the steep banks of the reservoir margin, as repeated wetting, drying and loading of previously stable slopes destabilises them.

Feature	Aswan High Dam (Egypt)	Three Gorges Dam (China)
River	Nile	Yangtze
Completion	1970	Main structure 2006; full project by 2012
Reservoir	Lake Nasser	Three Gorges Reservoir
Key benefit	Hydropower, flood/drought protection, expanded year-round irrigation	World's largest hydropower station by installed capacity; major flood control for the middle/lower Yangtze
Key cost/impact	End of annual natural silt deposition (increased chemical-fertiliser dependence); Nubian resettlement; delta/coastal erosion; large evaporative losses	Resettlement of over 1 million people; sedimentation behind the dam; increased landslide risk on reservoir banks

Summary comparison of two major dam case studies discussed in this Unit.

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Đập Aswan (Ai Cập, hoàn thành 1970) trên sông Nile tạo ra **hồ Nasser**. Lợi ích: thuỷ điện, kiểm soát lũ/hạn, mở rộng tưới tiêu quanh năm. Chi phí: chấm dứt lũ và bồi phù sa tự nhiên hàng năm từng nuôi dưỡng đất nông nghiệp Ai Cập suốt hàng nghìn năm — buộc nông dân phải tăng dùng **phân bón hoá học**; tái định cư người Nubia; xói lở bờ biển châu thổ do mất phù sa; tổn thất bốc hơi lớn từ hồ Nasser. **Đập Tam Hiệp (Trung Quốc, hoàn thành theo giai đoạn**

2006–2012) trên sông Dương Tử là nhà máy thuỷ điện có công suất lắp đặt **lớn nhất thế giới**, mang lại điện năng sạch và kiểm soát lũ quan trọng cho vùng trung–hạ lưu Dương Tử đông dân. Chi phí: **tái định cư hơn 1 triệu người**, bồi lắng trầm tích sau đập, và gia tăng nguy cơ sạt lở đất dọc bờ hồ chứa.

Ví dụ mẫu · Reservoir storage-and-yield calculation

A reservoir begins the year with 900 million m^3 of stored water. Over the year, average inflow (from precipitation, tributary rivers, and runoff into the reservoir) is $1\,100$ million m^3, while total outflow — irrigation and municipal supply, the compensation flow released downstream, and evaporative losses from the reservoir surface — totals $1\,250$ million m^3. (a) Calculate the change in reservoir storage, ΔS, over the year. (b) If this same annual imbalance continues unchanged every year, calculate how many years it would take before the reservoir's initial storage is fully exhausted, and comment on the sustainability of the current demand.

(a) ΔS = inflow − outflow $= 1\,100 - 1\,250 = -$**150** million m^3 (a deficit: the reservoir loses 150 million m^3 of stored water over the year).

(b) At a constant deficit of 150 million m^3 per year, the initial 900 million m^3 of storage would be exhausted after

$$\frac{900 \text{ million m}^3}{150 \text{ million m}^3\text{yr}^{-1}} = \textbf{6} \text{ years.}$$

This demonstrates that current demand (irrigation, municipal supply, compensation flow, and evaporation combined) exceeds inflow and is therefore **not sustainable** at current levels — without either a reduction in total outflow (e.g. more efficient irrigation, reduced allocations) or an increase in inflow (which basin managers cannot directly control), the reservoir would run dry within just a few years, a pattern of over-allocation seen in real heavily-used river systems such as the Colorado River (Section 4.9).

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Bài toán cân bằng hồ chứa áp dụng cùng logic với phương trình cân bằng nước lưu vực: $\Delta S =$ dòng vào − dòng ra. Nếu ΔS âm liên tục (dòng ra vượt dòng vào mỗi năm), hồ chứa sẽ cạn dần và có thể tính được số năm còn lại bằng cách lấy dung tích hiện có chia cho mức thâm hụt hàng năm — đây chính xác là tình trạng **phân bổ nước quá mức (over-allocation)** đang diễn ra ở nhiều hệ thống sông lớn trên thế giới.

4.9 Integrated Water Resources Management (IWRM)

Integrated Water Resources Management (IWRM) is a holistic approach to managing water, land, and related resources that aims to maximise economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems, by coordinating management across an entire drainage basin rather than allowing individual users, sectors, or administrative jurisdictions to make decisions in isolation. IWRM typically involves: managing water at the scale of the natural drainage basin (rather than being constrained purely by political/administrative boundaries, even where a basin crosses international borders); balancing competing demands from agriculture, industry, domestic supply, hydropower, navigation, and ecosystem needs; engaging multiple stakeholders (governments, water users, businesses, civil society, downstream and upstream communities) in transparent decision-making; and explicitly recognising the interconnections between water quantity, water quality, land use, and the wider environment.

IWRM manages water holistically at the **drainage-basin scale**, coordinating across competing uses (irrigation, domestic/industrial supply, hydropower, navigation, ecosystems) and involving **multiple stakeholders**, rather than leaving allocation decisions fragmented among individual users or agencies acting independently.

The **Colorado River Basin** (draining parts of the south-western United States before reaching Mexico) is a widely cited case of a heavily **over-allocated** river system, illustrating the practical difficulty of implementing effective basin-wide management once water has already been allocated on paper in excess of what the river can reliably deliver. The **1922 Colorado River Compact**, the foundational agreement dividing the river's water between US states, allocated water based on flow measurements taken during an unusually wet period in the early twentieth century — as a result, the volumes of water legally allocated on paper to the various states (and later, under a separate treaty, to Mexico) substantially exceed the river's actual average annual flow in most years, a structural over-allocation problem that has persisted for a century. Compounded by sustained regional drought and rising demand from agriculture and rapidly growing south-western cities, the level of **Lake Mead** (the reservoir held behind the Hoover Dam, one of the river's principal storage reservoirs) has fallen substantially since the early 2000s, at times dropping to historic lows and prompting mandatory water-use cutbacks among the states and users dependent on the river — a clear illustration of both physical over-allocation and the practical challenges of coordinating IWRM-style basin management across multiple states and an international border.

VN GIẢI THÍCH TIẾNG VIỆT

IWRM quản lý nước một cách tổng thể ở quy mô **lưu vực sông**, phối hợp giữa các nhu cầu cạnh tranh (tưới tiêu, sinh hoạt, công nghiệp, thuỷ điện, giao thông, hệ sinh thái) và có sự tham gia của **nhiều bên liên quan**, thay vì để từng đơn vị/địa phương tự quyết định riêng lẻ. **Lưu vực sông Colorado** (tây nam Hoa Kỳ và Mexico) là ví dụ điển hình về tình trạng **phân bổ nước quá mức**: **Hiệp ước sông Colorado năm 1922** phân chia nước dựa trên số liệu đo trong một giai đoạn ẩm ướt bất thường đầu thế kỷ 20, khiến tổng lượng nước được phân bổ trên giấy tờ cho các bang (và sau này cho Mexico) vượt quá lưu lượng trung bình thực tế của sông trong hầu hết các năm. Kết hợp với hạn hán kéo dài và nhu cầu gia tăng, mực nước **hồ Mead** (sau đập Hoover) đã giảm mạnh kể từ đầu những năm 2000, có lúc xuống mức thấp kỷ lục, buộc phải cắt giảm hạn ngạch sử dụng nước bắt buộc — minh hoạ rõ cả tình trạng phân bổ quá mức lẫn khó khăn thực tế trong việc phối hợp quản lý theo kiểu IWRM giữa nhiều bang và qua biên giới quốc gia.

4.10 Practice Bank

Bài tập 1 · Trắc nghiệm — global stores

Which of the following correctly ranks a major global water store by its approximate relative size?

(A) The atmosphere holds more water than all the world's lakes and rivers combined

(B) Oceans are the largest store of water on Earth, holding roughly 97% of the total

(C) Groundwater is a smaller store than soil moisture

(D) Ice caps and glaciers hold less water than lakes and rivers combined

Lời giải chi tiết

Oceans hold the overwhelming majority ($\approx 97\%$) of all water on Earth, making them by far the largest store; ice caps/glaciers are the largest *freshwater* store, groundwater the largest *liquid freshwater* store, and both far exceed lakes/rivers or soil moisture in volume. The atmosphere, despite its fast turnover, is one of the smallest stores by volume. **(B)**.

Bài tập 2 · Trắc nghiệm — residence time

Which store in the hydrological cycle has, on average, by far the *shortest* residence time?

(A) Deep groundwater
(B) Ocean water
(C) Atmospheric water vapour
(D) Ice sheets (e.g. Antarctica)

Lời giải chi tiết

Atmospheric water is continuously and rapidly cycled by evaporation and precipitation, giving a residence time of only about a week to ten days — vastly shorter than oceans ($\approx 3\,000$–$4\,000$ years), deep groundwater, or ice sheets (thousands to tens of thousands of years). **(C)**.

Bài tập 3 · Tính toán — residence time

A reservoir holds 6.0×10^7 m^3 of water. Combined outflow (supply plus evaporation) removes water at 1.2×10^7 m^3 per year. Calculate the residence time of water in this reservoir.

Lời giải chi tiết

$$\tau = \frac{M}{F} = \frac{6.0 \times 10^7}{1.2 \times 10^7} = \textbf{5}\ \text{years}.$$

Bài tập 4 · Tính toán — water balance for Q

A drainage basin receives $P = 1\,050$ mm of precipitation annually. Evapotranspiration is measured at $E = 400$ mm, and long-term storage is assumed stable ($\Delta S = 0$). Calculate the annual runoff, Q.

Lời giải chi tiết

$Q = P - E - \Delta S = 1\,050 - 400 - 0 = \textbf{650}$ mm.

Bài tập 5 · Tính toán — water balance for P

A basin's annual channel discharge is $Q = 310$ mm and evapotranspiration is $E = 480$ mm. Groundwater and soil surveys show storage *decreased* by $\Delta S = -60$ mm over the year (a drought year). Calculate the total annual precipitation, P.

Lời giải chi tiết

Rearrange the water balance equation $P = Q + E \pm \Delta S$ to solve for P: $P = Q + E + \Delta S$, where $\Delta S = -60$ mm is entered as a signed (negative) quantity because storage *decreased* over the year.

$$P = 310 + 480 + (-60) = \textbf{730}\ \text{mm}.$$

The basin received 730 mm of precipitation over the year. Because storage fell by 60 mm, channel discharge and evapotranspiration together ($310 + 480 = 790$ mm) exceeded precipitation (730 mm) — the extra 60 mm needed to balance the equation was drawn out of the basin's soil-moisture and groundwater stores, consistent with the drought conditions described.

Bài tập 6 · Trắc nghiệm — fluxes vs stores

Which of the following is *not* a flux (transfer) of the hydrological cycle, but is instead a store?

(A) Infiltration
(B) Percolation
(C) Groundwater storage
(D) Evapotranspiration

Lời giải chi tiết

Infiltration (surface → soil), percolation (soil → groundwater, continued downward movement), and evapotranspiration (surface/plant water → atmosphere) are all fluxes: named transfers that move water *between* stores. Groundwater storage, by contrast, is itself a reservoir where water is held — the water held in the saturated zone of an aquifer — not a movement of water, so it is a store, not a flux. **(C)**.

Bài tập 7 · Tính toán — residence time of a lake

A lake holds 2.4×10^{10} m^3 of water. Combined outflow (the outlet river plus evaporation from the lake surface) removes water at a rate of 6.0×10^{9} m^3 per year. Calculate the residence time of water in this lake.

Lời giải chi tiết

$$\tau = \frac{M}{F} = \frac{2.4 \times 10^{10}\ \text{m}^3}{6.0 \times 10^{9}\ \text{m}^3\text{yr}^{-1}} = \textbf{4}\ \text{years}.$$

This falls squarely within the typical range for lakes (years to decades), far longer than a river channel's residence time of weeks to months, but vastly shorter than the thousands of years typical of deep groundwater or ice sheets.

Bài tập 8 · Tính toán — water balance for ΔS

A drainage basin receives $P = 880$ mm of precipitation in a given year. Channel discharge is measured at $Q = 520$ mm and evapotranspiration at $E = 310$ mm for the same year. Calculate ΔS and state whether the basin's stores grew or shrank.

Lời giải chi tiết

Rearrange to solve for ΔS: $\Delta S = P - Q - E$.

$$\Delta S = 880 - 520 - 310 = +\textbf{50}\ \text{mm}.$$

Because ΔS is positive, the basin's combined stores (soil moisture, groundwater, channel/lake levels) **grew** by the equivalent of 50 mm of water depth over the year — precipitation exceeded the combined outputs of discharge and evapotranspiration, and the surplus was retained in storage.

Bài tập 9 · Trắc nghiệm — flashy hydrographs

Which of the following changes to a rural drainage basin would be most likely to produce a *flashier* hydrograph (shorter lag time, higher peak discharge) for an identical storm?

(A) An afforestation programme planting dense forest across most of the basin

(B) Construction of a new housing estate with paved roads and roofs, connected to an efficient storm-drain network

(C) Conversion of ploughed arable farmland to unploughed permanent grassland

(D) A prolonged drought immediately before the storm, leaving soils very dry

Lời giải chi tiết

Urbanisation (B) replaces permeable, vegetated surfaces with impermeable roofs and roads, virtually eliminating infiltration, while an efficient storm-drain network removes the resulting overland flow to the channel almost immediately — this combination sharply shortens lag time and raises peak discharge. The other three options all *increase* infiltration capacity or interception and would instead produce a more subdued hydrograph: afforestation (A) increases interception and root-zone infiltration; unploughed grassland (C) has a more developed soil structure and vegetation cover than bare ploughed soil, promoting infiltration; and dry antecedent soil (D) has spare infiltration capacity available to absorb new rainfall, delaying and reducing overland flow. **(B)**.

Bài tập 10 · Tính toán — basin shape, slope and lag time

Two neighbouring basins receive an identical storm, with rainfall peaking at hour 2 in both. Basin C is small, roughly circular, and steep-sided; its discharge peaks at 80 m^{3}s^{-1} at hour 5. Basin D is large, elongated, and gently sloping; its discharge peaks at 40 m^{3}s^{-1} at hour 20. (a) Calculate the lag time for each basin. (b) Explain, with reference to basin shape and slope, why Basin C produces the flashier response.

Lời giải chi tiết

(a) Basin C: lag time $= 5 - 2 =$ **3** hours. Basin D: lag time $= 20 - 2 =$ **18** hours.

(b) In a small, circular basin, rainfall falling anywhere in the basin has a broadly similar (short) distance to travel to reach the outlet, so runoff from across the whole basin arrives at the channel in a short, concentrated pulse; combined with steep slopes accelerating overland flow and throughflow, this produces Basin C's short 3-hour lag and high 80 m^{3}s^{-1} peak. In a large, elongated basin, runoff generated near the outlet arrives quickly while runoff from the distant, far end of the basin takes much longer to arrive, so the same total volume of storm runoff is spread out and staggered over a much longer period; combined with gentle slopes slowing overland flow, this produces Basin D's much longer 18-hour lag and lower, more subdued 40 m^{3}s^{-1} peak.

Bài tập 11 · Trắc nghiệm — defining lag time

Which of the following best defines the "lag time" on a storm hydrograph?

(A) The time between the start of rainfall and the start of the rise in discharge

(B) The time between the peak of rainfall intensity and the peak of discharge

(C) The total duration of the storm event, from the start of the rising limb to the end of the recession limb

(D) The time between peak discharge and the point where discharge returns to baseflow

Lời giải chi tiết

Lag time is specifically defined as the interval between the peak of the rainfall event (shown on an accompanying hyetograph) and the peak of the resulting discharge — it measures how quickly a basin translates the most intense rainfall into peak streamflow. Option (A) describes a different (and much shorter) interval sometimes called the initial response time; option (C) describes the total storm/hydrograph duration, which is typically far longer than the lag time and includes the whole recession limb; option (D) describes only part of the recession limb, not the lag time. **(B)**.

Bài tập 12 · Trắc nghiệm — erosion processes

A river's suspended sediment load is observed to become progressively smaller, smoother, and more rounded as it is carried downstream, even though no additional material has been eroded from the bed or banks in this particular reach. Which process best explains this observation?

(A) Hydraulic action

(B) Abrasion

(C) Attrition

(D) Solution

Lời giải chi tiết

Hydraulic action (the mechanical force of water prising material from the bed/banks) and abrasion (transported material scraping against the bed/banks) both act *on the channel itself*, which the question rules out (no material eroded from the bed/banks in this reach). Solution is the chemical dissolving of soluble rock, not a process that rounds particles. Attrition, however, is exactly the process of transported particles colliding *with one another* as they travel, progressively chipping, breaking and rounding each other — it changes the character of the load itself rather than eroding the channel, matching the observation precisely. **(C)**.

Bài tập 13 · Trắc nghiệm — transportation processes

During a flood, a river's water visibly turns a deep brown, muddy colour. Which transportation process is primarily responsible for this visible change, and what particle size does it typically carry?

(A) Traction — large boulders and stones rolled along the bed

(B) Saltation — sand-sized particles bouncing along the bed

(C) Suspension — fine silt and clay held up within the flow by turbulence

(D) Solution — dissolved chemical ions, invisible in the water

Lời giải chi tiết

Traction and saltation both move comparatively coarse material (boulders/stones and sand respectively) close to the bed, and neither discolours the water itself; solution transports dissolved ions, which are chemically invisible. It is suspension — fine silt and clay particles held up within the main body of the flow by turbulence, without regularly touching the bed — that is responsible for the visibly muddy, turbid appearance of a river in flood, since floods generate the high turbulence and increased erosive capacity needed to lift and hold large quantities of fine sediment in the water column. **(C)**.

Bài tập 14 · Tính toán — reading the Hjulström curve

A river reach flows at 15 cm s^{-1} over a bed containing coarse gravel (diameter ≈ 20 mm), for which the schematic Hjulström-style curve gives a critical erosion velocity of about 180 cm s^{-1} and a critical deposition velocity of about 120 cm s^{-1}. State, with reasoning, what is happening to this gravel.

Lời giải chi tiết

The flow velocity (15 cm s^{-1}) is far below *both* the critical erosion velocity (180 cm s^{-1}) and the critical deposition velocity (120 cm s^{-1}) for this particle size. Because v is below the deposition threshold, any gravel of this size that was previously in transport can no longer be kept moving and is being **actively deposited** onto the bed; and because v is also (a fortiori) below the erosion threshold, the river has nowhere near enough energy to newly erode stationary gravel of this size either. This is consistent with a river that has slowed considerably, for example approaching a wide, flat lower-course reach.

Bài tập 15 · Trắc nghiệm — the Hjulström curve and clay cohesion

Which of the following statements about the Hjulström curve is correct?

(A) Clay is the easiest particle size of all to erode from a stationary bed, because clay particles are the lightest

(B) Medium/coarse sand requires the lowest velocity of any particle size to be eroded from a stationary bed

(C) For any given particle size, the critical deposition velocity is always higher than the critical erosion velocity

(D) Larger particles such as gravel and boulders require lower erosion velocities than sand

Lời giải chi tiết

Consolidated clay is in fact one of the *hardest* particle sizes to erode from a stationary bed, despite being the lightest, because electrostatic/chemical **cohesion** between microscopic clay platelets binds them into a resistant mass — this rules out (A). It is medium/coarse sand (≈ 0.1–1 mm) that sits at the minimum of the erosion-velocity curve, requiring the lowest velocity of any particle size to be eroded, which makes (B) correct. Statement (C) has the relationship backwards: the deposition velocity for a given particle size is always *lower* than its erosion velocity, which is precisely what creates the "zone of transportation" between the two thresholds. Statement (D) is also wrong: larger particles such as gravel and boulders require *higher*, not lower, erosion velocities than sand, since they are heavier. **(B)**.

Bài tập 16 · Trắc nghiệm — waterfall formation

Which sequence correctly describes the formation and retreat of a waterfall?

(A) Soft rock erodes faster than an overlying resistant cap-rock, undercutting it until it collapses; continued hydraulic action scours a plunge pool, and repeated collapse causes the fall to retreat upstream, leaving a gorge

(B) A resistant cap-rock erodes faster than the underlying soft rock, causing the whole riverbed to collapse uniformly without any retreat

(C) Waterfalls form only where a river's gradient is uniformly steep throughout its course, with no change in rock resistance required

(D) A waterfall's plunge pool is formed entirely by chemical solution, with hydraulic action playing no role

Lời giải chi tiết

A waterfall forms where a river crosses a band of resistant rock overlying softer, less resistant rock: the soft rock is eroded faster (by hydraulic action and abrasion), undercutting the resistant cap-rock until it collapses under gravity; hydraulic action continues to scour a deep plunge pool at the base, and repeated collapse causes the waterfall to retreat gradually upstream, leaving a steep-sided gorge marking its former positions — this is (A). Option (B) reverses which layer erodes faster. Option (C) is wrong because a waterfall specifically requires a *change* in rock resistance, not a uniformly steep gradient. Option (D) is wrong because hydraulic action (the mechanical force of turbulent, swirling water), not solution, is the dominant process scouring the plunge pool. **(A)**.

Bài tập 17 · Free response — meanders

Using the concept of helicoidal flow, explain why the deepest, fastest-flowing water and the cut bank are found on the outer (concave) side of a meander bend, while the point bar is found on the inner (convex) side.

Lời giải chi tiết

Within a meander bend, water follows a corkscrew-like three-dimensional path called helicoidal flow. At the surface, centrifugal force throws the fastest-moving water toward the outer bank of the bend, concentrating flow energy there; this produces the deepest part of the channel and the greatest erosive power on the outer bank, cutting a steep, actively-eroding cut bank (river cliff). To conserve mass, a compensating undercurrent flows along the bed back toward the inner bank, carrying sediment with it; on the inner (convex) bank, water is correspondingly shallower and slower, so the sediment delivered by this undercurrent is deposited rather than eroded, gradually building up the gently-sloping point bar. Over time, this asymmetric erosion (outer bank) and deposition (inner bank) is what causes a meander bend to migrate laterally and become progressively more pronounced.

Bài tập 18 · Free response — levees and floodplains

Explain why levees are built up highest immediately next to the river channel, while the floodplain further from the channel receives only a thin layer of much finer sediment during the same flood.

Lời giải chi tiết

When a river's discharge exceeds the capacity of its channel, floodwater spreads out across the adjacent floodplain and, in doing so, loses velocity (and hence carrying capacity/kinetic energy) very abruptly as it leaves the confined, fast-flowing channel. Because deposition occurs once velocity falls below the threshold needed to keep a given particle size in transport, the coarsest, heaviest sediment being carried is dropped almost immediately, right next to the channel — and repeated over many floods, this builds up the raised, natural embankment called a levee. Water that continues spreading further out across the floodplain has already lost its coarse load and continues to slow further, so only progressively finer silt and clay remain in transport by the time it reaches the more distant parts of the floodplain, where it settles as a much thinner layer — producing the characteristic pattern of a raised, coarse-grained levee immediately bordering the channel and a broad, flat, fine-grained floodplain beyond it.

Bài tập 19 · Trắc nghiệm — deltas

What are "distributaries", and why do they form at a river delta?

(A) Tributary streams that join the main river far upstream, before it reaches the sea

(B) Smaller channels that the main river splits into as sediment deposits force its flow to divide near its mouth

(C) Artificial irrigation canals dug by farmers on the floodplain

(D) Underground channels through which groundwater reaches the river

Lời giải chi tiết

A tributary (A) is a stream that *joins* a larger river, the opposite relationship to a distributary; irrigation canals (C) are artificial and unrelated to delta formation; groundwater channels (D) do not describe a delta feature at all. At a river's mouth, the river loses velocity abruptly on entering the sea or a lake, so it deposits its sediment load there; as these deposits accumulate, they physically force the river's single channel to split into multiple smaller channels, called distributaries, each of which continues depositing further sediment and gradually extends the delta outward — this is (B). **(B)**.

Bài tập 20 · Tính toán — recurrence interval and AEP

A river gauging station has $n = 40$ years of discharge records. A flood of interest is ranked the 2nd-largest in that record ($m = 2$). Calculate its recurrence interval and its annual exceedance probability.

Lời giải chi tiết

$$RI = \frac{n+1}{m} = \frac{40+1}{2} = \frac{41}{2} = \textbf{20.5} \text{ years.}$$

$$AEP = \frac{1}{RI} = \frac{1}{20.5} \approx \textbf{4.9}\% \text{ per year.}$$

A flood at least this large is expected, on average, roughly once every 20.5 years, equivalent to about a 4.9% chance of such a flood occurring in any single given year.

Bài tập 21 · Tính toán — working backwards from RI

A 99-year discharge record ($n = 99$) contains a flood with a recurrence interval of exactly $RI = 25$ years. What is the rank, m, of this flood within the record?

Lời giải chi tiết

Rearrange the Weibull formula $RI = (n+1)/m$ to solve for m: $m = (n+1)/RI$.

$$m = \frac{99+1}{25} = \frac{100}{25} = \mathbf{4}.$$

This flood is the 4th-largest flood in the 99-year record.

Bài tập 22 · Trắc nghiệm — stationarity

The recurrence interval of a flood, calculated using the Weibull formula from a historical discharge record, rests on an assumption called "stationarity". Which statement best describes this assumption, and a realistic reason it might not hold today?

(A) That rainfall is identical in every year of the record; climate change makes this assumption trivially true, not false

(B) That the statistical properties of the flood-producing system remain unchanged over time; both climate change and land-use change (e.g. urbanisation) can invalidate this, causing older records to underestimate present-day flood risk

(C) That every flood in the record must have exactly the same peak discharge; this assumption is never used in practice

(D) That the river's channel geometry was surveyed only once, at the start of the record; this has no bearing on flood risk

Lời giải chi tiết

Option (A) misstates stationarity (it never requires identical rainfall every year, only unchanging statistical *properties* of the system) and wrongly claims climate change supports it. Option (C) describes no real statistical assumption used in flood-frequency analysis. Option (D) describes a survey detail that is not what stationarity refers to. Stationarity is correctly the assumption that the statistical properties of the flood-producing system — climate, land use, channel form — remain unchanged over time, so that a past discharge record reliably predicts future flood probability; both ongoing climate change (altering rainfall intensity/frequency) and land-use change within the basin (especially urbanisation, which raises peak discharge for a given rainfall) can invalidate this assumption, meaning an RI calculated from an older record may substantially underestimate present-day flood risk. **(B)**.

Bài tập 23 · Trắc nghiệm — physical vs. economic water scarcity

A country receives generous annual rainfall and has several large perennial rivers, so its total renewable freshwater resource is more than adequate on a per-capita basis. However, decades of under-investment mean it lacks the reservoirs, treatment plants, and piped distribution networks needed to deliver that water reliably, and large parts of the population lack safe, consistent access. Which type of water scarcity does this country experience?

(A) Physical water scarcity, because the rainfall is unevenly distributed through the year

(B) Economic water scarcity, because adequate water exists but infrastructure and investment are insufficient to capture, store, treat and distribute it

(C) Neither physical nor economic scarcity, since the water resource is described as adequate

(D) Both physical and economic scarcity simultaneously, since any lack of access counts as physical scarcity

Lời giải chi tiết

Physical water scarcity (A) is ruled out by the scenario itself, which explicitly states the renewable freshwater resource is adequate; option (C) is wrong because a lack of reliable access is exactly what defines a scarcity problem, even if the underlying resource is sufficient; option (D) incorrectly conflates the two categories, which are defined by different underlying causes (resource availability vs. infrastructure/governance) and should not both be applied to a case that is clearly one or the other. This scenario — adequate water resources present, but insufficient infrastructure, investment, or institutional capacity to capture, store, treat and distribute it, leaving people without reliable access — is the definition of **economic water scarcity**, the pattern widely described in much of sub-Saharan Africa. **(B)**.

Bài tập 24 · Tính toán — reservoir capacity and dam management

A reservoir currently holds $1\,200$ million m^3 of water and has a maximum safe capacity of $1\,500$ million m^3 before water must be released over a spillway. Average annual inflow is 450 million m^3 and average annual outflow (supply, compensation flow, and evaporation combined) is 375 million m^3. If this net imbalance continues unchanged each year, calculate how many years it will take before the reservoir reaches its maximum safe capacity.

Lời giải chi tiết

Step 1: Find the net annual change in storage. ΔS = inflow − outflow $= 450 - 375 = +75$ million m^3 per year (the reservoir is gaining water).

Step 2: Find the remaining capacity available before the reservoir is full. $1\,500 - 1\,200 = 300$ million m^3.

Step 3: Divide the remaining capacity by the annual net gain.

$$\frac{300 \text{ million m}^3}{75 \text{ million m}^3\text{yr}^{-1}} = \textbf{4 years}.$$

At the current rate of net inflow, the reservoir would reach its maximum safe capacity in 4 years, after which dam managers would need to increase controlled releases (e.g. for irrigation, compensation flow, or flood-control drawdown) to prevent uncontrolled spilling.

Bài tập 25 · Free response — IWRM and the Colorado River

Using the Colorado River Basin as an example, explain why implementing Integrated Water Resources Management (IWRM) is particularly difficult when a river basin crosses multiple state or international borders.

Lời giải chi tiết

IWRM requires coordinating water allocation across an entire drainage basin, balancing competing demands (irrigation, municipal supply, hydropower, ecosystems) among multiple stakeholders through unified, basin-wide decision-making. This becomes especially difficult once a basin crosses political boundaries, because each state or country retains its own legal authority, water rights framework, and political incentives, making it hard to renegotiate allocations even when circumstances change. The Colorado River illustrates this precisely: the 1922 Colorado River Compact allocated water among US states (and, under a later treaty, Mexico) based on flow measurements taken during an unusually wet period, so the volumes legally allocated on paper substantially exceed the river's actual average flow in most years. Because this allocation is enshrined in a century-old interstate/international legal agreement, correcting the resulting structural over-allocation requires every affected state (and Mexico) to agree to renegotiate their legal entitlements — politically very difficult, since each party has an incentive to protect its own allocation rather than accept cuts for the collective good. Compounded by sustained drought and rising demand, this has caused Lake Mead's level to fall to historic lows, forcing mandatory cutbacks and demonstrating that IWRM-style basin-wide coordination is far harder to achieve in practice across multiple jurisdictions than the concept suggests on paper.

Tổng kết nhanh chương Freshwater:

- **Vòng tuần hoàn nước**: bể chứa (đại dương, băng hà/chỏm băng, nước ngầm, hồ/sông, độ ẩm đất, sinh khối, khí quyển) nối với nhau qua các dòng chuyển (bốc hơi, thoát hơi nước, bốc thoát hơi nước, ngưng tụ, giáng thuỷ, thấm, thấm sâu, dòng chảy mặt, dòng chảy ngầm); **thời gian lưu trú** $\tau = M/F$ khác biệt rất lớn giữa các bể chứa (khí quyển: vài ngày; nước ngầm sâu/băng hà: hàng nghìn năm).
- **Lưu vực sông** là một hệ thống mở với đầu vào (giáng thuỷ), các bể chứa (interception, surface, soil-moisture, groundwater, channel), các dòng chuyển (throughflow, baseflow, v.v.) và hai đầu ra (bốc thoát hơi nước, lưu lượng dòng chảy); **phương trình cân bằng nước** $P = Q + E \pm \Delta S$.
- **Biểu đồ lũ**: baseflow, nhánh lên, đỉnh lũ, **lag time** (đỉnh mưa → đỉnh lũ), nhánh xuống. Lũ "flashy" (lag ngắn, đỉnh cao) do lưu vực nhỏ/tròn, dốc, đất không thấm, thực vật thưa, đất đã bão hoà, và đặc biệt là **đô thị hoá**; lũ "subdued" (lag dài, đỉnh thấp) do điều kiện ngược lại.
- **Quá trình sông**: xói mòn (hydraulic action, abrasion, attrition, solution); vận chuyển (traction, saltation, suspension, solution); lắng đọng theo **đường cong Hjulström** — cát trung bình dễ xói mòn nhất, sét khó xói mòn (cố kết) nhưng khó lắng khi đã lơ lửng.
- **Địa hình sông**: thượng nguồn (thung lũng chữ V, mỏm đồi xen kẽ, thác nước, hẻm vực, hố xoáy); trung–hạ lưu (khúc uốn/dòng chảy xoắn ốc, cut bank/point bar, hồ móng ngựa, đồng bằng ngập lũ, đê tự nhiên, châu thổ/distributaries).
- **Chu kỳ lặp lại lũ**: $RI = (n+1)/m$ (công thức Weibull), $AEP = 1/RI$; cần thận trọng với giả định tính ổn định (stationarity) và tránh ngộ nhận RI là một chu kỳ cố định.
- **Khan hiếm nước**: vật lý (không đủ nước tái tạo) và kinh tế (đủ nước nhưng thiếu hạ tầng/quản trị).
- **Đập và hồ chứa lớn**: lợi ích (thuỷ điện, kiểm soát lũ, tưới tiêu, giao thông, cấp nước) đi kèm chi phí (bồi lắng, tái định cư, bốc hơi, xáo trộn sinh thái hạ lưu) — minh hoạ qua đập Aswan (sông Nile) và đập Tam Hiệp (sông Dương Tử).
- **IWRM**: quản lý nước tổng thể ở quy mô lưu vực, phối hợp nhiều bên liên quan — minh hoạ qua tình trạng phân bổ nước quá mức ở lưu vực sông Colorado.

Oceans and Coastal Margins

Mục tiêu Unit: Sau khi hoàn thành Unit này, học sinh có thể: giải thích cơ chế hình thành dòng hải lưu bề mặt do gió (Ekman transport, hải lưu xoáy cận nhiệt đới, dòng Gulf Stream) và hoàn lưu nhiệt-muối sâu đại dương (băng tải đại dương toàn cầu, sự hình thành Nước Sâu Bắc Đại Tây Dương); phân tích tương tác đại dương–khí quyển qua hiện tượng ENSO (điều kiện bình thường, El Niño, La Niña) và tác động của nó tới nghề cá Peru cùng khí hậu toàn cầu; phân biệt sóng vỗ bờ mang tính xây dựng và sóng mang tính phá huỷ, giải thích hiện tượng khúc xạ sóng và vận chuyển bùn cát dọc bờ (longshore drift); mô tả các quá trình xâm thực bờ biển (thuỷ lực, mài mòn, va đập, hoà tan) và trình tự hình thành địa hình xâm thực (khe nứt–hang–vòm–trụ–gốc trụ); mô tả các dạng địa hình bồi tụ ven biển (bãi biển, doi cát, đập cát, mũi nối đảo); phân biệt biến đổi mực nước biển toàn cầu (eustatic) và biến đổi mực nước biển đẳng tĩnh cục bộ (isostatic); đánh giá các giải pháp quản lý bờ biển bằng công trình cứng và công trình mềm, cùng phương pháp quy hoạch tổng thể (Shoreline Management Plan) qua nghiên cứu điển hình bờ biển Holderness; và phân tích vai trò cùng các mối đe doạ đối với rạn san hô và rừng ngập mặn qua nghiên cứu điển hình Great Barrier Reef và Maldives.

5.1 5.1 Ocean Water Circulation

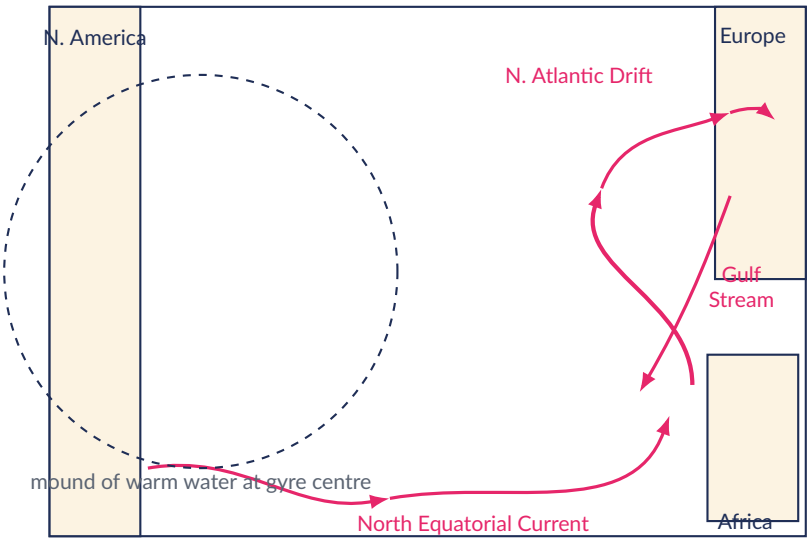
5.1.1 5.1.1 Wind-driven surface currents

Surface currents and the wind. The uppermost layer of the ocean, roughly the top 100–400 m, is set in motion primarily by the prevailing winds dragging across the sea surface through frictional stress. Because the Earth rotates, moving water (like moving air) is deflected by the **Coriolis effect** — to the right of its direction of travel in the Northern Hemisphere, and to the left in the Southern Hemisphere. A single layer of water set in motion by the wind does not simply flow in the wind's own direction: friction transmits motion downward from one thin layer of water to the layer beneath it, and each successive layer is progressively slower and deflected further from the wind direction by the Coriolis effect. The Norwegian oceanographer V. Walfrid Ekman formalized this in the early twentieth century: the theoretical net transport of water summed through the whole wind-driven layer, called **Ekman transport**, acts at 90° to the direction of the surface wind — to the right of the wind in the Northern Hemisphere, and to the left of the wind in the Southern Hemisphere.

Subtropical gyres. At the ocean-basin scale, the combination of the prevailing wind belts (the trade winds blowing from the subtropical highs toward the equator, and the mid-latitude westerlies blowing toward the poles) with the basin's bordering continents and the Coriolis deflection produces enormous, roughly circular current systems called **subtropical gyres**, centred close to 30°N/S in every major ocean basin. Ekman transport within a gyre is directed inward, piling up a broad, gentle mound of warm surface water at the gyre's centre; water then flows outward and around the mound's edge under the combined effect of this pressure gradient and the Coriolis deflection, producing a persistent basin-scale rotation. Gyres rotate **clockwise** in the Northern Hemisphere and **anticlockwise (counter-clockwise)** in the Southern Hemisphere — the same sense of rotation as the atmospheric subtropical high-pressure cells that help drive them, and for the same underlying reason (Coriolis deflection acting on air or water moving toward or away from a pressure centre).

The Gulf Stream. The **Gulf Stream** is the intense, narrow, fast-flowing western boundary current of the North Atlantic subtropical gyre. It originates in the Gulf of Mexico and the Caribbean, is compressed and accelerated as it threads through the Florida Straits, and then flows north-eastward along the eastern seaboard of the United States before swinging out across the North Atlantic toward

north-western Europe as the broader, slower North Atlantic Drift. Western boundary currents such as the Gulf Stream are characteristically narrow, deep, and fast (surface speeds can exceed 2 m/s), because the Coriolis effect and the shape of the ocean basin compress the gyre's return flow against the western margin of the basin — this asymmetry (fast, narrow currents on western margins; broad, slow currents on eastern margins) is known as **westward intensification**. The Gulf Stream transports an enormous quantity of warm tropical water polewards, and this heat is subsequently transferred to the overlying atmosphere, particularly in winter; the prevailing south-westerly winds then carry this warmed, moisture-laden air onward across the North Atlantic to north-western Europe. This is a principal reason why coastal cities of the British Isles, western Norway, and other parts of north-western Europe enjoy markedly milder winters than other locations at similar or even lower latitudes (for example, compared with parts of eastern Canada at a similar latitude, which lack a comparable warm western-boundary current offshore and experience much colder winters).



Schematic North Atlantic subtropical gyre (Northern Hemisphere, so rotation is clockwise): North Equatorial Current → Gulf Stream (fast, narrow western boundary current) → North Atlantic Drift (broad, slow eastern flow), carrying warm water and heat toward north-western Europe.

VN **GIẢI THÍCH TIẾNG VIỆT**

Dòng hải lưu bề mặt chủ yếu do **gió** tạo ra qua ma sát với mặt biển. Do Trái Đất tự quay, hiệu ứng **Coriolis** làm nước bị lệch hướng (phải ở Bắc bán cầu, trái ở Nam bán cầu); tổng hợp chuyển động của toàn bộ lớp nước bị gió tác động gọi là **vận chuyển Ekman**, lệch 90° so với hướng gió. Ở quy mô đại dương, gió mậu dịch và gió Tây ôn đới kết hợp với lục địa bao quanh tạo thành các **hải lưu xoáy cận nhiệt đới (subtropical gyres)** — quay **thuận chiều kim đồng hồ** ở Bắc bán cầu, **ngược chiều kim đồng hồ** ở Nam bán cầu. **Dòng Gulf Stream** là dòng biên tây nhanh, hẹp, sâu của hải lưu xoáy Bắc Đại Tây Dương (hiện tượng "tăng cường về phía tây" — westward intensification), mang nước ấm từ vùng nhiệt đới lên phía bắc, sưởi ấm không khí rồi được gió Tây Nam mang tới Tây Bắc Âu — lý do các nước như Anh, Na Uy có mùa đông ôn hoà hơn nhiều so với các vùng cùng vĩ độ không có dòng ấm tương tự (ví dụ miền đông Canada).

Ví dụ mẫu · Ekman transport and gyre rotation direction

A steady wind blows from the south toward the north along the eastern coast of a Southern Hemisphere continent (i.e., the wind blows toward 0°/north). (a) State the direction of the resulting Ekman transport. (b) Explain, in terms of Ekman transport acting all the way around a subtropical gyre, why Southern Hemisphere gyres rotate anticlockwise.

(a) In the Southern Hemisphere, Ekman transport acts at 90° to the *left* of the wind direction.

Facing north (the wind's direction of travel), 90° to the left points toward the west. So the net Ekman transport is directed **offshore, toward the west**.

(b) Around the full loop of a Southern Hemisphere gyre, the wind belts (trade winds nearer the equator, westerlies nearer the mid-latitudes) always deflect the net water transport 90° to the left of the local wind. Working through each side of the gyre in turn (equatorward, western boundary, poleward, eastern boundary) with this consistent "90° to the left of the wind" rule at every point produces a large-scale rotation in the anticlockwise sense — the opposite sense to Northern Hemisphere gyres, where the identical logic with a 90°-to-the-right deflection produces clockwise rotation.

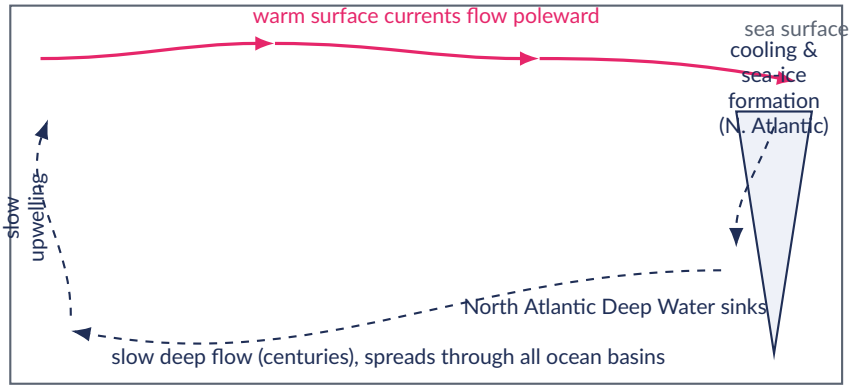
VN **GIẢI THÍCH TIẾNG VIỆT**

Ở Nam bán cầu, vận chuyển Ekman lệch 90° về bên **trái** so với hướng gió (khác với Bắc bán cầu, lệch về bên **phải**). Áp dụng nguyên tắc này liên tục quanh toàn bộ vòng hải lưu xoáy sẽ cho ra chiều quay tổng thể: **ngược chiều kim đồng hồ** ở Nam bán cầu, **thuận chiều kim đồng hồ** ở Bắc bán cầu.

5.1.2 5.1.2 Thermohaline circulation — the global conveyor belt

Density-driven deep circulation. Beneath the relatively thin, wind-driven surface layer, a completely different, far slower circulation operates throughout the full depth of the world ocean, driven not by wind but by differences in water **density**. Seawater density increases as temperature falls (**thermo-**) and as salinity rises (**-haline**) — hence **thermohaline circulation**. In the far North Atlantic (the Norwegian and Greenland Seas, and the Labrador Sea), surface water that has already travelled north as part of the Gulf Stream/North Atlantic Drift system is intensely cooled by cold polar air; simultaneously, as sea ice forms, salt is excluded from the growing ice crystals and left behind in the remaining liquid water, further raising its salinity. This combination of low temperature and high salinity makes the water exceptionally dense, so it sinks from the surface all the way to great depth, forming a deep, cold, salty water mass called **North Atlantic Deep Water (NADW)**.

The global conveyor belt. Once formed, North Atlantic Deep Water spreads slowly southward at depth through the Atlantic, eventually joining a similar, even denser bottom-water mass formed around Antarctica (Antarctic Bottom Water) and circulating into the Indian and Pacific Oceans. Over the course of centuries, this deep water gradually mixes upward and warms, eventually returning to the surface (upwelling) in parts of the Indian and Pacific Oceans, from where surface currents (aided by wind-driven circulation) carry it back toward the North Atlantic to begin the cycle again. This single, interconnected loop linking surface and deep circulation across every ocean basin is popularly called the **global conveyor belt** (or global thermohaline circulation); a complete circuit is estimated to take on the order of 1000 years. Unlike the fast, wind-driven surface gyres (which redistribute heat over days to months), the conveyor belt operates on timescales of centuries, but it is nonetheless critical to Earth's climate system: it continually redistributes heat from the tropics toward the poles and transports dissolved nutrients and oxygen throughout the deep ocean, sustaining deep-sea ecosystems that would otherwise be starved of both.



Schematic global thermohaline "conveyor belt": warm, wind-driven surface currents (pink) carry water poleward; in the North Atlantic, intense cooling and salt rejection during sea-ice formation make surface water dense enough to sink, forming North Atlantic Deep Water, which spreads slowly at depth (navy, dashed) through every ocean basin before eventually upwelling and returning to the surface — a full circuit takes on the order of 1000 years.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bên dưới lớp nước mặt do gió chi phối, tồn tại một hệ hoàn lưu khác vận hành trên toàn bộ chiều sâu đại dương, do **chênh lệch mật độ nước** (nhiệt độ thấp + độ mặn cao → mật độ cao) điều khiển — gọi là **hoàn lưu nhiệt-muối (thermohaline circulation)**. Tại Bắc Đại Tây Dương, nước bề mặt bị làm lạnh mạnh và mặn thêm do muối bị đẩy ra khi băng biển hình thành, trở nên đủ đặc để **chìm xuống đáy**, tạo thành khối **Nước Sâu Bắc Đại Tây Dương (NADW)**. Khối nước này di chuyển chậm ở tầng sâu qua mọi đại dương trong hàng **thế kỷ**, rồi từ từ trồi lên mặt (upwelling) ở Ấn Độ Dương và Thái Bình Dương, khép kín một vòng tuần hoàn gọi là **băng tải đại dương toàn cầu (global conveyor belt)** — phân phối lại nhiệt và dưỡng chất trên phạm vi toàn cầu, nuôi dưỡng hệ sinh thái biển sâu.

Two ocean circulations, two timescales: (1) wind-driven **surface currents** (Ekman transport, subtropical gyres, e.g. the Gulf Stream) operate in the upper few hundred metres and redistribute heat over days to months; (2) density-driven **thermohaline circulation** (the "global conveyor belt") operates through the full ocean depth, is triggered by sinking of cold, salty water in the North Atlantic (forming NADW), and redistributes heat and nutrients over a full circuit lasting roughly 1000 years.

5.2 5.2 Ocean--Atmosphere Interaction: The El Niño Southern Oscillation

5.2.1 5.2.1 Normal ("La Niña-like") conditions in the tropical Pacific

The Walker circulation. Under normal conditions, the tropical Pacific Ocean is dominated by strong, persistent easterly **trade winds** blowing from a zone of relatively high atmospheric pressure over the cooler eastern Pacific (off the coast of South America) toward a zone of low pressure over the warmer western Pacific (around Indonesia and northern Australia). This east-to-west pressure gradient, and the associated pattern of rising air and heavy convectional rainfall in the west and sinking, drier air in the east, is called the **Walker circulation** — an atmospheric loop lying roughly along the equator, at right angles to the more familiar north–south Hadley circulation.

Warm pool, thermocline tilt, and Peruvian upwelling. Driven by these trade winds, warm surface water is pushed steadily westward across the Pacific basin and piles up as a deep, warm "**warm pool**" near Indonesia and the western Pacific, where sea-surface temperatures are high and the boundary between warm surface water and cold deep water (the **thermocline**) lies very deep. As surface water is driven away from the eastern Pacific, it must be replaced from below: cold, nutrient-rich water from depth rises to the surface off the coast of Peru and northern Chile in a process called **upwelling** (reinforced by offshore Ekman transport along this coast). This upwelled water is exceptionally rich

in dissolved nutrients (nitrates, phosphates) brought up from depth, fuelling an extremely productive marine food web based on phytoplankton, which in turn supports one of the world's largest single-species fisheries: the Peruvian **anchoveta** (anchovy) fishery. Under these normal conditions, the eastern Pacific (coastal Peru, northern Chile) tends to be cool and dry, while the western Pacific (Indonesia, northern Australia) tends to be warm and wet.

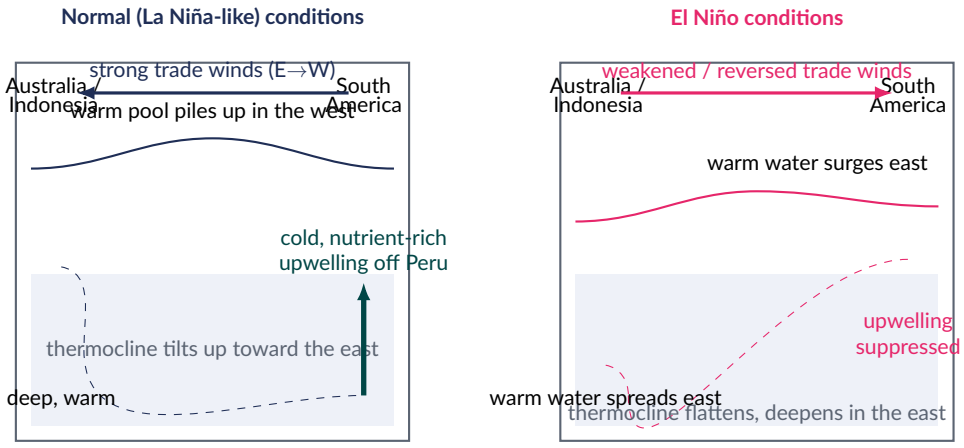
5.2.2 5.2.2 El Niño conditions

Weakening of the trade winds. Roughly every two to seven years, on an irregular cycle, the pressure gradient across the tropical Pacific weakens, and the easterly trade winds slacken or even briefly reverse to blow from the west. Without strong easterlies to hold it in the west, the warm pool of surface water that is normally banked up near Indonesia surges eastward across the Pacific basin, and the thermocline in the eastern Pacific deepens sharply. This large-scale ocean-atmosphere event is called **El Niño** (Spanish for "the (Christ) Child", after its tendency to develop around Christmas, as first noticed by Peruvian fishermen).

Consequences. With warm water now covering the eastern Pacific and the thermocline pushed deep offshore Peru, the normal upwelling of cold, nutrient-rich water off Peru is sharply suppressed or shut off entirely. Deprived of nutrients, phytoplankton productivity collapses, and the anchoveta population — along with the seabirds and other marine life that depend on it — suffers severe die-offs; historically, major El Niño events have caused the near-total collapse of the Peruvian anchoveta fishery in a given year, with serious economic consequences for Peru's fishing industry. The shift in the location of the main zone of warm water and rising air also drags the pattern of tropical rainfall with it: the western Pacific (Indonesia, Papua New Guinea, and eastern Australia) — normally wet — experiences suppressed rainfall and, in severe events, prolonged drought and increased wildfire risk, while parts of the central and eastern Pacific and the west coast of South America (normally dry) can experience unusually heavy rainfall and destructive flooding and landslides. El Niño's influence extends via atmospheric teleconnections well beyond the Pacific itself, altering storm tracks and rainfall/temperature patterns across parts of North America, southern Africa, and elsewhere.

5.2.3 5.2.3 La Niña conditions

An intensification of normal conditions. La Niña (Spanish for "the girl") is, broadly, the opposite phase of ENSO: trade winds strengthen beyond their normal intensity, pushing even more warm water than usual into the western Pacific warm pool, and Peruvian coastal upwelling of cold, nutrient-rich water is enhanced. The typical rainfall pattern is intensified in the same direction as normal conditions, rather than reversed: the western Pacific (Indonesia, northern Australia) tends to receive above-average rainfall and an increased risk of flooding, while the eastern Pacific coast (Peru) tends to be even drier than usual. Because ENSO's warm (El Niño) and cool (La Niña) phases alternate irregularly around a neutral state, and because sea-surface temperature anomalies in the tropical Pacific are continuously monitored by moored ocean buoys and satellites, ENSO is one of the most closely tracked ocean–atmosphere phenomena on Earth, since it has such widespread, well-documented effects on global weather, agriculture, and fisheries.



Left: normal (La Niña-like) conditions — strong easterly trade winds bank warm water in the western Pacific and drive cold, nutrient-rich upwelling off Peru. Right: El Niño conditions — trade winds weaken or reverse, the warm pool surges east across the Pacific, the thermocline flattens, and Peruvian upwelling is suppressed.

VN **GIẢI THÍCH TIẾNG VIỆT**

ENSO (El Niño Southern Oscillation) là dao động đại dương–khí quyển ở Thái Bình Dương nhiệt đới. **Điều kiện bình thường**: gió mậu dịch (trade winds) thổi mạnh từ đông sang tây, dồn nước ấm về phía tây (gần Indonesia — "vùng nước ấm"), tạo hoàn lưu **Walker**; ở phía đông (ngoài khơi Peru), nước lạnh giàu dinh dưỡng **trồi lên (upwelling)**, nuôi dưỡng nghề cá **anchoveta** (cá cơm) trù phú. **El Niño**: gió mậu dịch suy yếu hoặc đảo chiều, nước ấm tràn về phía đông Thái Bình Dương, hiện tượng trồi nước bị ngưng trệ → nghề cá Peru sụp đổ, đồng thời gây **hạn hán** ở Indonesia/Úc và **lũ lụt** ở Nam Mỹ. **La Niña**: về cơ bản là chiều ngược lại — gió mậu dịch mạnh hơn bình thường, làm tăng cường các hình thái thời tiết thông thường (mưa nhiều hơn ở phía tây, khô hơn ở phía đông).

Ví dụ mẫu · Classifying ENSO phase from sea-surface temperature anomaly data

The table below shows the monthly sea-surface temperature (SST) anomaly (departure from the long-term average, in °C) in the Niño 3.4 region of the central-eastern tropical Pacific, a standard index region used to monitor ENSO.

Month	Jan	Mar	May	Jul	Sep
SST anomaly (°C)	$+0.4$	$+0.9$	$+1.6$	$+2.1$	$+1.8$

By convention, a Niño 3.4 anomaly of at least $+0.5$°C sustained for several months indicates El Niño conditions; at least -0.5°C sustained for several months indicates La Niña conditions; values persistently between -0.5°C and $+0.5$°C indicate ENSO-neutral conditions. Classify the ENSO phase shown by this data, and explain the physical link to Peruvian coastal upwelling during these months.

Classify. From March onward the anomaly is consistently at or above $+0.9$°C, well above the $+0.5$°C threshold, peaking at $+2.1$°C in July. This sustained, strongly positive anomaly indicates **El Niño conditions**, strengthening through the year and peaking around July before beginning to ease slightly by September.

Link to upwelling. A strongly positive SST anomaly in this region means anomalously warm water has spread across the central and eastern tropical Pacific — consistent with a weakened

or reversed trade wind pattern that has allowed the western warm pool to surge eastward. Because this places a layer of unusually warm, less nutrient-rich water over the region where cold water would normally upwell off Peru, coastal upwelling is suppressed during these months; nutrient supply to the surface collapses accordingly, and a corresponding decline in the anchoveta fishery would be expected.

VN **GIẢI THÍCH TIẾNG VIỆT**

Để phân loại pha ENSO từ dữ liệu **độ lệch nhiệt độ mặt biển (SST anomaly)** tại vùng Niño 3.4: nếu độ lệch $\geq +0.5^{\circ}$C kéo dài nhiều tháng → **El Niño**; nếu $\leq -0.5^{\circ}$C kéo dài → **La Niña**; nếu nằm giữa hai ngưỡng đó → **trung tính (neutral)**. Nhiệt độ mặt biển dương bất thường ở khu vực này đồng nghĩa nước ấm đã lan sang phía đông Thái Bình Dương, gắn liền với gió mậu dịch suy yếu và hiện tượng trồi nước ngoài khơi Peru bị ức chế.

5.3 5.3 Coastal Wave Processes

5.3.1 5.3.1 Wave formation and wave characteristics

How waves form. Ocean waves are generated chiefly by wind blowing across the sea surface, transferring energy through frictional drag to produce oscillating movements of water. The size of the wave generated depends on three factors: wind **speed**, wind **duration** (how long it blows), and **fetch** (the uninterrupted distance of open water over which the wind blows) — greater values of all three generally produce larger, more powerful waves. As a wave travels, individual water particles move in roughly circular orbits, with the wave form (not the water itself) travelling forward; only very close to the shore, where the seabed shoals and interferes with these orbits, does the wave break and water is actually carried forward up the beach.

5.3.2 5.3.2 Constructive versus destructive waves

Constructive waves. **Constructive waves** are typically generated by distant weather systems and have travelled a long distance as regular, well-organized **swell**; they are characteristically **low** in height, have a **long wavelength** and correspondingly **low frequency** (relatively few waves arrive per minute, often around 6–8 per minute), and break gently as a spilling breaker. Because they are low-energy and gently sloping, the **swash** (the forward rush of water up the beach after a wave breaks) is strong relative to the **backwash** (the return flow of water down the beach under gravity), and a large proportion of the swash's water percolates into the permeable beach sand rather than flowing back as backwash. The net effect, repeated over many waves, is a steady net landward transport of sediment: constructive waves **build up and widen beaches**, and are typically associated with gently sloping beach profiles.

Destructive waves. **Destructive waves** are typically generated by local, energetic storm conditions close to the coast; they are **steep** and comparatively **high**, have a **short wavelength** and correspondingly **high frequency** (often around 12–14 waves per minute or more), and break abruptly as a plunging breaker that dumps its energy directly onto the beach. Their steep, rapid arrival means a comparatively weak swash but a strong backwash that drags a large volume of sediment back down the beach faster than the next wave can push new material up. Repeated over many waves, this produces a net seaward transport of sediment: destructive waves **erode beaches**, removing sand and shingle and often leaving a steeper beach profile and, at the top of the beach, a pronounced **storm beach** ridge of the coarsest material thrown up by the most powerful waves.

Characteristic	Constructive wave	Destructive wave
Wave height	Low	High
Wavelength	Long	Short
Frequency	Low (≈ 6–8/min)	High (≈ 12–14/min)
Breaker type	Spilling (gentle)	Plunging (abrupt)
Swash vs. backwash	Swash $>$ backwash	Backwash $>$ swash
Net sediment effect	Deposition — builds/widens the beach	Erosion — narrows/steepens the beach
Typical source	Distant swell, calm weather	Local storms

(!) Lỗi thường gặp: Học sinh thường **nhớ ngược** đặc điểm hai loại sóng. Mẹo ghi nhớ: sóng **xây dựng (constructive)** thì *"chậm mà chắc"* — **thấp**, **dài**, **ít con/phút**, swash mạnh hơn backwash → **bồi tụ**. Sóng **phá huỷ (destructive)** thì *"nhanh mà dữ"* — **cao**, **ngắn**, **nhiều con/phút**, backwash mạnh hơn swash → **xâm thực**. Đừng nhầm "sóng cao" với "sóng xây dựng" — sóng *cao* chính là sóng *phá huỷ*, không phải ngược lại.

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Sóng xây dựng (constructive waves): thấp, bước sóng dài, tần suất thấp, vỡ nhẹ nhàng (spilling breaker); **swash mạnh hơn backwash** vì phần lớn nước ngấm vào cát → bồi đắp, mở rộng bãi biển. **Sóng phá huỷ (destructive waves)**: cao, bước sóng ngắn, tần suất cao, vỡ đột ngột (plunging breaker); **backwash mạnh hơn swash** → cuốn trôi vật liệu ra biển, làm xói mòn và dốc hoá bãi biển, để lại **gờ bão (storm beach)** ở đỉnh bãi.

Ví dụ mẫu · Classifying wave data as constructive- or destructive-dominated

Two beaches are monitored during a single day. Beach X records an average wave height of 0.6 m and a frequency of 7 waves per minute. Beach Y records an average wave height of 1.8 m and a frequency of 13 waves per minute. (a) Classify the dominant wave type at each beach. (b) Predict the short-term change in beach profile at each location.

(a) Beach X: low wave height (0.6 m) and low frequency (7/min) match the profile of **constructive waves**. Beach Y: high wave height (1.8 m) and high frequency (13/min) match the profile of **destructive waves**.

(b) At Beach X, constructive waves should produce a strong swash relative to backwash, so sediment is progressively pushed up and landward: the beach should **widen and gain sediment** (net deposition), likely developing a gently sloping profile. At Beach Y, destructive waves should produce a strong backwash relative to swash, dragging sediment seaward faster than it is replaced: the beach should **narrow and lose sediment** (net erosion), likely developing a steeper profile with a prominent storm-beach ridge at its upper limit.

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Để phân loại sóng từ dữ liệu chiều cao và tần suất: sóng **thấp + tần suất thấp** → **xây dựng** (dự đoán bãi biển được bồi rộng ra); sóng **cao + tần suất cao** → **phá huỷ** (dự đoán bãi biển bị xói mòn, thu hẹp lại và dốc hơn).

5.3.3 5.3.3 Wave refraction

Refraction on an irregular coastline. Along an indented coastline of alternating **headlands** (projecting outcrops, typically of more resistant rock) and **bays** (recessed inlets, typically cut into less resistant

rock), incoming waves do not arrive with a uniform crest right across the whole coastline. As a wave approaches shore, the part of the wave crest approaching the shallower water in front of a headland is slowed by friction with the seabed sooner than the part of the same wave crest still travelling through the deeper water off an adjacent bay. This differential slowing bends (**refracts**) the wave crest so that it wraps around and becomes roughly parallel to the headland's outline. Because wave energy is spread along the length of a wave crest, and the crest becomes compressed as it wraps around a headland, wave energy is concentrated (converges) on headlands — explaining why headlands typically experience the most vigorous erosion along an indented coastline. Correspondingly, the wave crest is stretched out (diverges) as it crosses the wider mouth of an adjacent bay, spreading its energy over a greater length of shoreline and arriving with much reduced erosive power; bays are therefore typically zones of net deposition (sheltered, sediment-accumulating beaches), even along a coastline that is being eroded overall.

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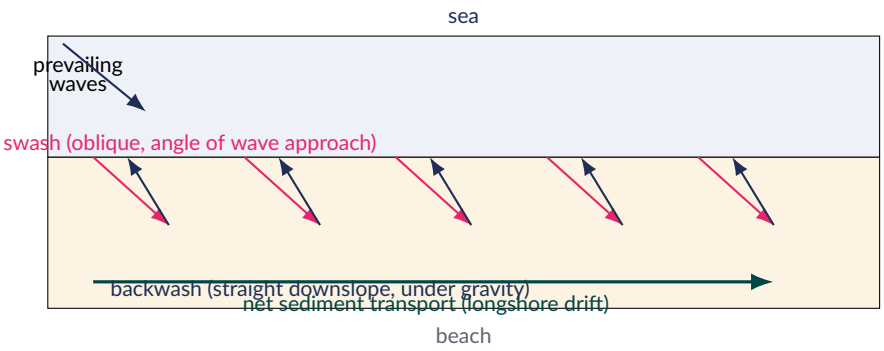
Khúc xạ sóng (wave refraction) xảy ra vì phần sóng tới gần **mũi đất (headland)** — nơi nước nông hơn — bị ma sát đáy biển làm chậm lại sớm hơn phần sóng còn ở **vịnh (bay)** nước sâu hơn, khiến đỉnh sóng bị uốn cong để ôm theo đường bờ mũi đất. Vì năng lượng sóng bị **tập trung (converge)** tại mũi đất nhưng **phân tán (diverge)** tại vịnh, mũi đất bị xâm thực mạnh trong khi vịnh có xu hướng **bồi tụ** (hình thành bãi biển được che chắn) — ngay cả khi toàn tuyến bờ biển đang bị xói mòn nhìn chung.

5.3.4 5.3.4 Longshore drift

The zig-zag mechanism. When waves approach a beach at an angle — as they very commonly do, because the prevailing wind and wave direction rarely arrives exactly perpendicular to the shoreline — the resulting **swash** runs up the beach at that same oblique angle, in the direction the waves are travelling. However, once the wave's energy is spent, the **backwash** drains straight back down the beach under gravity, following the steepest gradient of the beach profile rather than the oblique angle of the incoming wave. Repeated many thousands of times, this asymmetry between an oblique swash and a directly-downslope backwash causes sand and shingle particles to be shifted a small distance along the coast (in the net direction of the prevailing waves) with every wave cycle, tracing an overall zig-zag path. This net movement of sediment along a coastline is called **longshore drift** (or littoral drift), and its net direction is determined by the dominant angle from which waves approach that particular stretch of coast, which is itself set by the prevailing wind direction. Longshore drift is the dominant process supplying sediment to many depositional coastal landforms (beaches, spits, bars) and redistributing sediment along a coastline; it is also the process most directly disrupted by hard-engineering structures such as groynes, discussed in Section 5.7.



Longshore drift: swash (pink) carries sediment obliquely up the beach at the angle of wave approach; backwash (navy) drains straight down the beach slope under gravity. The asymmetry produces a net zig-zag transport of sediment along the coast (teal arrow) in the direction the waves are approaching from.

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Khi sóng tới bờ theo một **góc xiên** (do hướng gió/sóng thịnh hành hiếm khi vuông góc hoàn toàn với bờ), **swash** (dòng nước tràn lên) chạy lên bãi theo đúng góc xiên đó, nhưng **backwash** (dòng nước rút xuống) lại chảy thẳng xuống dốc theo trọng lực. Sự bất đối xứng này lặp lại hàng ngàn lần tạo ra chuyển động **hình chữ chi (zig-zag)** của bùn cát dọc theo bờ biển — gọi là **vận chuyển bùn cát dọc bờ (longshore drift)**, với hướng vận chuyển chung được quyết định bởi hướng sóng/gió thịnh hành.

Ví dụ mẫu · Determining the net direction of longshore drift

At a straight stretch of coastline running west to east, field observation shows that waves consistently approach from the south-west, striking the beach at an angle to the shoreline before breaking. Determine the net direction of longshore drift along this coast, and describe the reasoning process used.

Step 1 — identify the angle of wave approach. Waves from the south-west strike an east–west-trending coast obliquely (not head-on), so swash will run up the beach at that same south-west-to-north-east diagonal angle.

Step 2 — apply the swash/backwash asymmetry. Swash carries sediment up-beach along the oblique south-west→north-east line of wave approach; backwash then drains straight back down the beach slope under gravity (perpendicular to the shoreline, not back along the diagonal).

Step 3 — resolve the net vector. Each cycle nudges sediment a small distance further to the **north-east** along the shoreline (the "forward" component of the oblique swash that is not cancelled by the straight-down backwash). Repeated over many wave cycles, net longshore drift along this coast runs from **south-west to north-east** (i.e., toward the east along this particular west–east coastline).

General rule: net longshore drift always runs in the same alongshore direction that the prevailing waves are travelling toward (not the compass direction they originate from) — here, waves moving in from the south-west are travelling toward the north-east, so that is the net drift direction.

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Để xác định hướng vận chuyển bùn cát dọc bờ: xác định hướng sóng/gió **thịnh hành** tới bờ, sau đó suy ra hướng chuyển động ròng của bùn cát chính là hướng mà sóng đang **di chuyển tới** (không phải hướng sóng xuất phát) dọc theo đường bờ. Ví dụ sóng từ hướng Tây Nam thổi tới bờ chạy theo hướng Đông–Tây sẽ tạo ra vận chuyển bùn cát ròng theo hướng **Đông Bắc**.

5.4 5.4 Coastal Erosion: Processes and Landforms

5.4.1 5.4.1 Processes of coastal erosion

Waves erode rock and unconsolidated cliff material through four main mechanical and chemical processes, usually acting together and reinforcing one another.

Hydraulic action: the sheer force of moving water, and the compression of air trapped in cracks and joints under the pressure of a breaking wave, which can widen cracks and dislodge fragments of rock purely through the physical force and pressure of water and air. **Abrasion (corrasion)**: rock fragments, sand, and shingle carried within breaking waves are hurled against the cliff or shore platform, wearing it away much like sandpaper — generally the most effective erosional process where a wave is carrying a heavy load of coarse material. **Attrition**: rock fragments and sediment particles being transported collide with one another, gradually breaking each other down into smaller, smoother, and more rounded particles over time (this reduces the size of the load, but does not by itself erode the cliff or shore platform). **Solution (corrosion)**: chemical dissolution of soluble rock (such as limestone or chalk, which reacts with slightly acidic seawater) directly into solution — a slow but continuous process on susceptible rock types, independent of wave energy.

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Bốn quá trình xâm thực bờ biển: **thuỷ lực (hydraulic action)** — lực nén khí trong khe nứt và lực đập trực tiếp của nước; **mài mòn (abrasion/corrasion)** — vật liệu do sóng cuốn theo va đập vào vách đá (thường là quá trình mạnh nhất khi sóng mang nhiều vật liệu thô); **va đập lẫn nhau (attrition)** — các mảnh vật liệu va chạm nhau làm nhỏ và tròn dần (không trực tiếp bào mòn vách đá); **hoà tan (solution/corrosion)** — đá dễ hoà tan (đá vôi, đá phấn) bị hoà tan hoá học bởi nước biển hơi acid.

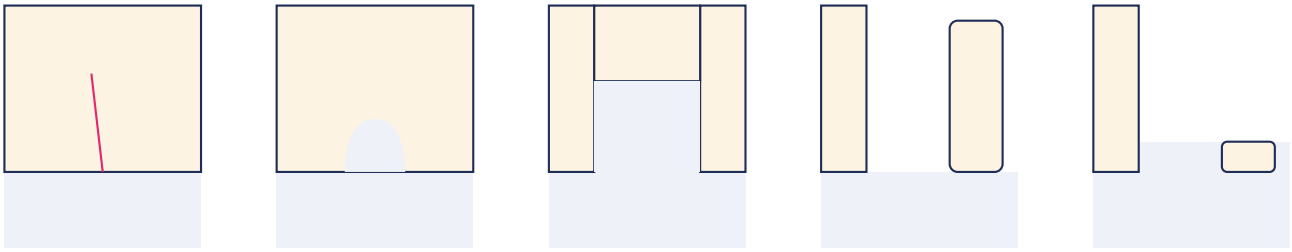
5.4.2 5.4.2 Differential erosion: headlands, bays, and wave-cut platforms

Headlands and bays. Along many coastlines, bands of geologically resistant rock (such as granite, chalk, or hard limestone) alternate with bands of weaker, less resistant rock (such as clay or soft sandstone), often lying roughly perpendicular or at an angle to the coastline (a "discordant" coastline). Because weaker rock erodes back faster than resistant rock under the same wave attack, this **differential erosion** carves the weaker bands into recessed **bays** while the more resistant bands are left projecting seaward as seaward-facing **headlands**. As discussed above, wave refraction then reinforces this pattern by concentrating erosive wave energy on the exposed headlands while sheltering the bays, where wave energy is dissipated and beach deposition is favoured.

Wave-cut platforms. As a cliff retreats under sustained erosion at its base (concentrated in a wave-cut notch, undercut by wave action around the mean high-water mark), the cliff face becomes progressively oversteepened and eventually collapses under gravity, and the point of active erosion migrates landward with the retreating cliff line. This process, repeated over a long period, leaves behind a gently sloping, wave-abraded rock surface at the foot of the retreating cliff, exposed at low tide: a **wave-cut platform** (or shore platform). The platform is widest where the cliff has retreated furthest, and its very gentle seaward slope reflects the level at which wave erosion is most effective (a narrow vertical zone around high-water mark), rather than any pre-existing land surface.

5.4.3 5.4.3 The headland erosion sequence: crack, cave, arch, stack, stump

A progressive sequence. On a resistant headland cut by lines of structural weakness (joints, faults, or bedding planes), erosion proceeds through a well-defined, progressive sequence of landforms as those weaknesses are preferentially exploited and enlarged over time.



1. Crack 2. Cave 3. Arch 4. Stack 5. Stump

The headland erosion sequence: (1) hydraulic action and abrasion exploit a line of weakness to form a **crack**; (2) sustained erosion enlarges it into a **cave**; (3) a cave eroding through a narrow headland, or two caves eroding back-to-back, breaks through to form an **arch**; (4) continued erosion and undercutting of the arch's roof causes it to collapse, isolating the seaward block as a **stack**; (5) further wave erosion at the base of the stack causes it to collapse and be reduced to a low, wave-washed **stump**, often visible only at low tide.

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Trên một mũi đất bị cắt bởi các đường yếu về cấu trúc (khe nứt, đứt gãy), xâm thực tiến triển theo trình tự: (1) **khe nứt (crack)** — thuỷ lực và mài mòn khoét sâu đường yếu; (2) **hang (cave)** — khe nứt được mở rộng; (3) **vòm (arch)** — hang xuyên thủng qua mũi đất hẹp hoặc hai hang đối lưng ăn thông nhau; (4) **trụ đá (stack)** — phần mái vòm sụp đổ, tách khối đá phía biển thành cột đá đứng độc lập; (5) **gốc trụ (stump)** — trụ đá tiếp tục bị xâm thực ở chân, sụp đổ và bị bào mòn thành mỏm đá thấp, thường chỉ lộ ra khi thuỷ triều xuống.

Ví dụ mẫu · Identifying stages in the erosion sequence

A survey of a headland describes four distinct rock features along its length: (i) a narrow, water-filled fissure a few metres deep, following a vertical joint in the cliff face; (ii) a tunnel of rock completely open at both ends, connecting the open sea to a small enclosed bay behind the headland; (iii) an isolated pillar of rock standing apart from the cliff, only reachable at low tide; (iv) a low, barely-emergent rock ledge just offshore, submerged at all but the lowest tides. Identify each feature using the headland erosion sequence, and place them in order from least to most eroded.

(i) A narrow fissure following a line of structural weakness, not yet a full cave, is a **crack** (or an early-stage cave if noticeably widened). (ii) A tunnel open at both ends connecting two bodies of water is an **arch**. (iii) An isolated standing pillar, separated from the mainland cliff, is a **stack**. (iv) A low, barely emergent ledge, mostly submerged, is a **stump** — the final, most eroded stage.

Order (least → most eroded): crack (i) → arch (ii) → stack (iii) → stump (iv). (Note that a fully developed *cave*, an intermediate stage between crack and arch, is not explicitly described here, illustrating that not every headland will show every single stage of the sequence clearly at once — some caves erode through to an arch before ever being observed as simple enclosed caves.)

VN **GIẢI THÍCH TIẾNG VIỆT**

Khi xác định giai đoạn xâm thực từ mô tả thực địa, hãy chú ý đặc điểm nhận dạng: khe nứt hẹp theo đường yếu = **crack**; hầm xuyên thông hai đầu = **arch**; cột đá đứng tách biệt = **stack**; mỏm đá thấp gần như chìm dưới nước = **stump**. Không phải mọi mũi đất đều thể hiện đầy đủ mọi giai đoạn của chuỗi (ví dụ có thể quan sát thấy vòm mà chưa từng thấy giai đoạn hang riêng biệt).

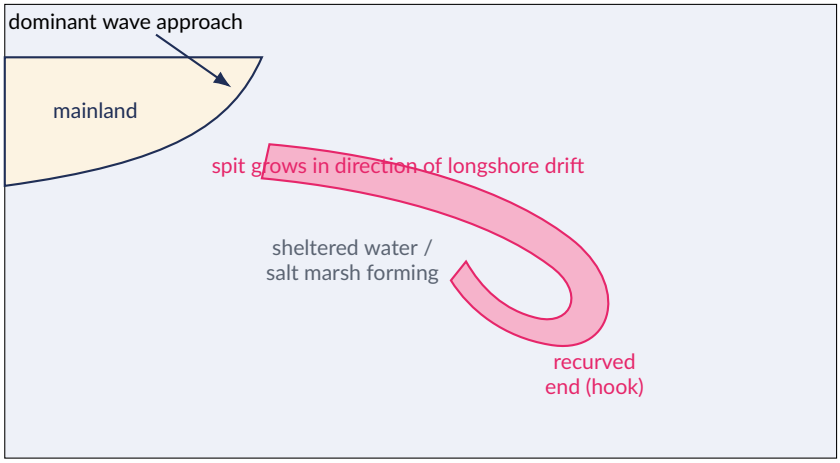
5.5 5.5 Coastal Depositional Landforms

Beaches. A **beach** is an accumulation of sand and/or shingle deposited between the low-water mark and the limit of storm wave action, formed where wave energy is predominantly depositional (constructive-wave-dominated) rather than erosional. Beach material is supplied both from local cliff erosion and, very often to a greater extent, from longshore drift bringing sediment along the coast from elsewhere.

Spits. A **spit** is a long, narrow ridge of sand or shingle, attached to the land at one end, that projects out into open water (across a bay mouth, or the mouth of a river estuary) and terminates in open water at its other, distal end. Spits form where longshore drift carries sediment along a coastline to a point where the coastline changes direction abruptly (for example, at a river mouth or bay entrance) — sediment continues to be deposited by longshore drift beyond this point, out into open, usually more sheltered, water, gradually building the spit further out over time. At its exposed distal end, the spit is often affected by a secondary wave direction or by wave refraction around the tip, which curves the growing end of the spit back toward the land, producing a distinctive **recurved end** (or "hook"); repeated changes in the dominant wave direction over time can produce a spit with multiple recurved hooks along its length. Sheltered water on the landward side of a spit (particularly where it partially encloses a bay or estuary mouth) frequently silts up with fine sediment and colonising vegetation to form a sheltered **salt marsh**.

Bars. A **bar** forms where a spit continues to grow until it extends completely across a bay or the mouth of a river estuary, connecting one side of the bay to the other and fully cutting off the water behind it from the open sea, often trapping a shallow lagoon.

Tombolos. A **tombolo** is a ridge of sand or shingle that connects the mainland to an offshore island. Tombolos form where wave refraction around an island reduces wave energy in its lee (the sheltered zone directly behind it, facing the mainland), so that sediment carried into this zone by converging wave and current patterns is deposited rather than removed, gradually building up a continuous connecting ridge over time (a well-known example is Chesil Beach, which links the English mainland to the Isle of Portland).



A spit growing out from the mainland in the direction of longshore drift, with a recurved end (hook) produced by wave refraction and a secondary wave direction acting around the exposed tip. Sheltered water on the landward side often silts up to form a salt marsh.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bãi biển: tích tụ cát/sỏi giữa mực triều thấp và giới hạn sóng bão, nơi năng lượng sóng chủ yếu mang tính bồi tụ. **Doi cát (spit)**: dải cát/sỏi dài, nối với đất liền một đầu, vươn ra vùng nước hở (ví dụ tại cửa sông hay cửa vịnh) do vận chuyển dọc bờ tiếp tục bồi đắp vượt qua điểm bờ biển đổi hướng; đầu ngoài của doi cát thường bị **uốn cong (recurved end)** do khúc xạ sóng hoặc hướng sóng phụ. **Đập cát (bar)**: doi cát phát triển vươn hẳn qua toàn bộ cửa vịnh/cửa

sông, cắt đứt hoàn toàn vùng nước phía sau khỏi biển khơi (thường tạo thành đầm phá). **Mũi nối đảo (tombolo)**: dải cát nối đất liền với một hòn đảo ngoài khơi, hình thành do khúc xạ sóng quanh đảo làm giảm năng lượng sóng ở phía khuất, khiến trầm tích lắng đọng dần thành dải nối liên tục (ví dụ Chesil Beach, Anh Quốc, nối đất liền với đảo Portland).

5.6 5.6 Sea-Level Change

Two fundamentally different mechanisms. Changes in the position of the shoreline relative to the land can arise from two entirely distinct physical mechanisms, which are frequently confused but must be clearly distinguished.

Eustatic change is a genuine change in the actual **volume** of water contained in the world's oceans (or, equivalently, a change in the average global sea level itself), and it therefore acts **globally** and essentially simultaneously everywhere, regardless of location. The two principal mechanisms are (1) **thermal expansion** of ocean water as it warms (water expands in volume as its temperature rises, so a warmer ocean simply occupies more space even at constant mass) and (2) changes in the total mass of water locked up on land as ice — melting of land-based ice sheets and glaciers (e.g., the Greenland and Antarctic ice sheets) adds water to the ocean and raises eustatic sea level, while the growth of ice sheets during a glacial period removes water from the ocean (locking it up as ice on land) and lowers eustatic sea level.

Isostatic change is a change in the **relative height of the land itself** at a particular location, with no requirement for any change in the actual volume of ocean water at all; it is therefore a **local or regional**, not global, phenomenon, and different stretches of coastline can experience isostatic change in opposite directions at the same time. The best-known mechanism is **post-glacial (isostatic) rebound**: during a glacial period, the immense weight of a thick ice sheet depresses the underlying crust and upper mantle downward; once the ice sheet melts (an event which is itself, separately, a cause of eustatic sea-level rise), the removed weight allows the crust to slowly rebound upward over thousands of years, causing relative sea level to *fall* at that location even while the ocean itself may be rising or holding steady elsewhere (parts of Scandinavia and northern Scotland, formerly beneath thick Pleistocene ice sheets, are still rising today for this reason). The converse process, **isostatic subsidence**, describes land sinking relative to the sea — for instance, where the crust adjacent to a formerly glaciated, now-rebounding region is being pulled or tilted downward as a compensating effect (a "forebulge collapse"), or where a river delta is subsiding under its own accumulated sediment load and compaction (e.g., parts of the Mississippi Delta and the Nile Delta), each of which raises relative sea level at that location without requiring any global change in ocean volume at all.

Feature	Eustatic change	Isostatic change
Scale	Global — affects every coastline simultaneously	Local/regional — varies from place to place, can differ in direction
Cause	Change in the actual volume/mass of ocean water (thermal expansion; ice-sheet melting/growth)	Change in the relative height of the land (post-glacial rebound; land subsidence; tectonic uplift/subsidence)
Typical example	Global sea-level rise from thermal expansion and glacier/ice-sheet melt under contemporary warming	Scandinavia/Scotland rising after loss of Pleistocene ice sheets; Mississippi/Nile delta subsiding under sediment load

(!) Lỗi thường gặp: Lỗi thường gặp nhất trong chủ đề này là **nhầm lẫn eustatic với isostatic**. Ghi nhớ: **eustatic = toàn cầu**, do *thể tích nước biển* thay đổi thực sự (giãn nở nhiệt, tan băng)

— ảnh hưởng *mọi nơi cùng lúc*. **Isostatic = cục bộ/khu vực**, do *độ cao mặt đất* thay đổi (đất trồi lên hoặc lún xuống) — *không nhất thiết* đi kèm bất kỳ thay đổi nào về tổng thể tích nước biển, và các khu vực khác nhau có thể biến đổi theo chiều *ngược nhau* cùng một thời điểm (ví dụ Scandinavia đang trồi lên trong khi đồng bằng châu thổ Mississippi đang lún xuống). Một câu hỏi thi thường gặp là yêu cầu phân biệt hai khái niệm này bằng một ví dụ cụ thể — hãy luôn nêu rõ *cơ chế vật lý* đằng sau, không chỉ nêu định nghĩa suông.

VN **GIẢI THÍCH TIẾNG VIỆT**

Biến đổi mực nước biển kiểu eustatic là thay đổi thực sự về **thể tích nước đại dương toàn cầu**, do giãn nở nhiệt hoặc băng tan/hình thành — tác động đồng thời lên mọi bờ biển trên thế giới. **Biến đổi kiểu isostatic** là thay đổi **độ cao tương đối của mặt đất** tại một địa phương, không đòi hỏi thay đổi thể tích nước biển toàn cầu — ví dụ điển hình là hiện tượng **trồi đất sau băng hà (post-glacial rebound)**: khi lớp băng dày tan đi, phần vỏ Trái Đất từng bị đè nén sẽ từ từ trồi lên trong hàng nghìn năm (Scandinavia, Bắc Scotland), trong khi một số châu thổ sông lại đang **lún xuống** do tự đè nén dưới trọng lượng trầm tích của chính nó (châu thổ Mississippi, sông Nile).

Ví dụ mẫu · Distinguishing eustatic and isostatic sea-level change

Two coastal observations are reported. Observation 1: tide gauges across every ocean basin on Earth record a rise in mean sea level of approximately 3.5 mm/year over the past three decades, closely tracking the observed rate of global glacier and ice-sheet mass loss and ocean thermal expansion. Observation 2: a stretch of coastline in northern Scotland shows a long-term *fall* in relative sea level, with raised, wave-cut platforms now stranded well above the present shoreline, dated to a period when the region was covered by a thick Pleistocene ice sheet. Classify each observation and justify your classification.

Observation 1: a change measured consistently across every ocean basin worldwide, and directly linked to changes in the actual mass/volume of water in the ocean system (glacier and ice-sheet melt add water; thermal expansion increases the volume of existing water) is a global phenomenon acting through a change in ocean-water volume — the definition of **eustatic** sea-level rise.

Observation 2: a change confined to one specific regional stretch of coastline, in the opposite direction (relative sea-level *fall*, not rise), explained by the land itself moving vertically (rebounding upward following the removal of a formerly overlying ice sheet), with no requirement for any change in the volume of the ocean itself, is **isostatic** — specifically, post-glacial isostatic rebound.

Both processes can and do operate simultaneously on the same coastline: even in northern Scotland, ongoing eustatic sea-level rise is currently occurring alongside isostatic rebound, and the *net*, locally observed change in relative sea level at any given point on Earth's coastline is the combined result of both effects operating together.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khi phân biệt eustatic và isostatic trong một câu hỏi cụ thể: nếu hiện tượng được ghi nhận **đồng thời trên toàn cầu** và gắn với thay đổi **thể tích nước biển** → **eustatic**; nếu hiện tượng chỉ xảy ra tại **một khu vực cụ thể** và gắn với **độ cao mặt đất** thay đổi (không nhất thiết liên quan thể tích nước biển) → **isostatic**. Lưu ý cả hai quá trình có thể diễn ra **đồng thời** tại cùng một bờ biển, và mực nước biển tương đối quan sát được trên thực tế là kết quả **tổng hợp** của cả hai.

5.7 5.7 Coastal Management

5.7.1 5.7.1 Hard engineering versus soft engineering

Hard engineering refers to large, permanent, artificial structures built to resist and directly oppose natural coastal processes — typically effective in the immediate location where they are built, but expensive to construct and maintain, often visually intrusive, and prone to interfering with, rather than working with, natural sediment budgets and longshore transport. **Soft engineering** refers to management approaches that work with, rather than against, natural coastal processes, generally less immediately dramatic in appearance, often cheaper over the long term, and lower in negative side effects elsewhere along the coast, though frequently requiring ongoing maintenance and recurrent expenditure of their own.

Approach	Mechanism	Advantage	Disadvantage
Hard engineering			
Sea wall	Solid concrete/rock barrier at the cliff or beach top, reflecting wave energy back to sea	Very effective, immediate protection; often doubles as a promenade	Very expensive; can increase erosion at its base (wave reflection); visually intrusive
Groynes	Wooden or rock barriers built out from the beach, perpendicular to the shore, trapping sediment moving by longshore drift	Cheap to build; widens/-maintains the local beach (a natural buffer)	Starves beaches further along the coast (downdrift) of sediment, accelerating erosion there
Rock armour / rip-rap	Large boulders piled at the base of a cliff or sea wall, absorbing and dissipating wave energy	Relatively cheap; effective at dissipating energy	Can look unnatural; boulders may be sourced from elsewhere at environmental cost
Gabions	Wire cages filled with rocks, placed at the cliff foot or on a slope	Cheap, flexible, allows some drainage	Wire cages corrode/break over time (typically 5–10 years); modest capacity
Soft engineering			
Beach nourishment	Sand/shingle dredged from elsewhere (often offshore) and pumped/deposited onto an eroding beach	Looks natural; widens the beach, absorbing wave energy; enhances tourism value	Expensive and must be repeated periodically as new material is itself eroded
Dune regeneration	Planting vegetation (e.g. marram grass) to stabilize and rebuild coastal sand dunes	Cheap; enhances natural habitat; dunes buffer storm surge	Slow to establish; vulnerable to trampling and storm damage while young
Managed realignment	Deliberately breaching or removing a section of existing defence, allowing the sea to flood a controlled inland area (often creating salt marsh)	Cheap long-term; creates valuable intertidal habitat; reduces wave energy naturally	Loss of land/agricultural use; requires compensation for affected owners

(!) Lỗi thường gặp: Đừng cho rằng công trình cứng (hard engineering) chỉ có tác dụng **tích cực** và không gây hậu quả gì ở nơi khác. Một lỗi phổ biến là bỏ qua **hệ quả lan truyền dọc bờ (downdrift effect)**: **đê chắn sóng ngang (groynes)** tuy giữ được cát tại chỗ nhưng đồng thời **ngăn chặn vận chuyển bùn cát dọc bờ (longshore drift)**, khiến các bãi biển ở phía hạ lưu của

dòng vận chuyển (downdrift) bị **thiếu hụt trầm tích** và xói mòn nhanh hơn. Luôn đánh giá công trình bảo vệ bờ biển trong bối cảnh **toàn tuyến bờ biển**, không chỉ tại vị trí công trình được xây dựng.

VN GIẢI THÍCH TIẾNG VIỆT

Công trình cứng (hard engineering): kè biển (sea wall), đê chắn sóng ngang (groynes), đá hộ chân (rock armour/rip-rap), rọ đá (gabions) — hiệu quả tại chỗ nhưng tốn kém và thường gây xói mòn nghiêm trọng hơn ở nơi khác dọc bờ biển (đặc biệt groynes gây thiếu hụt trầm tích ở khu vực hạ lưu vận chuyển). **Công trình mềm (soft engineering)**: bồi cát nhân tạo (beach nourishment), phục hồi cồn cát (dune regeneration), tái điều chỉnh có quản lý/rút lui có kiểm soát (managed realignment) — làm việc thuận theo tự nhiên, thường rẻ hơn về lâu dài và ít tác động tiêu cực lan truyền hơn, nhưng cần bảo trì liên tục hoặc đánh đổi bằng diện tích đất.

5.7.2 5.7.2 The holistic approach: Shoreline Management Plans

A whole-coastline strategy. Because hard defences built at one point on a coast can starve neighbouring stretches of sediment and accelerate erosion there, many coastal authorities (notably in the United Kingdom) have moved toward a more holistic, whole-coastline planning approach rather than defending every individual location in isolation. A **Shoreline Management Plan (SMP)** divides an entire length of coastline into discrete management units and assigns each unit one of four broad policy options, chosen after weighing the costs and benefits of protecting (or not protecting) that particular stretch:

Hold the line: maintain and, where necessary, upgrade existing defences to keep the shoreline in essentially its current position — typically applied where there is high-value property, infrastructure, or population to protect. **Advance the line**: build new defences seaward of the existing coastline, reclaiming land from the sea — typically only justified where land is extremely valuable. **Managed realignment** (managed retreat): allow the shoreline to retreat in a controlled, planned way, often by removing or relocating existing defences further inland, deliberately sacrificing some land to reduce long-term cost and to create natural habitat (e.g. salt marsh) that itself provides a buffer against future erosion and storm surge. **No active intervention**: allow natural processes to proceed completely unhindered, with no new defences built and existing ones left to fail — typically applied where the cost of protection would far exceed the value of what is being protected (e.g. sparsely populated farmland or an already-retreating soft cliff with no significant infrastructure at risk).

VN GIẢI THÍCH TIẾNG VIỆT

Vì công trình cứng xây tại một điểm có thể làm cạn kiệt trầm tích của các khu vực lân cận, nhiều cơ quan quản lý bờ biển (đặc biệt tại Anh Quốc) áp dụng cách tiếp cận **tổng thể (holistic)** thông qua **Kế hoạch Quản lý Bờ biển (Shoreline Management Plan — SMP)**, chia toàn tuyến bờ biển thành nhiều đơn vị quản lý và gán mỗi đơn vị một trong bốn chính sách: **giữ nguyên tuyến (hold the line)** — duy trì/nâng cấp công trình hiện có; **tiến ra biển (advance the line)** — xây công trình mới lấn ra biển; **tái điều chỉnh có quản lý (managed realignment)** — cho phép bờ biển lùi lại có kiểm soát, thường tạo đầm lầy mặn tự nhiên; **không can thiệp (no active intervention)** — để tự nhiên vận hành hoàn toàn, áp dụng khi chi phí bảo vệ vượt xa giá trị cần bảo vệ.

5.7.3 5.7.3 Case study: the Holderness Coast, East Yorkshire, UK

Geological vulnerability. The Holderness Coast, stretching roughly 60 km along the North Sea coast of East Yorkshire in eastern England, is composed of soft, unconsolidated **boulder clay** (glacial till)

left behind by ice sheets of the last glacial period. This material offers very little resistance to wave attack compared with the hard, resistant rock found on many other British coastlines, and the coast additionally faces very long fetch across the North Sea toward Scandinavia, allowing large, energetic waves to build up before arriving on shore. As a consequence, the Holderness Coast is very widely cited as one of the fastest-eroding coastlines in Europe, with average historical retreat rates commonly cited in the region of roughly 1–2 metres per year (with substantial year-to-year and place-to-place variability, and occasional single storm events removing several metres of cliff line at once); over recorded history, this cumulative retreat has destroyed a number of villages that once stood along this coast.

Mappleton and the groyne scheme. In the late 1980s/early 1990s, in response to a serious and immediate threat to the coastal village of **Mappleton** (including the main coast road linking it to neighbouring settlements, which was at direct risk of collapse), the UK authorities constructed a hard-engineering scheme at Mappleton consisting of a rock revetment along the frontage together with two large rock **groynes** projecting from the beach. This scheme has been broadly successful in its stated, local objective: it has protected Mappleton itself and stabilized the cliff line directly in front of the village.

Downdrift consequences at Cowden. However, because longshore drift along this stretch of the Holderness Coast moves sediment predominantly from north to south, the groynes at Mappleton — by design — trap sand and shingle travelling south along the coast, building up the beach on their updrift (northern) side. This starves beaches further south, **downdrift** of Mappleton (notably in the vicinity of **Cowden**), of the sediment they would otherwise have received. A beach starved of sediment offers less of a natural buffer against wave energy, so the cliffs behind it are exposed to more direct wave attack; erosion rates at Cowden and other downdrift locations have consequently been observed to *accelerate* beyond their already-rapid background rate following the construction of the Mappleton scheme. The Holderness case is very widely used as a clear, well-documented illustration of the general principle that hard engineering protecting one stretch of coast can transfer, rather than eliminate, the underlying erosion problem to a neighbouring, undefended stretch further along the same coast.

Ví dụ mẫu · Linear extrapolation of cliff retreat, and its limits

A stretch of the Holderness Coast has retreated at a historical average rate of 1.5 m/year over the past several decades. (a) Using simple linear extrapolation, calculate the expected total cliff-line retreat over the next 40 years if this average rate continues unchanged. (b) A clifftop farmhouse currently stands 75 m back from the cliff edge. Estimate, under the same assumption, how many years remain before the cliff reaches the farmhouse. (c) Explain two specific reasons why real cliff retreat at Holderness is very unlikely to proceed as smoothly and linearly as this calculation assumes.

(a) Total retreat $=$ rate $\times$ time $= 1.5$ m/yr $\times\ 40$ yr $=$ **60** m.

(b) Rearranging the same relationship to solve for time: time $=$ distance $\div$ rate $=\ 75$ m $\div\ 1.5$ m/yr $=$ **50** years.

(c) *Reason 1 — episodic, storm-driven retreat.* Boulder-clay cliffs like those at Holderness do not erode at a smooth, continuous rate; instead, retreat tends to happen in sudden episodic jumps, where a single severe storm (with unusually large, high-energy destructive waves and/or an exceptional storm surge) can remove several metres of cliff line in a single event, followed by comparatively quiet periods of little or no further retreat until the next major storm. *Reason 2 — spatial and geological variability.* Erosion rate is not uniform along the coastline or through time: it depends on local variations in the exact composition and structure of the boulder clay, on changing beach-sediment supply (itself affected by hard-engineering structures such as groynes elsewhere on the coast, as at Mappleton/Cowden), and on changing wave climate and

storm frequency (which may itself be affected by longer-term factors such as climate change). A single long-term average rate is a useful planning approximation but will systematically over- or under-predict retreat at any specific place and time.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ngoại suy tuyến tính tốc độ xói lở vách biển: **khoảng cách lùi** = **tốc độ** × **thời gian**, có thể biến đổi để tìm số năm còn lại trước khi vách biển chạm tới một công trình cụ thể (thời gian = khoảng cách ÷ tốc độ). Tuy nhiên, xói lở thực tế **hiếm khi diễn ra đều đặn**: thường xảy ra theo từng đợt gắn với các cơn bão lớn (mỗi đợt bão có thể cuốn trôi vài mét vách biển trong một lần), và tốc độ xói lở thay đổi theo không gian (do cấu trúc địa chất khác nhau, do công trình cứng ở nơi khác làm thay đổi nguồn cung trầm tích) và theo thời gian (biến đổi khí hậu có thể thay đổi tần suất bão).

Ví dụ mẫu · Coastal defence cost–benefit comparison

A local council is deciding whether to build a 2 km rock revetment to protect a stretch of coast. The revetment costs an estimated $\$3.2$ million per km to construct. Property and agricultural land directly at risk along this 2 km stretch over the coming 50 years (in the absence of any defence) is valued at approximately $\$4.5$ million in total. (a) Calculate the total construction cost of the scheme. (b) Compare this cost with the value of what is being protected, and suggest which broad SMP policy option (from Section 5.7.2) this comparison might support. (c) State one important limitation of using a simple cost–benefit comparison of this kind on its own to make coastal management decisions.

(a) Total cost $= \$3.2$ million/km $\times$ 2 km $=$ $\$$**6.4** million.

(b) The construction cost ($\$6.4$ million) substantially *exceeds* the value of the property and land it would protect ($\$4.5$ million) — in narrow financial terms, this stretch would cost more to defend than the assets it protects are worth. This purely financial comparison would tend to support a policy of **no active intervention** (or, if some intervention were still politically desirable, a cheaper soft-engineering option rather than a full hard-engineering scheme) rather than "hold the line" with expensive rock armour.

(c) A simple cost–benefit comparison of this kind captures only the directly quantifiable, monetary value of property and land at risk; it typically omits harder-to-monetize but socially important factors, such as the number of people who would need to be relocated and the social/psychological cost of displacement, loss of a community's historical or cultural identity tied to a specific place, and potential political or equity considerations (for example, whether it is fair that a materially poorer community's homes are abandoned simply because the land beneath them has lower market value than a wealthier area's, even though the human cost to the residents may be just as severe).

VN **GIẢI THÍCH TIẾNG VIỆT**

Bài toán so sánh chi phí–lợi ích công trình bảo vệ bờ biển: tính **tổng chi phí xây dựng** (đơn giá/km × chiều dài) rồi so sánh với **giá trị tài sản/đất đai** được bảo vệ để đề xuất chính sách SMP phù hợp. Tuy nhiên, phép so sánh thuần tuý tài chính này **bỏ sót** các yếu tố khó định lượng bằng tiền — chi phí xã hội của việc di dời dân cư, giá trị văn hoá/lịch sử của cộng đồng, và các vấn đề công bằng (liệu có công bằng không khi cộng đồng nghèo hơn bị bỏ mặc chỉ vì đất đai của họ có giá trị thị trường thấp hơn).

5.8 5.8 Coral Reefs and Mangroves as Coastal Ecosystems

5.8.1 5.8.1 Ecosystem services

Coral reefs (built by colonies of tiny coral polyps that secrete calcium carbonate skeletons, cemented together over centuries into a rigid limestone framework) and **mangroves** (salt-tolerant trees and shrubs that colonize sheltered, muddy intertidal coastlines in tropical and subtropical latitudes, with distinctive stilt/prop roots or pneumatophores that project above the waterlogged, low-oxygen mud) are two of the most valuable coastal ecosystems on Earth, providing a comparable and overlapping set of ecosystem services. **Natural coastal protection**: both ecosystems dissipate incoming wave energy before it reaches the shoreline — coral reefs through wave-breaking friction over the shallow reef structure, and mangroves through the dense physical resistance of their root systems and trunks — substantially reducing the erosive power of storm waves and storm surge that would otherwise reach the coast directly, in effect functioning as a natural, self-maintaining and self-repairing form of soft coastal engineering. **Fisheries and biodiversity**: both ecosystems provide critical nursery habitat, shelter, and feeding grounds for an enormous diversity of marine life — coral reefs, despite covering under 1% of the ocean floor, are estimated to support around a quarter of all known marine species, while mangrove root systems shelter juvenile fish and shellfish that later populate adjacent open-water and reef fisheries. **Tourism revenue**: both attract very substantial tourism activity (diving, snorkelling, and wildlife/eco-tourism), generating major revenue and employment for coastal communities and national economies, particularly in the tropics.

VN **GIẢI THÍCH TIẾNG VIỆT**

Rạn san hô (do các polyp san hô nhỏ tiết ra bộ khung đá vôi tích luỹ qua hàng thế kỷ) và **rừng ngập mặn** (cây chịu mặn với hệ rễ chống/rễ thở đặc trưng, mọc ở vùng bờ triều bùn được che chắn) đều cung cấp các **dịch vụ hệ sinh thái** tương tự: **bảo vệ bờ biển tự nhiên** (tiêu tán năng lượng sóng, giảm xói lở và tác động bão); **nơi cư trú/sinh sản cho thuỷ sản** và **đa dạng sinh học** rất cao (rạn san hô chiếm chưa tới 1% diện tích đáy đại dương nhưng hỗ trợ khoảng một phần tư số loài sinh vật biển đã biết); và **doanh thu du lịch** đáng kể (lặn biển, du lịch sinh thái).

5.8.2 5.8.2 Threats to coral reefs and mangroves

Ocean acidification. The ocean absorbs a substantial proportion of the carbon dioxide (CO2) emitted into the atmosphere by human activity, where it reacts with seawater to form carbonic acid, progressively lowering ocean **pH** — a process called **ocean acidification**. Lower pH reduces the concentration of carbonate ions available in seawater, directly impairing the ability of corals (and other calcifying organisms such as shellfish) to build and maintain their calcium carbonate skeletons, slowing reef growth and making existing reef structures more vulnerable to erosion and breakage.

Coral bleaching. Reef-building corals live in an essential mutualistic partnership with microscopic photosynthetic algae called **zooxanthellae**, which live within the coral polyp's tissue, supply the coral with the majority of its energy through photosynthesis, and give the coral its characteristic colour. When corals are exposed to thermal stress — most commonly, sea temperatures elevated even a degree or two above the normal seasonal maximum for a sustained period, as occurs during a marine heatwave — the coral expels its zooxanthellae, turning pale or white (**coral bleaching**). A bleached coral is not immediately dead: if the thermal stress is brief and temperatures return to normal reasonably quickly, corals can reacquire zooxanthellae and recover; but prolonged or repeated bleaching leaves corals starved of energy and highly vulnerable to disease, and can lead to widespread coral death if the stress persists.

Mangrove clearance. Mangrove forests worldwide have been very extensively cleared, most commonly to construct shrimp and other aquaculture ponds, and also for coastal urban/tourism development, timber, and conversion to agricultural land; a large proportion of the world's original mangrove area is estimated to have been lost over the past half-century. Because mangroves both provide direct nursery habitat for fisheries and serve as a natural coastal buffer, their clearance si-

multaneously reduces fisheries productivity and leaves the adjacent coastline far more exposed to storm surge, erosion, and flooding.

VN **GIẢI THÍCH TIẾNG VIỆT**

Acid hoá đại dương: đại dương hấp thụ một phần lớn CO2 khí quyển, phản ứng tạo acid carbonic làm giảm **pH** nước biển, giảm nồng độ ion carbonate cần thiết để san hô xây dựng bộ khung đá vôi — làm chậm tăng trưởng và tăng tính dễ vỡ của rạn san hô. **Tẩy trắng san hô (coral bleaching)**: san hô sống cộng sinh với tảo **zooxanthellae** (cung cấp năng lượng qua quang hợp và tạo màu sắc); khi bị stress nhiệt (sóng nhiệt biển kéo dài), san hô **trục xuất** tảo cộng sinh, chuyển sang màu trắng nhợt — nếu stress nhiệt kéo dài hoặc lặp lại nhiều lần, san hô có thể chết hàng loạt. **Phá rừng ngập mặn**: chủ yếu để làm ao nuôi tôm và phát triển đô thị/du lịch ven biển — làm giảm năng suất thuỷ sản đồng thời khiến bờ biển mất đi lớp đệm tự nhiên chống bão và xói lở.

5.8.3 5.8.3 Case study: the Great Barrier Reef, Australia

Scale and significance. The **Great Barrier Reef**, stretching over $2\,300$ km along the north-eastern coast of Queensland, Australia, is the largest coral reef system on Earth, listed as a UNESCO World Heritage Site and supporting a very substantial tourism industry as well as globally important marine biodiversity.

Recurrent mass bleaching. The reef has experienced a series of well-documented mass coral bleaching events associated with marine heatwaves, notably in **2016**, **2017**, **2020**, and **2022**. The back-to-back 2016 and 2017 events were especially severe, together affecting a very large proportion of the reef's total length and causing substantial coral mortality in the worst-hit northern sections; the short interval between successive bleaching events is itself a major concern, since it leaves corals too little recovery time between episodes of thermal stress before the next occurs. Marine heatwave events of this kind are widely attributed by climate scientists to the combined effect of underlying long-term ocean warming (linked to global climate change) and periodic short-term ENSO-related warm anomalies (as discussed in Section 5.2) temporarily pushing sea-surface temperatures still further above the coral's thermal tolerance threshold. Ongoing management responses include water-quality regulation (reducing agricultural runoff and sediment reaching the reef), reef restoration research (including coral propagation and selective breeding for heat tolerance), and continued international attention to the reef's long-term climate vulnerability.

VN **GIẢI THÍCH TIẾNG VIỆT**

Great Barrier Reef (Úc), dài hơn $2\,300$ km, là hệ thống rạn san hô lớn nhất thế giới, di sản UNESCO. Rạn san hô đã trải qua nhiều đợt **tẩy trắng hàng loạt** gắn với sóng nhiệt biển, đáng chú ý vào các năm **2016, 2017, 2020, và 2022** — hai đợt liên tiếp 2016–2017 đặc biệt nghiêm trọng, gây chết san hô diện rộng ở phần phía bắc và không cho san hô đủ thời gian phục hồi giữa các đợt. Nguyên nhân được cho là sự kết hợp giữa **ấm lên đại dương dài hạn** (biến đổi khí hậu toàn cầu) và các đợt **dị thường nhiệt ngắn hạn liên quan ENSO**. Các biện pháp ứng phó bao gồm kiểm soát chất lượng nước, nghiên cứu phục hồi/nhân giống san hô chịu nhiệt tốt hơn.

5.8.4 5.8.4 Case study: the Maldives

An existential threat. The **Maldives** is a nation in the Indian Ocean made up of roughly $1\,200$ small coral islands grouped into atolls, with an average land elevation only about 1–1.5 m above mean sea level — among the very lowest-lying countries on Earth. This makes the Maldives exceptionally vulnerable to even relatively modest amounts of eustatic sea-level rise, which threatens not merely coastal erosion but the potential loss of habitable land area altogether, together with saltwater intrusion into the limited freshwater lens beneath many islands and increased vulnerability to storm surge inundation.

Adaptation: Hulhumalé. In response, the Maldives has pursued significant adaptation measures, most prominently the construction of **Hulhumalé**, an artificially raised, reclaimed island near the capital, **Malé**, built up using dredged sand and rock to an elevation intentionally higher than most of the nation's natural islands, specifically to provide a more sea-level-resilient site for housing, infrastructure, and future population growth. Hulhumalé is intended to relieve severe overcrowding on Malé itself (one of the most densely populated islands in the world) while offering a longer-term, more defensible base against rising seas; it illustrates a broader national strategy of adaptation and managed relocation of population and infrastructure toward more resilient sites, alongside international diplomatic efforts by the Maldives to draw global attention to the existential risk that eustatic sea-level rise poses to low-lying small-island states.

VN **GIẢI THÍCH TIẾNG VIỆT**

Maldives là quốc đảo san hô vòng (atoll) ở Ấn Độ Dương gồm khoảng $1\,200$ đảo nhỏ, độ cao trung bình chỉ 1–1.5 m trên mực nước biển — một trong những quốc gia thấp nhất thế giới, cực kỳ dễ tổn thương trước **mực nước biển dâng (eustatic)**, đe doạ mất đất ở, xâm nhập mặn vào nguồn nước ngọt, và ngập lụt do bão. Để thích ứng, Maldives xây dựng **Hulhumalé** — đảo nhân tạo bồi đắp cao hơn gần thủ đô **Malé**, nhằm giảm tải dân số cho Malé (một trong những đảo đông dân nhất thế giới) và tạo nền tảng bền vững hơn trước nguy cơ nước biển dâng, đồng thời là một phần trong nỗ lực ngoại giao toàn cầu của Maldives nhằm cảnh báo về rủi ro sống còn đối với các quốc đảo nhỏ, thấp trũng.

Ví dụ mẫu · Ecosystem services lost following mangrove clearance

A coastal district clears 40 hectares of mangrove forest to construct shrimp aquaculture ponds. Local fisheries scientists estimate that each hectare of intact mangrove forest supports, on average, an annual fisheries yield (from adjacent coastal waters that depend on mangrove nursery habitat) worth approximately $\$1\,200$ per year, sustained indefinitely if the forest remains intact. Aquaculture operators expect the ponds to generate $\$3\,500$ per hectare per year, but with an expected productive lifespan of only about 12 years before pond soils are degraded by acidification and salinization and the ponds are abandoned. (a) Estimate the total annual fisheries value lost by clearing the 40 hectares. (b) Estimate the total value generated by the aquaculture ponds over their full expected lifespan, and compare it with the fisheries value that would have been sustained over the same period. (c) Identify one important coastal protection service, not captured in either monetary estimate, that is also lost when mangroves are cleared.

(a) Fisheries value lost per year $= 40$ ha $\times\ \$1\,200/\text{ha/yr} = \$\mathbf{48\,000}/\text{yr}$.

(b) Aquaculture value over 12 years $= 40$ ha $\times\ \$3\,500/\text{ha/yr} \times 12$ yr $= \$1\,680\,000$. Fisheries value that would have been sustained over the same 12-year period $= \$48\,000/\text{yr} \times 12$ yr $= \$576\,000$, and — critically — would have continued indefinitely thereafter, whereas the aquaculture ponds generate *no* further value once abandoned after year 12 (and may require costly remediation). Over exactly 12 years, aquaculture appears more profitable in simple monetary terms ($\$1\,680\,000$ vs. $\$576\,000$), but this comparison reverses over any longer time horizon, since mangrove-supported fisheries value continues to accrue while abandoned, degraded pond land generates nothing further.

(c) Coastal protection from storm surge and wave energy is not captured in either the fisheries or aquaculture monetary estimate; loss of mangrove cover leaves the coastline directly exposed to storm damage and erosion, an unpriced cost that may only become apparent (and very expensive) at the time of the next major storm.

VN **GIẢI THÍCH TIẾNG VIỆT**

Bài toán so sánh giá trị kinh tế giữa rừng ngập mặn (thuỷ sản) và ao nuôi tôm: nhân **diện tích** × **giá trị/ha/năm** để so sánh, nhưng phải chú ý **thời gian**: ao nuôi tôm có **tuổi thọ hữu hạn** (đất bị nhiễm mặn/acid hoá rồi bị bỏ hoang) trong khi rừng ngập mặn nguyên vẹn tạo giá trị **bền vững vô thời hạn** — phép so sánh có thể đảo ngược nếu tính trên khung thời gian dài hơn. Ngoài ra, **dịch vụ bảo vệ bờ biển** (chống bão, chống xói lở) của rừng ngập mặn thường không được định giá bằng tiền nhưng vẫn là tổn thất thực sự khi rừng bị phá.

5.9 5.9 Practice Bank

Problem 1

Which of the following best describes Ekman transport in the Northern Hemisphere?

(A) Directly along the wind direction
(B) 90° to the right of the wind direction
(C) 90° to the left of the wind direction
(D) Directly opposite the wind direction

Solution 1

In the Northern Hemisphere, the Coriolis effect deflects moving water to the right of its direction of travel; the net transport summed through the wind-driven layer (Ekman transport) acts 90° to the right of the surface wind. **(B)**.

Problem 2

Explain why the Gulf Stream is described as a "western boundary current" and why such currents are typically narrower, deeper, and faster than the corresponding eastern boundary current of the same gyre.

Solution 2

The Gulf Stream flows along the *western* margin of the North Atlantic basin (past the eastern coast of North America) as part of the clockwise-rotating North Atlantic subtropical gyre. The combined effect of the Coriolis force and the basin's shape compresses the gyre's poleward-flowing return current against this western margin — a phenomenon called westward intensification — concentrating the same volume of water transport into a much narrower, faster, and deeper current than the broad, slow, shallow flow (e.g., the Canary Current) found on the gyre's eastern margin.

Problem 3

A coastal town in the British Isles experiences markedly milder winters than a town at a similar latitude on the eastern coast of Canada. Explain this difference with reference to ocean circulation.

Solution 3

The British Isles lie downwind of the Gulf Stream/North Atlantic Drift, which transports large quantities of warm water north-eastward across the Atlantic from the Gulf of Mexico region; this heat is transferred to the overlying atmosphere and carried onward by the prevailing south-westerly winds, warming the coastal climate of north-western Europe well above what its latitude alone would predict. Eastern Canada, by contrast, lies on the western side of the

North Atlantic basin, downwind of the cold Labrador Current rather than a comparable warm current, and experiences correspondingly colder winters at a similar latitude.

Problem 4

Which statement correctly describes the formation of North Atlantic Deep Water (NADW)?

(A) Warm equatorial water rises and flows north at the surface only

(B) Cold, low-salinity meltwater floats and spreads across the North Atlantic surface

(C) Cold, high-salinity surface water in the North Atlantic becomes dense enough to sink to depth

(D) Deep water forms exclusively through tidal mixing, unrelated to temperature or salinity

Solution 4

NADW forms where surface water in the North Atlantic is intensely cooled and its salinity is further raised by salt rejection during sea-ice formation, making it dense enough to sink from the surface to great depth, driving the thermohaline "conveyor belt" circulation. **(C)**.

Problem 5

Estimate roughly how long a complete circuit of the global thermohaline conveyor belt is generally considered to take, and explain why this contrasts so strongly with the timescale of wind-driven surface gyre circulation.

Solution 5

A full circuit of the thermohaline conveyor belt is generally estimated to take on the order of 1000 years, since it involves the very slow bulk movement of dense water through the full depth of every ocean basin before it gradually mixes upward, warms, and returns to the surface. This contrasts with wind-driven surface gyres, which respond to daily-to-seasonal changes in wind patterns and circulate relatively shallow surface water at much higher speeds (metres per second in a current like the Gulf Stream), completing meaningful redistribution of heat on a timescale of days to months rather than centuries.

Problem 6

The table shows Niño 3.4 SST anomalies for six consecutive months: $-0.8,\ -1.1,\ -1.3,\ -0.9,\ -0.7,\ -0.6$ (°C). Classify the ENSO phase shown and describe the expected impact on rainfall in northern Australia and Indonesia during this period.

Solution 6

All six values are at or beyond -0.5°C and sustained over several consecutive months, indicating **La Niña conditions**. Under La Niña, trade winds are stronger than normal, pushing even more warm water than usual into the western Pacific warm pool; northern Australia and Indonesia would therefore be expected to experience **above-average rainfall**, with an increased risk of flooding, as the normal wet-season pattern is intensified rather than reversed.

Problem 7

During a strong El Niño event, which of the following is the most likely outcome for the Peruvian anchoveta fishery, and why?

(A) Sharp decline, because suppressed upwelling cuts off the nutrient supply that sustains phytoplankton and the food web

(B) Sharp increase, because warmer water speeds up anchoveta reproduction

(C) No change, because anchoveta populations are unaffected by sea-surface temperature

(D) Sharp increase, because El Niño strengthens the Walker circulation

Solution 7

El Niño weakens or reverses the trade winds, allowing warm water to spread east across the Pacific and suppressing the normal cold-water upwelling off Peru. Without upwelled nutrients, phytoplankton productivity collapses, and the food web that supports the anchoveta fishery collapses with it. **(A)**.

Problem 8

A beach records an average wave height of 0.4 m and a frequency of 6 waves per minute over a calm week. Classify the dominant wave type and predict the resulting change to the beach profile.

Solution 8

A low wave height (0.4 m) combined with a low frequency (6/min) is characteristic of **constructive waves**. Constructive waves produce a swash stronger than the backwash (much of the swash percolates into the beach rather than draining back), so the beach should experience net **deposition** — it should widen and gain sediment, likely developing a gently sloping profile over the course of the week.

Problem 9

Explain, in terms of wave refraction, why headlands tend to be zones of net erosion while adjacent bays tend to be zones of net deposition, even along a coastline that is eroding overall.

Solution 9

As a wave crest approaches an indented coastline, the part of the crest nearest a headland enters shallow water and is slowed by seabed friction sooner than the part of the same crest still crossing the deeper water off an adjacent bay. This differential slowing bends the wave crest so it wraps around and becomes roughly parallel to the headland, compressing wave energy onto the headland (convergence) while stretching the crest out and spreading its energy over the wider bay mouth (divergence). Concentrated high-energy wave attack erodes the headland, while the much-reduced wave energy reaching the bay favours deposition of sediment there, building sheltered beaches even while the coastline as a whole retreats.

Problem 10

Waves along a stretch of coast consistently approach from the north-east, striking a shoreline that trends roughly north–south. Determine the net direction of longshore drift, and explain your reasoning.

Solution 10

Waves from the north-east strike this north–south shoreline obliquely, so swash runs up the beach along that north-east-to-south-west diagonal; backwash then drains straight back down the beach slope under gravity rather than returning along the same diagonal. Each wave cycle therefore nudges sediment a small distance further to the **south** along the shoreline (the alongshore component of the oblique swash not cancelled by the straight-down backwash). Net longshore drift along this coast runs from **north to south** — in the direction the waves are travelling toward, not the direction they originate from.

Problem 11

A short section of eroding cliff has retreated at a historical average rate of 0.8 m/year. Calculate the expected total retreat over the next 25 years by linear extrapolation, and state one reason this projection might underestimate the true retreat if the cliff is composed of soft, unconsolidated material like boulder clay.

Solution 11

Total retreat $=$ rate $\times$ time $= 0.8$ m/yr $\times$ 25 yr $=$ **20** m.

This linear projection likely **underestimates** the true retreat, because soft, unconsolidated boulder clay does not erode at a smooth, continuous rate. Once saturated by rainfall or groundwater, such material loses much of its shear strength and is prone to sudden, non-linear failure — most commonly **rotational slumping** or other mass-movement collapse, in which a substantial block of cliff face fails and slides down all at once, removing several metres of cliff line in a single event rather than the steady 0.8 m trickle assumed by the linear model. Retreat of this kind is also likely to **accelerate** over time (rather than continue at its historical average) if sea-level rise or increased storminess delivers more frequent and more powerful wave attack to the cliff base, further undercutting it and triggering slumps more often than in the past. A single historical average rate is therefore a useful first approximation but tends to smooth over the true episodic, potentially accelerating nature of soft-cliff retreat.

Problem 12

A wave crashes against a cliff and forces air into a narrow crack in the rock face; the sudden compression of this trapped air under the wave's pressure widens the crack and dislodges a small rock fragment. Which coastal erosion process does this describe?

(A) Hydraulic action
(B) Abrasion
(C) Attrition
(D) Solution

Solution 12

The description involves air trapped in a crack being compressed by wave pressure and physically widening the crack — this is precisely the mechanism of **hydraulic action**. It is not abrasion, since no rock fragments or sediment are described being hurled against the cliff; not attrition, since no fragments are shown colliding with one another; and not solution, since no chemical dissolution of soluble rock is involved. **(A)**.

Problem 13

A discordant coastline consists of alternating bands of resistant limestone and weaker clay running roughly perpendicular to the shoreline. Explain how differential erosion acting on this geology produces an alternating sequence of headlands and bays.

Solution 13

Under the same wave attack, the weaker clay bands offer far less resistance to erosion than the resistant limestone bands, so the clay is worn back much more rapidly. Over time this **differential erosion** carves the weaker clay bands into recessed **bays**, while the more resistant limestone bands, eroding far more slowly, are left projecting out to sea as **headlands**. This initial pattern is then reinforced by wave refraction, which concentrates erosive wave energy on the exposed headlands and disperses it across the sheltered bays, further accentuating the alternating headland-and-bay morphology.

Problem 14

Describe how a wave-cut platform is formed, and explain why its surface typically has a very gentle seaward slope.

Solution 14

Sustained wave attack (hydraulic action and abrasion) undercuts the base of a cliff around the mean high-water mark, forming a wave-cut notch. As the notch deepens, the cliff face above becomes progressively oversteepened until it collapses under gravity, and the zone of active erosion shifts landward with the newly retreated cliff line. Repeated over a long period, this process leaves behind a gently sloping, wave-abraded rock surface at the foot of the retreating cliff — the **wave-cut platform** — exposed at low tide. Its very gentle slope reflects the fact that wave erosion is most effective only within a narrow vertical band around high-water mark, not any pre-existing land surface; the platform is simply the accumulated trace of many successive positions of that narrow high-energy erosion zone as the cliff retreated.

Problem 15

Two caves eroding back-to-back through a narrow headland eventually break through, connecting open water on both sides of the headland. This landform is best described as a:

(A) Crack
(B) Cave
(C) Arch
(D) Stump

Solution 15

A crack is only an early, narrow fissure that has not yet been enlarged into an open feature; a cave is enclosed at one end, not open at both; a stump is the final, heavily eroded remnant left after a stack has collapsed. A feature that is open at both ends, connecting water on either side of the headland, is by definition an **arch**. **(C)**.

Problem 16

A headland survey identifies two features: (i) a tall, free-standing rock pillar, cut off from the main cliff, reachable on foot only at low tide; and (ii) a low, wave-washed rock knob visible only at the very lowest spring tides. Identify each feature, and state which one represents the

later stage in the headland erosion sequence.

Solution 16

Feature (i), an isolated standing pillar separated from the main cliff, is a **stack**. Feature (ii), a low, barely emergent rock feature submerged at all but the lowest tides, is a **stump**. Since a stump forms only after continued wave erosion undercuts and collapses a stack, reducing it to this low, wave-washed remnant, feature (ii), the **stump**, represents the later, more advanced stage of erosion.

Problem 17

A coastline running broadly east to west experiences a sharp change in direction at a river mouth, where it turns northward into a sheltered estuary. Longshore drift along this coast moves sediment from west to east. Explain how a spit might form at this river mouth, and why its distal (far) end might develop a recurved, hooked shape.

Solution 17

Longshore drift carries sediment eastward along the coast; when the coastline abruptly turns north at the river mouth, drift continues to deposit sediment beyond this bend, out into the deeper, more sheltered water of the estuary mouth, since there is no longer a coastline there to constrain it. Repeated over many years, this builds a long, narrow ridge of sand and shingle — a **spit** — projecting across the estuary mouth, attached to the land at its western end. At its exposed distal (eastern) end, the spit is more directly exposed to a secondary wave direction and to wave refraction wrapping around the tip; this bends the growing end of the spit back toward the shore, producing a distinctive **recurved (hooked)** end.

Problem 18

Which depositional landform results when a spit continues to grow until it extends completely across a bay, joining one side to the other and cutting off a lagoon from the open sea?

(A) Spit
(B) Bar
(C) Tombolo
(D) Wave-cut platform

Solution 18

A spit is only partly attached to the land, with one end remaining open to the sea; a tombolo connects the mainland to an offshore *island*, not one side of a bay to the other; a wave-cut platform is an erosional, not depositional, feature. A ridge that grows completely across a bay mouth, connecting both sides and enclosing a lagoon, is by definition a **bar**. **(B)**.

Problem 19

Sediment tracer studies along a stretch of coast show that marked pebbles move a net average distance of 15 m per month in the direction of longshore drift. (a) Using linear extrapolation, calculate the expected net distance travelled by a pebble over 3 years at this rate. (b) State one reason the actual distance travelled might differ from this linear prediction.

Solution 19

(a) 3 years $= 36$ months, so net distance $= 15$ m/month $\times 36$ months $=$ **540** m.

(b) The dominant wave (and therefore drift) direction is unlikely to remain perfectly constant over three years — seasonal shifts in prevailing wind direction can temporarily reverse or slow net drift in some months, and any obstacle encountered along the way (a natural headland, or a man-made structure such as a groyne) could trap the pebble and halt its onward movement entirely, so the true net distance travelled is unlikely to accumulate as a smooth straight-line total.

Problem 20

A small island nation records a rate of sea-level rise that matches tide-gauge measurements taken across every ocean basin worldwide over the same decade. Separately, a river delta at the mouth of a major river records a much faster rate of local relative sea-level rise than the global average, which geologists attribute to compaction of thick, water-saturated sediment under its own weight. Classify each observation as eustatic or isostatic, and explain how both processes can combine at the delta.

Solution 20

The island nation's observation — matching measurements taken simultaneously across every ocean basin worldwide — reflects a genuine, global change in ocean-water volume, so it is **eustatic**. The delta's observation — a local process confined to one specific site, driven by the land itself sinking under the weight of its own compacting sediment rather than by any change in ocean-water volume — is **isostatic** (specifically, isostatic subsidence). At the delta, both processes operate together: the site experiences the same underlying eustatic sea-level rise affecting every coastline, *plus* its own local isostatic subsidence on top of that, so its measured relative sea-level rise is faster than the eustatic rate alone — the combined result of both mechanisms acting simultaneously.

Problem 21

Raised beaches and wave-cut platforms are found tens of metres above current sea level in parts of Scandinavia, dated to the period immediately following the end of the last glacial period. This is best explained by:

(A) Global eustatic sea-level fall caused by renewed ice-sheet growth

(B) Isostatic rebound of the land following removal of a thick Pleistocene ice sheet

(C) Regional tectonic subduction causing crustal uplift

(D) Thermal contraction of the ocean during a cooling period

Solution 21

Option (A) is incorrect because renewed ice-sheet growth would lower sea level globally, not raise old shorelines above the present level in one specific region, and in any case ice loss (not growth) followed the glacial period here. Option (C) is incorrect, since Scandinavia is not a subduction margin. Option (D) is incorrect, since thermal contraction during cooling is a genuine eustatic mechanism but does not explain a strictly local, regional pattern confined to a formerly ice-covered area. The correct explanation is that removal of the immense weight of the Pleistocene ice sheet allowed the previously depressed crust to slowly rebound upward over thousands of years, raising former shorelines well above present sea level — **isostatic**

rebound. (B).

Problem 22

Global mean sea level has risen at an average rate of 3.6 mm/year over the past two decades, driven by thermal expansion and glacier/ice-sheet melt. (a) Using linear extrapolation, calculate the expected additional global sea-level rise over the next 50 years at this rate. (b) Convert your answer to (a) into metres. (c) Give one reason this linear extrapolation may underestimate future sea-level rise.

Solution 22

(a) Additional rise $= 3.6$ mm/yr $\times\ 50$ yr $=$ **180** mm.

(b) 180 mm $=$ **0.18** m.

(c) The historical average rate may understate future rise if the underlying processes accelerate rather than continue at a constant pace — for example, if warming temperatures trigger faster, non-linear ice loss from the Greenland and Antarctic ice sheets (through processes such as ice-shelf collapse and accelerated glacier flow), the rate of eustatic sea-level rise itself could increase over the coming decades rather than remaining fixed at 3.6 mm/yr.

Problem 23

A local council builds a series of rock groynes along an eroding beach to trap sediment moving by longshore drift. Explain why this scheme, while protecting the beach directly behind the groynes, is likely to cause increased erosion at a settlement further along the coast in the downdrift direction.

Solution 23

Groynes are barriers built out from the beach, roughly perpendicular to the shore, that deliberately interrupt longshore drift, trapping sediment moving along the coast on their updrift side and widening the local beach there. However, the sediment trapped by the groynes is sediment that would otherwise have continued travelling further along the coast by longshore drift to replenish beaches downdrift. Deprived of this normal sediment supply, the downdrift settlement's beach becomes progressively thinner over time, offering far less of a natural buffer to absorb incoming wave energy; with less beach protection, the cliffs or coastline behind it are exposed to more direct wave attack, and erosion there accelerates beyond its previous background rate — the same downdrift effect documented at Mappleton and Cowden on the Holderness Coast.

Problem 24

A short stretch of coastline consists of sparsely populated farmland with no significant buildings or infrastructure, backed by cliffs eroding at a moderate rate. Given that the cost of any coastal defence here would far exceed the value of the land at risk, which Shoreline Management Plan policy is most likely to be applied to this stretch?

(A) Hold the line
(B) Advance the line
(C) Managed realignment
(D) No active intervention

Solution 24

"Hold the line" is applied where there is high-value property or infrastructure worth defending, which is absent here. "Advance the line" is reserved for cases where land is so valuable that reclaiming new land from the sea is justified, which does not apply to low-value farmland. "Managed realignment" involves a deliberate, planned programme of relocating or removing existing defences — implying active management effort, which is unnecessary where there is nothing significant to protect or relocate. Where the cost of any protection would far exceed the value of what is being protected, and there is no valuable asset requiring a managed retreat plan, the appropriate policy is to let natural processes proceed unhindered: **no active intervention**. **(D)**.

Problem 25

A 3.5 km rock revetment is proposed to protect a coastal town, at an estimated cost of $\$2.8$ million per km. Property and infrastructure at risk along this stretch over the next 60 years, in the absence of any defence, is valued at approximately $\$14$ million. (a) Calculate the total construction cost of the scheme. (b) Compare this cost with the value of what is being protected, and state which broad policy this financial comparison would tend to support.

Solution 25

(a) Total cost $= \$2.8$ million/km $\times 3.5$ km $= \$$**9.8** million.

(b) The construction cost ($\$9.8$ million) is *less* than the value of the property and infrastructure it would protect ($\$14$ million) — in purely financial terms, the scheme costs less than the value of the assets it defends. This comparison would tend to support building the revetment, i.e. a policy of **hold the line**, rather than allowing the coastline to erode unhindered.

Problem 26

With reference to the Holderness Coast case study, explain why building rock groynes at Mappleton to protect the village led to accelerated erosion at Cowden, further south along the coast.

Solution 26

Longshore drift along this stretch of the Holderness Coast moves sediment predominantly from north to south. The groynes built at Mappleton trap sand and shingle travelling south, building up the beach on their updrift (northern) side and successfully protecting Mappleton itself. However, this necessarily starves beaches further south — downdrift of Mappleton, notably around Cowden — of the sediment they would otherwise have received. With less beach material to dissipate incoming wave energy, the cliffs at Cowden are left more exposed to direct wave attack, and erosion rates there have been observed to accelerate beyond their already-rapid background rate following the Mappleton scheme's construction — a clear illustration of how hard engineering can transfer, rather than eliminate, the underlying erosion problem to an undefended neighbouring stretch of coast.

Problem 27

Coral bleaching occurs when reef-building corals are exposed to prolonged thermal stress. Which of the following best explains the process?

(A) Corals absorb excess dissolved CO2 directly, which turns their skeletons white

(B) Corals expel their symbiotic zooxanthellae algae, losing both their colour and a major energy source

(C) Rising sea levels physically strip coral polyps from the reef structure

(D) Ocean acidification instantly dissolves coral skeletons on contact with warm water

Solution 27

Option (A) describes a mechanism closer to ocean acidification, not bleaching, and corals do not directly absorb CO2 to produce whitening. Option (C) is unrelated to bleaching, which is a thermal-stress response, not a physical, sea-level-driven process. Option (D) mischaracterizes ocean acidification as an instant reaction rather than the slow, cumulative chemical process it actually is. Under sustained thermal stress, corals expel the microscopic photosynthetic algae (**zooxanthellae**) living in their tissue that normally supply most of their energy and give them their colour, leaving the coral pale or white and starved of energy. **(B)**.

Problem 28

Explain, in terms of ocean chemistry, why increasing atmospheric CO2 concentrations threaten the ability of corals to build their calcium carbonate skeletons.

Solution 28

The ocean absorbs a substantial proportion of the CO2 emitted into the atmosphere by human activity. Once dissolved in seawater, this CO2 reacts to form carbonic acid, progressively lowering ocean pH — a process called **ocean acidification**. A lower pH reduces the concentration of carbonate ions available in seawater, and corals (along with other calcifying organisms) rely on an adequate supply of carbonate ions to precipitate and build their calcium carbonate skeletons. With fewer carbonate ions available, coral calcification is impaired, slowing reef growth and leaving existing reef structures more vulnerable to erosion and breakage.

Problem 29

A coastal district clears 25 hectares of mangrove forest to build a tourism resort. Fisheries scientists estimate each hectare of intact mangrove supports a sustained annual fisheries value of $\$950$ per hectare per year, indefinitely. The resort is expected to generate $\$5\,000$ per hectare per year, but only for an expected 15-year lease before the site requires costly redevelopment. (a) Calculate the total annual fisheries value lost by clearing the 25 hectares. (b) Calculate total resort revenue over the 15-year lease and compare it with the fisheries value that would have accrued over the same period. (c) State one reason the long-term outlook favours mangrove conservation despite the resort's higher revenue over the 15-year lease.

Solution 29

(a) Fisheries value lost per year $= 25$ ha $\times\ \$950/\text{ha/yr} = \$\mathbf{23\,750}/\text{yr}$.

(b) Resort revenue over 15 years $= 25$ ha $\times\ \$5\,000/\text{ha/yr} \times 15$ yr $= \$1\,875\,000$. Fisheries value over the same 15 years $= \$23\,750/\text{yr} \times 15$ yr $= \$356\,250$. Over exactly 15 years, the resort generates substantially more revenue ($\$1\,875\,000$ vs. $\$356\,250$).

(c) This comparison reverses over a longer time horizon: mangrove-supported fisheries value continues to accrue indefinitely, whereas the resort generates no further revenue after year 15 and may require expensive redevelopment or site remediation once abandoned; the man-

grove's unpriced coastal protection service (dissipating storm waves and surge) is also lost the moment the forest is cleared, an additional real cost not captured in either revenue figure.

Problem 30

Which of the following correctly matches a coastal ecosystem with the primary threat responsible for its large-scale global decline?

(A) Coral reefs — clearance for shrimp aquaculture ponds

(B) Mangroves — ocean acidification lowering seawater pH

(C) Coral reefs — thermal stress causing mass bleaching events

(D) Mangroves — Coriolis-deflected longshore drift

Solution 30

Option (A) mismatches the threat: clearance for aquaculture ponds is the primary threat to *mangroves*, not coral reefs. Option (B) mismatches the threat the other way: ocean acidification's most direct impact is on calcifying organisms such as corals, not mangroves. Option (D) is not a genuine threat mechanism — longshore drift is a sediment-transport process, not a driver of mangrove decline. Mass bleaching driven by thermal stress (marine heatwaves, reinforced by long-term ocean warming and short-term ENSO warm anomalies) is indeed the primary threat responsible for large-scale coral reef decline worldwide, as illustrated by the Great Barrier Reef case study. **(C)**.

Geophysical Hazards

Mục tiêu Unit: Sau khi hoàn thành Unit này, học sinh có thể: trình bày thuyết trôi dạt lục địa của Alfred Wegener và bằng chứng tách giãn đáy đại dương (địa từ cổ) làm nền tảng cho thuyết kiến tạo mảng hiện đại; phân biệt ba loại ranh giới mảng — phân kỳ (divergent), hội tụ (convergent), trượt ngang (transform) — cùng các dạng địa hình đặc trưng, minh hoạ bằng các ví dụ thực tế (thung lũng tách giãn Đông Phi, dãy Andes, rãnh Mariana, dãy Himalaya, đứt gãy San Andreas); phân tích mối liên hệ giữa thành phần/độ nhớt magma và kiểu phun trào núi lửa (núi lửa hình khiên và núi lửa tầng dạng nón), phân biệt hiểm hoạ núi lửa sơ cấp và thứ cấp (dòng dung nham, dòng chảy pyroclastic, tro bụi, khí độc, lahar, jökulhlaup) qua hai nghiên cứu điển hình Pinatubo (1991) và Nevado del Ruiz/Armero (1985); giải thích thuyết hồi phục đàn hồi (elastic rebound), phân biệt tiêu điểm (focus) và chấn tâm (epicentre), các loại sóng địa chấn, thang độ lớn (Richter, mô-men địa chấn) và thang cường độ (Mercalli cải tiến), hiện tượng hoá lỏng đất (liquefaction), qua ba nghiên cứu điển hình Haiti (2010), Tōhoku (2011) và Gorkha, Nepal (2015); mô tả cơ chế hình thành và hành vi lan truyền của sóng thần; áp dụng phương trình rủi ro thiên tai Rủi ro = (Hiểm hoạ × Tính dễ tổn thương)/Năng lực ứng phó; diễn giải đường cong phục hồi thảm hoạ của Park và chu trình quản lý hiểm hoạ (giảm nhẹ – chuẩn bị – ứng phó – phục hồi); phân tích nghiên cứu điển hình đảo Montserrat; và trình bày tóm lược Khung hành động Sendai về giảm nhẹ rủi ro thiên tai.

6.1 Plate Tectonics Theory

6.1.1 Continental drift and the evidence for seafloor spreading

Continental drift. In 1912, the German meteorologist **Alfred Wegener** proposed that today's continents were once joined together in a single supercontinent, which he called **Pangaea**, and that they have since drifted slowly apart to their present positions. Wegener assembled several independent lines of evidence in support of this idea. First, the coastlines of continents on opposite sides of the Atlantic — most strikingly the eastern bulge of South America and the western coast of Africa — fit together like pieces of a jigsaw puzzle. Second, bands of distinctive rock strata and entire mountain belts (for example, the Appalachian Mountains of eastern North America and the Caledonian mountains of Scotland and Scandinavia) line up in age, rock type, and structural trend when the continents are reassembled, but appear as unrelated, disconnected fragments in today's geography. Third, fossils of the same land-dwelling or freshwater species — *Mesosaurus*, a small freshwater reptile, and *Glossopteris*, a seed fern — are found on multiple continents now separated by wide oceans that neither organism could plausibly have crossed. Fourth, paleoclimatic evidence — glacial striations (scratch marks left by moving ice) found today in warm tropical regions such as India and Brazil, and coal deposits (which form only in warm, swampy conditions) found today in polar regions such as Antarctica — makes sense only if those land masses were once located at very different latitudes. Despite this substantial body of evidence, Wegener could not identify a physically plausible mechanism capable of moving entire continents through solid oceanic crust, and his hypothesis was largely rejected or ignored by the geological establishment of his time.

VN **GIẢI THÍCH TIẾNG VIỆT**

Alfred Wegener (1912) đề xuất rằng các lục địa ngày nay từng gắn liền thành một siêu lục địa duy nhất gọi là **Pangaea**, sau đó trôi dạt tách rời dần đến vị trí hiện tại. Bằng chứng gồm: (1) đường bờ biển hai bên Đại Tây Dương khớp nhau như mảnh ghép hình (Nam Mỹ – châu Phi);

(2) các dải đá và dãy núi cùng tuổi, cùng cấu trúc bị ngắt quãng giữa các lục địa (dãy Appalachian – dãy Caledonia); (3) hoá thạch cùng loài (*Mesosaurus*, *Glossopteris*) xuất hiện ở nhiều lục địa cách xa nhau bởi đại dương mà loài đó không thể vượt qua; (4) bằng chứng khí hậu cổ — vết xước băng hà ở vùng nhiệt đới ngày nay, mỏ than (hình thành ở vùng đầm lầy ấm) ở Nam Cực ngày nay. Tuy nhiên Wegener không đưa ra được **cơ chế vật lý** khả dĩ để giải thích lực nào đẩy lục địa trôi qua lớp vỏ đại dương rắn chắc, nên giả thuyết của ông phần lớn bị giới khoa học đương thời bác bỏ.

Seafloor spreading and paleomagnetic evidence. The missing mechanism was supplied decades later. In the early 1960s, **Harry Hess** proposed **seafloor spreading**: new oceanic crust is continuously created at mid-ocean ridges, where magma rises from the mantle, cools, and solidifies, then is pushed sideways in both directions as even newer material wells up behind it — so the seafloor itself acts as a slow conveyor belt. The decisive supporting evidence came from **paleomagnetism**. As molten basalt at a mid-ocean ridge cools through a critical temperature, magnetic minerals within it (chiefly magnetite) align with the Earth's magnetic field at that moment and lock in a permanent record of its direction. Because the Earth's magnetic field has repeatedly and irregularly reversed polarity throughout geological history, magnetometer surveys of the ocean floor revealed a striking pattern: bands of alternating magnetic polarity running parallel to, and symmetrically on either side of, mid-ocean ridges — a pattern that could only be explained if new crust were forming continuously at the ridge axis and splitting apart as it recorded each successive magnetic reversal. This was reinforced by deep-sea drilling, which showed that oceanic crust is progressively **older** the farther it lies from a ridge crest, and that no oceanic crust anywhere on Earth is older than about 200 million years (far younger than the oldest continental rocks) — consistent with oceanic crust being continuously created, recycled, and destroyed. Together, continental drift, seafloor spreading, and paleomagnetic striping provided both the observational pattern and the physical mechanism (driven ultimately by convection currents in the mantle, supplemented by **ridge push** and **slab pull** forces) that became modern **plate tectonic theory**: the rigid outer shell of the Earth (the lithosphere) is broken into a mosaic of large and small **plates** that move slowly — typically a few centimetres per year, about the rate fingernails grow — relative to one another over the more plastic asthenosphere beneath.

Evidence for plate tectonic theory: jigsaw fit of continental coastlines; matching rock strata and mountain belts across oceans; matching fossil distributions (*Mesosaurus*, *Glossopteris*); paleoclimatic anomalies (tropical glacial striations, polar coal); symmetric paleomagnetic striping either side of mid-ocean ridges; oceanic crust age increasing systematically with distance from the ridge axis; driving mechanism supplied by mantle convection, ridge push, and slab pull.

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Tách giãn đáy đại dương (seafloor spreading), đề xuất bởi Harry Hess (thập niên 1960): vỏ đại dương mới liên tục hình thành tại sống núi giữa đại dương (mid-ocean ridge) nơi magma trào lên, nguội và cứng lại, sau đó bị đẩy dần sang hai bên. Bằng chứng quyết định là **địa từ cổ (paleomagnetism)**: khoáng vật từ tính trong đá bazan nguội đi ghi lại hướng từ trường Trái Đất tại thời điểm đó; vì từ trường Trái Đất từng đảo cực nhiều lần trong lịch sử địa chất, khảo sát từ kế phát hiện các dải cực từ xen kẽ, đối xứng hai bên sống núi — chỉ có thể giải thích nếu vỏ mới liên tục hình thành tại đó. Tuổi vỏ đại dương cũng tăng dần theo khoảng cách từ sống núi (không nơi nào già quá ~ 200 triệu năm). Các bằng chứng này kết hợp với cơ chế đối lưu manti, lực đẩy sống núi (ridge push) và lực kéo mảng chìm (slab pull) tạo thành **thuyết kiến tạo mảng** hiện đại: thạch quyển bị chia thành các mảng cứng di chuyển chậm (vài cm/năm) trên lớp quyển mềm (asthenosphere) bên dưới.

6.1.2 Plate boundary types

Where adjacent plates meet, three fundamentally different types of boundary occur, distinguished by the relative direction of plate motion and by whether crust is created, destroyed, or simply displaced.

Divergent (constructive) boundaries. Here two plates move apart from one another. In the ocean basins, this produces **mid-ocean ridges**: as the plates separate, pressure on the underlying mantle drops, triggering partial melting; low-viscosity basaltic magma rises to fill the widening gap, erupts relatively gently along the ridge axis, and cools to create new oceanic crust — the process of seafloor spreading described above. On continents, divergence instead produces a **continental rift valley**: the crust is stretched and thinned, normal faulting drops a central block downward relative to the flanks, and volcanism and shallow earthquakes accompany the rifting. The clearest active continental example is the **East African Rift**, where the African Plate is slowly splitting into the Somali (Nubian) and Nubian sub-plates; the rift is expressed at the surface as a chain of deep valleys running through countries such as Kenya, Tanzania, and Ethiopia, punctuated by active and dormant volcanoes (e.g., Mount Kilimanjaro, Ol Doinyo Lengai, Mount Nyiragongo) and by the elongated rift lakes (e.g., Lake Tanganyika, Lake Malawi) that occupy the down-dropped valley floor. If rifting continues for long enough, the valley can eventually flood with seawater and widen into a new, narrow ocean basin — the Red Sea, further north along the same rift system, is often cited as an early-stage example of exactly this process.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ranh giới phân kỳ (divergent/constructive): hai mảng tách xa nhau. Ở đại dương tạo thành **sống núi giữa đại dương**: magma bazan độ nhớt thấp trào lên lấp đầy khe hở, tạo vỏ đại dương mới. Ở lục địa tạo thành **thung lũng tách giãn (rift valley)**: vỏ bị kéo giãn, mỏng đi, đứt gãy thuận hạ thấp phần trung tâm; ví dụ điển hình là **Thung lũng tách giãn Đông Phi (East African Rift)** — mảng châu Phi đang tách thành hai mảng con, tạo chuỗi thung lũng sâu qua Kenya, Tanzania, Ethiopia, kèm núi lửa (Kilimanjaro, Ol Doinyo Lengai) và các hồ tách giãn dài hẹp (hồ Tanganyika, Malawi). Nếu quá trình tiếp diễn đủ lâu, thung lũng có thể ngập nước biển và mở rộng thành đại dương mới — Biển Đỏ ở phía bắc cùng hệ thống tách giãn này thường được xem là ví dụ giai đoạn đầu của quá trình này.

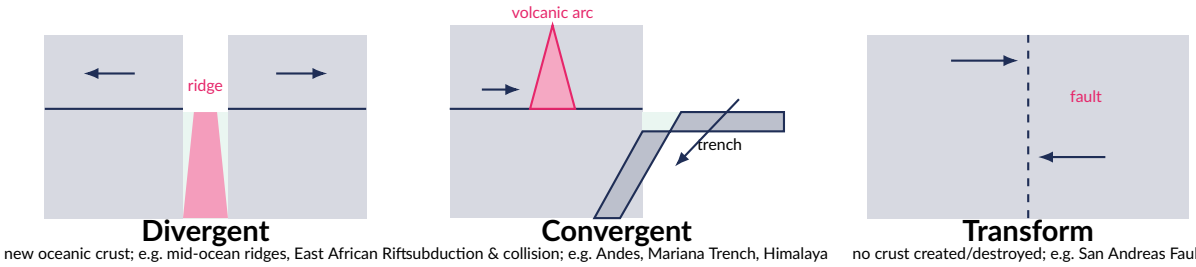
Convergent (destructive) boundaries. Here two plates move toward one another, and the outcome depends on the density of the two plates involved. In **oceanic–continental subduction**, the denser oceanic plate bends downward and slides (subducts) beneath the more buoyant continental plate along a deep offshore **trench**; as the descending slab is heated and releases water into the overlying mantle wedge, partial melting generates magma that rises to feed a chain of explosive volcanoes on the overriding continental plate, while the immense friction and bending stresses along the subduction interface generate frequent, often very powerful earthquakes. The textbook example is the western margin of South America, where the oceanic **Nazca Plate** subducts beneath the continental **South American Plate**: this single process is directly responsible for the uplift of the **Andes** mountain chain, the volcanic arc that runs along it, the offshore Peru–Chile Trench, and the region's frequent major earthquakes. In **oceanic–oceanic subduction**, one oceanic plate (typically the older, denser, and therefore colder one) subducts beneath another oceanic plate, producing a curved chain of volcanic islands (an **island arc**) on the overriding plate and an adjacent deep-sea trench; where the Pacific Plate subducts beneath the Philippine Sea Plate, the resulting **Mariana Trench** contains the deepest point on the entire ocean floor (the Challenger Deep, roughly 11 km below sea level), with the volcanic Mariana Islands forming the associated island arc. In **continental–continental collision**, both plates carry buoyant continental crust that is too low-density to subduct fully; instead, the crust on both sides crumples, folds, thickens, and is forced upward, without a well-developed subduction zone or associated volcanic arc. The collision of the **Indian Plate** into the **Eurasian Plate**, ongoing since roughly 50 million years ago, has produced the world's highest mountain range, the **Himalaya**, together with the uplifted Tibetan Plateau; this boundary remains

highly seismically active (producing large, often shallow earthquakes as accumulated crustal stress is periodically released) even though it generates essentially no active volcanism.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ranh giới hội tụ (convergent/destructive): hai mảng tiến lại gần nhau. **Hội tụ đại dương–lục địa**: mảng đại dương đặc hơn chìm xuống dưới mảng lục địa tại rãnh đại dương, tan chảy tạo magma nuôi chuỗi núi lửa nổ mạnh, gây động đất lớn — ví dụ mảng **Nazca** chìm dưới mảng **Nam Mỹ**, tạo ra dãy **Andes**, cung núi lửa, rãnh Peru–Chile và động đất thường xuyên. **Hội tụ đại dương–đại dương**: mảng đại dương già/đặc hơn chìm dưới mảng đại dương khác, tạo cung đảo núi lửa và rãnh sâu — ví dụ mảng Thái Bình Dương chìm dưới mảng Biển Philippine tạo **rãnh Mariana** (điểm sâu nhất đại dương, ~ 11 km) và quần đảo Mariana. **Hội tụ lục địa–lục địa**: cả hai mảng đều nhẹ, không chìm được hoàn toàn, vỏ bị nén, gấp nếp, dày lên và nâng cao — ví dụ mảng **Ấn Độ** va chạm mảng **Á-Âu** tạo dãy **Himalaya** và cao nguyên Tây Tạng; ranh giới này vẫn rất hoạt động về địa chấn dù gần như không có núi lửa hoạt động.

Transform (conservative) boundaries. Here two plates slide horizontally past one another along a roughly vertical fault, with motion parallel to the boundary itself; crust is neither significantly created nor destroyed, which is why these are also called **conservative** boundaries. Because the plates are in direct frictional contact rather than gliding smoothly, stress builds up until it is released in sudden, often shallow, earthquakes, but there is typically no associated volcanism, since no melting is triggered by this type of motion. The best-known example is the **San Andreas Fault** in California, which marks part of the boundary between the Pacific Plate (moving northwest) and the North American Plate; frequent slippage along this fault system is responsible for many of California's earthquakes, including the major 1906 San Francisco earthquake.



Simplified cross-sections of the three plate boundary types. Divergent (left): plates move apart, low-viscosity basaltic magma rises to create new crust at a ridge. Convergent (centre, oceanic–continental case shown): the denser oceanic plate subducts, generating a trench, a volcanic arc, and strong earthquakes; continental–continental collision instead thickens and uplifts crust without subduction (e.g. Himalaya). Transform (right): plates slide horizontally past each other along a near-vertical fault; crust is neither created nor destroyed.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ranh giới trượt ngang (transform/conservative): hai mảng trượt ngang qua nhau dọc theo một đứt gãy gần như thẳng đứng, chuyển động song song với ranh giới; vỏ Trái Đất không bị tạo mới hay phá huỷ đáng kể. Do ma sát trực tiếp giữa hai mảng, ứng suất tích luỹ rồi giải phóng đột ngột thành động đất nông, nhưng thường không có núi lửa đi kèm. Ví dụ điển hình: **đứt gãy San Andreas** ở California, ranh giới giữa mảng Thái Bình Dương (di chuyển về phía tây bắc) và mảng Bắc Mỹ — nguyên nhân của nhiều trận động đất ở California, kể cả trận động đất San Francisco năm 1906.

Ví dụ mẫu · Plate convergence rate and long-term displacement

GPS geodetic surveys indicate that the Nazca Plate converges with the South American Plate at an average rate of approximately 7 cm per year. Assuming this rate has stayed roughly constant, estimate the total relative displacement between the two plates over the past 5 million years, and express the answer in kilometres.

Set up the calculation. Displacement $=$ rate $\times$ time. Convert the rate to a convenient unit first: 7 cm/yr $= 7 \times 10^{-5}$ km/yr (since 1 km $= 100{,}000$ cm).

Compute.

$$\text{Displacement} = (7 \times 10^{-5}\ \text{km/yr}) \times (5 \times 10^{6}\ \text{yr}) = 350\ \text{km}.$$

Over 5 million years — a short interval on the geological timescale — the plates would have converged by roughly 350 km. This order-of-magnitude result is consistent with independent geological estimates of the total crustal shortening associated with Andean mountain building, and it illustrates a general principle in tectonics: plate motion rates that feel imperceptibly slow on a human timescale (only a few centimetres a year, comparable to the growth rate of a fingernail) accumulate into enormous displacements and correspondingly large amounts of mountain-building and strain energy over millions of years.

VN **GIẢI THÍCH TIẾNG VIỆT**

Vì tốc độ hội tụ mảng thường được cho theo cm/năm, cần đổi đơn vị về km trước khi nhân với thời gian tính theo năm: dùng 1 km $= 100{,}000$ cm. Dù tốc độ trôi mảng có vẻ rất chậm (chỉ vài cm/năm, tương đương tốc độ mọc móng tay), nhưng tích luỹ qua hàng triệu năm địa chất sẽ tạo ra khoảng cách dịch chuyển và năng lượng biến dạng rất lớn — đây là lý do các dãy núi uốn nếp khổng lồ như Andes hay Himalaya có thể hình thành từ một quá trình diễn ra "chậm" đến vậy.

6.2 Volcanic Hazards

6.2.1 Magma composition, viscosity, and eruption style

The single most important factor controlling how explosively a volcano erupts is the **silica (SiO2) content** of its magma, because silica content directly controls **viscosity** — how resistant the magma is to flow. **Basaltic magma** has relatively low silica content (around 50%) and correspondingly low viscosity: it flows relatively freely, allowing dissolved gases to escape gradually and gently rather than building up dangerous pressure. This produces relatively gentle, **effusive eruptions** dominated by flowing lava rather than violent explosions, and over repeated eruptions builds a **shield volcano** — a very broad volcano with gently sloping sides (typically only a few degrees), formed from many successive thin, far-travelling lava flows. Basaltic shield volcanoes are typically associated with divergent boundaries and with intraplate hotspots; the Hawaiian volcanoes (e.g., Mauna Loa and Kīlauea) are the textbook example. **Andesitic** and **rhyolitic** magmas, by contrast, contain much higher silica content (roughly 60–70% or more) and are correspondingly far more viscous — thick and sluggish, strongly resisting the escape of dissolved gases. As magma slowly rises toward the surface, gas bubbles cannot easily escape and instead accumulate, building enormous internal pressure until it is released catastrophically as a violent, highly **explosive eruption**, hurling ash, rock fragments, and pyroclastic material high into the atmosphere. Repeated eruptions of this style, alternating layers of viscous lava and pyroclastic debris, build a steep-sided **stratovolcano** (composite volcano) with slopes commonly exceeding 30 degrees near the summit. Andesitic and rhyolitic stratovolcanoes are typically associated with subduction zones, where water released from the subducting oceanic plate promotes the partial melting that generates this more silica-rich magma; Mount Pinatubo, Mount St. Helens, and Mount Fuji are all classic stratovolcanoes.

Shield volcano: low-silica basaltic magma, low viscosity, effusive eruptions, gentle slopes (~ 2–10°), typically divergent-boundary or hotspot setting (e.g., Hawaii). **Stratovolcano (composite volcano):** higher-silica andesitic/rhyolitic magma, high viscosity, explosive eruptions, steep slopes ($\sim 30^{\circ}+$), typically subduction-zone setting (e.g., Pinatubo, Mount St. Helens, Mount Fuji).

VN **GIẢI THÍCH TIẾNG VIỆT**

Yếu tố quan trọng nhất quyết định mức độ nổ của núi lửa là **hàm lượng silica** trong magma, vì nó quyết định **độ nhớt**. **Magma bazan** có hàm lượng silica thấp ($\sim 50\%$), độ nhớt thấp, khí thoát ra dễ dàng → **phun trào êm dịu (effusive)**, tạo **núi lửa hình khiên (shield volcano)** với sườn thoải, điển hình ở ranh giới phân kỳ hoặc điểm nóng (Hawaii). **Magma andesit/rhyolit** có hàm lượng silica cao (~ 60–$70\%+$), độ nhớt cao, khí bị giữ lại tích tụ áp suất lớn rồi giải phóng đột ngột → **phun trào nổ mạnh (explosive)**, tạo **núi lửa hình tầng/nón (stratovolcano)** sườn dốc đứng, điển hình ở đới hút chìm (Pinatubo, St. Helens, Phú Sĩ).

6.2.2 Primary and secondary volcanic hazards

Primary hazards are the direct products of an eruption itself. **Lava flows** are streams of molten rock; basaltic lava flows can move quickly enough to threaten property but rarely move fast enough to threaten a person who is not trapped, so they mainly cause damage to infrastructure, agriculture, and settlements rather than large numbers of deaths. **Pyroclastic flows** are fast-moving, ground-hugging currents of extremely hot gas, ash, and rock fragments (commonly reaching temperatures of several hundred degrees Celsius and speeds exceeding 100 km/h); because they can outrun a person and incinerate everything in their path, pyroclastic flows are typically the single deadliest volcanic hazard associated with explosive stratovolcano eruptions. **Ashfall (tephra)** — fine volcanic particles ejected into the atmosphere and deposited over a wide area — can collapse roofs under its weight, contaminate water supplies and farmland, cause severe respiratory problems, and ground aircraft over huge distances. **Toxic volcanic gases** (including sulfur dioxide, carbon dioxide, and hydrogen sulfide) can poison people and animals directly, and sulfur dioxide in particular reacts in the atmosphere to form sulfate aerosols with significant climatic effects (discussed further below). **Secondary hazards** occur as an indirect consequence of the eruption, often after the main event and often reaching well beyond the volcano's immediate vicinity. A **lahar** is a volcanic mudflow: a fast-moving slurry of volcanic ash, rock debris, and water — the water may come from intense eruption-related rainfall, from a breached crater lake, or (most dangerously) from summit snow and ice suddenly melted by eruptive heat — that surges down river valleys leading away from the volcano, capable of burying towns many kilometres from the summit. A **jökulhlaup** is a related but distinct hazard: a sudden glacial outburst flood, in which meltwater that has been accumulating beneath or within a glacier (often due to geothermal or volcanic heat) is suddenly released, most famously associated with ice-covered volcanoes in Iceland.

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Hiểm hoạ sơ cấp (trực tiếp từ vụ phun trào): **dòng dung nham** (chủ yếu phá huỷ tài sản, ít gây chết người vì di chuyển chậm); **dòng chảy pyroclastic** (hỗn hợp khí nóng, tro, đá di chuyển cực nhanh > 100 km/h, nhiệt độ hàng trăm độ C — hiểm hoạ gây chết người nhiều nhất ở núi lửa nổ mạnh); **tro bụi (tephra)** (sập mái nhà, ô nhiễm nước/đất nông nghiệp, bệnh hô hấp, cản trở hàng không); **khí độc núi lửa** (SO_2, CO_2, H_2S). **Hiểm hoạ thứ cấp** (gián tiếp, thường xảy ra sau và xa miệng núi lửa): **lahar** — dòng bùn núi lửa hình thành khi tro/đá trộn với nước (mưa lớn, hồ miệng núi lửa vỡ, hoặc băng/tuyết trên đỉnh tan chảy đột ngột do nhiệt phun trào); **jökulhlaup** — lũ vỡ băng đột ngột do nước tan tích tụ dưới sông băng bị giải phóng bất ngờ, thường gặp ở núi lửa phủ băng tại Iceland.

Ví dụ mẫu · Comparing eruption sizes on the Volcanic Explosivity Index

The Volcanic Explosivity Index (VEI) is a roughly logarithmic scale of eruption size, in which each whole-number increase represents approximately a tenfold increase in the volume of erupted tephra. The 1991 Pinatubo eruption is classified as VEI 6 (ejecting on the order of 10 km^3 of material); the 1985 Nevado del Ruiz eruption is classified as VEI 3. Estimate the ratio of erupted volume between the two eruptions, and comment on what this implies about the relationship between eruption size and disaster impact.

Apply the logarithmic relationship. The difference in VEI is $6 - 3 = 3$ whole units, so the ratio of erupted volumes is approximately

$$10^3 = 1000.$$

Interpret. The Pinatubo eruption ejected roughly 1000 **times more** material than the Nevado del Ruiz eruption — yet Nevado del Ruiz, despite being a comparatively tiny eruption, caused a far larger direct death toll (on the order of tens of thousands, discussed below) than Pinatubo did, precisely because a well-executed, science-based evacuation drastically reduced deaths at the much larger eruption, while a poor hazard-communication response turned a small eruption at Nevado del Ruiz into a catastrophic loss of life. This is a clear numerical illustration of a central theme of this unit: physical hazard magnitude alone is a poor predictor of human disaster impact, which instead depends heavily on the vulnerability of the exposed population and the capacity of the responsible authorities to warn and protect them.

VN **GIẢI THÍCH TIẾNG VIỆT**

Thang **VEI (Volcanic Explosivity Index)** có tính chất gần như logarit: mỗi bậc tăng 1 tương ứng thể tích vật liệu phun trào tăng khoảng 10 lần. Pinatubo (VEI 6) phun trào gấp khoảng 1000 lần thể tích của Nevado del Ruiz (VEI 3), nhưng chính Nevado del Ruiz — vụ phun trào nhỏ hơn rất nhiều — lại gây số người chết trực tiếp lớn hơn nhiều so với Pinatubo, vì công tác cảnh báo/ứng phó kém. Đây là minh chứng số học rõ ràng cho nguyên lý xuyên suốt chương này: **độ lớn vật lý của hiểm hoạ không quyết định mức độ thảm hoạ đối với con người** — tính dễ tổn thương và năng lực ứng phó mới là yếu tố then chốt.

6.2.3 Case study: Mount Pinatubo, Philippines (1991)

Mount Pinatubo, a stratovolcano on the island of Luzon in the Philippines, had been dormant for roughly 500 years before it began showing signs of unrest in early 1991. Volcanologists from the Philippine Institute of Volcanology and Seismology (PHIVOLCS), working with the United States Geological Survey (USGS), closely monitored escalating seismic activity, ground deformation, and sulfur dioxide gas emissions in the weeks leading up to the climactic eruption, and used this monitoring to issue a series of increasingly urgent hazard warnings and a graduated evacuation. On June 15, 1991, Pinatubo produced one of the largest volcanic eruptions of the twentieth century, rated **VEI** 6. Because of the careful monitoring and the resulting evacuation of roughly $60{,}000$ or more people from the surrounding danger zone — including the evacuation of the nearby U.S. Clark Air Base — the direct death toll from the climactic eruption itself was kept comparatively low (several hundred deaths, many caused by the collapse of ash-laden roofs, a toll made significantly worse by the coincidental arrival of Typhoon Yunya, which brought heavy rain that turned dry ash into a much heavier, wet load). Beyond its immediate local impact, the eruption injected an enormous quantity of sulfur dioxide (on the order of 15–20 million tonnes) high into the stratosphere, where it converted into a global veil of reflective sulfate aerosol particles; by scattering incoming solar radiation back to space, this aerosol layer is estimated to have cooled average global surface temperatures by roughly 0.5°C over the following one to two years — one of the clearest observed examples of a

single volcanic eruption measurably altering global climate.

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Núi lửa Pinatubo, Philippines (1991): núi lửa dạng tầng, ngủ yên ~ 500 năm, tái hoạt động năm 1991. Nhờ giám sát chặt chẽ (địa chấn, biến dạng mặt đất, khí SO_2) của PHIVOLCS và USGS, chính quyền đã sơ tán thành công hơn $60{,}000$ người trước vụ phun trào chính (VEI 6, một trong những vụ lớn nhất thế kỷ 20) ngày 15/6/1991 — giữ số người chết trực tiếp ở mức tương đối thấp (vài trăm người, phần lớn do sập mái nhà chứa tro ẩm nặng bởi mưa của bão Yunya trùng thời điểm). Vụ phun trào phóng thích lượng lớn SO_2 (~ 15–20 triệu tấn) lên tầng bình lưu, tạo lớp sol khí sulfat phản xạ ánh sáng mặt trời, làm nhiệt độ trung bình toàn cầu giảm khoảng 0.5°C trong 1–2 năm sau đó — một trong những bằng chứng rõ nhất về tác động khí hậu toàn cầu của một vụ phun trào núi lửa đơn lẻ.

6.2.4 Case study: Nevado del Ruiz and Armero, Colombia (1985)

Nevado del Ruiz is a glacier-capped stratovolcano in Colombia. On November 13, 1985, it produced a comparatively modest eruption (VEI 3) — vastly smaller than Pinatubo's — yet it became one of the deadliest volcanic disasters of the twentieth century. The eruption's hot pyroclastic material rapidly melted a substantial portion of the summit's ice and snow cap; the resulting meltwater mixed with loose volcanic ash and debris to form fast-moving **lahars** that swept down river valleys leading away from the volcano. One of these lahars struck the town of **Armero**, roughly 50 km from the summit, several hours after the eruption began, burying much of the town and killing an estimated $20{,}000$ or more of its residents. What makes this disaster especially significant for the study of hazard management is that the physical hazard itself was not exceptional: hazard maps identifying the lahar risk to Armero already existed, and scientists had issued explicit warnings hours before the lahar arrived. However, a combination of poor communication between scientists and local officials, confusing or delayed evacuation orders, underestimation of the risk by local authorities, and a degree of public complacency (some earlier false alarms had bred skepticism) meant that no effective evacuation was carried out in time. Nevado del Ruiz is therefore widely cited in disaster-management literature as a disaster caused primarily by failures of preparedness, communication, and response capacity, rather than by the scale of the eruption itself.

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Nevado del Ruiz, Colombia (1985): vụ phun trào nhỏ (VEI 3) làm tan chảy phần lớn băng/tuyết trên đỉnh núi lửa phủ băng, tạo **lahar** tràn xuống thung lũng sông, chôn vùi thị trấn **Armero** cách đỉnh ~ 50 km, làm khoảng $20{,}000$ người thiệt mạng. Bản đồ hiểm hoạ lahar đã có sẵn và các nhà khoa học đã cảnh báo trước nhiều giờ, nhưng do **truyền thông kém, ra lệnh sơ tán chậm/không rõ ràng, chính quyền địa phương đánh giá thấp rủi ro**, không có cuộc sơ tán hiệu quả nào được thực hiện kịp thời. Đây là ví dụ kinh điển được trích dẫn để minh hoạ rằng thảm hoạ này chủ yếu do **thất bại trong chuẩn bị, truyền thông và năng lực ứng phó**, chứ không phải do quy mô vụ phun trào.

6.3 Seismic Hazards

6.3.1 Elastic rebound theory, focus, and epicentre

Most earthquakes occur along pre-existing fault lines, where rock on either side of the fault is not free to slide smoothly past one another but instead becomes locked in place by friction, even as the surrounding tectonic plates continue their steady, ongoing motion. **Elastic rebound theory**, first proposed by Harry Fielding Reid after studying the 1906 San Francisco earthquake, describes what then happens: because the rock on either side of the locked fault is still being dragged along by plate motion, it gradually bends and stores **elastic strain energy**, much like a bent archery bow, for years, decades, or even centuries. Once the accumulated stress finally exceeds the frictional strength

holding the fault locked, the rock suddenly ruptures and slips, snapping back ("rebounding") toward its unstrained shape and releasing the stored strain energy almost instantaneously as **seismic waves** — an earthquake. Because strain re-accumulates immediately afterward at the newly relocked fault, this is fundamentally a **cyclical** process: earthquakes on a given fault segment tend to recur, though rarely at strictly predictable intervals. The point *within the Earth* where the rupture actually begins and energy is first released is called the **focus** (or **hypocentre**); the point on the Earth's *surface* located directly above the focus is called the **epicentre**. Shaking is generally most intense near the epicentre and close to the focus, and — all else being equal — a shallow-focus earthquake tends to cause more severe surface shaking than a deep-focus earthquake of the same magnitude, because the seismic energy has less distance to travel (and therefore less opportunity to attenuate) before reaching the surface.

(!) Lỗi thường gặp: Đừng nhầm **tiêu điểm (focus/hypocentre)** với **chấn tâm (epicentre)**. Tiêu điểm là điểm *bên trong* vỏ Trái Đất nơi đứt gãy thực sự bắt đầu và năng lượng được giải phóng lần đầu; chấn tâm chỉ đơn giản là điểm trên *bề mặt* Trái Đất nằm ngay phía trên tiêu điểm. Khi đề bài hỏi về "tâm chấn của trận động đất" trên bản đồ, đó luôn là chấn tâm (một điểm bề mặt); khi hỏi về độ sâu (10 km, 70 km,...), đó là độ sâu của tiêu điểm.

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Thuyết hồi phục đàn hồi (elastic rebound theory), Reid (sau động đất San Francisco 1906): đá hai bên một đứt gãy bị khoá bởi ma sát trong khi mảng kiến tạo vẫn tiếp tục di chuyển, khiến đá bị uốn cong và tích luỹ **năng lượng biến dạng đàn hồi** qua nhiều năm/thế kỷ. Khi ứng suất tích luỹ vượt quá lực ma sát giữ đứt gãy, đá đột ngột vỡ và trượt, "bật lại" gần hình dạng ban đầu, giải phóng năng lượng gần như tức thời dưới dạng **sóng địa chấn**. Đây là quá trình mang tính **chu kỳ**: ứng suất lại bắt đầu tích luỹ ngay sau đó tại đứt gãy vừa khoá lại. **Tiêu điểm (focus)** là điểm trong lòng đất nơi đứt gãy bắt đầu; **chấn tâm (epicentre)** là điểm trên bề mặt ngay phía trên tiêu điểm. Động đất tiêu điểm nông thường gây rung chấn mặt đất mạnh hơn động đất tiêu điểm sâu ở cùng độ lớn, vì năng lượng đi quãng đường ngắn hơn để tới bề mặt.

6.3.2 Seismic waves

An earthquake releases energy as several distinct types of seismic wave, which travel at different speeds and cause different kinds of ground motion. **P-waves** (primary, or compressional, waves) are the fastest seismic waves and therefore always the first to arrive at a given location; they travel by alternately compressing and expanding the material they pass through (motion parallel to the direction of travel, like a slinky pushed end-to-end), and — unlike S-waves — they can travel through both solids and liquids. **S-waves** (secondary, or shear, waves) travel more slowly than P-waves and arrive later; their particle motion is perpendicular to the direction of travel (a side-to-side or up-and-down shearing motion), and critically, S-waves cannot travel through liquids, a property used to help map the Earth's liquid outer core. **Surface waves** (including Love waves and Rayleigh waves) travel along the Earth's surface rather than through its interior; they are the slowest of the three wave types to arrive, but they typically have the largest amplitude and the longest duration of shaking, and are responsible for the majority of the structural damage caused by large, shallow earthquakes.

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Sóng P (sơ cấp): nhanh nhất, đến đầu tiên, dao động nén-giãn song song hướng truyền, đi được qua cả chất rắn và lỏng. **Sóng S (thứ cấp)**: chậm hơn P, đến sau, dao động vuông góc hướng truyền, chỉ đi được qua chất rắn (không qua được chất lỏng — dùng để xác định lõi ngoài Trái Đất ở trạng thái lỏng). **Sóng mặt (surface waves — Love, Rayleigh)**: truyền dọc bề mặt Trái Đất, đến chậm nhất nhưng biên độ lớn nhất, kéo dài nhất — nguyên nhân chính gây phá huỷ công trình ở các trận động đất nông, lớn.

Ví dụ mẫu · Locating an epicentre from the S–P time interval

A seismograph station records an earthquake's P-wave arriving at $10{:}02{:}00$ and its S-wave arriving at $10{:}02{:}40$ — an S–P time interval of 40 seconds. Using typical average crustal wave speeds of $V_P = 6.0$ km/s and $V_S = 3.5$ km/s, estimate the station's distance from the epicentre.

Set up the relationship. Travel time for each wave is distance divided by speed: $T_P = d/V_P$ and $T_S = d/V_S$. The observed interval is the difference:

$$\Delta T = T_S - T_P = \frac{d}{V_S} - \frac{d}{V_P} = d\left(\frac{V_P - V_S}{V_P V_S}\right).$$

Rearrange for distance:

$$d = \Delta T \times \frac{V_P V_S}{V_P - V_S}.$$

Substitute the values ($\Delta T = 40$ s, $V_P = 6.0$ km/s, $V_S = 3.5$ km/s):

$$d = 40 \times \frac{(6.0)(3.5)}{6.0 - 3.5} = 40 \times \frac{21.0}{2.5} = 40 \times 8.4 = 336 \text{ km}.$$

The epicentre lies approximately **336** km from this station. A single station can only fix a *distance*, placing the epicentre somewhere on a circle of that radius centred on the station; in practice, seismologists combine the distance estimates from at least three separated stations and find where their three circles intersect (trilateration) to pinpoint the epicentre's exact location.

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Vì sóng P luôn đến trước sóng S, khoảng thời gian chênh lệch $\Delta T = T_S - T_P$ (khoảng cách S–P) tại một trạm quan trắc cho phép tính khoảng cách d từ trạm đến chấn tâm bằng công thức $d = \Delta T \times \frac{V_P V_S}{V_P - V_S}$. Tuy nhiên một trạm đơn lẻ chỉ xác định được **khoảng cách** (một đường tròn khả dĩ quanh trạm) chứ chưa xác định được vị trí chính xác; cần ít nhất **ba trạm** quan trắc để giao ba đường tròn và xác định chính xác vị trí chấn tâm bằng phương pháp tam giác đạc (trilateration).

6.3.3 Magnitude and intensity scales

Two conceptually different kinds of scale are used to describe the size of an earthquake. **Magnitude** scales quantify the amount of energy released at the earthquake's source; critically, magnitude is a single, fixed number for a given earthquake, regardless of where or by whom it is measured. The original **(Richter) local magnitude scale** (M_L), developed in the 1930s, measures the maximum amplitude of seismic waves recorded on a specific type of seismograph at a standard distance; it is logarithmic (each whole-number increase corresponds to roughly a tenfold increase in recorded wave amplitude), but it was calibrated for, and works best on, moderate, relatively local earthquakes, and becomes progressively less accurate (it "saturates," underestimating true energy release) for very large earthquakes. The **moment magnitude scale** (M_w), developed later and now the standard scale used by seismologists worldwide for significant earthquakes, is based directly on the physical **seismic moment** of the rupture — the product of the average slip (displacement) along the fault, the total area of the fault that ruptured, and the rigidity of the rock involved — and does not saturate even for the very largest earthquakes, making it far more robust for comparing major events such as Tōhoku (2011) or the 1960 Chile earthquake. Seismic energy release scales approximately as $E \propto 10^{1.5M}$, meaning each whole-number increase in M_w corresponds to roughly $10^{1.5} \approx 31.6$ times more energy

released. In contrast, **intensity** scales — most commonly the **Modified Mercalli Intensity (MMI) scale** — measure the observed *effects* of an earthquake at a particular location: how strongly it was felt, and how much damage it caused to structures and landscape, expressed as a category from I (not felt) to XII (total destruction). Because shaking intensity depends on distance from the epicentre, focal depth, local geology (soft sediments amplify shaking; solid bedrock dampens it), and building construction, a single earthquake produces *one* magnitude value but generates a *different* intensity value at every location it affects.

Energy vs. magnitude: $E \propto 10^{1.5M}$, so each whole-number increase in M_w releases roughly $31.6\times$ more energy, and each increase of 2.0 releases roughly $31.6^2 \approx 1000\times$ more energy. **Magnitude** (Richter M_L; moment magnitude M_w, preferred for large events): a single fixed value describing energy released at the source. **Intensity** (Modified Mercalli scale, I–XII): describes observed shaking/damage at a specific location; varies across the affected area depending on distance from the epicentre, focal depth, local geology, and building quality.

(!) Lỗi thường gặp: **Độ lớn (magnitude)** và **cường độ (intensity)** không phải là một. Độ lớn (thang Richter M_L hoặc thang mô-men M_w) là **một con số cố định duy nhất** cho mỗi trận động đất, mô tả năng lượng giải phóng tại nguồn. Cường độ (thang Mercalli cải tiến, MMI, từ I đến XII) mô tả **mức độ rung chấn/thiệt hại quan sát được tại một địa điểm cụ thể** — và do đó **thay đổi theo từng nơi**: cùng một trận động đất có thể có cường độ XI gần chấn tâm nhưng chỉ III–IV ở nơi cách xa hàng trăm km. Nói "trận động đất này có cường độ 7.0" là sai thuật ngữ — 7.0 là *độ lớn*, không phải cường độ.

Ví dụ mẫu · Comparing energy release using moment magnitude

The 2011 Tōhoku earthquake had a moment magnitude of $M_w = 9.0$; the 2010 Haiti earthquake had $M_w = 7.0$. Using the relationship that each whole-number increase in M_w corresponds to a factor of approximately 31.6 in energy release, calculate approximately how many times more energy the Tōhoku earthquake released compared to the Haiti earthquake.

Find the difference in magnitude: $\Delta M = 9.0 - 7.0 = 2.0$.

Apply the energy-scaling factor for each whole unit ($\approx 31.6\times$), raised to the power of the magnitude difference:

$$\text{Energy ratio} \approx (31.6)^{2.0} \approx 10^{(1.5\times 2.0)} = 10^3 = 1000.$$

The Tōhoku earthquake released approximately 1000 **times more** seismic energy than the Haiti earthquake. Despite this enormous difference in physical energy release, the Haiti earthquake killed far more people than Tōhoku's shaking alone did (Tōhoku's very high death toll was driven overwhelmingly by the tsunami it generated, not by ground shaking) — a striking numerical demonstration that raw energy release at the source is a poor predictor of human casualties, which depend far more on population density, building quality, and secondary hazards than on magnitude itself.

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Vì năng lượng tỉ lệ với $10^{1.5M}$, chênh lệch độ lớn $\Delta M = 2.0$ (Tōhoku $M_w 9.0$ so với Haiti $M_w 7.0$) tương ứng tỉ lệ năng lượng $10^{1.5\times 2.0} = 10^3 = 1000$ lần. Tuy năng lượng giải phóng của Tōhoku lớn hơn Haiti tới 1000 lần, số người chết do **rung chấn trực tiếp** ở Haiti lại nhiều hơn hẳn — vì phần lớn người chết ở Tōhoku là do **sóng thần**, không phải rung chấn. Đây là minh chứng số học cho thấy năng lượng vật lý tại nguồn không phải là yếu tố dự đoán tốt cho số thương vong; mật độ dân số, chất lượng xây dựng và các hiểm hoạ thứ cấp mới là yếu tố quyết định.

6.3.4 Liquefaction

In certain ground conditions — typically loose, sandy or silty soil that is saturated with groundwater — intense seismic shaking can trigger **liquefaction**: the shaking increases the water pressure in the tiny spaces (pores) between soil grains faster than that pressure can dissipate, temporarily pushing the grains apart and destroying the frictional contact between them that normally gives soil its solid-like strength. For as long as this elevated pore pressure persists, the soil-water mixture behaves less like a solid and more like a dense liquid, unable to support the weight of buildings, roads, or underground pipes founded on it; structures can tilt, sink unevenly into the ground, or even fully topple over, and buried tanks or pipes can float upward, even though the shaking itself may not have been severe enough to structurally damage the buildings directly.

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Hoá lỏng đất (liquefaction) xảy ra ở đất rời (cát, bùn) bão hoà nước ngầm khi rung chấn mạnh làm tăng áp suất nước lỗ rỗng giữa các hạt đất nhanh hơn tốc độ thoát nước, khiến các hạt mất tiếp xúc ma sát và đất-nước tạm thời cư xử như **chất lỏng đặc**. Nền đất khi đó không còn khả năng chịu tải công trình phía trên — nhà có thể nghiêng, lún không đều, thậm chí đổ sập dù bản thân rung chấn không đủ mạnh để phá huỷ trực tiếp kết cấu công trình.

6.3.5 Case study: Haiti (2010)

On January 12, 2010, an earthquake of moment magnitude $M_w = 7.0$ struck Haiti, with its epicentre only about 25 km from, and its focus at a shallow depth close to, the densely populated capital city of **Port-au-Prince**. Estimates of the death toll vary considerably between sources, ranging from roughly $100{,}000$ into the low hundreds of thousands, with the Haitian government's own figures cited at the higher end of that range; whichever figure is used, this earthquake ranks among the deadliest in modern history, despite its only moderate magnitude. The scale of the disaster is explained not by unusual physical severity but by extreme **vulnerability** combined with very low **capacity** to cope: widespread poor-quality, poorly-enforced concrete-frame construction throughout the capital collapsed catastrophically in the shaking; Port-au-Prince had an extremely high population density; Haiti was (and remains) one of the poorest countries in the Western Hemisphere, with a GDP per capita at the time on the order of only a few hundred US dollars; and pre-existing weak governance and limited institutional capacity severely hampered the speed and effectiveness of the emergency response, including search-and-rescue efforts and the distribution of aid.

VN **GIẢI THÍCH TIẾNG VIỆT**

Haiti (2010): động đất $M_w 7.0$, chấn tâm rất gần thủ đô đông dân **Port-au-Prince**, tiêu điểm nông. Số người chết ước tính dao động rộng (khoảng $100{,}000$ đến vài trăm nghìn tuỳ nguồn), thuộc nhóm thảm hoạ chết chóc nhất thời hiện đại dù độ lớn chỉ ở mức trung bình. Nguyên nhân chính không phải do độ lớn vật lý bất thường mà do **tính dễ tổn thương cực cao** và **năng lực ứng phó cực thấp**: công trình bê tông xây dựng kém chất lượng, không tuân thủ quy chuẩn xây dựng, sập hàng loạt; mật độ dân số thủ đô rất cao; Haiti là một trong những nước nghèo nhất Tây Bán Cầu (GDP đầu người chỉ vài trăm USD); quản trị nhà nước yếu kém làm chậm trễ nghiêm trọng công tác cứu hộ và cứu trợ.

6.3.6 Case study: Tōhoku, Japan (2011)

On March 11, 2011, an earthquake of moment magnitude $M_w = 9.0$ — one of the largest earthquakes ever instrumentally recorded — struck off the Pacific coast of the Tōhoku region of Japan, generated by a massive megathrust rupture where the Pacific Plate subducts beneath the Okhotsk Plate. The sudden vertical displacement of the seafloor during the rupture generated a catastrophic **tsunami**, with waves reaching heights of up to roughly 40 metres in some coastal locations, that overwhelmed coastal defences (seawalls) that had been engineered for smaller events. The great majority of the

roughly $18{,}000$ to $20{,}000$ deaths attributed to the disaster were caused directly by the tsunami's inundation, rather than by the earthquake's ground shaking itself; the tsunami also disabled the backup diesel generators at the Fukushima Daiichi nuclear power plant, triggering a loss of reactor cooling and a major nuclear accident. Japan's extremely strict, rigorously enforced seismic building codes and decades of investment in earthquake engineering meant that the shaking itself — despite the earthquake's enormous magnitude — caused comparatively few building collapses relative to what an equivalent-magnitude earthquake would cause in a country with weaker construction standards; the overwhelming majority of the human cost came from the tsunami, a hazard for which the existing physical defences, though extensive, ultimately proved insufficient for a wave of this scale.

Feature	Haiti, 2010	Tōhoku, Japan, 2011
Moment magnitude	$M_w = 7.0$	$M_w = 9.0$
Approximate deaths	$100{,}000$+ (estimates vary widely, up to $200{,}000$+)	$\approx 18{,}000$–$20{,}000$
Approx. GDP per capita (year of event)	≈US$$700$	≈US$$46{,}000$
Building codes / preparedness	Weak, poorly enforced; low institutional capacity	Extremely strict seismic codes; extensive early-warning and drill infrastructure
Dominant cause of death	Building collapse from ground shaking	Tsunami inundation (shaking itself caused comparatively few collapses)

Comparison of the 2010 Haiti and 2011 Tōhoku earthquakes. Despite releasing roughly $1000\times$ more seismic energy, Tōhoku caused a far smaller death toll than the much smaller-magnitude Haiti earthquake — illustrating that vulnerability and capacity, not magnitude, are the dominant determinants of human disaster impact.

Ví dụ mẫu · Interpreting the Haiti–Tōhoku comparison table

Using the table above, explain why the smaller-magnitude Haiti earthquake caused a substantially larger death toll than the far larger-magnitude Tōhoku earthquake.

Identify the counter-intuitive pattern. Tōhoku ($M_w 9.0$) released roughly 1000 times more energy than Haiti ($M_w 7.0$), yet Haiti's death toll was several times larger.

Apply the risk framework (Risk $\propto$ Hazard $\times$ Vulnerability, and Risk is reduced by Capacity). Haiti's *hazard* was smaller in energy terms, but its *vulnerability* was extremely high (widely non-compliant, poor-quality construction; very high population density in Port-au-Prince close to the epicentre) and its *capacity* to prepare for and respond to the event was very low (GDP per capita only a few hundred dollars; weak governance; limited emergency infrastructure). Japan's *hazard* was far larger, but its *vulnerability* to shaking was greatly reduced by strict, well-enforced building codes, and its *capacity* to prepare and respond was very high (one of the world's largest economies; extensive early-warning systems, evacuation drills, and disaster-response infrastructure).

Note the exception within Tōhoku. Japan's high capacity substantially reduced deaths from *shaking*, but its tsunami defences were still overwhelmed by a wave larger than they had been designed for — showing that even very high capacity does not eliminate risk if the hazard exceeds the scale planned for, though it still sharply reduces overall casualties compared to a similarly high-magnitude event striking a low-capacity, high-vulnerability population.

(!) Lỗi thường gặp: Đừng cho rằng **độ lớn động đất càng cao thì số người chết càng nhiều** — đây là một trong những lỗi tư duy phổ biến nhất khi học về hiểm hoạ địa chất. Bảng so sánh Haiti ($M_w 7.0$, hơn $100{,}000$ người chết) và Tōhoku ($M_w 9.0$, năng lượng gấp ~ 1000 lần Haiti nhưng chỉ $\sim 18{,}000$–$20{,}000$ người chết) cho thấy rõ **tính dễ tổn thương** (chất lượng xây dựng, mật độ dân số) và **năng lực ứng phó** (thu nhập, quản trị, hệ thống cảnh báo sớm) mới là yếu tố quyết định số thương vong, không phải riêng độ lớn vật lý của hiểm hoạ.

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Tōhoku, Nhật Bản (2011): động đất $M_w 9.0$ — một trong những trận động đất lớn nhất từng ghi nhận — gây **sóng thần** cao tới ~ 40 m ở một số nơi, vượt qua các đê chắn sóng được thiết kế cho sự kiện nhỏ hơn. Phần lớn trong số $\sim 18{,}000$–$20{,}000$ người chết là do **sóng thần**, không phải rung chấn; sóng thần cũng làm hỏng máy phát điện dự phòng của nhà máy điện hạt nhân Fukushima Daiichi, gây sự cố hạt nhân nghiêm trọng. Nhờ quy chuẩn xây dựng chống động đất cực nghiêm ngặt, số công trình sập do rung chấn tương đối ít so với độ lớn khủng khiếp của trận động đất — nhưng hệ thống phòng chống sóng thần vẫn bị áp đảo bởi con sóng vượt quá thiết kế.

6.3.7 Case study: Gorkha earthquake, Nepal (2015)

On April 25, 2015, an earthquake of moment magnitude $M_w = 7.8$ struck Nepal, with its epicentre near the town of Gorkha, roughly 80 km northwest of the capital, Kathmandu. The earthquake killed approximately $9{,}000$ people and injured many more, with especially severe damage concentrated in the **Kathmandu Valley**, where the underlying geology — soft, deep sedimentary deposits left behind by an ancient lake bed — significantly amplified and prolonged the shaking compared to surrounding areas of harder bedrock, a well-documented example of local geology strongly influencing shaking *intensity* even at a fixed earthquake *magnitude*. The disaster destroyed or badly damaged numerous historic temples and UNESCO World Heritage monuments in the Kathmandu Valley, along with a large number of vulnerable rural buildings constructed from unreinforced stone and mud mortar, and triggered dangerous avalanches in the Everest region and landslides throughout Nepal's mountainous terrain. As in Haiti, the scale of the disaster reflected Nepal's status as one of the world's lower-income countries (GDP per capita on the order of a few hundred US dollars at the time), with limited resources available for enforcing seismic building codes or funding rapid post-disaster response and reconstruction.

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Động đất Gorkha, Nepal (2015): $M_w 7.8$, chấn tâm gần Gorkha, cách thủ đô Kathmandu ~ 80 km, làm khoảng $9{,}000$ người chết. Thiệt hại nặng nề nhất tập trung ở **thung lũng Kathmandu** vì nền địa chất là trầm tích hồ cổ mềm, khuếch đại và kéo dài thời gian rung chấn hơn hẳn khu vực đá gốc cứng xung quanh — minh hoạ rõ cách địa chất địa phương ảnh hưởng đến **cường độ** rung chấn dù **độ lớn** động đất là cố định. Thảm hoạ phá huỷ nhiều di tích lịch sử/di sản UNESCO và nhà cửa nông thôn xây bằng đá/vữa đất không gia cố, gây lở tuyết ở khu vực Everest và sạt lở đất trên diện rộng. Như ở Haiti, quy mô thảm hoạ phản ánh vị thế thu nhập thấp của Nepal, hạn chế nguồn lực thực thi quy chuẩn xây dựng và ứng phó/tái thiết sau thảm hoạ.

6.4 Tsunami Generation and Behaviour

Most large, destructive tsunamis are generated by a sudden **vertical displacement of the seafloor** during a **subduction-zone megathrust earthquake**: when a long-locked segment of a subduction interface finally ruptures, a large section of seafloor above it is abruptly thrust upward or drops downward, displacing the entire water column above it and setting off waves that radiate outward in

all directions. Tsunamis can also be generated, less commonly, by submarine landslides, by landslides falling from coastal cliffs directly into the sea, or by the sudden collapse of a volcanic flank into the ocean. A tsunami's behaviour is governed by simple wave physics: in the open, deep ocean, a tsunami has an extremely long **wavelength** (often on the order of 100 km or more) and a correspondingly very low **amplitude** (wave height frequently under one metre), so it can pass beneath a ship without even being noticed; despite this low profile, because wave speed in shallow-water wave theory depends on water depth ($v \approx \sqrt{gd}$, where g is gravitational acceleration and d is water depth), a tsunami travels extremely fast across the deep ocean — often several hundred kilometres per hour, comparable to the speed of a jet airliner. As the tsunami approaches the coast and enters progressively shallower water, its speed falls (because d decreases), but the total energy carried by the wave is approximately conserved; this forces the wavelength to compress and the wave height to increase dramatically, a process called **shoaling**, which is why a tsunami that was imperceptible in the open ocean can strike the coast as a wall of water many metres high.

Shallow-water wave speed: $v \approx \sqrt{g\,d}$ ($g \approx 9.8$ m/s^2; d = water depth). Deep ocean ($d \sim 4000$ m): very fast ($v \sim 700$ km/h), long wavelength, low amplitude. Shallow coastal water: speed falls sharply, but energy is conserved, so wavelength shortens and wave height increases sharply (**shoaling**).

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Phần lớn sóng thần lớn hình thành do **dịch chuyển thẳng đứng đột ngột của đáy biển** trong một trận động đất siêu lớn (megathrust) tại đới hút chìm; cũng có thể do trượt lở đất ngầm dưới biển, trượt lở bờ biển rơi xuống nước, hoặc sườn núi lửa sụp đổ vào đại dương. Ở đại dương sâu, sóng thần có **bước sóng rất dài** và **biên độ rất thấp** (thường dưới 1 m) nên gần như không thể nhận ra, nhưng lại di chuyển **rất nhanh** vì tốc độ sóng nước nông tỉ lệ với $\sqrt{gd}$ — có thể đạt hàng trăm km/h, tương đương tốc độ máy bay phản lực. Khi vào vùng nước nông ven bờ, tốc độ giảm mạnh nhưng năng lượng sóng gần như được bảo toàn, buộc bước sóng rút ngắn và chiều cao sóng tăng vọt — hiện tượng ***shoaling*** — biến một con sóng vô hình ngoài khơi thành bức tường nước cao nhiều mét khi vào bờ.

Ví dụ mẫu · Tsunami wave speed and travel time

A subduction-zone earthquake generates a tsunami 500 km from the coast. Assume the average open-ocean depth along this path is 4000 m. (a) Calculate the tsunami's wave speed in the open ocean, in km/h. (b) Estimate the travel time to reach the coast. (c) Calculate the wave speed once the tsunami reaches a nearshore depth of 20 m, and comment on the change.

(a) Open-ocean speed. Using $v = \sqrt{gd}$ with $g = 9.8$ m/s^2 and $d = 4000$ m:

$$v = \sqrt{9.8 \times 4000} = \sqrt{39{,}200} \approx 198 \text{ m/s}.$$

Converting to km/h: 198 m/s $\times\, 3.6 \approx$ **713** km/h — comparable to a commercial jet airliner's cruising speed.

(b) Travel time. time $= \dfrac{\text{distance}}{\text{speed}} = \dfrac{500 \text{ km}}{713 \text{ km/h}} \approx 0.70$ h $\approx$ **42 minutes** (this is an idealized estimate; in reality the wave slows somewhat as it crosses the continental shelf, so real arrival times are found using detailed bathymetric models, but this order-of-magnitude estimate correctly conveys how little time coastal communities may have to respond).

(c) Nearshore speed. At $d = 20$ m: $v = \sqrt{9.8 \times 20} = \sqrt{196} = 14$ m/s $\approx$ **50** km/h. The wave has slowed to roughly one-fourteenth of its open-ocean speed — but because its energy is conserved rather than lost, this dramatic slowdown is accompanied by a dramatic *increase* in

wave height as the wave shoals, which is precisely why tsunamis are unnoticeable at sea but devastating at the coast.

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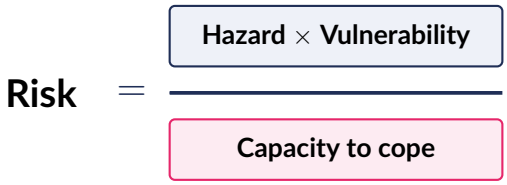
Áp dụng công thức $v = \sqrt{gd}$: ở đại dương sâu ($d = 4000$ m), tốc độ sóng thần đạt ~ 713 km/h — nhanh như máy bay phản lực — nên thời gian di chuyển 500 km chỉ khoảng 42 phút, cho thấy cộng đồng ven biển gần chấn tâm có rất ít thời gian để phản ứng. Khi vào vùng nước nông ($d = 20$ m), tốc độ giảm mạnh còn ~ 50 km/h (chỉ bằng $1/14$ tốc độ ngoài khơi), nhưng vì năng lượng sóng được bảo toàn, sự chậm lại này đi kèm với **chiều cao sóng tăng vọt** — đây là lý do sóng thần vô hại ngoài khơi nhưng cực kỳ nguy hiểm khi vào bờ.

6.5 The Hazard Risk Equation

A widely used conceptual model expresses the level of disaster **risk** faced by a population as a function of three separate factors:

$$\textbf{Risk} = \frac{\textbf{Hazard} \times \textbf{Vulnerability}}{\textbf{Capacity to cope}}.$$

Hazard refers to the probability and physical magnitude of a potentially damaging natural event occurring in a given place (for example, the frequency and expected magnitude of earthquakes along a given fault, or of eruptions at a given volcano). **Vulnerability** refers to the degree to which the exposed population and its built environment are susceptible to harm and unable to cope without external assistance — driven by factors such as poverty, population density, the quality and enforcement of building construction, level of public hazard awareness, and social or political marginalization. **Capacity to cope** (sometimes called "capacity to manage") refers to the resources and institutional strength available to prepare for, mitigate, respond to, and recover from a hazard event — including national wealth, the quality of governance, the existence of early-warning systems and trained emergency services, insurance coverage, and international support networks. Because vulnerability and capacity can each vary enormously between two places facing an objectively similar physical hazard, this equation explains why nominally similar hazard events routinely produce vastly different real-world disaster outcomes: a society with low vulnerability and high capacity can absorb even a very large hazard with comparatively modest loss of life (as in the shaking impact of Tōhoku), while a society with high vulnerability and low capacity can suffer a catastrophic disaster from a comparatively modest hazard (as at Armero).



The hazard risk equation, shown as a balance: risk rises with a larger physical hazard or greater population vulnerability (numerator), and falls as a society's capacity to prepare for, respond to, and recover from the event increases (denominator).

Ví dụ mẫu · Applying the hazard risk equation with proxy scores

Two countries face an earthquake hazard of similar underlying physical magnitude. Analysts assign each country a proxy score from 1 (lowest) to 10 (highest) for Hazard (H), Vulnerability

(V), and Capacity to cope (C):

	H	V	C
Country X (low-income, weak governance)	8	9	2
Country Y (high-income, well-prepared)	8	3	9

Calculate a relative risk score for each country using Risk $= \dfrac{H \times V}{C}$, and compare.

Country X: Risk $= \dfrac{8 \times 9}{2} = \dfrac{72}{2} =$ **36**.

Country Y: Risk $= \dfrac{8 \times 3}{9} = \dfrac{24}{9} \approx$ **2.7**.

Compare. Although both countries face an identical hazard score ($H = 8$), Country X's calculated relative risk (36) is more than 13 times higher than Country Y's (≈ 2.7), driven entirely by the difference in vulnerability and capacity. This is a simplified, illustrative model — real vulnerability and capacity cannot be reduced to a single clean number, and the equation should be understood conceptually rather than as a precise predictive formula — but it captures accurately why two places exposed to a statistically similar hazard can face dramatically different real-world risk.

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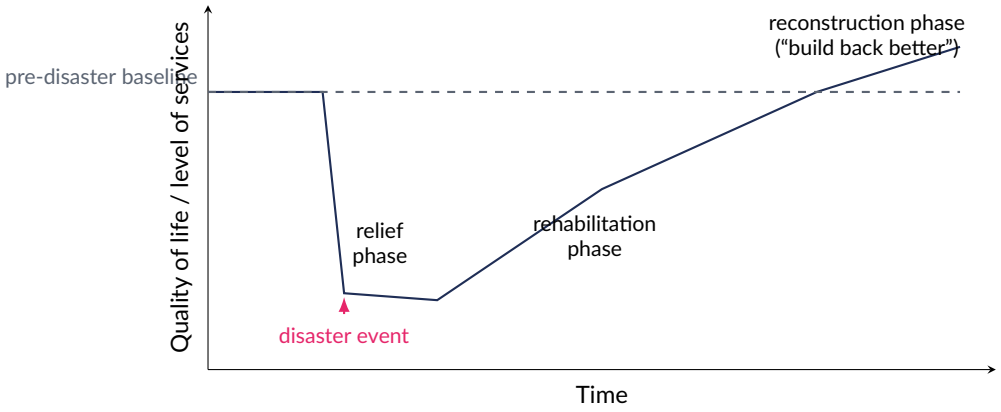
Phương trình rủi ro **Rủi ro** $= \dfrac{\text{Hiểm hoạ} \times \text{Tính dễ tổn thương}}{\text{Năng lực ứng phó}}$: **Hiểm hoạ (Hazard)** là xác suất/độ lớn vật lý của sự kiện tự nhiên; **Tính dễ tổn thương (Vulnerability)** là mức độ dân cư/công trình dễ bị tổn hại và khó tự ứng phó (nghèo đói, mật độ dân số, chất lượng xây dựng, nhận thức cộng đồng); **Năng lực ứng phó (Capacity)** là nguồn lực/thể chế để chuẩn bị, ứng phó và phục hồi (thu nhập quốc gia, chất lượng quản trị, hệ thống cảnh báo sớm, bảo hiểm). Ví dụ điểm số minh hoạ cho thấy dù cùng điểm hiểm hoạ $H = 8$, quốc gia có tính dễ tổn thương cao và năng lực thấp (Country X) có rủi ro tính toán cao hơn hơn 13 lần so với quốc gia giàu, chuẩn bị tốt (Country Y) — lý giải vì sao cùng một hiểm hoạ vật lý tương tự lại dẫn đến hậu quả thực tế rất khác nhau.

6.6 Park's Disaster Response and Recovery Curve

Geographer R. W. (Chris) Park's disaster **response and recovery curve** models how a population's **quality of life** (or, equivalently, the level of services and infrastructure available to it) changes over time, before, during, and after a major hazard event. Before the disaster, the population sits at some **pre-disaster baseline** level of quality of life. At the moment the hazard strikes, quality of life falls **suddenly and sharply**, reflecting the immediate loss of life, homes, infrastructure, and services. In the **relief phase** immediately afterward — typically lasting from days to a few weeks — quality of life remains at or near its lowest point while emergency responders focus on search and rescue and on meeting immediate survival needs (water, food, shelter, medical care); this phase corresponds to the **response** stage of the hazard management cycle described in the next section. During the subsequent **rehabilitation phase** — typically weeks to a year or more — temporary repairs are made, some services are restored (even if only partially or provisionally), and quality of life begins a gradual, uneven climb back toward normal. Finally, in the longer **reconstruction phase** — which can take years or even decades for a very severe disaster — permanent infrastructure, housing, and economic activity are rebuilt; quality of life may simply return to its original pre-disaster baseline, but if reconstruction deliberately applies **"build back better"** principles (stricter building codes, improved

infrastructure resilience, better early-warning systems, more resilient economic diversification), the final level of quality of life can actually **exceed** the pre-disaster baseline.



Park's disaster response and recovery curve. Quality of life sits at a pre-disaster baseline, falls sharply at the moment of the hazard event, remains near its lowest point during the short relief phase, climbs gradually through rehabilitation as services are partially restored, and eventually reaches reconstruction, which may return quality of life to baseline or exceed it if "build back better" principles are applied.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đường cong phục hồi thảm hoạ của **Park** biểu diễn **chất lượng cuộc sống / mức độ dịch vụ** theo thời gian: bắt đầu ở **mức nền trước thảm hoạ**, giảm **đột ngột** khi thảm hoạ xảy ra, giữ ở mức thấp trong **giai đoạn cứu trợ (relief)** ngắn (cứu hộ, nhu cầu sống còn), sau đó tăng dần trong **giai đoạn phục hồi tạm thời (rehabilitation)** khi một số dịch vụ được khôi phục, và cuối cùng đạt **giai đoạn tái thiết (reconstruction)** — có thể chỉ trở về mức nền ban đầu, hoặc **vượt qua** mức nền nếu áp dụng nguyên tắc **"tái thiết tốt hơn" (build back better)**: quy chuẩn xây dựng chặt chẽ hơn, hạ tầng bền vững hơn, hệ thống cảnh báo sớm tốt hơn.

Ví dụ mẫu · Identifying a phase of Park's model

Eighteen months after a major earthquake, a coastal town's central business district has been permanently rebuilt to a new, stricter seismic building code; a modern early-warning siren network — which did not previously exist — has been installed across the town; and the local economy has diversified into new industries, with average household income now measurably higher than it was before the earthquake. Identify which phase of Park's model this scenario best represents, and justify your answer.

Identify. This is the **reconstruction phase**, and specifically an example of **"build back better."**

Justify. The rebuilding described is *permanent* (a new building code applied to reconstructed infrastructure), not merely temporary or partial (which would indicate the earlier rehabilitation phase), and the described outcomes — improved early-warning infrastructure that did not exist before, and higher average household income than the pre-disaster baseline — indicate that the town's quality of life has not merely returned to, but has actually **exceeded**, its pre-disaster level. This combination (permanence of rebuilding + measurable improvement beyond baseline) is the defining signature of successful "build back better" reconstruction, as opposed to reconstruction that simply restores the status quo ante.

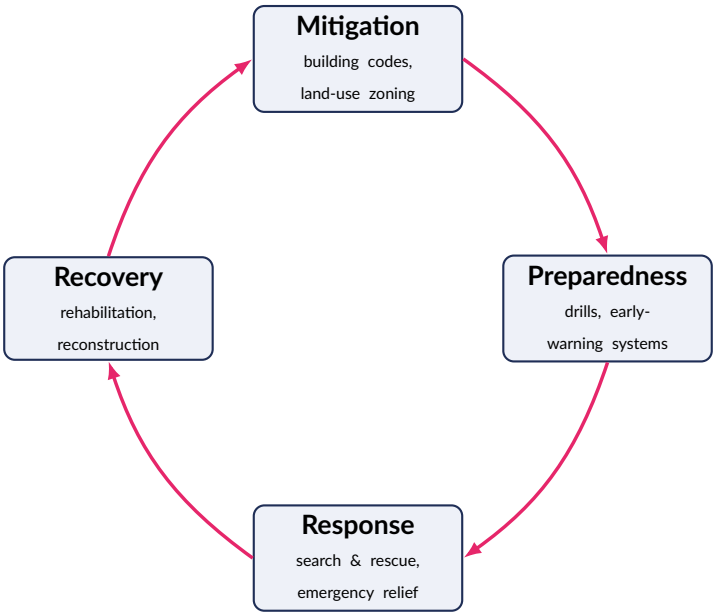
VN **GIẢI THÍCH TIẾNG VIỆT**

Để xác định giai đoạn trong mô hình Park, cần chú ý hai dấu hiệu: (1) việc tái thiết là **tạm thời** (rehabilitation) hay **vĩnh viễn** (reconstruction); (2) kết quả cuối cùng chỉ **bằng** mức nền trước

thảm hoạ hay đã **vượt qua** mức đó (dấu hiệu của "tái thiết tốt hơn" — build back better). Trong ví dụ trên, việc xây dựng lại theo quy chuẩn mới, lắp đặt hệ thống cảnh báo sớm chưa từng có, và thu nhập hộ gia đình cao hơn trước cho thấy đây là giai đoạn **tái thiết** với kết quả vượt mức nền ban đầu.

6.7 The Hazard Management Cycle

Disaster risk reduction is often organized around a continuous **hazard management cycle** of four phases, each feeding into the next. **Mitigation** comprises actions taken well before a hazard event to reduce its future severity or impact — enforcing strict building codes and seismic engineering standards, land-use zoning and planning that restricts new construction in known high-hazard areas (such as active floodplains, lahar-hazard river valleys, or liquefaction-prone ground), engineering defences such as seawalls or levees, and mechanisms such as hazard insurance that spread financial risk. **Preparedness** comprises actions taken in anticipation of a hazard that is expected to occur eventually but whose exact timing is uncertain — public education and evacuation drills, installing and maintaining early-warning systems (seismometer and tsunami-buoy networks, volcanic monitoring instruments), pre-positioning emergency supplies, and training emergency responders. **Response** comprises the immediate actions taken during and in the direct aftermath of a hazard event — search and rescue, emergency medical care, and the distribution of emergency food, water, and shelter; this phase corresponds closely to the "relief" phase of Park's model. **Recovery** comprises the medium- and long-term work of rehabilitation and reconstruction that restores, and ideally improves, affected communities — corresponding to the rehabilitation and reconstruction phases of Park's model. Crucially, the cycle does not end with recovery: the lessons learned during response and recovery — which building types failed, which warning systems worked or failed, which land uses proved most hazardous — directly inform a renewed and improved round of mitigation, making hazard management a genuinely continuous, self-reinforcing cycle rather than a one-off, linear sequence of steps.



The hazard management cycle: mitigation (reducing future impact) → preparedness (getting ready for an anticipated event) → response (immediate relief during/after the event) → recovery (rehabilitation and reconstruction) → feeding back into renewed, improved mitigation. The cycle is continuous rather than linear.

VN **GIẢI THÍCH TIẾNG VIỆT**

Chu trình quản lý hiểm hoạ gồm bốn giai đoạn nối tiếp liên tục: **Giảm nhẹ (mitigation)** — hành động trước khi thảm hoạ xảy ra để giảm tác động tương lai (quy chuẩn xây dựng, quy hoạch sử dụng đất); **Chuẩn bị (preparedness)** — chuẩn bị cho một hiểm hoạ được dự đoán sẽ xảy ra nhưng chưa rõ thời điểm (diễn tập, hệ thống cảnh báo sớm); **Ứng phó (response)** — hành động ngay trong/sau sự kiện (cứu hộ, cứu trợ khẩn cấp — tương ứng giai đoạn "cứu trợ" trong mô hình Park); **Phục hồi (recovery)** — phục hồi tạm thời và tái thiết lâu dài (tương ứng hai giai đoạn sau của mô hình Park). Bài học từ ứng phó và phục hồi sẽ quay lại cải thiện vòng **giảm nhẹ** tiếp theo — đây là một **chu trình liên tục**, không phải chuỗi bước một chiều.

Ví dụ mẫu · Classifying actions within the hazard management cycle

Following a major eruption on a Caribbean island, the following actions are taken over the following years. Classify each into one of the four phases of the hazard management cycle: (a) an emergency shipment of food, water, and medical supplies arrives on the island within 48 hours of the eruption; (b) three years later, a permanent exclusion zone and updated volcanic hazard map are formally adopted to guide all future land-use planning; (c) a new seismometer and ashfall-monitoring network, plus a public evacuation drill, are installed and rehearsed the following year, in anticipation of further activity; (d) over the following decade, destroyed roads, housing, and the island's administrative capital are permanently rebuilt in a safer location.

(a) Response — an immediate emergency relief action carried out in the direct aftermath of the event.

(b) Mitigation — a longer-term measure (updated hazard mapping and land-use zoning) intended to reduce the severity of *future* events, adopted using lessons learned from this eruption.

(c) Preparedness — action taken in anticipation of an ongoing or future hazard (further volcanic activity was expected), including monitoring infrastructure and a rehearsed evacuation plan.

(d) Recovery — the long-term rehabilitation/reconstruction of permanent infrastructure and settlements, corresponding to the rehabilitation and reconstruction phases of Park's model.

Note that (b) and (d) both occur years after the eruption, but they are conceptually distinct: (b) is about reducing the impact of *future* hazard events (mitigation), while (d) is about rebuilding what was lost from *this* event (recovery) — the two frequently occur together and reinforce one another, but they answer different questions.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khi phân loại một hành động vào chu trình quản lý hiểm hoạ, cần tự hỏi: hành động này nhằm (1) **giảm tác động của sự kiện tương lai** (giảm nhẹ — mitigation), (2) **chuẩn bị cho một sự kiện được dự đoán sẽ đến** (chuẩn bị — preparedness), (3) **đáp ứng nhu cầu ngay lập tức** của sự kiện vừa xảy ra (ứng phó — response), hay (4) **khôi phục/tái thiết** những gì đã mất do chính sự kiện đó (phục hồi — recovery)? Lưu ý (b) và (d) trong ví dụ trên đều xảy ra nhiều năm sau, nhưng khác nhau về bản chất: một cái nhằm vào *tương lai*, một cái nhằm khôi phục *quá khứ*.

6.8 Case Study: Montserrat and the Soufrière Hills Volcano

Montserrat is a small British Overseas Territory in the eastern Caribbean, home before the 1990s to a population of roughly $11{,}000$ people concentrated around its capital, **Plymouth**. The island's **Soufrière Hills** volcano, a stratovolcano that had been dormant for roughly 350 years, began showing renewed activity in July 1995 and went on to produce a series of major eruptions and dome-collapse events from 1995 through 1997 (and, at a reduced level, intermittently in the years since).

Repeated pyroclastic flows and heavy ashfall progressively devastated the southern part of the island; by 1997, Plymouth — the island's capital, main port, and economic centre — had been buried under several metres of ash and volcanic debris and was permanently destroyed and abandoned, a striking and unusual case of a national capital city being wholly and irreversibly lost to a natural hazard. In the years following the worst eruptions, roughly two-thirds of Montserrat's pre-eruption population emigrated permanently, many relocating to the United Kingdom (facilitated by Montserratians' status as British Overseas Territory citizens) and to other Caribbean islands, causing a profound and lasting demographic and economic contraction for the territory. A permanent **exclusion zone**, off-limits to permanent habitation, was established covering the volcanically hazardous southern roughly two-thirds of the island, including Plymouth itself; the surviving population and a newly designated administrative centre relocated to the safer northern part of the island. Decades later, Montserrat's population, economy, and infrastructure remain far smaller than before 1995, illustrating how a sustained, multi-year geophysical hazard can permanently reshape the human geography of a small, vulnerable island territory.

VN **GIẢI THÍCH TIẾNG VIỆT**

Montserrat: đảo nhỏ vùng Caribbean thuộc Anh, dân số trước thảm hoạ $\sim 11{,}000$ người, thủ phủ **Plymouth**. Núi lửa **Soufrière Hills** ngủ yên ~ 350 năm, tái hoạt động từ tháng 7/1995, gây các vụ phun trào lớn và sập vòm dung nham từ 1995 đến 1997. Các dòng chảy pyroclastic và tro bụi lặp đi lặp lại đã chôn vùi **Plymouth** dưới lớp tro/đá dày nhiều mét — thủ phủ bị phá huỷ và bỏ hoang vĩnh viễn, một trường hợp hiếm gặp một thủ phủ quốc gia bị mất hoàn toàn do thiên tai. Khoảng **hai phần ba dân số** di cư vĩnh viễn (phần lớn sang Anh nhờ quy chế công dân lãnh thổ hải ngoại Anh). Một **vùng cấm vĩnh viễn (exclusion zone)** được thiết lập trên khoảng hai phần ba phía nam đảo, bao gồm cả Plymouth; trung tâm hành chính mới chuyển lên phía bắc đảo an toàn hơn. Nhiều thập kỷ sau, dân số và kinh tế Montserrat vẫn nhỏ hơn nhiều so với trước 1995 — minh hoạ cách một hiểm hoạ địa chất kéo dài nhiều năm có thể tái định hình vĩnh viễn địa lý nhân văn của một lãnh thổ đảo nhỏ, dễ tổn thương.

6.9 International Policy: The Sendai Framework

The current leading international policy framework guiding global disaster risk reduction efforts is the **Sendai Framework for Disaster Risk Reduction 2015–2030**, adopted at the Third United Nations World Conference on Disaster Risk Reduction, held in Sendai, Japan, in March 2015 — a symbolically significant location, given the Tōhoku disaster only four years earlier. The Sendai Framework is the successor to the earlier Hyogo Framework for Action $(2005–2015)$, and it sets out seven global targets (including substantially reducing disaster mortality, the number of people affected, direct economic loss, and damage to critical infrastructure) and four priorities for action: understanding disaster risk; strengthening disaster risk governance to manage that risk; investing in disaster risk reduction for resilience; and enhancing disaster preparedness for effective response, together with applying "build back better" principles in recovery, rehabilitation, and reconstruction. Although non-binding, the framework provides a common set of goals and vocabulary — including the same "build back better" principle central to Park's recovery model and the same mitigation–preparedness–response–recovery structure of the hazard management cycle — that guides national disaster-risk-reduction policy and international cooperation worldwide.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khung hành động Sendai về Giảm nhẹ Rủi ro Thiên tai 2015–2030, thông qua tại Hội nghị Thế giới lần thứ ba của Liên Hợp Quốc về Giảm nhẹ Rủi ro Thiên tai, tổ chức tại Sendai, Nhật Bản, tháng 3/2015 — kế thừa Khung hành động Hyogo (2005–2015). Khung này đặt ra 7 mục tiêu toàn cầu (giảm tử vong, số người bị ảnh hưởng, thiệt hại kinh tế, thiệt hại hạ tầng thiết yếu do thiên tai) và 4 ưu tiên hành động: hiểu rõ rủi ro thiên tai; tăng cường quản trị rủi ro

thiên tai; đầu tư vào giảm nhẹ rủi ro để tăng khả năng chống chịu; và tăng cường sẵn sàng ứng phó hiệu quả, áp dụng nguyên tắc "tái thiết tốt hơn". Dù không mang tính ràng buộc pháp lý, khung này cung cấp mục tiêu và ngôn ngữ chung, định hướng chính sách giảm nhẹ rủi ro thiên tai của các quốc gia và hợp tác quốc tế trên toàn thế giới.

6.10 Practice Bank

Bài tập luyện tập

Which type of evidence was **not** available to Alfred Wegener when he first proposed continental drift in 1912, but later became the decisive evidence confirming plate tectonic theory?

(A) The jigsaw fit of continental coastlines

(B) Symmetric paleomagnetic striping either side of mid-ocean ridges

(C) Matching fossil distributions across continents

(D) Matching rock strata and mountain belts across oceans

Lời giải chi tiết

Wegener's original 1912 case relied on coastline fit, matching rock strata/mountain belts, and matching fossil distributions — all available to him at the time (though he lacked a mechanism). Paleomagnetic striping was only discovered and interpreted in the 1950s–60s, decades after Wegener's death, and it was this seafloor-spreading evidence, combined with a plausible mechanism (mantle convection), that finally confirmed the theory. **(B)**.

Bài tập luyện tập

The East African Rift is best classified as which type of plate boundary?

(A) Oceanic–oceanic convergent

(B) Continental divergent

(C) Continental–continental convergent

(D) Transform (conservative)

Lời giải chi tiết

The East African Rift is a continental rift valley where the African Plate is splitting into two sub-plates that are moving *apart* from one another — this is a divergent boundary occurring on continental (not oceanic) crust. **(B)**.

Bài tập luyện tập

Explain, in terms of magma composition and viscosity, why a shield volcano such as Mauna Loa has much gentler slopes than a stratovolcano such as Mount Pinatubo.

Lời giải chi tiết

Shield volcanoes such as Mauna Loa are built from low-silica **basaltic** magma, which has low viscosity and flows relatively freely; dissolved gases escape gradually rather than building up pressure, producing gentle, effusive eruptions whose thin, far-travelling lava flows accumulate into a broad volcano with very gentle slopes. Stratovolcanoes such as Pinatubo are built from higher-silica **andesitic/rhyolitic** magma, which is much more viscous; gas cannot escape easily, pressure builds until it is released explosively, and the resulting alternating layers of viscous

lava and pyroclastic debris pile up close to the vent, producing a much steeper-sided cone.

Bài tập luyện tập

Which of the following is classified as a **secondary** (rather than primary) volcanic hazard?

(A) Pyroclastic flow
(B) Lava flow
(C) Lahar
(D) Ashfall

Lời giải chi tiết

Pyroclastic flows, lava flows, and ashfall are all direct products of the eruption itself (primary hazards). A **lahar** is an indirect, secondary hazard: a volcanic mudflow generated when ash/debris mixes with water (often from melted snow/ice), typically occurring after the main eruptive event and often reaching well beyond the volcano's summit. **(C)**.

Bài tập luyện tập

Explain why the 1985 Nevado del Ruiz eruption is widely cited in disaster-management case studies as a failure of preparedness and response rather than simply a disaster of large physical scale.

Lời giải chi tiết

Nevado del Ruiz's 1985 eruption was physically modest (VEI 3, roughly 1000 times smaller in erupted volume than Pinatubo's 1991 VEI 6 eruption). What made it catastrophic was that hazard maps already existed identifying Armero's risk from lahars, and scientists issued explicit warnings hours before the fatal lahar arrived — yet poor communication between scientists and local officials, delayed or unclear evacuation orders, and public complacency (partly from earlier false alarms) meant no effective evacuation occurred. Roughly $20{,}000$+ people died as a result. This demonstrates that a comparatively small hazard combined with high vulnerability and low institutional response capacity can produce a disaster far larger than the physical eruption alone would predict.

Bài tập luyện tập

Distinguish between the **focus** and the **epicentre** of an earthquake, and explain why a shallow-focus earthquake typically causes more intense surface shaking than a deep-focus earthquake of the same magnitude.

Lời giải chi tiết

The **focus** (or hypocentre) is the point *within* the Earth's crust where the fault rupture begins and seismic energy is first released; the **epicentre** is the point on the Earth's *surface* located directly above the focus. Seismic waves lose energy (attenuate) as they travel through rock, so the further the waves must travel from the focus to reach the surface, the more their energy is dissipated before arrival. A shallow-focus earthquake releases its energy much closer to the surface, so waves arrive with less attenuation and produce more intense shaking, even if the total energy released (magnitude) is identical to a deep-focus event.

Bài tập luyện tập

A seismograph station records an S–P time interval of 56 seconds. Using $V_P = 6.0$ km/s and $V_S = 3.5$ km/s, calculate the station's distance from the epicentre.

Lời giải chi tiết

Using $d = \Delta T \times \dfrac{V_P V_S}{V_P - V_S}$:

$$d = 56 \times \frac{(6.0)(3.5)}{6.0 - 3.5} = 56 \times \frac{21.0}{2.5} = 56 \times 8.4 = 470.4 \text{ km}.$$

The station is approximately **470** km from the epicentre. As with any single-station estimate, this fixes only a distance (a circle of possible locations); combining this result with distance estimates from at least two other stations (trilateration) would be needed to pinpoint the epicentre's exact location.

Bài tập luyện tập

Which of the following best describes the key difference between an earthquake's **magnitude** and its **intensity**?

(A) Magnitude is measured in the field; intensity is measured by seismograph

(B) Magnitude is a single fixed value for the whole earthquake; intensity varies by location and depends on local geology and construction

(C) Intensity is always higher than magnitude for large earthquakes

(D) Magnitude only applies to earthquakes above $M_w 7.0$

Lời giải chi tiết

Magnitude (Richter M_L or moment magnitude M_w) quantifies the energy released at the earthquake's source and is a single, fixed number regardless of where it is measured. Intensity (Modified Mercalli scale) measures the *observed effects* — shaking felt, damage caused — at a specific location, and therefore varies across the area affected, depending on distance from the epicentre, focal depth, local geology (e.g., soft sediment basins amplify shaking, as in Kathmandu in 2015), and building quality. **(B)**.

Bài tập luyện tập

The 2015 Gorkha earthquake in Nepal ($M_w 7.8$) is compared with a smaller aftershock of $M_w 6.8$. Approximately how many times more energy did the main Gorkha earthquake release compared to this aftershock?

Lời giải chi tiết

The magnitude difference is $\Delta M = 7.8 - 6.8 = 1.0$. Since each whole-number increase in M_w corresponds to a factor of approximately 31.6 in energy release:

$$\text{Energy ratio} \approx 31.6^{1.0} = 31.6.$$

The main Gorkha earthquake released approximately **31.6 times** more energy than the $M_w 6.8$ aftershock, even though the two events differ by only one whole magnitude unit — illustrating

how quickly energy release grows with each additional unit of moment magnitude.

Bài tập luyện tập

Explain why the underlying geology of the Kathmandu Valley made the 2015 Gorkha earthquake's impact there especially severe, even though the earthquake's magnitude was a single fixed value for the whole event.

Lời giải chi tiết

The Kathmandu Valley sits atop deep, soft sedimentary deposits left behind by an ancient lake bed. Soft sediment amplifies and prolongs seismic shaking far more than solid bedrock does, because seismic waves slow down and increase in amplitude as they pass from harder rock into softer material (an effect analogous to shoaling in tsunami waves). Because *intensity* (unlike magnitude) varies by location and depends partly on local geology, the Kathmandu Valley experienced far more intense shaking and damage than the earthquake's single fixed magnitude value alone would suggest for a location at that distance from the epicentre.

Bài tập luyện tập

Which condition is necessary for **liquefaction** to occur during an earthquake?

(A) Deep-focus rupture beneath solid granite bedrock

(B) Loose, water-saturated sandy or silty soil

(C) A magnitude below $M_w 5.0$

(D) A transform plate boundary setting

Lời giải chi tiết

Liquefaction requires loose, unconsolidated, water-saturated sediment (typically sand or silt); strong shaking raises pore-water pressure between grains faster than it can dissipate, destroying inter-grain friction and causing the soil-water mixture to behave temporarily like a liquid. Solid bedrock (A) does not liquefy; liquefaction is unrelated to focal depth being deep, magnitude being low, or the boundary type. **(B)**.

Bài tập luyện tập

Two hypothetical countries are each assigned proxy risk scores (scale 1–10) for an earthquake hazard: Country M has $H = 6$, $V = 7$, $C = 3$; Country N has $H = 6$, $V = 2$, $C = 8$. Using $\text{Risk} = \dfrac{H \times V}{C}$, calculate the risk score for each country and state which faces the greater calculated risk.

Lời giải chi tiết

Country M: $\text{Risk} = \dfrac{6 \times 7}{3} = \dfrac{42}{3} = 14$.

Country N: $\text{Risk} = \dfrac{6 \times 2}{8} = \dfrac{12}{8} = 1.5$.

Country M's calculated risk (14) is more than 9 times higher than Country N's (1.5), despite both facing an identical hazard score ($H = 6$) — driven entirely by Country M's higher vulnerability and lower capacity to cope.

Bài tập luyện tập

A subduction-zone earthquake generates a tsunami 800 km from the coast, travelling across open ocean with an average depth of 4000 m. Using $v \approx \sqrt{gd}$ ($g = 9.8$ m/s^2), estimate the tsunami's open-ocean speed (in km/h) and its approximate travel time to the coast.

Lời giải chi tiết

Speed: $v = \sqrt{9.8 \times 4000} = \sqrt{39{,}200} \approx 198$ m/s $= 198 \times 3.6 \approx$ **713** km/h.

Travel time: time $= \dfrac{800 \text{ km}}{713 \text{ km/h}} \approx 1.12$ h $\approx$ **67** minutes (idealized estimate, ignoring the additional slowing that occurs as the wave crosses the shallower continental shelf near the coast).

Bài tập luyện tập

Explain why a tsunami that is barely noticeable to a ship in the open ocean can strike the coast as a wave many metres high.

Lời giải chi tiết

In the open ocean, water depth is very large, so tsunami wave speed (governed by $v \approx \sqrt{gd}$) is very high, and correspondingly the wavelength is very long and the amplitude (wave height) is very low — often under a metre, easily passed beneath a ship unnoticed. As the tsunami reaches shallow coastal water, depth decreases sharply, so wave speed falls; because the wave's total energy is approximately conserved during this process, the wavelength compresses and the wave height increases dramatically to compensate — a process called shoaling. The result is that the same wave that was imperceptible in deep water can arrive at the coast as a devastating wall of water several metres or more in height.

Bài tập luyện tập

Three years after a major flood disaster, a region's roads and bridges have only received temporary patch repairs, electricity has been partially restored to about 70% of affected households, and quality of life remains noticeably below its pre-disaster level, though it is steadily improving. Identify the phase of Park's model this scenario best represents.

Lời giải chi tiết

This is the **rehabilitation phase**. The repairs described are explicitly *temporary* (patch repairs, not permanent rebuilding) and *partial* (only 70% of households, not full restoration), and quality of life, while improving, has not yet returned to its pre-disaster baseline. This falls between the relief phase (which would show almost no improvement yet) and the reconstruction phase (which would involve permanent rebuilding and, ideally, a return to or improvement beyond the pre-disaster baseline).

Bài tập luyện tập

Classify each of the following actions into one phase of the hazard management cycle (mitigation, preparedness, response, or recovery): (a) enforcing a new coastal building setback law after a tsunami; (b) distributing emergency blankets and clean water immediately after a cyclone makes landfall; (c) rehearsing a school tsunami-evacuation drill; (d) rebuilding a destroyed hospital to a more resilient design over the following five years.

Lời giải chi tiết

(a) **Mitigation** — a permanent land-use restriction reducing the severity of future events.
(b) **Response** — immediate emergency relief during/just after the event.
(c) **Preparedness** — action taken in anticipation of a future hazard event.
(d) **Recovery** — long-term reconstruction of permanent infrastructure (and, since it is rebuilt to a more resilient design, an example of "build back better").

Bài tập luyện tập

Which international policy framework, adopted in 2015 in the same country as the world's largest instrumentally recorded earthquake only four years earlier, currently guides global disaster risk reduction efforts through 2030?

(A) The Hyogo Framework for Action
(B) The Paris Agreement
(C) The Sendai Framework for Disaster Risk Reduction
(D) The Ramsar Convention

Lời giải chi tiết

The **Sendai Framework for Disaster Risk Reduction 2015–2030** was adopted at the Third UN World Conference on Disaster Risk Reduction, held in Sendai, Japan, in March 2015 — four years after the 2011 Tōhoku earthquake and tsunami. It succeeded the earlier Hyogo Framework for Action (2005–2015). The Paris Agreement concerns climate-change mitigation, and the Ramsar Convention concerns wetland conservation; neither is a disaster-risk-reduction framework. **(C)**.

Bài tập luyện tập

Explain, using the concept of vulnerability and capacity, why Montserrat's Soufrière Hills eruptions (1995–1997) caused such a large proportional loss of population (roughly two-thirds emigrated) despite Montserrat being a relatively small hazard event compared to Pinatubo (1991).

Lời giải chi tiết

Montserrat's very small size and population (roughly $11{,}000$ people concentrated in and around Plymouth) meant that even a moderate, sustained eruption directly threatened a large *proportion* of the entire national territory and population — unlike a large country such as the Philippines, where even a very large eruption (Pinatubo) only directly affected a fraction of the national population and economy. Montserrat's economic base and administrative capital were concentrated almost entirely in Plymouth, so its permanent destruction represented a catastrophic, largely irreplaceable loss of national economic and institutional capacity, rather than a loss that a much larger national economy could more easily absorb and rebuild elsewhere. Montserrat's capacity to independently fund reconstruction was also limited by its very small economy, though its status as a British Overseas Territory did provide UK government support and facilitated emigration (many residents held right of abode in the UK). Together, small absolute size, geographic concentration of the population and economy in the hazard zone, and limited independent capacity explain the disproportionately large relative impact.

Bài tập luyện tập

Which single factor is most directly responsible for the difference between a shield volcano and a stratovolcano's characteristic eruption style?

(A) The latitude of the volcano

(B) The silica content (and therefore viscosity) of its magma

(C) The height of the volcano above sea level

(D) Whether the volcano is currently monitored by satellite

Lời giải chi tiết

Silica content directly controls magma viscosity: low-silica basaltic magma is runny and allows gas to escape gradually, producing effusive shield-volcano eruptions; high-silica andesitic/rhyolitic magma is viscous and traps gas until it is released explosively, producing stratovolcano eruptions. Latitude, volcano height, and monitoring status do not determine eruption style. **(B)**.

Bài tập luyện tập

Essay-plan question: Examine why two earthquakes of broadly similar or even smaller magnitude can produce very different impacts on human populations compared with a much larger earthquake, using named examples.

Lời giải chi tiết

Introduction: State the risk equation, Risk $= \dfrac{\text{Hazard} \times \text{Vulnerability}}{\text{Capacity}}$, and the thesis that magnitude (hazard) alone is a poor predictor of human impact; vulnerability and capacity are frequently the dominant factors.

Point 1 — contrasting magnitude and impact: Present the core comparison: Haiti (2010), $M_w 7.0$, death toll estimated at over $100{,}000$ (some estimates far higher); Tōhoku, Japan (2011), $M_w 9.0$ — roughly $1000\times$ more energy released — yet a substantially smaller death toll of roughly $18{,}000$–$20{,}000$.

Point 2 — explaining Haiti's high impact via vulnerability and capacity: Widespread poor-quality, poorly-enforced concrete construction; extremely high population density in Port-au-Prince close to the epicentre; very low GDP per capita (a few hundred US dollars); weak governance and limited institutional capacity slowing search-and-rescue and aid distribution.

Point 3 — explaining Tōhoku's comparatively lower shaking-related impact via capacity: Extremely strict, well-enforced seismic building codes; extensive investment in earthquake engineering and early-warning systems; high national wealth (GDP per capita roughly $\$46{,}000$) enabling rapid, well-resourced emergency response — meaning ground shaking itself caused comparatively few structural collapses despite the enormous magnitude.

Point 4 — the important caveat/nuance: Note that Tōhoku's death toll, though lower than Haiti's, was still driven overwhelmingly by the *tsunami*, a hazard for which even Japan's substantial capacity (existing seawalls) was overwhelmed — showing that high capacity reduces but does not eliminate risk when a hazard exceeds the scale planned for. A second comparison, Nepal's 2015 Gorkha earthquake ($M_w 7.8$, $\sim 9{,}000$ deaths, low GDP per capita, soft-sediment amplification in the Kathmandu Valley), can be used to reinforce that low-capacity, high-vulnerability countries remain highly exposed even at magnitudes well below Tōhoku's.

Conclusion: Restate that disaster impact is a function of vulnerability and capacity as much

as (or more than) raw hazard magnitude, and that reducing vulnerability (building codes, land-use planning) and strengthening capacity (governance, wealth, early-warning systems, preparedness) — the mitigation and preparedness stages of the hazard management cycle — are the most effective long-term levers for reducing human impact, since hazard magnitude itself cannot be controlled.

Bài tập luyện tập

Essay-plan question: Evaluate the effectiveness of the hazard management cycle as applied to a volcanic hazard, using the Montserrat (Soufrière Hills, 1995–1997) case study.

Lời giải chi tiết

Introduction: Briefly outline the hazard management cycle (mitigation, preparedness, response, recovery) and state that Montserrat illustrates both partial successes (few direct deaths from the main pyroclastic flows, due to prior evacuation of the exclusion zone) and severe long-term costs (permanent loss of the capital and roughly two-thirds of the population).

Mitigation: A permanent exclusion zone was established over the volcanically hazardous southern two-thirds of the island, based on ongoing hazard monitoring and mapping — an effective mitigation measure that has prevented habitation in the highest-risk zone in subsequent years.

Preparedness: The Montserrat Volcano Observatory was established to monitor the volcano's activity continuously, enabling timely evacuation warnings as the eruptive activity escalated through 1995–1997 — a key reason why Plymouth's destruction, though total, resulted in comparatively few direct deaths from the pyroclastic flows themselves.

Response: Emergency evacuation of Plymouth and the southern zone was carried out ahead of the most destructive pyroclastic flows and dome collapses, an effective, if disruptive, response.

Recovery: This is the weakest link in the cycle for Montserrat: given the very small size of the island's economy and population, reconstruction of an equivalent capital and economic base within the exclusion zone was never possible; instead, recovery took the form of long-term relocation of the administrative centre to the north of the island and large-scale, permanent emigration (roughly two-thirds of the population, many to the UK) — a form of "recovery" that fundamentally and permanently reduced the scale of the affected society rather than restoring it.

Conclusion: The cycle worked effectively for the mitigation, preparedness, and response stages (explaining the comparatively low direct death toll despite total destruction of the capital), but recovery in the full sense of rebuilding pre-disaster quality of life within the original settlement was not achievable given the island's small size and the permanence of the exclusion zone — illustrating that the hazard management cycle's later stages can be constrained by fundamental limits of scale and geography that mitigation and preparedness alone cannot overcome.

Bài tập luyện tập

A country experiences a series of moderate earthquakes over several decades along a locked fault segment. According to elastic rebound theory, what is happening to the fault **between** these earthquakes, and why does strain not simply dissipate harmlessly over time?

Lời giải chi tiết

Between earthquakes, the fault remains **locked** by friction even though the tectonic plates on either side continue their steady long-term motion; because the rock cannot slip freely, it bends and gradually accumulates **elastic strain energy**, much like a bent bow, for as long as the fault stays locked. This strain does not dissipate harmlessly because the rock is elastic (not plastic) at these stress levels over these timescales — it stores the energy rather than deforming permanently — until the accumulated stress finally exceeds the fault's frictional strength, at which point it ruptures suddenly, releasing the stored energy as an earthquake and "resetting" the cycle at the newly relocked fault.

Bài tập luyện tập

Explain why the Modified Mercalli Intensity scale, unlike the moment magnitude scale, cannot be summarized as a single number for an entire earthquake.

Lời giải chi tiết

Moment magnitude quantifies energy released at the earthquake's *source* (via seismic moment: slip $\times$ rupture area $\times$ rock rigidity), a physical quantity that has one fixed value regardless of where or by whom it is later measured. Modified Mercalli Intensity instead measures the *observed effects* — how strongly shaking was felt, and how much damage occurred — at each specific location affected by the earthquake. Because shaking intensity depends on distance from the epicentre, depth of focus, local geological conditions (e.g., soft sediment basins amplify shaking, as in the Kathmandu Valley in 2015), and the quality of local construction, the same earthquake necessarily produces a *range* of different intensity values across the area it affects — it cannot be reduced to one number the way magnitude can.

Bài tập luyện tập

A comparative study lists two earthquakes: Earthquake P, $M_w 6.8$, occurring in a country with widespread poorly-reinforced, prefabricated concrete construction, causing an estimated $25{,}000$ deaths; Earthquake Q, $M_w 6.9$, occurring the following year in a wealthy country with strict seismic building codes, causing 63 deaths. Explain this outcome using the hazard risk equation.

Lời giải chi tiết

Despite Earthquake Q having a very slightly *larger* magnitude than Earthquake P (essentially the same hazard, if anything marginally larger), its death toll was several hundred times smaller. Using Risk $= \dfrac{H \times V}{C}$: the hazard term (H) was essentially equal (or even slightly higher for Q), so the huge difference in outcome must come from vulnerability and capacity. Earthquake P's country had widespread poorly-reinforced, prefabricated concrete construction — buildings of this type are known to fail catastrophically under seismic loading, indicating very high *vulnerability* and (implicitly) lower capacity for rapid, well-resourced response. Earthquake Q's country had strict, well-enforced seismic building codes — low vulnerability — together with a wealthy economy and strong institutions capable of rapid emergency response — high capacity. The result is a dramatically lower Risk value for Earthquake Q despite its marginally higher Hazard score, directly illustrating that vulnerability and capacity, not hazard magnitude, are the primary determinants of an earthquake's human toll.

Bài tập luyện tập

Which of the following best explains why Mount Pinatubo's 1991 eruption had a measurable effect on **global average temperature** in the following one to two years?

(A) The lava flows covered a very large surface area, reducing the Earth's albedo

(B) Sulfur dioxide injected into the stratosphere formed reflective sulfate aerosols that scattered incoming solar radiation

(C) The eruption released large amounts of carbon dioxide, enhancing the greenhouse effect

(D) The ashfall blocked sunlight over the Philippines only, lowering the global average

Lời giải chi tiết

Pinatubo's eruption injected roughly 15–20 million tonnes of sulfur dioxide high into the **stratosphere**, where it converted into a global layer of reflective sulfate aerosol particles; because the stratosphere is far above weather systems, this aerosol veil persisted and spread globally for one to two years, scattering incoming solar radiation back to space and cooling average global surface temperatures by roughly 0.5°C. Lava flows and localized ashfall over the Philippines could not plausibly lower the *global average* temperature, and while volcanic eruptions do release CO_2, the quantity is far too small relative to atmospheric CO_2 levels to explain measurable cooling — indeed, the dominant and well-documented mechanism is aerosol-driven cooling, not a warming greenhouse effect. **(B)**.

Bài tập luyện tập

A small island nation with a population of $15{,}000$ experiences a moderate but sustained volcanic crisis lasting several years, ultimately rendering two-thirds of the island permanently uninhabitable. Using the Montserrat case study as a reference, explain why such a hazard can have a disproportionately large impact on a small island territory compared with an equivalent hazard affecting a small region of a large country.

Lời giải chi tiết

In a large country, even a severe, sustained hazard typically affects only a small fraction of the national territory, population, and economy, leaving the great majority of national infrastructure, governance capacity, and economic activity intact to support the affected region's response and recovery. On a small island territory such as Montserrat, however, the same absolute hazard footprint (a volcanic exclusion zone covering the most hazardous roughly two-thirds of the island) can encompass the *entire* national capital, most of the population, and the near-totality of the economic base, since there is very little unaffected national territory left over to absorb the impact or fund reconstruction independently. This explains why Montserrat suffered a proportionally catastrophic, permanent restructuring (two-thirds emigration, permanent loss of its capital) from a hazard that, if it had struck an equivalent-sized region within a large country, would likely have been a serious but nationally survivable regional disaster.

Urban Environments

Mục tiêu Unit: Định nghĩa và phân biệt đô thị hoá (urbanisation), tăng trưởng đô thị (urban growth), phi đô thị hoá ngược (counter-urbanisation), ngoại ô hoá (suburbanisation) và tái đô thị hoá (re-urbanisation); phân tích xu hướng đô thị hoá toàn cầu và các yếu tố đẩy–kéo của di cư nông thôn–đô thị; trình bày mô hình đô thị hoá khác biệt (differential urbanisation) và khái niệm siêu đô thị/thành phố toàn cầu; mô tả và phản biện ba mô hình cấu trúc đô thị cổ điển (Burgess, Hoyt, Harris–Ullman); phân tích nguyên nhân, đặc điểm và giải pháp nâng cấp khu định cư phi chính thức ở các nước đang phát triển (Dharavi, Kibera); phân tích suy thoái nội đô, phi công nghiệp hoá, ngoại ô hoá tràn lan, cải tạo đô thị (gentrification) và tái phát triển đô thị ở các nước phát triển; giải thích cơ chế đảo nhiệt đô thị, tắc nghẽn giao thông, ô nhiễm, quản lý rác thải và ngập lụt đô thị; và đánh giá các chiến lược xây dựng thành phố bền vững/có khả năng chống chịu (thành phố thông minh, hạ tầng xanh, mô hình thành phố nén, các nghiên cứu điển hình Curitiba, Singapore, Copenhagen).

7.1 Urbanisation Processes and Trends

7.1.1 Defining urbanisation, urban growth and related processes

Urbanisation is the process by which an increasing *proportion* of a country's or region's population comes to live in urban areas (towns and cities) rather than rural areas. It is measured as a percentage — the **level of urbanisation** — and is driven by rural-to-urban migration, the natural increase of the existing urban population, and the reclassification of expanding settlements from rural to urban status. **Urban growth**, by contrast, is the increase in the *absolute number* of people living in urban areas. The distinction matters: a country's urban population can grow rapidly in absolute terms even where the level of urbanisation is changing only slowly, and vice versa.

Beyond these two core terms, several related processes describe how population redistributes between city and countryside as an economy develops. **Suburbanisation** is the outward growth of urban areas into the surrounding rural–urban fringe, as rising car ownership, cheaper peripheral land and a preference for more space and greenery pull people and increasingly businesses away from the crowded centre. **Counter-urbanisation** is a further stage in which people and economic activity move *out* of large cities altogether into smaller towns and rural areas beyond the urban fringe, enabled by improved transport, remote/flexible working and a search for a perceived better quality of life; it became a marked feature of many high-income countries (for example parts of the United Kingdom and the United States) from the 1970s onward. **Re-urbanisation** describes a subsequent reversal, in which population and investment return to the inner city — often following deliberate regeneration schemes, new city-centre housing ("loft living"), and cultural or employment attractions — reviving areas that had earlier been hollowed out by decline.

Four processes on the urban–rural continuum

- **Urbanisation** — rising *share* of population living in urban areas.
- **Suburbanisation** — outward spread of the built-up area into the urban fringe.
- **Counter-urbanisation** — net movement of people/activity *away* from large cities to smaller settlements and rural areas.

- **Re-urbanisation** — renewed growth of population and investment back in the inner city/urban core.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đô thị hoá (urbanisation) là quá trình tỉ lệ dân số sống ở đô thị tăng lên, đo bằng % dân số đô thị. **Tăng trưởng đô thị (urban growth)** là sự tăng về *số lượng tuyệt đối* dân đô thị (do di cư, tăng tự nhiên, và tái phân loại ranh giới đô thị). **Ngoại ô hoá (suburbanisation)**: đô thị lan rộng ra vùng ven đô. **Phi đô thị hoá ngược (counter-urbanisation)**: dân cư và hoạt động kinh tế rời hẳn thành phố lớn về thị trấn nhỏ/nông thôn. **Tái đô thị hoá (re-urbanisation)**: dân số và đầu tư quay trở lại trung tâm đô thị sau các chương trình cải tạo.

7.1.2 Global trends and the drivers of rural-urban migration

The world crossed a historic threshold around 2007–2008 when, for the first time, more than half of the global population lived in urban areas; by the mid-2020s the figure stood at roughly 57% and continues to rise. The *rate* of urbanisation, however, is highly uneven. High-income regions — North America, Europe, and most of Latin America — are already predominantly urban (commonly 75–85% or more) and are urbanising only slowly, since there is little rural population left to redistribute. **Sub-Saharan Africa** and parts of **South Asia**, by contrast, remain majority-rural but are urbanising *fastest* in relative terms, and are expected to account for most of the world's future urban population growth as their large, still-growing rural populations move to towns and cities.

Rural-to-urban migration is conventionally explained using a **push–pull** framework. **Push factors** driving people from rural areas include: limited or fragmented landholdings and rural poverty; agricultural mechanisation reducing the demand for farm labour; poor access to health care, education and other services; and, in some regions, conflict, land degradation or natural hazards. **Pull factors** drawing people to cities include: the (often only perceived) availability of better-paid jobs in industry and services; access to superior education, health care and infrastructure; and the presence of family or community networks already established in the city, which lower the risk and cost of moving (chain migration). Migration decisions are rarely based on complete information, so many migrants arrive to find that urban opportunity is more limited than expected — a key reason informal settlements form (Section 3).

VN **GIẢI THÍCH TIẾNG VIỆT**

Thế giới vượt mốc **quá nửa dân số sống ở đô thị** vào khoảng năm 2007–2008; đến giữa thập niên 2020 con số này khoảng 57%. Bắc Mỹ, châu Âu, phần lớn Mỹ Latinh đã đô thị hoá cao (75–$85\%+$) nên tốc độ tăng chậm lại; **châu Phi cận Sahara** và **Nam Á** vẫn chủ yếu là nông thôn nhưng đô thị hoá *nhanh nhất* tương đối. Mô hình **đẩy–kéo**: yếu tố đẩy (đất canh tác ít/manh mún, nghèo đói nông thôn, cơ giới hoá nông nghiệp giảm nhu cầu lao động, thiếu dịch vụ y tế–giáo dục, xung đột/thiên tai) và yếu tố kéo (cơ hội việc làm — dù đôi khi chỉ là cảm nhận, dịch vụ tốt hơn, mạng lưới người quen đã ở thành phố). Vì thông tin không đầy đủ, nhiều người di cư đến nơi nhận ra cơ hội ít hơn kỳ vọng — một nguyên nhân hình thành khu định cư phi chính thức.

Ví dụ mẫu · Computing the level of urbanisation

A country has a total population of 45.0 million, of which 27.0 million live in towns and cities. Compute the level of urbanisation and state, with reasons, whether the country is likely closer to the early or late stages of urban development.

Level of urbanisation $= \dfrac{27.0}{45.0} \times 100 = 60.0\%$.

Interpretation: at 60% urban, the country sits in an intermediate position — well past the early stage of rapid, low-base urbanisation, but still short of the 75–$85\%+$ typical of mature, high-income urban systems. This profile is consistent with a middle-income country still experiencing substantial rural-to-urban migration, rather than one already in counter-urbanisation.

Ví dụ mẫu · Urban growth rate versus urbanisation

A city's population grows from 8.4 million to 12.6 million over 10 years. (a) Compute the average annual urban growth rate using $P_2 = P_1(1+r)^t$. (b) Explain why this rapid urban growth rate does not by itself prove that the country's overall level of urbanisation has also risen.

(a) $12.6 = 8.4(1+r)^{10} \Rightarrow (1+r)^{10} = 1.5$.
Taking logarithms: $10\ln(1+r) = \ln(1.5) = 0.4055 \Rightarrow \ln(1+r) = 0.04055 \Rightarrow 1+r = 1.0414$.
So $r \approx 4.1\%$ per year — a very rapid rate of urban growth.

(b) Urban *growth* measures only the absolute increase in city population. If the country's total (rural + urban) population is *also* growing quickly — through high natural increase nationwide — the urban *share* of the total population might rise only modestly, or even stay flat, even though the city itself is adding millions of people. Urbanisation level depends on the urban growth rate relative to the *total* population growth rate, not on urban growth in isolation.

7.1.3 The differential urbanisation model, megacities and world cities

The **differential urbanisation model** (associated with Geyer and Kontuly) links the pace and direction of urban growth to a country's broad level of development. In an early stage, migration concentrates disproportionately in one dominant **primate city**, which grows far faster than any other settlement in the country as it absorbs the bulk of rural-to-urban migration. As development proceeds, growth spreads to secondary cities and regional centres (*polarisation reversal*), easing pressure on the primate city. In the most developed, later stage, net migration reverses again — this is essentially counter-urbanisation — as people and investment move from the largest cities toward smaller towns and rural areas offering a lower cost of living and higher perceived quality of life. The model is a useful generalisation rather than a rigid law: real countries do not always pass through the stages in strict sequence, and government policy (for example, deliberate investment in secondary cities) can accelerate or interrupt the pattern.

A **megacity** is conventionally defined as a metropolitan area with a population of at least **10 million**. The number of megacities has grown from a handful in the 1970s to more than thirty today, with the fastest-growing examples now concentrated in Asia and Africa. Megacities generate powerful **agglomeration economies** — shared infrastructure, a deep and specialised labour market, knowledge spillovers between firms — but the same concentration of people can outpace the capacity of housing, transport, water and sanitation systems, producing acute urban problems (see Section 3). A **world city** (or *global city*) is a distinct concept, defined less by population size than by its command of global economic functions: headquarters of multinational corporations and banks, international financial markets, and dense flows of capital, information and highly skilled labour. London, New York, Tokyo and Singapore are commonly cited world cities; a city can be a megacity without being a world city, and a world city (e.g. Singapore) need not be a megacity by population alone.

VN **GIẢI THÍCH TIẾNG VIỆT**

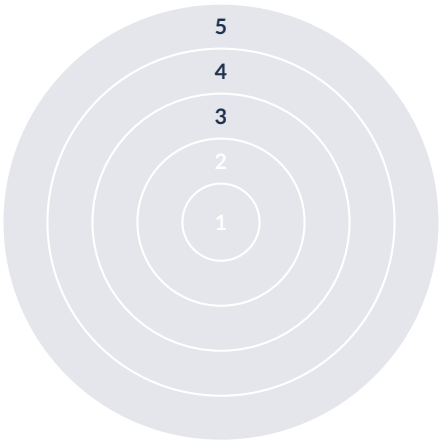
Mô hình đô thị hoá khác biệt (differential urbanisation): giai đoạn đầu, di cư tập trung vào một **thành phố đầu đàn (primate city)**; khi phát triển hơn, tăng trưởng lan sang các thành phố cấp hai (*đảo ngược phân cực*); ở giai đoạn phát triển cao nhất, dòng di cư đảo ngược lần nữa thành phi đô thị hoá ngược. **Siêu đô thị (megacity)**: vùng đô thị ≥ 10 triệu dân, mang lại lợi

thế tích tụ nhưng cũng gây áp lực lớn lên nhà ở, giao thông, nước sạch. **Thành phố toàn cầu (world city)**: được định nghĩa bởi vai trò tài chính–kinh tế toàn cầu (trụ sở tập đoàn đa quốc gia, thị trường tài chính) chứ không chỉ bởi quy mô dân số — ví dụ London, New York, Tokyo, Singapore.

7.2 Models of Urban Structure and Land Use

7.2.1 The Burgess concentric zone model

In 1925 the sociologist **Ernest Burgess** proposed that cities grow outward from a single centre in a series of concentric rings, based on his study of Chicago. The model assumes an **isotropic plain** — flat land with no physical barriers, uniform transport accessibility in every direction, and free competition for land such that the highest bidder always secures the most central location. As the city expands, each zone grows by encroaching on the zone immediately outside it, a process Burgess called **invasion and succession**, and socio-economic status broadly *rises* with distance from the centre.



The Burgess concentric zone model: (1) Central Business District — retail, offices, highest land values; (2) zone of transition — light industry mixed with the oldest, poorest housing, often the first stop for new migrants; (3) zone of low-class (working-class) housing; (4) zone of medium/better-quality housing; (5) commuter zone — highest-income households, largest homes, longest commute to the centre.

VN **GIẢI THÍCH TIẾNG VIỆT**

Mô hình vòng tròn đồng tâm Burgess (1925, dựa trên Chicago) giả định một **mặt phẳng đẳng hướng**: đất bằng phẳng, khả năng tiếp cận giao thông như nhau mọi hướng, cạnh tranh đất tự do (ai trả giá cao nhất chiếm vị trí trung tâm nhất). Thành phố lớn dần qua quá trình **xâm lấn–kế thừa (invasion and succession)**: vùng (1) CBD — trung tâm thương mại; (2) vùng chuyển tiếp — công nghiệp nhẹ và nhà ở cũ nát, nơi người nhập cư mới thường ở đầu tiên; (3) nhà ở công nhân; (4) nhà ở trung lưu; (5) vùng ngoại ô người đi làm (commuter) — thu nhập cao nhất, nhà lớn nhất, đi lại xa nhất. Địa vị kinh tế–xã hội tăng dần theo khoảng cách tới trung tâm.

7.2.2 The Hoyt sector model and the Harris–Ullman multiple nuclei model

In 1939 the land economist **Homer Hoyt** argued that urban growth is better described by **wedge-shaped sectors** radiating outward from the CBD along the main lines of transport (roads, railways, rivers) than by simple rings. Similar land uses cluster along a given transport corridor and, crucially, tend to *persist* in the same direction as the city expands: once a high-status residential sector becomes established (often moving away from industry and toward attractive natural features such as high ground, parkland or a coastline), new high-status development continues to extend outward

along that same axis, because established transport links, existing high-value development and social prestige all reinforce the pattern. Industrial and low-income residential sectors similarly persist along their original transport corridors, often near railway lines, rivers or the direction the earliest factories were built.

The **Harris–Ullman multiple nuclei model** (1945) rejects the idea of a single dominant centre altogether. Instead, a city develops around *several separate nodes* (nuclei), each specialised for a different function — for example a historic CBD, a university district, a port or airport-related node, an out-of-town retail park, and one or more industrial estates. Multiple nuclei emerge because different activities have different locational requirements (heavy industry needs rail/water access and cheap land; retail needs high accessibility and footfall; some land uses actively repel each other — high-income housing avoids locating next to heavy industry, for instance) and because, once a nucleus is established, similar activities cluster around it through agglomeration economies. The model fits large, car-dependent, polycentric cities — where widespread private car ownership and ring roads/highways allow development to disperse to multiple, semi-independent centres — better than the single-centre logic of Burgess or Hoyt.

Model	Structural pattern	Key organising principle	Main critique
Burgess (1925)	Concentric rings around one CBD	Isotropic plain; status rises with distance from centre; invasion–succession	Ignores relief, transport routes and multiple centres; Western/1920s Chicago bias
Hoyt (1939)	Wedge-shaped sectors along transport routes	Land value and transport corridors; sectors persist outward over time	Still assumes one dominant CBD; ignores car-based dispersal
Harris–Ullman (1945)	Several separate specialised nuclei	Differing locational needs of activities; agglomeration around each nucleus	Loses the simplicity/predictive power of a single clear pattern

Comparison of the three classical models of urban land-use structure.

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Mô hình khu vực Hoyt (1939): các khu chức năng phát triển thành **hình nêm/quạt** dọc theo trục giao thông chính (đường bộ, đường sắt, sông), thay vì vòng tròn đồng tâm; khu nhà ở cao cấp có xu hướng *duy trì hướng phát triển* ra ngoại ô dọc trục đó. **Mô hình đa nhân Harris–Ullman** (1945): thành phố không chỉ có một trung tâm mà phát triển quanh **nhiều hạt nhân riêng biệt** (CBD, khu đại học, cảng, khu công nghiệp, trung tâm thương mại ngoại ô) do mỗi hoạt động có yêu cầu vị trí khác nhau và có hoạt động "đẩy nhau" (công nghiệp nặng và nhà ở cao cấp thường tách biệt). Mô hình này phù hợp hơn với các thành phố lớn, phụ thuộc ô tô, đa trung tâm.

7.2.3 Assessing the models: strengths and critiques

All three classical models share the same core value: they simplify the immense complexity of a real city into a testable, comparable pattern, and they highlight genuinely important processes — the pull of land value toward the centre, the channelling effect of transport routes, and the tendency of similar activities to cluster. Their limitations, however, are serious and well documented. All three were developed from — and best fit — early-to-mid twentieth-century **Western, industrial cities** (chiefly Chicago), and each assumes a relatively free land market, a single historically dominant CBD,

and a transport technology (walking, tram, early rail and, for Hoyt, early car ownership) that has since been transformed by mass car ownership, ring roads and out-of-town development.

The models fit **Global South cities** poorly. Many cities shaped by colonial planning follow patterns closer to the alternative *Latin American city model* (Griffin and Ford): a prestigious commercial spine extends outward from the CBD, elite housing clusters along this spine rather than at the urban edge, quality of housing still generally declines with distance from the centre in a loose concentric pattern, but informal settlements form in a peripheral "zone of disamenity" or on hazardous, unwanted land (steep slopes, floodplains, land near railways or waste sites) rather than in an orderly outer ring. This inverts a core Burgess assumption — that status simply rises with distance from the centre. The classical models also fit **car-dependent, polycentric cities** poorly: once ring roads, highways and mass car ownership are in place, retail, offices and housing can disperse to multiple edge-of-city nodes largely independent of the original CBD, a pattern the Harris–Ullman model captures far better than Burgess or Hoyt, but which none of the models anticipated in their original, transit- and rail-based form.

(!) Lỗi thường gặp: Đừng viết rằng mô hình Burgess "áp dụng đúng cho mọi thành phố hiện đại". Ba mô hình cổ điển được xây dựng từ các thành phố công nghiệp phương Tây đầu–giữa thế kỷ 20; chúng thường **không phù hợp** với thành phố ở Nam bán cầu (nơi giới thượng lưu thường sống gần trung tâm, còn khu ổ chuột nằm ở ngoại vi/đất nguy hiểm) và không phù hợp với thành phố phụ thuộc ô tô, đa trung tâm hiện đại.

Ví dụ mẫu · Matching a described city to a model

A city has a historic CBD, but its wealthiest residential neighbourhood forms a narrow corridor running from the CBD out to a lake shore, following the route of the city's oldest railway line; heavy industry occupies a separate corridor along a river on the opposite side of the city. Which classical model best fits this description, and why?

Answer: this matches the **Hoyt sector model**. The defining clue is that high-status housing and industry each form a linear *wedge* radiating from the centre along a specific transport/physical corridor (the railway line toward the lake; the river for industry), rather than uniform rings (which would fit Burgess) or several unconnected specialised nodes scattered across the city (which would fit Harris–Ullman). The lakeside amenity explains *why* the high-status sector took that particular direction and, per Hoyt, is likely to keep extending outward along the same axis as the city grows.

7.3 Urban Issues in the Global South

7.3.1 Informal settlements: causes and characteristics

An **informal settlement** (commonly called a *slum* or *squatter settlement*) is, in the UN-Habitat definition, a residential area lacking one or more of: secure legal tenure, access to safe water, access to adequate sanitation, sufficient living area (not overcrowded), and durable, structurally safe housing. Informal settlements arise where rapid rural-to-urban migration and natural urban population growth outpace the capacity — and often the willingness — of city authorities and formal housing markets to supply affordable serviced land and housing. Migrants and low-income urban residents who cannot afford formal housing or land instead build their own dwellings, frequently using low-cost materials (corrugated iron, timber, salvaged material), on land that is unclaimed, unsuitable for formal development, or simply overlooked by planning authorities — commonly steep slopes, floodplains, railway margins, or land close to waste sites and polluting industry, precisely because such land is cheap or free and carries no competing formal claim.

Two frequently studied examples illustrate the pattern. **Dharavi**, in Mumbai, India, is one of Asia's largest and most densely populated informal settlements, occupying roughly 2 km^2 of land in

the heart of the city and housing a very large population at extremely high density. Despite minimal formal infrastructure, Dharavi supports an extensive **informal economy** — recycling and plastics reprocessing, leather goods, garment and textile production, and pottery (notably the Kumbharwada potters' quarter) — generating substantial economic output that is largely untaxed and unrecorded. **Kibera**, in Nairobi, Kenya, is similarly one of Africa's best-known large informal settlements, located only a few kilometres from Nairobi's city centre; it is characterised by very high housing density, predominantly corrugated-iron dwellings, limited formal sanitation (with widespread reliance on shared pit latrines and, historically, so-called "flying toilets"), and a strong community and NGO presence working on local mapping, sanitation and livelihood projects.

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Khu định cư phi chính thức (informal settlement/slum) theo UN-Habitat thiếu ít nhất một trong: quyền sử dụng đất hợp pháp, nước sạch, vệ sinh đầy đủ, diện tích ở đủ (không quá tải), nhà kiên cố an toàn. Hình thành do di cư nông thôn–đô thị và tăng dân số đô thị vượt quá khả năng cung cấp đất/nhà ở chính thức; người dân tự xây nhà trên đất bị bỏ trống, không thích hợp phát triển chính thức (sườn dốc, vùng lũ, ven đường sắt) vì rẻ hoặc miễn phí. **Dharavi** (Mumbai) — khoảng 2 km^2, mật độ cực cao, có nền kinh tế phi chính thức lớn (tái chế, đồ da, dệt may, gốm). **Kibera** (Nairobi) — gần trung tâm thành phố, mật độ cao, nhà tôn, thiếu vệ sinh chính thức, có nhiều dự án cộng đồng/NGO hỗ trợ.

7.3.2 Infrastructure deficits and the informal economy

Informal settlements typically suffer severe deficits across every basic urban service. **Water**: few homes have piped connections, so residents rely on shared standpipes, water vendors, or boreholes, often at a higher effective price per litre than piped water costs wealthier residents elsewhere in the same city. **Sanitation**: sewer networks rarely reach these areas, so households depend on shared or communal pit latrines, and untreated waste can contaminate water sources and increase the risk of water-borne disease. **Electricity**: connections are often informal and unsafe (illegal tapping into the grid), raising fire risk. **Housing and roads**: unplanned, densely packed construction leaves streets too narrow for vehicles, hampering emergency services (fire engines, ambulances) and formal waste collection.

Facing exclusion from the formal labour market, a very large share of urban Global South residents earn a living through the **informal economy**: unregistered, untaxed activity such as street vending, small workshops, waste-picking and recycling, and informal transport. The informal economy offers low barriers to entry, flexibility and a vital livelihood safety net, but workers typically lack legal protection, job security, or access to benefits such as health insurance or pensions, and the sector as a whole is largely invisible to formal tax and planning systems.

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Khu định cư phi chính thức thiếu hụt nghiêm trọng về **nước sạch** (dùng vòi chung/mua nước, giá thực tế trên mỗi lít có khi cao hơn khu giàu), **vệ sinh** (nhà vệ sinh chung, nguy cơ ô nhiễm nguồn nước), **điện** (đấu nối trái phép, nguy cơ cháy nổ), và **đường/nhà ở** (xây dựng dày đặc, đường quá hẹp cho xe cứu hoả/cứu thương). **Kinh tế phi chính thức** (bán hàng rong, xưởng nhỏ, nhặt/tái chế rác, xe ôm/vận tải không đăng ký) tạo sinh kế quan trọng nhưng thiếu bảo vệ pháp lý, bảo hiểm, lương hưu.

7.3.3 Upgrading strategies

City governments and international agencies have pursued three broad strategies to address informal settlements. **Site-and-service schemes** provide residents with a serviced plot of land — basic infrastructure such as water, sanitation and a road already installed, sometimes with a small starter structure — on which residents build their own homes incrementally as resources allow; this is relatively low-cost for government, gives residents legal tenure and a stake in their home, but sites are

sometimes located far from existing jobs and social networks. **In-situ upgrading** improves an existing settlement *in place*: adding piped water, sewerage, electricity, paved footpaths and street lighting, and formalising land tenure, without displacing residents. This preserves established livelihoods, social networks and the informal economy built up around the settlement, and is often the most cost-effective option, though high existing densities and unclear or contested land ownership can complicate it. **Slum clearance and resettlement** demolishes informal housing and relocates residents to new housing elsewhere, sometimes improving the physical quality of dwellings, but frequently relocating people to peripheral sites far from jobs and markets, raising transport costs, disrupting social networks and livelihoods built on proximity to the city centre, and — where evictions are forced rather than negotiated — provoking serious human-rights concerns.

Ví dụ mẫu · Evaluating upgrading strategies

A city government must choose between (i) clearing a well-established, centrally located informal settlement and relocating its 40,000 residents to new housing 25 km away, or (ii) in-situ upgrading of water, sanitation and electricity within the existing settlement. Evaluate which approach is likely to be more sustainable.

Clearance and resettlement may deliver better-built housing, but relocating residents 25 km from the city centre severs their access to existing jobs (often in the informal economy, which depends on central, high-footfall locations), schools and social networks, effectively imposing large new transport costs and reducing household income precisely among those least able to absorb the loss — while often proving highly disruptive and contested. **In-situ upgrading** keeps residents where their livelihoods and social capital already exist, is typically far cheaper per household than building entirely new housing and infrastructure elsewhere, and can be phased gradually. **Judgement:** in-situ upgrading is generally the more sustainable approach wherever the settlement's location is not itself hazardous (e.g. a floodplain or unstable slope); clearance/resettlement is better justified mainly where the site poses a genuine safety risk that upgrading cannot remove.

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Site-and-service: cấp đất đã có hạ tầng cơ bản, dân tự xây nhà dần — chi phí thấp cho chính quyền, tạo quyền sở hữu, nhưng đôi khi xa việc làm. **Nâng cấp tại chỗ (in-situ upgrading)**: cải thiện hạ tầng ngay tại khu định cư hiện có, giữ được sinh kế và mạng lưới xã hội, thường tiết kiệm chi phí nhất. **Giải toả–tái định cư (clearance/resettlement)**: phá bỏ và di dời dân đến nơi khác, có thể cải thiện chất lượng nhà nhưng thường đẩy dân ra xa việc làm, phá vỡ sinh kế và mạng lưới xã hội, và có nguy cơ cưỡng chế.

Ví dụ mẫu · Density and pressure on services

A generic informal settlement occupies 1.8 km^2 and is home to an estimated $270{,}000$ people. Compute its population density and compare it with a typical formal suburban density of around $3{,}000$ persons/km^2.

Density $= \dfrac{270{,}000}{1.8} = 150{,}000$ persons/km^2.

Interpretation: this is roughly **50 times** the density of a typical formal suburb. At such extreme density, even modest per-capita infrastructure deficits (litres of water per person, latrines per household) translate into enormous absolute shortfalls, explaining why disease transmission, fire risk and pressure on shared facilities are disproportionately severe in the highest-density informal settlements.

7.4 Urban Issues in the Global North

7.4.1 Inner-city decline and deindustrialisation

Many cities in high-income countries built their early growth on manufacturing industry concentrated in or near the urban core — steel, shipbuilding, textiles, heavy engineering. From the mid-twentieth century onward, **deindustrialisation** — the decline of manufacturing employment, driven by automation, the relocation of production to lower-cost countries, and the wider shift of high-income economies toward services — closed factories and eliminated jobs concentrated precisely in these traditional inner-city and "rust belt" districts (for example parts of Detroit and other US Rust Belt cities, or former shipbuilding and steel towns in the United Kingdom such as Glasgow and Sheffield). The result was **inner-city decline**: population loss as those who could afford to leave moved to the suburbs or beyond (contributing to suburbanisation and counter-urbanisation), a shrinking tax base, rising unemployment and deprivation among those left behind, and derelict, contaminated former industrial land — **brownfield sites** — left vacant at the heart of the city.

7.4.2 Suburban sprawl

Suburban sprawl is the largely unplanned, low-density outward expansion of a city's built-up area, enabled above all by mass car ownership and highway construction, and by the relatively cheap cost of peripheral land compared with the city centre. Sprawl imposes significant costs. **Environmental costs** include the loss of agricultural land and natural habitat at the urban fringe, habitat fragmentation, increased carbon emissions from longer average commutes, and a larger area of impermeable surface generating more surface runoff. **Social costs** include entrenched car dependency (low-density development makes public transport and walking impractical), longer commuting times, and increased spatial segregation by income. **Economic costs** include the higher per-capita cost of extending roads, water, sewerage and electricity across a more dispersed area, and the further erosion of the inner-city tax base as residents and businesses continue to relocate outward.

Ví dụ mẫu · Quantifying sprawl through density

A metropolitan area's population grows from $500{,}000$ to $750{,}000$ over 20 years, while its built-up (urbanised) area expands from 120 km^2 to 210 km^2 over the same period. Compute the population density at the start and end of the period, and explain why this is a signature of sprawl.

Initial density $= \dfrac{500{,}000}{120} = 4167$ persons/km^2.

Final density $= \dfrac{750{,}000}{210} = 3571$ persons/km^2.

Interpretation: even though the population grew by 50%, the built-up area grew even faster (75%), so overall density actually *fell* by about 14%. This — population and urban area both growing, but land being consumed faster than population — is precisely the defining signature of low-density suburban sprawl, as distinct from compact growth (where density would rise or stay constant).

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Suy thoái nội đô do phi công nghiệp hoá: nhà máy đóng cửa, việc làm mất đi, người có điều kiện chuyển ra ngoại ô, để lại đất công nghiệp bỏ hoang (**brownfield**), giảm thu ngân sách, gia tăng nghèo đói. **Ngoại ô hoá tràn lan (sprawl)**: đô thị mở rộng mật độ thấp nhờ ô tô và đường cao tốc, gây mất đất nông nghiệp/tự nhiên, tăng phát thải carbon do đi lại xa, phụ thuộc ô tô, chi phí hạ tầng trên đầu người cao hơn. Dấu hiệu của sprawl: diện tích đô thị tăng nhanh hơn dân số, khiến mật độ giảm dù dân số vẫn tăng.

7.4.3 Gentrification and urban regeneration

Gentrification is the process by which a previously lower-income, often inner-city neighbourhood is transformed by an influx of wealthier residents and investment, typically attracted by cheap housing stock, proximity to the city centre and jobs, and distinctive historic or cultural character. It commonly begins with a small "pioneer" wave of artists, students or young professionals, followed by wider middle-class in-migration, renovation of the existing housing stock, and the arrival of new cafes, boutiques and services catering to higher-income tastes — driving up property values and rents. The **effects** are genuinely double-edged. On one hand, gentrification brings renewed investment, improved and safer building stock, reduced vacancy and blight, and a larger local tax base that can fund better services. On the other hand, rising rents and property values frequently **displace** the original lower-income residents — directly, when they can no longer afford rent, or indirectly ("exclusionary displacement"), as the rising general cost of living pushes them out even without an explicit eviction — while small, long-established local businesses are often replaced and the neighbourhood's original community character and social networks are eroded.

Urban regeneration refers more broadly to deliberate schemes to revive declining urban areas, frequently through **brownfield redevelopment** — converting former industrial or derelict land within the existing urban footprint into new housing, offices or mixed-use development. This is generally preferred over building on undeveloped **greenfield** land at the urban edge, since it reuses land already served by existing infrastructure and reduces pressure for further sprawl. The redevelopment of London's former docklands — abandoned as containerisation moved shipping downriver — into the Canary Wharf financial district and surrounding housing is a widely cited example of large-scale brownfield-led regeneration transforming a declining inner-city area.

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Cải tạo đô thị (gentrification): dân cư và nhà đầu tư thu nhập cao chuyển vào khu vực nội đô từng có thu nhập thấp, cải tạo nhà cũ, kéo theo quán cà phê/cửa hàng mới, đẩy giá nhà–tiền thuê tăng. Mặt tích cực: đầu tư mới, nhà ở an toàn hơn, tăng thu thuế địa phương. Mặt tiêu cực: **di dời (displacement)** cư dân thu nhập thấp trực tiếp (không đủ tiền thuê) hoặc gián tiếp (chi phí sinh hoạt tăng), mất bản sắc cộng đồng. **Tái phát triển đất công nghiệp bỏ hoang (brownfield)** — ví dụ khu bến cảng cũ London (Docklands) thành khu tài chính Canary Wharf — giúp tái sinh đô thị mà không lấn thêm đất nông thôn (greenfield).

Dimension	Typical Global North challenge	Typical Global South challenge
Housing	Inner-city decline, vacant brownfield land; sprawl at the edge	Acute shortage of formal, affordable housing; informal settlements
Economy	Deindustrialisation; loss of manufacturing jobs	Large informal economy; limited formal employment
Infrastructure	Ageing infrastructure; car-dependent sprawl	Severe deficits in water, sanitation, electricity, drainage
Growth driver	Slow growth; counter-urbanisation/re-urbanisation	Rapid rural–urban migration and natural increase
Typical response	Brownfield regeneration; gentrification (with displacement risk)	In-situ upgrading; site-and-service schemes

Contrasting urban challenges commonly associated with cities in the Global North and Global South.

7.5 Urban Environmental Challenges

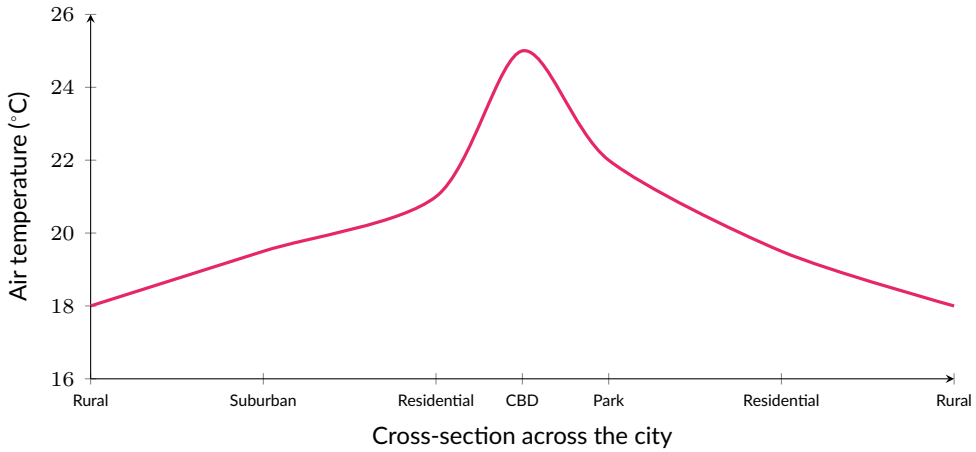
7.5.1 Traffic congestion and transport

Rising car ownership, especially in cities built or expanded around private vehicle use, produces chronic **traffic congestion**: delays, wasted fuel, lost economic productivity, and elevated vehicle

emissions concentrated exactly where population density — and therefore exposure — is highest. Investment in **public transit** (buses, light rail, metro/underground systems, and cheaper bus rapid transit systems) can shift trips away from private cars, reducing congestion and per-passenger emissions, provided the service is frequent, reliable and affordable enough to compete with driving. **Transit-oriented development (TOD)** takes this further by deliberately concentrating higher-density, mixed-use development (housing, offices, retail) within convenient walking distance of a transit station, so that daily trips are naturally short and easily made on foot, by bicycle, or by transit rather than by car — reducing car dependency structurally rather than relying only on people's individual travel choices.

7.5.2 The urban heat island effect

Cities are consistently warmer than their surrounding rural areas, an effect known as the **urban heat island (UHI)**. Several mechanisms combine to produce it. **Albedo**: dark surfaces such as asphalt roads and tarred roofs absorb far more incoming solar radiation, and reflect far less, than vegetated rural surfaces, storing heat during the day. **Anthropogenic heat**: cities release large quantities of waste heat directly from vehicle engines, industrial processes, and heating and air-conditioning systems. **Reduced evapotranspiration**: rural areas lose a great deal of incoming energy to evaporation from soil and water and to transpiration from vegetation, both of which cool the surface; cities, with far less vegetation and exposed soil, lose comparatively little energy this way, so more energy remains to heat the air. The **urban canyon effect**: tall buildings lining narrow streets trap incoming shortwave radiation through repeated reflection between building walls during the day, and at night reduce the *sky view factor*, trapping outgoing longwave radiation and slowing radiative cooling; the same canyon geometry also reduces wind speed at street level, limiting the dispersal of heat. Because rural areas cool quickly after sunset (open sky, vegetation, little thermal mass) while cities retain stored heat and continue to release anthropogenic heat, the UHI is typically most intense a few hours after sunset rather than at midday.



Idealised urban heat-island temperature cross-section on a calm, clear night. Temperature rises through the suburbs toward the dense, high-albedo, low-vegetation CBD, dips over an urban park (extra vegetation and evapotranspiration provide local cooling), then declines symmetrically back out to the rural surroundings.

Ví dụ mẫu · Calculating the urban heat island intensity

On a calm, clear night, the rural minimum temperature is 14.0°C while the city-centre (CBD) minimum temperature is 19.5°C. (a) Calculate the urban heat island intensity. (b) State two mechanisms that could explain most of this difference.

(a) UHI intensity $= 19.5 - 14.0 = 5.5^{\circ}$C.

(b) Albedo/heat storage: dark road and roof surfaces in the CBD absorbed and stored far more

solar energy during the day than vegetated rural land, and release it slowly overnight. **Canyon effect:** tall, closely spaced buildings in the CBD reduce the sky view factor, trapping outgoing longwave radiation and slowing nighttime cooling compared with the open rural sky. (Reduced evapotranspiration and anthropogenic heat from traffic/buildings would also contribute.)

7.5.3 Pollution, waste and urban flooding

Vehicle exhaust and industrial emissions concentrate fine particulates ($PM_{2.5}$, PM_{10}), nitrogen oxides and ground-level ozone in and around cities, producing **air pollution**/smog linked to elevated rates of respiratory and cardiovascular disease. **Water pollution** arises as surface runoff washes oil, heavy metals, litter and other contaminants from roads and roofs into rivers and coastal waters, and as heavy storms can overwhelm combined sewer systems, discharging untreated sewage directly into waterways. **Solid waste management** is a growing challenge as urban populations grow faster than collection capacity, particularly in informal settlements, leading to open dumping and burning (itself a source of air pollution), blocked drains, and public-health risks from disease vectors; more sustainable approaches follow a **waste hierarchy** — reduce, reuse and recycle before final disposal — supported by formal recycling and composting schemes and, in higher-income cities, engineered sanitary landfill or waste-to-energy facilities.

Urban flooding results chiefly from the sheer extent of **impermeable surfaces** — roads, roofs, car parks and pavements — which prevent rainwater infiltrating into the ground and instead route it rapidly, as concentrated surface runoff, into storm drains and sewers. Where sewer capacity was designed for an earlier, less built-up city, or for a less intense rainfall regime, sudden heavy storms can overwhelm the system, causing rapid, localised **flash flooding**. Urban expansion onto floodplains and the loss of wetlands that once stored floodwater naturally compounds the problem, removing capacity precisely as impermeable surface area — and therefore runoff volume — increases.

Ví dụ mẫu · Impermeable surfaces and runoff volume

A 5.0 km^2 catchment receives a storm delivering 40 mm of rainfall. Before urbanisation, an estimated 20% of rainfall became surface runoff (the remainder infiltrated or evaporated); after urbanisation, impermeable surfaces raise this runoff coefficient to 75%. Calculate the runoff volume before and after urbanisation.

Total rainfall volume $= 0.040 \text{ m} \times 5{,}000{,}000 \text{ m}^2 = 200{,}000 \text{ m}^3$.

Before urbanisation: runoff $= 0.20 \times 200{,}000 = 40{,}000 \text{ m}^3$.
After urbanisation: runoff $= 0.75 \times 200{,}000 = 150{,}000 \text{ m}^3$.

Interpretation: for exactly the same storm, urbanisation more than **tripled** the runoff volume delivered to drains and sewers (an extra $110{,}000$ m^3), because impermeable surfaces prevent infiltration that previously absorbed most of the rain. This is precisely why ageing, pre-urbanisation sewer capacity is increasingly overwhelmed by storms that would not have caused flooding before development.

VN **GIẢI THÍCH TIẾNG VIỆT**

Đảo nhiệt đô thị (UHI): đô thị nóng hơn nông thôn do (1) **suất phản chiếu (albedo)** thấp của mặt đường/mái nhà sẫm màu; (2) **nhiệt nhân tạo** từ xe cộ, điều hoà, công nghiệp; (3) **giảm thoát hơi nước** do ít cây xanh; (4) **hiệu ứng hẻm núi đô thị** (nhà cao tầng, đường hẹp giữ nhiệt, giảm tốc độ gió). UHI thường rõ nhất vài giờ sau hoàng hôn. **Ô nhiễm không khí/nước**: khí thải xe cộ–công nghiệp, nước mưa cuốn chất ô nhiễm, cống chung quá tải khi mưa lớn. **Ngập lụt đô thị**: bề mặt không thấm nước (đường, mái nhà) làm tăng dòng chảy mặt, hệ thống cống cũ không đủ sức chứa khi mưa lớn, mất vùng ngập lũ tự nhiên do mở rộng đô thị.

7.6 Building Sustainable and Resilient Cities

7.6.1 Smart cities and green infrastructure

A **smart city** uses digital technology and real-time data — sensors, networked monitoring, mobile applications — to manage urban services more efficiently: adaptive traffic-signal systems that respond to live congestion, smart metering that helps households and utilities manage water and electricity demand, and real-time public transit information that makes transit more convenient to use. Smart-city approaches can improve resource efficiency and residents' quality of life, but raise legitimate concerns over the up-front cost of the technology, data privacy, and the risk that benefits accrue mainly to wealthier, already well-served districts unless equity is built into planning.

Green infrastructure takes a complementary, nature-based approach. Urban greening — parks, street trees, and green corridors — improves air quality, reduces the urban heat island through shading and evapotranspiration, supports biodiversity, and benefits residents' physical and mental health. **Sustainable urban drainage systems (SuDS)** — permeable paving, rain gardens, bioswales and detention basins — are designed to mimic natural drainage: they slow, store and gradually release rainfall rather than routing it immediately into sewers, directly reducing the peak flows responsible for urban flash flooding. **Green roofs** extend this idea vertically: a vegetated roof layer absorbs and delays rainfall, provides additional building insulation (reducing heating and cooling energy demand), and — because vegetation has a higher albedo and supports evapotranspiration compared with bare dark roofing — helps to reduce the urban heat island effect at the same time.

VN **GIẢI THÍCH TIẾNG VIỆT**

Thành phố thông minh (smart city) dùng công nghệ số và dữ liệu thời gian thực (cảm biến, đèn giao thông thích ứng, đồng hồ đo thông minh) để quản lý dịch vụ đô thị hiệu quả hơn, nhưng cần lưu ý chi phí, quyền riêng tư dữ liệu và công bằng tiếp cận. **Hạ tầng xanh**: cây xanh đô thị giảm ô nhiễm và đảo nhiệt; **hệ thống thoát nước bền vững (SuDS)** — mặt đường thấm nước, vườn mưa, kênh sinh học — mô phỏng thoát nước tự nhiên, làm chậm và giảm đỉnh dòng chảy, hạn chế ngập lụt; **mái nhà xanh** vừa giữ nước mưa, vừa cách nhiệt, vừa giảm đảo nhiệt nhờ suất phản chiếu cao hơn và thoát hơi nước.

7.6.2 Compact city versus dispersed city

Planners debate two broad models for accommodating urban growth sustainably. The **compact city** model favours higher-density, mixed-use development contained within a relatively small urban footprint: this reduces land consumption at the fringe, supports frequent and efficient public transit and walking/cycling because more people live within convenient reach of services, and lowers per-capita infrastructure and carbon costs — but risks overcrowding, higher land and housing costs, and less private outdoor space. The **dispersed (sprawling) city** model allows larger private homes and gardens and can ease congestion *within* individual neighbourhoods, but at the cost of much greater car dependency, higher per-capita infrastructure costs, larger land-take and habitat loss at the urban fringe, and generally higher per-capita transport carbon emissions. Most planning authorities in practice now favour compact, transit-oriented growth wherever feasible, precisely because of the cumulative environmental and infrastructure-cost advantages, while acknowledging the trade-off in living space and short-term affordability.

7.6.3 Case studies in sustainable urban planning

Curitiba, Brazil, is widely cited for pioneering an affordable **Bus Rapid Transit (BRT)** system from the 1970s onward: dedicated bus-only lanes separate buses from congested general traffic, tube-shaped stations with pre-boarding fare payment and level, multi-door boarding allow buses to load and unload almost as quickly as a train, and the whole system was integrated from the outset with land-use planning that directed higher-density development along the transit corridors themselves. The result is a mass-transit system delivering much of the speed and capacity of a metro at a fraction of the construction cost, and it has been used as a reference model by bus-rapid-transit schemes in

many other cities worldwide.

Singapore is a leading example of integrated water and green-space planning under severe land constraints. Its water strategy combines extensive rainwater catchment across a large share of the island's surface with **NEWater** — wastewater that is highly treated and reclaimed for industrial use and, blended into reservoirs, for indirect potable supply — reducing historical dependence on imported water. In parallel, Singapore has pursued sustained urban greening (extensive park networks, a connected system of park connectors linking green spaces across the city, and mandatory greenery requirements in new developments) under a long-standing "City in a Garden" planning philosophy, embedding nature within a very high-density urban form rather than treating density and greenery as incompatible.

Copenhagen, Denmark, is consistently cited as one of the world's leading cycling cities, having invested for decades in an extensive network of dedicated, physically separated cycle tracks and cycle-friendly intersections as a core part of transport planning rather than an afterthought; this has produced one of the highest cycling mode shares of any major world city, substantially reducing car trips, local air pollution and transport carbon emissions for a large share of daily journeys, alongside complementary investment in harbour water-quality improvements that allow safe swimming close to the city centre.

Ví dụ mẫu · Evaluating the compact-versus-dispersed debate with case-study evidence

Using Curitiba's BRT system and Copenhagen's cycling network as evidence, argue for or against the claim: "Reducing car dependency requires expensive new metro infrastructure."

Answer: the claim is not well supported. Curitiba achieved metro-like capacity and speed using dedicated bus lanes, efficient tube stations and integrated land-use planning — a far lower capital cost than building underground rail — and still substantially reduced reliance on private cars along its main corridors. Copenhagen reduced car dependency for a large share of trips not through rail investment at all, but through sustained, decades-long investment in safe, separated cycling infrastructure, which is cheaper per kilometre than either metro or BRT. Both cases show that reducing car dependency depends less on the specific (and potentially expensive) technology chosen than on sustained political commitment to prioritising space, funding and planning around alternatives to the private car — dedicated lanes, integrated land use, and continuity of the network — rather than requiring the most capital-intensive option by default.

VN **GIẢI THÍCH TIẾNG VIỆT**

Curitiba (Brazil) tiên phong hệ thống **BRT** (xe buýt nhanh) với làn riêng, trạm dạng ống thanh toán trước, lên xuống nhanh, kết hợp quy hoạch mật độ cao dọc các trục — đạt hiệu quả gần bằng tàu điện ngầm với chi phí thấp hơn nhiều. **Singapore** quy hoạch nước tích hợp (hứng nước mưa diện rộng, **NEWater** tái chế nước thải) và phủ xanh đô thị mật độ cao (mạng lưới công viên, quy định cây xanh bắt buộc) theo triết lý "Thành phố trong Vườn". **Copenhagen** đầu tư bền bỉ vào mạng lưới làn xe đạp tách biệt, đạt tỉ lệ sử dụng xe đạp thuộc hàng cao nhất thế giới, giảm đáng kể ô tô và ô nhiễm.

Ôn tập nhanh

- Đô thị hoá = tỉ lệ dân đô thị tăng; tăng trưởng đô thị = số dân đô thị tăng tuyệt đối; phân biệt suburbanisation, counter-urbanisation, re-urbanisation.
- Đẩy–kéo (di cư nông thôn–đô thị); mô hình đô thị hoá khác biệt gắn với trình độ phát triển; megacity ≥ 10 triệu dân; world city = vai trò tài chính toàn cầu.
- Ba mô hình cấu trúc đô thị: Burgess (vòng tròn đồng tâm), Hoyt (hình quạt theo giao thông), Harris–Ullman (đa nhân) — đều mang thiên kiến thành phố phương Tây, không phù hợp Nam bán cầu/thành phố phụ thuộc ô tô.
- Khu định cư phi chính thức: thiếu quyền sử dụng đất, nước, vệ sinh, nhà kiên cố (Dharavi, Kibera); giải pháp: site-and-service, nâng cấp tại chỗ, giải toả–tái định cư.
- Nước phát triển: suy thoái nội đô/phi công nghiệp hoá, ngoại ô hoá tràn lan, gentrification (di dời vs. tái sinh), tái phát triển đất brownfield.
- Đảo nhiệt đô thị: albedo, nhiệt nhân tạo, giảm thoát hơi nước, hiệu ứng hẻm núi; ngập lụt đô thị do bề mặt không thấm nước và cống quá tải.
- Thành phố bền vững: thành phố thông minh, hạ tầng xanh/SuDS/mái xanh, tranh luận thành phố nén vs. phân tán, Curitiba (BRT), Singapore (nước–cây xanh), Copenhagen (xe đạp).

7.7 Practice Problems

Bài tập luyện tập

1. Which term best describes an increase in the *proportion* of a country's population living in urban areas, as opposed to an increase in the absolute number of urban residents?

(A) Urban growth
(B) Urbanisation
(C) Suburbanisation
(D) Counter-urbanisation

Lời giải chi tiết

(B). Urbanisation is defined specifically as the rising *share* (percentage) of the population living in urban areas. **Urban growth** (A) refers to the absolute increase in urban population and can occur without urbanisation rising if the total population is also growing quickly. Suburbanisation (C) and counter-urbanisation (D) describe outward and reversing movements of population *within* or *away from* the urban system, not the urban share of the national population.

Bài tập luyện tập

2. Distinguish between counter-urbanisation, suburbanisation and re-urbanisation, giving the typical driver of each.

Lời giải chi tiết

Suburbanisation is the outward growth of the built-up area into the rural–urban fringe, driven mainly by car ownership and cheaper peripheral land, while people still work in or near the city. **Counter-urbanisation** is a net movement of people and activity *beyond* the urban fringe into smaller towns and rural areas altogether, driven by improved long-distance transport, remote/flexible working, and a preference for lower costs and perceived quality of life. **Re-**

urbanisation is the reverse movement, back *into* the inner city, typically driven by deliberate regeneration schemes, new city-centre housing and renewed cultural/employment attractions after a period of decline.

Bài tập luyện tập

3. A country has a total population of 52.0 million and an urban population of 31.2 million. Calculate its level of urbanisation.

Lời giải chi tiết

Level of urbanisation $= \dfrac{31.2}{52.0} \times 100 = 60.0\%$. Six in every ten people in the country live in an urban area.

Bài tập luyện tập

4. A city's population rises from 6.0 million to 9.0 million over 8 years. Using $P_2 = P_1(1+r)^t$, estimate its average annual urban growth rate.

Lời giải chi tiết

$(1+r)^8 = 9.0/6.0 = 1.5$. Taking logs: $8\ln(1+r) = \ln(1.5) = 0.4055 \Rightarrow \ln(1+r) = 0.0507 \Rightarrow 1+r = 1.052$, so $r \approx 5.2\%$ per year — very rapid urban growth, consistent with a city undergoing strong rural-to-urban in-migration.

Bài tập luyện tập

5. Classify each of the following as a push factor or a pull factor for rural–urban migration: (a) fragmented, unproductive landholdings; (b) perceived higher urban wages; (c) family members already living in the city; (d) agricultural mechanisation reducing farm labour demand.

Lời giải chi tiết

(a) Push — poor rural land quality/size drives people to leave. **(b) Pull** — the attraction of higher income draws migrants to the city. **(c) Pull** — existing social networks (chain migration) reduce the risk/cost of moving and attract further migrants. **(d) Push** — mechanisation reduces the need for rural labour, freeing/forcing workers to seek employment elsewhere.

Bài tập luyện tập

6. Outline the differential urbanisation model and explain how it links urban change to a country's level of development.

Lời giải chi tiết

The model proposes that, at an early stage of development, migration concentrates in a single dominant **primate city**, producing very rapid growth there relative to the rest of the urban system. As development proceeds, growth spreads to secondary/regional cities (*polarisation reversal*). In the most developed stage, net migration reverses again toward smaller towns and rural areas — effectively counter-urbanisation. The model therefore links the *direction* of internal migration (toward the primate city, toward secondary cities, or away from large cities)

to a country's broad stage of economic development, though it is a generalisation rather than a strict universal sequence.

Bài tập luyện tập

7. What is the standard population threshold used to define a megacity?

(A) 1 million
(B) 5 million
(C) 10 million
(D) 20 million

Lời giải chi tiết

(C). A megacity is conventionally defined as a metropolitan area with a population of at least **10 million**. Cities of 1 or 5 million (A, B) are large but do not meet the megacity threshold; 20 million (D) describes only the very largest megacities, not the minimum threshold.

Bài tập luyện tập

8. Explain why a city can be a "world city" without being a megacity, using an example.

Lời giải chi tiết

A **world city** is defined by its command of global economic functions — international finance, corporate headquarters, flows of capital and information — not by population size, whereas a **megacity** is defined purely by having at least 10 million people. **Singapore** is a leading world city because of its role as a global financial and trading hub, yet its population is well below the 10-million megacity threshold, showing that global economic importance and sheer population size are distinct dimensions of a city's status.

Bài tập luyện tập

9. Which assumption is central to the Burgess concentric zone model?

(A) Wedge-shaped sectors follow transport routes
(B) A flat, isotropic plain with equal accessibility in all directions
(C) Several separate specialised nuclei
(D) Growth is driven mainly by car ownership

Lời giải chi tiết

(B). Burgess's model assumes an **isotropic plain** — uniform land and equal transport accessibility in every direction from the centre — so that land use forms simple concentric rings. (A) describes Hoyt's sector model; (C) describes the Harris–Ullman multiple nuclei model; (D) is a later, car-based influence not part of Burgess's original 1920s assumptions.

Bài tập luyện tập

10. Explain two reasons the Burgess, Hoyt and Harris–Ullman models are poor descriptions of many cities in the Global South.

Lời giải chi tiết

(i) All three models assume status *rises* with distance from the centre (Burgess) or is organised mainly around transport corridors from a single CBD (Hoyt); in many colonially planned Global South cities, however, elite housing often clusters *close* to the centre along a prestigious commercial spine, while informal settlements occupy peripheral or hazardous land — closer to the alternative Latin American city model. (ii) The classical models were built from early-to-mid twentieth-century Western industrial cities with a formal land market; they do not account for the scale of **informal settlement** formation, informal land occupation, or the informal economy that shapes land use in many Global South cities today.

Bài tập luyện tập

11. In the Hoyt sector model, what mainly determines the direction in which a high-status residential sector extends as a city grows?

(A) Random chance with no persistent pattern

(B) The direction of the best existing transport routes and amenities, which the sector continues to follow outward

(C) Government-mandated zoning only

(D) Proximity to heavy industry

Lời giải chi tiết

(B). Hoyt argued that once a high-status sector becomes established — often along a route toward an attractive amenity (high ground, parkland, waterfront) and served by good transport — new high-status development continues to extend outward along that *same* axis as the city grows, because existing transport links, established high land values and social prestige all reinforce the pattern. It is not random (A), is not solely a zoning artefact in Hoyt's original 1930s reasoning (C), and high-status housing typically develops *away from*, not toward, heavy industry (D).

Bài tập luyện tập

12. Explain why the Harris–Ullman multiple nuclei model developed several separate centres rather than one.

Lời giải chi tiết

Different urban activities have different locational requirements: heavy industry needs cheap land and rail/water access; retail needs high accessibility and footfall; a port needs waterfront access; some activities actively repel each other (high-income housing avoids locating beside heavy industry). As a city grows and mass car ownership/highways allow development to disperse, each specialised activity clusters around its own most suitable location — forming a separate nucleus — while agglomeration economies draw similar activities to gather around each nucleus, producing several distinct centres rather than a single dominant CBD.

Bài tập luyện tập

13. A city has a historic CBD, a large out-of-town retail park near a motorway junction, a university campus with its own surrounding district, and a separate airport-logistics zone, each functioning fairly independently. Which model best fits, and why?

Lời giải chi tiết

This fits the **Harris–Ullman multiple nuclei model**. The defining feature is several *separate*, *specialised* centres (retail park, university district, airport-logistics zone) that function largely independently of the historic CBD, rather than land use organised purely as concentric rings (Burgess) or as wedges radiating from one dominant centre (Hoyt). The motorway-junction retail park in particular reflects car-based dispersal typical of the polycentric pattern the multiple nuclei model captures.

Bài tập luyện tập

14. Outline the causes of informal settlement formation and describe two characteristics common to informal settlements such as Dharavi or Kibera.

Lời giải chi tiết

Informal settlements form where rapid rural-to-urban migration and natural urban population growth outpace the supply of affordable formal housing and serviced land, so low-income arrivals build their own housing on land that is cheap, unclaimed or unsuitable for formal development (steep slopes, floodplains, land near industry or railways). Common characteristics: (i) lack of secure legal tenure and durable housing; (ii) severe deficits in piped water, sanitation and safe electricity; (iii) extremely high population density; (iv) an extensive informal economy (recycling, small-scale manufacturing, street trade) providing livelihoods despite limited access to the formal labour market.

Bài tập luyện tập

15. Which of the following is the most direct consequence of an informal settlement lacking piped sanitation?

(A) Lower land values

(B) Contamination of local water sources and elevated risk of water-borne disease

(C) Reduced population density

(D) Increased formal-sector employment

Lời giải chi tiết

(B). Without sewerage, waste is disposed of via shared or communal pit latrines (or worse), which readily contaminates nearby water sources used for drinking, cooking or washing, directly raising the risk of water-borne disease such as cholera and diarrhoeal illness. Lower land values (A) may be a contributing cause rather than a consequence of lacking sanitation; density (C) is typically very *high*, not reduced; and sanitation deficits do not increase formal employment (D).

Bài tập luyện tập

16. A generic informal settlement of 2.4 km^2 houses an estimated $360{,}000$ people. Calculate its population density and compare it qualitatively to a typical formal city density of around $4{,}000$ persons/km^2.

Lời giải chi tiết

Density $= 360{,}000/2.4 = 150{,}000$ persons/km^2 — roughly **37–38 times** the typical formal city density of $4{,}000$ persons/km^2. Such extreme density magnifies even small per-person infrastructure gaps into severe absolute shortages of water, sanitation and space, and sharply increases the risk of disease transmission and fire.

Bài tập luyện tập

17. "In-situ upgrading is always preferable to slum clearance and resettlement." Discuss.

Lời giải chi tiết

Support: in-situ upgrading preserves residents' existing livelihoods, informal economic activity and social networks, is typically cheaper per household than building entirely new housing elsewhere, and avoids the disruption and rights concerns associated with forced eviction. **Qualification:** in-situ upgrading is not always feasible or safe — where a settlement occupies genuinely hazardous land (an active floodplain, an unstable slope, land beneath high-voltage lines), no amount of infrastructure upgrading removes the underlying risk, and relocation to a safer, well-connected site may be the more responsible option. **Judgement:** in-situ upgrading should be the default wherever the site itself is not hazardous; clearance/resettlement is better justified only where safety risk cannot otherwise be addressed, and even then should be negotiated, adequately compensated and located close to existing livelihoods wherever possible.

Bài tập luyện tập

18. Explain two advantages and one disadvantage of the informal economy for urban residents in the Global South.

Lời giải chi tiết

Advantages: (i) low barriers to entry mean almost anyone can find some form of income (street vending, waste-picking, small workshops) even without formal qualifications or capital; (ii) it provides flexibility and a vital livelihood safety net where formal employment is scarce. **Disadvantage:** informal workers typically lack legal protection, job security, and access to benefits such as health insurance or pensions, leaving them vulnerable to income shocks, exploitation, or eviction from informal trading sites.

Bài tập luyện tập

19. Explain how deindustrialisation contributed to inner-city decline in many high-income cities.

Lời giải chi tiết

Many high-income cities grew historically around inner-city manufacturing (steel, shipbuilding, textiles). As automation, globalised competition and the relocation of production to lower-cost countries reduced manufacturing employment (deindustrialisation), job losses were concentrated precisely in these traditional inner-city districts. Those who could afford to leave moved to the suburbs or beyond, shrinking the local tax base and population, while unemployment and deprivation rose among those left behind and former factory sites were abandoned

as vacant, contaminated brownfield land — the combined process of inner-city decline.

Bài tập luyện tập

20. A city's population grows from $400{,}000$ to $560{,}000$ over 15 years while its urbanised area grows from 100 km^2 to 200 km^2. Calculate the density at each date and state whether this represents sprawl.

Lời giải chi tiết

Initial density $= 400{,}000/100 = 4{,}000$ persons/km^2. Final density $= 560{,}000/200 = 2{,}800$ persons/km^2. Density falls by 30% even though population grew by 40%, because the urbanised area grew even faster (100%). This is a clear signature of **sprawl**: land is being consumed faster than population is growing.

Bài tập luyện tập

21. Which of the following best describes gentrification?

(A) Government demolition of housing to build new social housing

(B) An influx of higher-income residents and investment into a lower-income area, raising property values and often displacing original residents

(C) The construction of new suburbs on greenfield land at the urban edge

(D) The relocation of manufacturing industry to lower-cost countries

Lời giải chi tiết

(B). Gentrification is precisely this process: wealthier residents and investment move into a previously lower-income area, renovating housing and raising property values/rents, which frequently displaces the original residents. (A) describes slum clearance/social housing schemes; (C) describes suburban sprawl; (D) describes deindustrialisation/offshoring, a separate (though related) process.

Bài tập luyện tập

22. Evaluate the view that gentrification is, on balance, beneficial for a declining inner-city neighbourhood.

Lời giải chi tiết

Benefits: renewed investment improves and modernises the housing stock, reduces vacancy and blight, raises the local tax base (funding better services), and can improve safety and amenities. **Costs:** rising rents and property values frequently displace the original lower-income residents, either directly (unable to afford rent) or through exclusionary displacement (rising general cost of living); long-standing local businesses are often replaced, eroding community character and social networks built up over decades. **Judgement:** whether gentrification is beneficial overall depends heavily on *who* benefits — outcomes are far more equitable where policy actively protects existing residents (rent controls, affordable-housing quotas, support for displaced businesses) alongside the physical and economic renewal, rather than leaving the process purely to the market.

Bài tập luyện tập

23. Distinguish between brownfield and greenfield redevelopment, and explain why planners generally favour the former.

Lời giải chi tiết

Brownfield land is previously developed, often derelict or contaminated former industrial or urban land within the existing built-up area; **greenfield** land is previously undeveloped land, typically agricultural or natural, at the urban fringe. Planners generally favour brownfield redevelopment because it reuses land already served by existing roads, utilities and transit, revitalises declining inner-city areas, and avoids consuming further agricultural or natural land and contributing to sprawl — as illustrated by the redevelopment of London's former docklands into the Canary Wharf district.

Bài tập luyện tập

24. Explain the concept of transit-oriented development (TOD) and how it reduces car dependency.

Lời giải chi tiết

TOD concentrates higher-density, mixed-use development (housing, offices, retail) within convenient walking distance of a public transit station. Because daily destinations — home, work, shops — are close together and close to the station, a large share of trips can realistically be made on foot, by bicycle, or by transit rather than by car. This reduces car dependency structurally, by shaping the built environment itself, rather than relying only on individual travel choices or on transit service quality alone.

Bài tập luyện tập

25. On a calm, clear night the rural temperature is 13.5°C and the CBD temperature is 20.0°C. (a) Calculate the urban heat island intensity. (b) Explain why the urban canyon effect is especially important to this particular *nighttime* difference.

Lời giải chi tiết

(a) UHI intensity $= 20.0 - 13.5 = 6.5^{\circ}$C. **(b)** At night there is no incoming solar radiation, so daytime mechanisms like albedo differences matter less; instead, the urban canyon's reduced sky view factor traps outgoing longwave radiation between tall buildings, slowing the release of heat stored during the day, while the open rural sky allows rapid radiative cooling. This is why UHI intensity is typically greatest a few hours after sunset rather than at midday.

Bài tập luyện tập

26. A 3.0 km^2 catchment receives 50 mm of rainfall. The runoff coefficient is 0.25 before development and 0.80 after urbanisation. Calculate the increase in runoff volume caused by urbanisation, and suggest one green-infrastructure measure that could offset it.

Lời giải chi tiết

Total rainfall volume $= 0.050\,\text{m} \times 3{,}000{,}000\,\text{m}^2 = 150{,}000\,\text{m}^3$. Before: runoff $= 0.25 \times 150{,}000 = 37{,}500\ \text{m}^3$. After: runoff $= 0.80 \times 150{,}000 = 120{,}000\ \text{m}^3$. Increase $= 120{,}000 - 37{,}500 = 82{,}500\ \text{m}^3$ — nearly a 220% rise in runoff for the same storm. A **sustainable urban drainage system (SuDS)** — permeable paving, rain gardens or green roofs — could intercept and slowly release much of this additional runoff, reducing the peak flow reaching storm drains and lowering flood risk.

Bài tập luyện tập

27. Using evidence from Curitiba, Singapore and Copenhagen, evaluate the claim that "the compact city model cannot deliver a high quality of life."

Lời giải chi tiết

The claim is not well supported by these cases. **Curitiba** shows that a compact, transit-oriented urban form — supported by an efficient BRT system integrated with land-use planning — can deliver fast, affordable, high-capacity mobility without the sprawl and car dependency associated with dispersed cities. **Singapore** shows that very high density is compatible with abundant greenery and secure water supply when green infrastructure (park networks, mandatory greenery, water reclamation) is deliberately embedded within compact development, rather than density and liveability being treated as opposites. **Copenhagen** shows that compact, well-connected urban form combined with dedicated cycling infrastructure can deliver low car dependency, low local pollution and high everyday convenience. **Judgement:** these cases suggest that quality of life under the compact city model depends less on density itself and more on whether density is paired with deliberate investment in efficient transit, green space and active travel infrastructure — where it is, compact cities can match or exceed the liveability of more dispersed alternatives while consuming far less land and generating fewer transport emissions per capita.

Global Interactions I: Power, Places and Networks

HIGHER LEVEL (HL) EXTENSION

Mục tiêu Unit: Sau khi hoàn thành Unit này, học sinh có thể: định nghĩa **toàn cầu hoá** là quá trình gia tăng kết nối giữa các nơi trên thế giới thông qua bốn dòng chảy chính — **vốn** (đầu tư trực tiếp nước ngoài, FDI), **lao động** (di cư quốc tế), **hàng hoá** (thương mại quốc tế) và **thông tin** (internet, truyền thông toàn cầu) — và giải thích khái niệm **nén không gian–thời gian** (time–space compression); mô tả **mạng lưới** gồm các **nút** (node) và **liên kết** (link), áp dụng vào mạng lưới vận tải biển (các cảng container lớn như Thượng Hải, Singapore, Rotterdam) và cấu trúc hàng không **trục–nan hoa (hub-and-spoke)** so với mạng **điểm nối điểm (point-to-point)**; giải thích internet như một mạng lưới cáp quang biển vật lý và khái niệm **khoảng cách số (digital divide)**; định nghĩa **công ty đa quốc gia (TNC)** và **mạng lưới sản xuất toàn cầu**, minh hoạ qua chuỗi cung ứng của Apple (thiết kế tại Hoa Kỳ, lắp ráp chủ yếu bởi Foxconn tại Trung Quốc, linh kiện từ Hàn Quốc, Nhật Bản, Đài Loan); phân biệt **quyền lực cứng (hard power)** và **quyền lực mềm (soft power)** theo khái niệm của Joseph Nye, cùng **quyền lực kinh tế** (GDP, kiểm soát dòng chảy thương mại/tài chính) và **quyền lực chính trị** (quyền phủ quyết của 5 thành viên thường trực Hội đồng Bảo an Liên Hợp Quốc); trình bày các thể chế **quản trị toàn cầu** — Liên Hợp Quốc, Tổ chức Thương mại Thế giới (WTO), nhóm G7/G20, và các khối thương mại khu vực (Liên minh châu Âu EU, ASEAN, USMCA); sử dụng các chỉ số định lượng — dòng FDI ròng, cán cân thương mại, **tỉ lệ phụ thuộc thương mại** (trade dependency ratio), và **kiều hối** — để đo mức độ hội nhập của một quốc gia vào nền kinh tế toàn cầu; phân tích nghiên cứu tình huống **Sáng kiến Vành đai và Con đường (Belt and Road Initiative – BRI)** của Trung Quốc, bao gồm tranh luận về "ngoại giao bẫy nợ" qua ví dụ cảng Hambantota (Sri Lanka); giải thích cách **trợ cấp nông nghiệp** ở các nước thu nhập cao có thể tạo ra sân chơi thương mại không bình đẳng; và bước đầu giới thiệu khái niệm **lõi–ngoại vi (core–periphery)**, được phát triển đầy đủ hơn ở Unit tiếp theo.

8.1 Globalisation: Processes and Drivers

8.1.1 Defining globalisation

Globalisation is the process by which places, economies, cultures and societies across the world have become progressively more interconnected and interdependent, driven by rapidly growing flows of **capital**, **labour**, **goods** and **information** that cross national borders with increasing ease, speed and volume. It is not a single event but an ongoing, uneven process: some places (major financial centres, large container ports, capital cities with international airports) are deeply and continuously plugged into global networks, while other places remain comparatively isolated from them. Geographers generally describe four interlinked global flows that together constitute globalisation.

Khái niệm cốt lõi: Bốn dòng chảy toàn cầu

Capital: **foreign direct investment (FDI)** — money invested by a firm or individual in one country into productive assets (factories, infrastructure, businesses) located in another country, together with international portfolio investment and cross-border bank lending. **Labour**: **international migration** — the movement of workers across borders in search of employment,

higher wages, or better opportunities, ranging from low-skilled contract labour to highly skilled professional migration. **Goods**: **international trade** — the exchange of manufactured products, raw materials, agricultural commodities and services across borders, carried overwhelmingly by containerised shipping for physical goods. **Information**: the **internet** and **global media** — instantaneous transmission of data, news, entertainment, financial transactions and ideas across the planet via a physical infrastructure of cables and satellites.

VN GIẢI THÍCH TIẾNG VIỆT

Toàn cầu hoá là quá trình các nơi, nền kinh tế, văn hoá và xã hội trên thế giới ngày càng gắn kết và phụ thuộc lẫn nhau chặt chẽ hơn, nhờ vào sự gia tăng nhanh chóng của bốn dòng chảy xuyên biên giới: **vốn** (đầu tư trực tiếp nước ngoài – FDI, đầu tư gián tiếp, cho vay ngân hàng xuyên biên giới), **lao động** (di cư quốc tế tìm việc làm, mức lương cao hơn hoặc cơ hội tốt hơn), **hàng hoá** (thương mại quốc tế, chủ yếu vận chuyển bằng tàu container), và **thông tin** (internet và truyền thông toàn cầu, truyền tải dữ liệu, tin tức, giải trí và giao dịch tài chính gần như tức thời). Đây không phải một sự kiện đơn lẻ mà là một quá trình liên tục và **không đồng đều** — một số nơi (trung tâm tài chính lớn, cảng container lớn, thủ đô có sân bay quốc tế) kết nối rất sâu vào mạng lưới toàn cầu, trong khi nhiều nơi khác vẫn tương đối biệt lập.

8.1.2 Time–space compression: the "shrinking world"

A central idea underlying globalisation is **time–space compression** (also called the "shrinking world" effect): the perceived reduction, over the past several decades, in the relative time and cost required to move people, goods, capital and information between any two points on Earth. This is not because physical distances have literally changed, but because technological and organisational innovations have made covering those distances dramatically faster and cheaper relative to the past. Several specific developments drove this compression. **Containerisation** — the standardisation of cargo into uniform steel shipping containers from the 1950s–1970s onward — slashed the cost and time of loading and unloading ships, allowing goods to move seamlessly between ship, rail and truck without being repeatedly unpacked, and enabling the huge, low-cost container vessels that dominate global trade today. **Jet air travel**, commercialised from the late 1950s, cut intercontinental passenger and high-value freight journeys from days (by ocean liner) to hours. **Digital communication** — first international telephone cables, then the internet, broadband, and mobile networks — has made the transmission of information across the globe effectively instantaneous and nearly free at the margin, compared to the weeks once required for a letter to cross an ocean. The cumulative effect is that the "friction of distance" — the extent to which sheer physical separation limits interaction between places — has fallen sharply for those able to access these technologies, even though it has not fallen at all for the roughly one-third of the world's population that still lacks reliable internet access (see the digital divide, Section 8.2).

Time–space compression describes the falling relative cost and time of moving people, goods, capital and information over distance, driven chiefly by container shipping (goods), jet travel (people, high-value freight) and digital communication (information, capital). It compresses *relative*, not *absolute*, distance: London and Tokyo are no closer in kilometres than a century ago, but they are far "closer" in the time and cost it now takes to move money, data or a passenger between them.

VN GIẢI THÍCH TIẾNG VIỆT

Nén không gian–thời gian (time–space compression), còn gọi là hiệu ứng "thế giới thu nhỏ", mô tả sự sụt giảm về thời gian và chi phí *tương đối* để di chuyển người, hàng hoá, vốn và thông tin qua khoảng cách, trong vài thập kỷ gần đây. Khoảng cách vật lý (km) không thay đổi, nhưng

nhờ **container hoá** (chuẩn hoá hàng hoá vào các container thép từ thập niên 1950–1970, giúp bốc dỡ nhanh và rẻ hơn), **hàng không phản lực** (rút ngắn hành trình liên lục địa từ nhiều ngày xuống còn vài giờ), và **truyền thông kỹ thuật số** (internet giúp truyền thông tin gần như tức thời), "lực cản của khoảng cách" (friction of distance) đã giảm mạnh đối với những ai tiếp cận được các công nghệ này – dù vẫn chưa giảm đối với khoảng một phần ba dân số thế giới chưa có internet ổn định (xem khoảng cách số, mục 8.2).

(!) Lỗi thường gặp: A common error is to assume that globalisation and time–space compression benefit all places and all people *equally*. In reality, the process is highly uneven: well-connected global cities and export-oriented regions capture the large majority of new trade, investment and information flows, while remote rural areas, land-locked countries, and low-income households with no internet access are left largely outside these networks — and some places (e.g. manufacturing regions in high-income countries that lost factories to offshoring) can be actively disadvantaged by the same processes that benefit others. Always qualify claims about globalisation's benefits with *who* gains and *where*.

8.2 Networks and Nodes in the Global System

8.2.1 Transport networks: shipping routes and container ports

A **network** is a set of interconnected **nodes** (points, such as cities, ports or airports) joined by **links** (routes, such as shipping lanes, cables or flight paths) along which flows of goods, people, capital or information travel. Roughly 80–90% of the volume of world merchandise trade travels by sea, the overwhelming majority of it in standardised steel shipping containers carried on purpose-built container vessels. These ships follow a limited number of major shipping routes that link manufacturing regions (chiefly East and Southeast Asia) to consumption markets (North America and Europe), passing through key chokepoints such as the Strait of Malacca, the Suez Canal and the Panama Canal, which concentrate an enormous share of global maritime trade into narrow physical corridors. **Container ports** are the key nodes of this network: a small number of ports, mostly in East Asia, handle a disproportionate share of world container throughput. By total containers handled (measured in twenty-foot equivalent units, TEU), the port of **Shanghai** has for over a decade ranked as the world's busiest container port, followed closely by other major Chinese ports (Ningbo-Zhoushan, Shenzhen) and **Singapore**, historically the leading transshipment hub of Southeast Asia; in Europe, the port of **Rotterdam** in the Netherlands is by far the largest container port, acting as the principal gateway for goods entering and leaving the European single market.

VN **GIẢI THÍCH TIẾNG VIỆT**

Một **mạng lưới** (network) gồm các **nút** (node – ví dụ thành phố, cảng, sân bay) nối với nhau bằng các **liên kết** (link – ví dụ tuyến vận tải biển, cáp, đường bay). Khoảng 80–90% khối lượng thương mại hàng hoá thế giới được vận chuyển bằng đường biển, phần lớn trong các **container** thép chuẩn hoá. Các tàu container đi theo một số ít tuyến vận tải chính, đi qua các "điểm nghẽn" (chokepoint) như eo biển Malacca, kênh đào Suez và kênh đào Panama. **Cảng container** là các nút quan trọng nhất: **Thượng Hải** (Trung Quốc) hiện là cảng container nhộn nhịp nhất thế giới tính theo sản lượng TEU, theo sau là các cảng lớn khác của Trung Quốc và **Singapore** – trung tâm trung chuyển hàng đầu Đông Nam Á; ở châu Âu, cảng **Rotterdam** (Hà Lan) là cảng container lớn nhất, đóng vai trò cửa ngõ chính cho hàng hoá ra vào thị trường chung châu Âu.

Ví dụ mẫu · Comparing two container shipping routes

A shipping line must move containers from Shanghai to Rotterdam. **Route 1** (via the Suez Canal) covers approximately $19\,000$ km. **Route 2** (around the Cape of Good Hope, avoiding the Suez Canal) covers approximately $26\,000$ km. Both routes are sailed by the same class of vessel at an average service speed of 20 knots (approximately 37 km/h). (a) Calculate the transit time in days for each route. (b) Explain, in general terms, why a shipping line might nonetheless choose the longer Cape route.

(a) Route 1 (Suez):

$$t = \frac{\text{distance}}{\text{speed}} = \frac{19\,000 \text{ km}}{37 \text{ km/h}} \approx 513 \text{ hours} \approx \mathbf{21.4} \text{ days}.$$

Route 2 (Cape of Good Hope):

$$t = \frac{26\,000 \text{ km}}{37 \text{ km/h}} \approx 703 \text{ hours} \approx \mathbf{29.3} \text{ days}.$$

The Cape route takes roughly 8 days (about 190 hours) longer than the Suez route.

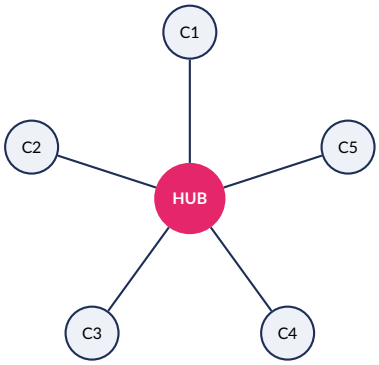
(b) Although the Cape route costs more in fuel, crew time, and delivery delay, a shipping line may still choose it if the Suez Canal becomes unusable or unacceptably risky — for example, due to canal transit fees becoming very high relative to fuel costs, physical blockage of the canal, or a heightened security/war-risk-insurance premium for transiting a conflict-affected chokepoint (as occurred when many container lines rerouted around the Cape of Good Hope in response to attacks on shipping in the Red Sea in 2023–2024). This illustrates that network routing decisions weigh distance and time against cost, risk and insurance, not distance alone.

VN **GIẢI THÍCH TIẾNG VIỆT**

Thời gian di chuyển t = quãng đường ÷ tốc độ. Tuyến qua kênh Suez ngắn hơn nên nhanh hơn và thường rẻ hơn, nhưng các hãng tàu đôi khi vẫn chọn tuyến vòng qua Mũi Hảo Vọng (Nam Phi) nếu kênh Suez gặp rủi ro an ninh, tắc nghẽn, hoặc phí quá cảnh quá cao – như đã xảy ra khi nhiều hãng tàu container chuyển hướng tránh Biển Đỏ trong giai đoạn 2023–2024. Bài học quan trọng: quyết định chọn tuyến đường trong mạng lưới vận tải không chỉ dựa vào khoảng cách và thời gian, mà còn cân nhắc chi phí, rủi ro và bảo hiểm.

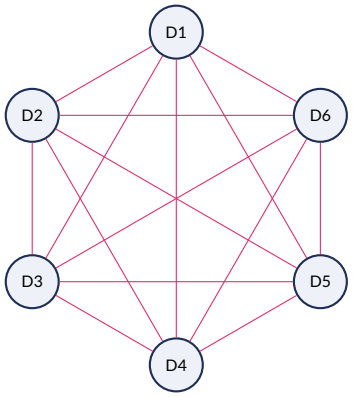
8.2.2 Airline networks: hub-and-spoke versus point-to-point

Air transport networks (for passengers, mail, and high-value or time-sensitive freight) are typically organised according to one of two contrasting structural logics. In a **hub-and-spoke** network, a small number of major **hub airports** (such as Dubai, Atlanta, Frankfurt, or Singapore Changi) concentrate the majority of long-haul connections: passengers travelling between two smaller cities are routed through a hub, changing planes, rather than flying directly. This allows an airline to consolidate passengers from many origins onto fewer, larger, more fully-booked long-haul flights between hubs, achieving economies of scale, but it adds a layover and generally a longer total journey time for passengers whose true origin and destination are not the hub itself. In a **point-to-point** network, by contrast, airlines (particularly many low-cost carriers) fly aircraft directly between pairs of cities without routing through a central hub, offering shorter, more direct journeys, but requiring many more individual routes to connect the same number of cities, each of which must attract enough passenger demand on its own to be commercially viable.



Hub-and-spoke network

6 cities (incl. hub) → 5 direct routes



Point-to-point network

6 cities → 15 direct routes

Both networks link the same total of 6 cities. Left: a hub-and-spoke structure – one city acts as the hub, connecting to the other 5; only 5 direct routes are required. Right: a point-to-point structure – all 6 cities connect directly to one another, requiring 15 direct routes. Hub-and-spoke systems concentrate traffic onto fewer, higher-volume routes; point-to-point systems offer direct travel at the cost of many more individual routes.

Ví dụ mẫu · Counting connections in hub-and-spoke vs point-to-point networks

An airline wants to connect 8 cities. (a) If it uses a pure point-to-point network connecting every city directly to every other city, how many direct routes are required? (b) If instead it uses a hub-and-spoke network, with one of the 8 cities designated as the hub and the other 7 as spokes (no direct spoke-to-spoke routes), how many direct routes are required? (c) Comment on the difference.

(a) Point-to-point. For n cities all connected directly to one another, the number of unique routes is given by the combination formula for pairs:

$$\text{Routes} = \frac{n(n-1)}{2} = \frac{8 \times 7}{2} = \textbf{28 routes.}$$

(b) Hub-and-spoke. With one hub and $n-1$ spokes, only the hub-to-spoke links exist:

$$\text{Routes} = n - 1 = 8 - 1 = \textbf{7 routes.}$$

(c) Connecting the same 8 cities requires 4 times as many routes in a point-to-point network (28) as in a hub-and-spoke network (7). This is why major airline alliances rely heavily on hub-and-spoke structures: it is far more route-efficient to serve many smaller cities, and it allows aircraft on the (comparatively few) hub-to-hub or hub-to-spoke trunk routes to fly nearly full, lowering the average cost per passenger — at the price of longer overall journeys and layovers for passengers not travelling to or from the hub itself.

VN **GIẢI THÍCH TIẾNG VIỆT**

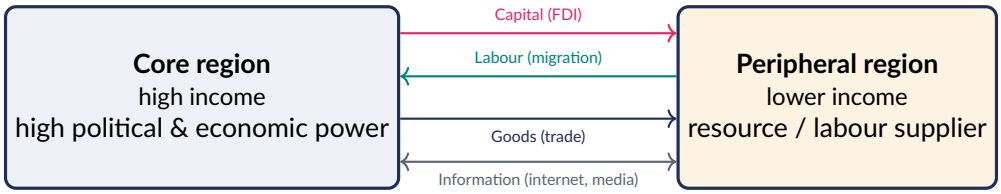
Với mạng **điểm nối điểm** (point-to-point) gồm n thành phố, số tuyến trực tiếp cần thiết để nối mọi cặp thành phố là $n(n-1)/2$. Với mạng **trục–nan hoa** (hub-and-spoke) gồm 1 trục (hub) và $n-1$ "nan hoa" (spoke), chỉ cần $n-1$ tuyến (mỗi nan hoa nối với trục, không có tuyến nối trực tiếp giữa hai nan hoa). Vì vậy mạng hub-and-spoke luôn cần *ít tuyến hơn nhiều* để phục vụ cùng số thành phố – đây là lý do các hãng hàng không lớn ưu tiên cấu trúc này để đạt hiệu quả kinh tế theo quy mô, dù hành khách phải quá cảnh và mất thêm thời gian nếu điểm đến của họ không phải là trục.

8.2.3 The internet as a physical network, and the digital divide

Although it is often imagined as something intangible, the **internet** is, at its physical foundation, a network of hardware: routers, data centres, and — crucially for connecting continents — an extensive system of **submarine fibre-optic cables** laid along the sea floor, carrying the overwhelming majority of the world's international internet traffic and intercontinental phone/data traffic (satellite links carry only a small fraction, mainly to remote or hard-to-cable locations). These cables physically link major coastal cities and data-centre hubs across the Atlantic, the Pacific, and other ocean basins, making the internet itself a transport network of nodes (data centres, internet exchange points) and links (cables), directly analogous to the shipping and airline networks described above. Access to this network, however, is profoundly unequal. The **digital divide** refers to the persistent gap in access to the internet, broadband infrastructure, and digital devices, both *between* countries (high-income countries and East Asian economies generally have near-universal broadband and mobile internet access, while many low-income countries, particularly in parts of Sub-Saharan Africa and South Asia, have far lower penetration rates, especially in rural areas) and *within* countries (urban versus rural areas; wealthier versus poorer households; older versus younger generations). Because participation in the modern information economy — e-commerce, remote work, digital financial services, access to online education — increasingly depends on reliable internet access, the digital divide is not merely a matter of convenience but a significant structural factor shaping which people and places can benefit from globalisation's information flows at all.

GIẢI THÍCH TIẾNG VIỆT VN

Internet, xét về mặt vật lý, là một **mạng lưới cáp quang biển** (submarine fibre-optic cable) nối các lục địa, mang phần lớn lưu lượng internet và dữ liệu quốc tế của thế giới (vệ tinh chỉ chiếm một phần nhỏ). **Khoảng cách số (digital divide)** là sự bất bình đẳng dai dẳng trong khả năng tiếp cận internet băng thông rộng, cả *giữa các quốc gia* (các nước thu nhập cao và Đông Á có tỉ lệ phủ sóng gần như toàn dân, trong khi nhiều vùng ở châu Phi hạ Sahara và Nam Á có tỉ lệ thấp hơn nhiều, đặc biệt ở nông thôn) lẫn *trong nội bộ một quốc gia* (thành thị so với nông thôn, hộ giàu so với hộ nghèo, thế hệ trẻ so với thế hệ lớn tuổi). Vì việc tham gia vào nền kinh tế thông tin hiện đại (thương mại điện tử, làm việc từ xa, dịch vụ tài chính số, giáo dục trực tuyến) ngày càng phụ thuộc vào internet, khoảng cách số là một yếu tố cấu trúc quan trọng quyết định ai và nơi nào thực sự hưởng lợi từ các dòng chảy thông tin toàn cầu.



The four principal global flows linking a core region to a peripheral region: capital (FDI) and goods (trade) flow predominantly core → periphery in this simplified schematic; labour (migration) flows predominantly periphery → core; information flows in both directions. In reality every flow can move both ways (e.g. profits repatriated from periphery to core, skilled emigration from core to periphery), and most real places sit somewhere between a pure "core" and a pure "periphery" rather than at either extreme (core–periphery is developed fully in Section 8.9 and the following unit).

8.3 Transnational Corporations and Global Production Networks

8.3.1 What is a TNC?

A **transnational corporation (TNC)**, sometimes called a multinational corporation (MNC), is a company that owns or controls productive assets — factories, offices, subsidiaries, franchises — in more than one country, typically with a **headquarters** in its country of origin (the "home country") coordinating operations and subsidiaries spread across a number of "host countries." TNCs range from

long-established manufacturing and resource-extraction firms to contemporary technology and retail giants, and collectively they organise a very large share of world trade, investment and production. TNCs expand internationally for several overlapping reasons: to access new consumer markets; to access raw materials or resources located only in certain countries; to reduce production costs by taking advantage of lower wages, cheaper land, or less stringent regulation in host countries; and to access specialised labour skills, infrastructure, or technology clusters concentrated in particular places.

VN **GIẢI THÍCH TIẾNG VIỆT**

Một **công ty đa quốc gia (TNC)** là công ty sở hữu hoặc kiểm soát tài sản sản xuất (nhà máy, văn phòng, công ty con) tại nhiều quốc gia, thường có **trụ sở chính** tại nước gốc ("nước chủ nhà" của công ty) điều phối hoạt động ở các "nước tiếp nhận". TNC mở rộng ra quốc tế vì nhiều lý do: tiếp cận thị trường tiêu thụ mới, tiếp cận nguyên liệu chỉ có ở một số quốc gia nhất định, giảm chi phí sản xuất (nhờ lương thấp hơn, đất đai rẻ hơn, hoặc quy định lỏng lẻo hơn ở nước tiếp nhận), và tiếp cận lao động có kỹ năng chuyên biệt hoặc cụm công nghệ tập trung ở một số nơi.

8.3.2 Global supply chains, outsourcing and offshoring

Modern TNCs, especially in manufacturing, rarely design, make and sell a product in a single country. Instead, they organise a **global supply chain** (also called a **global production network**): the design, component manufacture, assembly, and final sale of a product are split up and located in whichever countries offer the greatest advantage for that particular stage, exploiting international differences in labour cost, specialised skills, available technology, and regulatory environment. **Outsourcing** refers to contracting a stage of production out to a separate, independently-owned company (which may or may not be in another country); **offshoring** refers specifically to relocating a stage of production to a different country (which may be done in-house within the same TNC, or simultaneously outsourced to a foreign contractor). High-value stages requiring specialised knowledge, creativity, or proximity to corporate decision-makers — product design, research and development, marketing, software — are typically retained in the TNC's home country or another high-income location, while labour-intensive stages such as component assembly are typically offshored/outsourced to countries with lower labour costs and large, flexible manufacturing workforces.

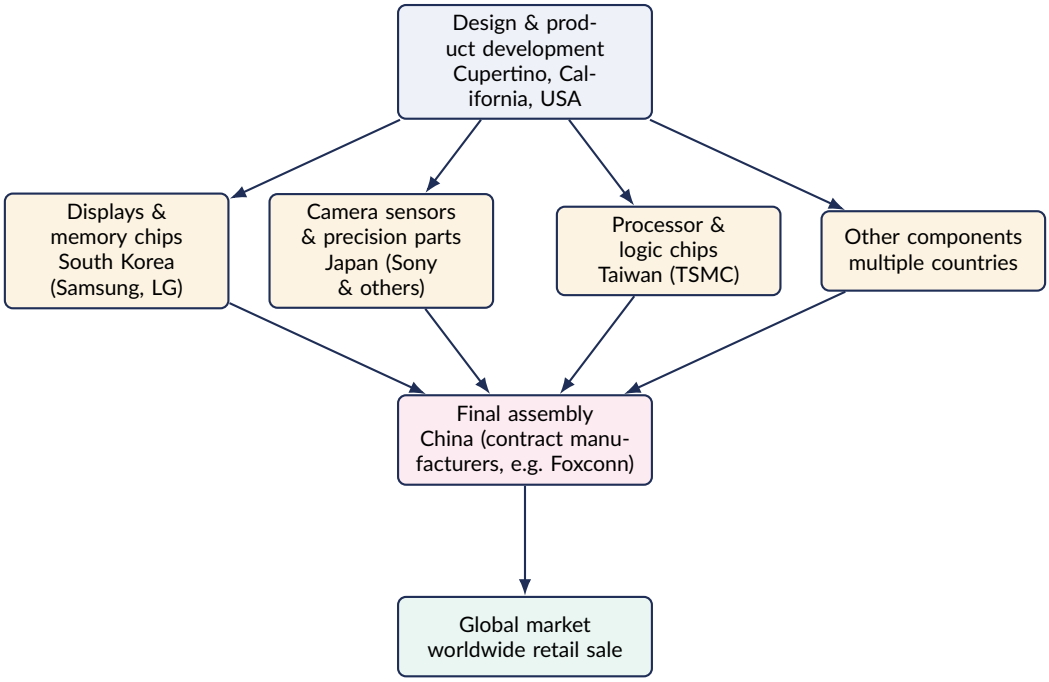
VN **GIẢI THÍCH TIẾNG VIỆT**

Một **chuỗi cung ứng toàn cầu** (global supply chain / global production network) là khi các công đoạn khác nhau của sản xuất (thiết kế, chế tạo linh kiện, lắp ráp, bán hàng) được đặt tại các quốc gia khác nhau, mỗi nơi được chọn vì lợi thế riêng (chi phí lao động, kỹ năng chuyên môn, công nghệ, hoặc quy định pháp lý). **Thuê ngoài (outsourcing)** là giao một công đoạn cho một công ty độc lập khác thực hiện; **dịch chuyển ra nước ngoài (offshoring)** là chuyển một công đoạn sang một quốc gia khác (có thể vẫn do chính TNC thực hiện, hoặc đồng thời thuê ngoài cho nhà thầu nước ngoài). Các công đoạn giá trị cao đòi hỏi tri thức chuyên sâu (thiết kế, R&D, marketing) thường được giữ lại ở nước gốc của TNC, trong khi các công đoạn thâm dụng lao động (lắp ráp) thường được chuyển đến các nước có chi phí lao động thấp hơn.

8.3.3 Case study: Apple's global supply chain

Apple Inc., headquartered in Cupertino, California, USA, illustrates this pattern clearly. Product **design** and engineering — the stage that determines the device's appearance, user interface, software, and much of its brand value — is concentrated almost entirely at Apple's own facilities in California. **Final assembly** of Apple's flagship devices (notably the iPhone) is carried out mainly by contract electronics manufacturers, above all **Foxconn** (the trading name of Hon Hai Precision Industry, a company headquartered in Taiwan but operating its largest assembly plants inside mainland **China**, including a very large complex in Zhengzhou often nicknamed "iPhone City"), alongside other con-

tract assemblers such as Pegatron. Individual **components**, meanwhile, are sourced from specialist manufacturers spread across several countries: display panels and memory chips substantially from **South Korea** (companies such as Samsung Electronics and LG Display), camera sensors and other precision components from **Japan** (including Sony), and advanced processor chips fabricated by **Taiwan**'s TSMC, among numerous other suppliers worldwide. The finished device is then sold in a genuinely global market. Academic research analysing this kind of supply chain (notably the widely-cited work of Kraemer, Linden and Dedrick on Apple's iPhone and iPad value chains) has found that value is captured very unevenly along the chain: assembly in China typically captures only a small, low single-digit percentage of a device's final retail value (reflecting the comparatively low-skill, easily-replicated nature of assembly labour), component suppliers in South Korea, Japan and Taiwan capture a moderate share reflecting their specialised technology, while Apple itself, through its control of design, software, brand and retail, captures by far the largest single share of the value created.



A schematic simplification of Apple's global production network for a smartphone. Design and high-value intellectual property are concentrated in the USA; components are sourced from specialist suppliers across several countries; final assembly is contracted out mainly to manufacturers such as Foxconn operating large-scale plants in China; the finished product is then sold worldwide. Actual sourcing arrangements are more complex, involve many more suppliers, and change over time — this diagram illustrates the general pattern, not a complete or current parts list.

Ví dụ mẫu · Estimating value capture along a smartphone supply chain

A simplified smartphone has a final retail price of $\$1000$. Based on approximate component-cost breakdowns reported in industry teardown analyses, suppose: displays and memory (South Korea) cost approximately $\$120$; processor and logic chips (Taiwan) cost approximately $\$80$; camera/sensor components (Japan) cost approximately $\$30$; miscellaneous other components cost approximately $\$70$; and final assembly labour and overhead (China) costs approximately $\$30$. (a) Calculate the total manufacturing/component cost. (b) Calculate the value remaining, which is captured by the design/brand-owning company (covering R&D, software, marketing, retail margin and profit). (c) Express the assembly country's share and the design/brand-owner's share as percentages of the final retail price.

(a) Total component + assembly cost $= 120 + 80 + 30 + 70 + 30 = \$330$.

(b) Value captured by the design/brand-owning company $= \$1000 - \$330 = \$670$.

(c) Assembly country's share $= \frac{30}{1000} \times 100\% =$ **3**%. Design/brand-owner's share $= \frac{670}{1000} \times 100\% =$ **67**%. Combined component-supplier share (South Korea, Taiwan, Japan, others) $= \frac{300}{1000} \times 100\% = 30\%$.

This illustrates a general and well-documented finding from real supply-chain research: the country that physically assembles a high-technology product (here, roughly 3% of final value) often captures a far smaller share of total value than the country where the product is designed, branded and sold (here, roughly 67%), even though assembly is visible, labour-intensive, and often mistaken by casual observers for the most economically significant stage. Value in modern global production networks tends to concentrate wherever scarce knowledge, intellectual property, and brand control are held, not wherever the physical labour is performed.

VN **GIẢI THÍCH TIẾNG VIỆT**

Trong ví dụ chuỗi cung ứng điện thoại thông minh, tổng chi phí linh kiện và lắp ráp chỉ chiếm một phần nhỏ giá bán lẻ cuối cùng; phần còn lại (**giá trị gia tăng**) được công ty sở hữu thương hiệu/thiết kế nắm giữ. Bài học địa lý quan trọng: quốc gia *lắp ráp* sản phẩm (ở đây chỉ khoảng 3% giá trị) thường nhận được phần giá trị nhỏ hơn nhiều so với quốc gia *thiết kế, xây dựng thương hiệu và bán* sản phẩm (khoảng 67%), dù công đoạn lắp ráp sử dụng nhiều lao động và dễ thấy hơn. Giá trị trong mạng lưới sản xuất toàn cầu hiện đại có xu hướng tập trung ở nơi nắm giữ tri thức, sở hữu trí tuệ và thương hiệu – không phải nơi thực hiện lao động chân tay.

(!) Lỗi thường gặp: Do not assume that where a product is physically *made* is the same as where most of its economic value is *captured*. Labels such as "Assembled in China" or "Made in Vietnam" describe only the final assembly stage of a global supply chain and can seriously mislead students into overestimating how much value, profit, or economic benefit actually accrues to the assembling country, when design, branding and component technology located elsewhere often capture a substantially larger share.

8.3.4 Footloose industry and production linkages

A further useful concept for classifying TNC activity is the **footloose industry**: a type of manufacturing or assembly operation that is not tied to any particular raw-material source, energy supply, or local market, and can therefore be relocated relatively easily to wherever labour costs, government incentives, or logistics are most favourable at a given time — consumer-electronics assembly (as in the Apple/Foxconn case above) is a classic footloose industry, in contrast to, say, an aluminium smelter that must be located near a cheap, reliable electricity supply, or a fish cannery that must be located near the fishing grounds it processes. Geographers also distinguish two kinds of **linkage** that a TNC investment can create in a host economy: a **backward linkage** exists when a TNC's local operation purchases inputs, components, or services from domestic suppliers in the host country, stimulating the growth of local supplier industries; a **forward linkage** exists when the TNC's output is itself used as an input by other domestic firms further down the value chain (for example, a domestically-processed raw material being sold on to local manufacturers). Host countries generally benefit most from TNC investment when it generates strong backward and forward linkages with the wider domestic economy, rather than operating as an isolated "enclave" that imports nearly all its inputs and exports its entire output with minimal connection to local firms.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ngành công nghiệp "chân không bám rễ" (footloose industry) là loại hình sản xuất/lắp ráp không bị ràng buộc vào nguồn nguyên liệu, năng lượng, hay thị trường địa phương cụ thể nào, nên có thể dễ dàng di dời đến nơi có chi phí lao động hoặc ưu đãi thuận lợi nhất (ví dụ: lắp ráp thiết bị điện tử tiêu dùng như trường hợp Apple/Foxconn), khác với các ngành phải gắn với vị trí cố định (như nhà máy luyện nhôm cần nguồn điện rẻ, hay nhà máy đóng hộp cần gần ngư trường). **Liên kết ngược (backward linkage)** là khi hoạt động của TNC mua nguyên liệu/linh kiện/dịch vụ từ các nhà cung cấp trong nước, thúc đẩy ngành công nghiệp phụ trợ nội địa phát triển. **Liên kết xuôi (forward linkage)** là khi sản phẩm đầu ra của TNC được các doanh nghiệp nội địa khác sử dụng làm đầu vào cho công đoạn tiếp theo. Nước tiếp nhận đầu tư hưởng lợi nhiều nhất khi đầu tư TNC tạo ra liên kết ngược và xuôi mạnh với nền kinh tế trong nước, thay vì hoạt động như một "khu biệt lập" nhập gần như toàn bộ đầu vào và xuất toàn bộ đầu ra mà ít kết nối với doanh nghiệp địa phương.

8.4 Power and Influence in the Global System

8.4.1 Hard power and soft power

Not all countries participate in and shape the global system equally: some exert far greater **power** — the capacity to influence the decisions and behaviour of other states, institutions, or actors — than others. Political scientist **Joseph Nye** introduced an influential distinction between two broad forms of power. **Hard power** is the ability to influence others through coercion or inducement, typically backed by military or economic strength — "sticks and carrots" such as the threat or use of military force, economic sanctions, tariffs, or conditional aid. **Soft power**, by contrast, is the ability to influence others' preferences and behaviour through attraction and persuasion rather than coercion — getting others to want the same outcomes you want, because they find your values, culture, or way of life appealing, rather than because they are forced or paid to comply.

Feature	Hard power	Soft power
Definition	The ability to influence the behaviour of other actors through coercion, force, or material inducement	The ability to influence the behaviour of other actors through attraction and persuasion rather than coercion
Typical mechanism	Military force and alliances, economic sanctions, tariffs, conditional aid	Cultural appeal, values, diplomacy, education/exchange programmes, media and entertainment, spread of language
Named example	Economic sanctions imposed on a rival state; military alliances such as NATO	South Korea's "Korean Wave" (Hallyu) – K-pop and Korean television dramas – boosting South Korea's international cultural appeal; the global reach of Hollywood film and the worldwide spread of the English language as vehicles of soft power

Hard power and soft power (Joseph Nye's distinction) are not mutually exclusive – most influential states deploy a combination of both, sometimes described as "smart power."

VN **GIẢI THÍCH TIẾNG VIỆT**

Nhà khoa học chính trị Joseph Nye phân biệt **quyền lực cứng (hard power)** – khả năng gây ảnh hưởng thông qua ép buộc hoặc dụ dỗ vật chất (sức mạnh quân sự, trừng phạt kinh tế, thuế quan) – với **quyền lực mềm (soft power)** – khả năng gây ảnh hưởng thông qua **sự hấp dẫn và**

thuyết phục, khiến đối tượng *tự nguyện* mong muốn điều mình mong muốn, thay vì bị ép buộc. Ví dụ quyền lực cứng: lệnh trừng phạt kinh tế, liên minh quân sự (như NATO). Ví dụ quyền lực mềm: "làn sóng Hàn Quốc" (Hallyu – K-pop, phim truyền hình Hàn Quốc), sức ảnh hưởng toàn cầu của điện ảnh Hollywood, và sự lan rộng của tiếng Anh như một ngôn ngữ quốc tế.

Ví dụ mẫu · Classifying hard power versus soft power

For each of the following actions, state whether it is primarily an example of hard power or soft power, and briefly justify your answer.
(1) A country imposes trade sanctions on a rival state to pressure it to change policy.
(2) A country's television dramas and pop music become hugely popular with young audiences worldwide.
(3) Two countries sign a mutual-defence military alliance treaty.
(4) A university heavily recruits international students, who then return home with a favourable view of the host country.

(1) Hard power. Sanctions are a coercive economic tool intended to force a change in behaviour through material cost, not through persuasion or attraction.

(2) Soft power. Popularity of cultural exports works purely through attraction: audiences are not coerced into liking the content, and the resulting positive association with its country of origin is a classic soft-power effect (as with South Korea's Hallyu wave).

(3) Hard power. A mutual-defence treaty is fundamentally about deterrence and the credible threat/promise of military force, even though it is achieved through diplomacy.

(4) Soft power. International education and exchange programmes work by exposing people to a country's values, institutions and way of life, generating goodwill and favourable attitudes through genuine attraction rather than coercion – a mechanism Nye explicitly identifies as a soft-power channel.

VN **GIẢI THÍCH TIẾNG VIỆT**
Bí quyết phân loại: nếu hành động dựa trên **ép buộc, đe doạ, hoặc trao đổi vật chất** (trừng phạt, liên minh quân sự, thuế quan) → **quyền lực cứng**. Nếu hành động dựa trên **sự hấp dẫn tự nguyện** (văn hoá, giáo dục, giá trị, truyền thông) khiến đối tượng tự thay đổi thái độ mà không bị ép → **quyền lực mềm**. Nhiều hành động ngoại giao trong thực tế kết hợp cả hai ("smart power").

(!) Lỗi thường gặp: A frequent error is confusing hard power with soft power simply because a soft-power channel (education exchange, cultural diplomacy) is organised or funded *by a government*. What determines the category is the *mechanism of influence*, not who runs the programme: a government-funded cultural festival that changes attitudes through genuine attraction is still soft power, whereas government-funded coercive tools (sanctions, military aid conditional on policy change) remain hard power. Similarly, do not assume soft power is "weaker" or less important than hard power – soft power can shift long-term public opinion and diplomatic alignment in ways that coercive hard power cannot achieve.

8.4.2 Economic power and political power

Beyond the hard/soft distinction, global power operates along other dimensions. **Economic power** refers to a country's ability to influence the global system through the sheer size of its economy (commonly measured by **gross domestic product, GDP**), its control over key international trade and financial flows, its currency's role in international transactions, and its capacity to set standards and

terms that other economies must accommodate. **Political power** refers to a country's formal standing and influence within international institutions and diplomatic processes. The clearest example of formal political power is **permanent membership of the United Nations Security Council (UNSC)**: five countries — the **United States, the United Kingdom, France, Russia, and China** — hold permanent seats and, uniquely, each can exercise a **veto**, blocking any substantive UNSC resolution regardless of how the other Council members vote. This veto power gives these five states disproportionate influence over decisions concerning international peace and security compared with any other UN member state.

Ví dụ mẫu · Reasoning through UNSC veto power

A UNSC resolution proposing coordinated international sanctions against a particular state receives 14 votes in favour out of the 15 Security Council members, with one permanent member (say, Russia) voting against. Explain the outcome, and state which countries hold this same veto capability.

Despite an overwhelming 14-to-1 majority in favour, the resolution **fails to pass**, because a single "no" vote cast by *any* permanent member constitutes a **veto** that blocks the resolution outright, regardless of the size of the majority supporting it. The five states holding this veto power are the **UN Security Council's five permanent members (the "P5")**: the **United States, the United Kingdom, France, Russia, and China**. This example illustrates why permanent Security Council membership is such a concentrated form of **political power**: it allows a single one of these five states to unilaterally block collective international action on matters of peace and security, a form of influence held by no other country in the UN system, however large its economy or population.

VN **GIẢI THÍCH TIẾNG VIỆT**

Quyền lực kinh tế được đo bằng quy mô GDP, khả năng kiểm soát dòng chảy thương mại/tài chính quốc tế, và vai trò của đồng tiền quốc gia trong giao dịch quốc tế. **Quyền lực chính trị** thể hiện rõ nhất qua tư cách **thành viên thường trực Hội đồng Bảo an Liên Hợp Quốc (UNSC)**: 5 quốc gia – **Hoa Kỳ, Anh, Pháp, Nga, và Trung Quốc** – có ghế thường trực và **quyền phủ quyết (veto)**, nghĩa là chỉ cần MỘT trong năm nước này bỏ phiếu chống là nghị quyết bị chặn lại hoàn toàn, bất kể đa số các nước còn lại ủng hộ ra sao. Đây là một dạng quyền lực chính trị đặc biệt tập trung, không quốc gia nào khác trong hệ thống Liên Hợp Quốc có được, dù quy mô kinh tế hay dân số của họ lớn đến đâu.

8.5 Global Governance: Institutions and Trade Blocs

8.5.1 The United Nations system

The **United Nations (UN)**, founded in 1945, is the principal global institution for international cooperation on peace and security, human rights, humanitarian assistance, and sustainable development, comprising nearly every sovereign state in the world as a member. Its main decision-making bodies include the **General Assembly** (where every member state has one equal vote, but resolutions are generally non-binding recommendations) and the **Security Council** (which can pass binding resolutions, including authorising sanctions or military action, but where the five permanent members hold veto power, as described above). A wide family of specialised UN agencies and programmes — covering health, refugees, children, food and agriculture, and much else — extends the UN system's reach into nearly every dimension of global governance, even though the organisation has no independent enforcement power beyond what member states, especially the P5, are willing to authorise and support.

VN **GIẢI THÍCH TIẾNG VIỆT**

Liên Hợp Quốc (UN), thành lập năm 1945, là thể chế toàn cầu chính cho hợp tác quốc tế về hoà bình, an ninh, nhân quyền, viện trợ nhân đạo và phát triển bền vững. **Đại hội đồng** (General Assembly) mỗi nước một phiếu bình đẳng nhưng nghị quyết thường không có tính ràng buộc; **Hội đồng Bảo an** (Security Council) có thể ra nghị quyết ràng buộc nhưng 5 thành viên thường trực có quyền phủ quyết. Nhiều cơ quan chuyên môn của Liên Hợp Quốc (y tế, người tị nạn, trẻ em, lương thực...) mở rộng phạm vi quản trị toàn cầu, dù bản thân tổ chức không có quyền cưỡng chế độc lập ngoài những gì các nước thành viên, đặc biệt là P5, sẵn sàng cho phép.

8.5.2 The World Trade Organization, G7 and G20

The **World Trade Organization (WTO)**, established in 1995 as the successor to the earlier General Agreement on Tariffs and Trade (GATT), is the principal global institution governing international trade rules. Its core functions are to negotiate agreements that progressively liberalise trade among member states (reducing tariffs and other barriers), to provide a common set of trade rules that members agree to follow, and — distinctively — to **adjudicate trade disputes** between member states through a formal dispute-settlement process, allowing a country that believes another member has violated agreed trade rules to bring a case and, if successful, obtain authorisation for proportionate retaliatory measures. The **G7** (Group of Seven) is an informal forum bringing together the leaders of seven major advanced economies — the United States, the United Kingdom, France, Germany, Italy, Japan, and Canada (with the European Union also participating) — to coordinate policy on economic, security and global issues; it has no formal treaty basis or binding authority, relying instead on political consensus among its members. The **G20** (Group of Twenty) is a broader, similarly informal forum that includes the G7 members plus major emerging economies such as China, India, Brazil, Indonesia, Mexico, South Africa, Saudi Arabia, Turkey, South Korea, Argentina, Australia and Russia, together with the European Union, collectively representing the large majority of world GDP and population; it was elevated to a leaders'-level summit following the 2008 global financial crisis, reflecting a recognition that major economic coordination could no longer be managed by advanced economies alone.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tổ chức Thương mại Thế giới (WTO), thành lập năm 1995, là thể chế toàn cầu chính điều chỉnh quy tắc thương mại quốc tế: đàm phán tự do hoá thương mại (giảm thuế quan) và đặc biệt là **phân xử tranh chấp thương mại** giữa các nước thành viên. **G7** là diễn đàn không chính thức của 7 nền kinh tế phát triển lớn (Hoa Kỳ, Anh, Pháp, Đức, Ý, Nhật, Canada, cùng EU tham gia), không có cơ sở hiệp ước ràng buộc. **G20** là diễn đàn rộng hơn, gồm G7 cộng thêm các nền kinh tế mới nổi lớn (Trung Quốc, Ấn Độ, Brazil, Indonesia, Mexico, Nam Phi, Ả Rập Saudi, Thổ Nhĩ Kỳ, Hàn Quốc, Argentina, Australia, Nga) và EU, đại diện phần lớn GDP và dân số thế giới – được nâng lên cấp thượng đỉnh nguyên thủ sau khủng hoảng tài chính toàn cầu năm 2008.

8.5.3 Regional trade blocs

Alongside global institutions, groups of neighbouring countries often form **regional trade blocs**: formal agreements that reduce or eliminate trade barriers (tariffs, quotas) among member states, while frequently maintaining or even raising a common external barrier against non-member countries. The **European Union (EU)** operates the world's most deeply integrated regional **single market**, in which member states have agreed to the "four freedoms" – free movement of goods, services, capital, and labour – across internal borders, alongside a common external tariff for goods entering from outside the bloc. **ASEAN** (the Association of Southeast Asian Nations), comprising ten Southeast Asian states (including Indonesia, Malaysia, the Philippines, Singapore, Thailand and Vietnam), promotes regional economic integration and reduced internal tariffs among its members, alongside political and security cooperation, though with looser integration than the EU. The **USMCA** (United

States–Mexico–Canada Agreement), which came into force in 2020 as the direct successor to the earlier **NAFTA** (North American Free Trade Agreement, in force from 1994), eliminates most tariffs on trade among the United States, Mexico and Canada, while updating rules on issues such as digital trade, labour standards and rules of origin for manufactured goods (particularly automobiles) that did not exist when NAFTA was first negotiated.

VN **GIẢI THÍCH TIẾNG VIỆT**

Một **khối thương mại khu vực** là thoả thuận giữa các nước láng giềng nhằm giảm/xoá bỏ rào cản thương mại nội khối, đồng thời thường duy trì hoặc thậm chí nâng cao rào cản chung với các nước ngoài khối. **Liên minh châu Âu (EU)** có **thị trường chung** hội nhập sâu nhất thế giới, với "bốn quyền tự do" (hàng hoá, dịch vụ, vốn, lao động) di chuyển tự do nội khối. **ASEAN** gồm 10 nước Đông Nam Á, thúc đẩy hội nhập kinh tế khu vực nhưng lỏng lẻo hơn EU. **USMCA** (Hoa Kỳ–Mexico–Canada), có hiệu lực từ năm 2020, là hiệp định kế thừa trực tiếp của **NAFTA** (có hiệu lực từ 1994), xoá bỏ phần lớn thuế quan nội khối Bắc Mỹ và cập nhật quy định về thương mại số, tiêu chuẩn lao động, và quy tắc xuất xứ hàng hoá (đặc biệt là ô tô).

8.6 Measuring Global Flows and Integration

8.6.1 Foreign direct investment (FDI)

A country's **net FDI flow** in a given period is calculated as its **FDI inflow** (investment received from foreign firms and individuals) minus its **FDI outflow** (investment made abroad by its own firms and individuals):

$$\text{Net FDI} = \text{FDI inflow} - \text{FDI outflow}.$$

A positive net FDI figure indicates the country is a **net capital importer** (it receives more foreign investment than it sends abroad), typically characteristic of economies attracting foreign manufacturing, resource extraction, or infrastructure investment. A negative net FDI figure indicates the country is a **net capital exporter** (its own firms invest more abroad than foreign firms invest domestically), typically characteristic of economies with large, internationally-active corporations seeking growth opportunities, resources or markets overseas.

Ví dụ mẫu · Calculating and interpreting net FDI flow

In a given year, "Nation Solvara" records an FDI inflow of $\$48$ billion and an FDI outflow of $\$12$ billion. (a) Calculate the net FDI flow. (b) State whether Nation Solvara is a net capital importer or a net capital exporter, and interpret what this suggests about its role in the global economy.

(a)

$$\text{Net FDI} = 48 - 12 = +\$\mathbf{36}\text{ billion}.$$

(b) Because net FDI is positive, Nation Solvara is a **net capital importer**: it received substantially more foreign direct investment than its own residents and firms invested abroad. This pattern is typical of economies that are attractive destinations for foreign manufacturing plants, extractive industry, or infrastructure projects – for instance, because of relatively low labour costs, a large domestic consumer market, natural resource endowments, or government incentives for foreign investors – and it suggests Nation Solvara is currently a relatively strong recipient node within global capital flow networks.

VN **GIẢI THÍCH TIẾNG VIỆT**

Công thức: **FDI ròng** = FDI vào − FDI ra. Nếu dương → quốc gia là **nước nhập khẩu vốn ròng** (net capital importer, nhận nhiều đầu tư nước ngoài hơn đầu tư ra ngoài) – thường là các nền kinh tế thu hút đầu tư sản xuất, khai khoáng, hoặc hạ tầng từ nước ngoài. Nếu âm → quốc gia là **nước xuất khẩu vốn ròng** (net capital exporter) – thường là các nền kinh tế có tập đoàn lớn

tìm kiếm cơ hội tăng trưởng ở nước ngoài.

Ví dụ mẫu · Net FDI flow – a net capital exporter

"Republic of Kestrel" records an FDI inflow of $\$19$ billion and an FDI outflow of $\$63$ billion in the same year. Calculate the net FDI flow and classify the country.

$$\text{Net FDI} = 19 - 63 = -\$\mathbf{44}\text{ billion}.$$

Because net FDI is negative, Republic of Kestrel is a **net capital exporter**: its own firms invested $\$44$ billion more abroad than foreign firms invested within its borders. This pattern is typical of economies with large, mature, internationally-competitive TNCs that are actively seeking new markets, resources or lower-cost production locations overseas – a very different global economic role from Nation Solvara above, even though both figures describe the same underlying flow (FDI), simply with the balance reversed.

VN **GIẢI THÍCH TIẾNG VIỆT**

Ngược lại với ví dụ trước, khi FDI ra lớn hơn FDI vào, FDI ròng âm, quốc gia đó là **nước xuất khẩu vốn ròng** – các doanh nghiệp trong nước đầu tư ra nước ngoài nhiều hơn đầu tư nước ngoài chảy vào. Đây thường là đặc điểm của các nền kinh tế có nhiều tập đoàn đa quốc gia lớn, có năng lực cạnh tranh quốc tế mạnh.

8.6.2 Trade balance and the trade-dependency ratio

Two related but distinct indicators describe a country's trade position. The **trade balance** measures the *direction and size* of net trade in a given period:

$$\text{Trade balance} = \text{Exports} - \text{Imports},$$

giving a **trade surplus** (positive, exports exceed imports) or **trade deficit** (negative, imports exceed exports). The **trade-dependency ratio**, by contrast, measures how *structurally exposed* an economy is to international trade overall, regardless of whether that trade is balanced:

$$\text{Trade-dependency ratio} = \frac{\text{Exports} + \text{Imports}}{\text{GDP}} \times 100\%.$$

A high trade-dependency ratio (which can exceed 100% for very open, trade-oriented economies, since total trade can exceed the value of a country's own domestic output in a given year) indicates that a large share of the country's total economic activity is bound up in international trade, making it highly exposed to external shocks such as a global recession, a sudden shift in commodity prices, or disruption to shipping networks. A low ratio indicates an economy that is comparatively insulated from external trade shocks, typically because it is very large and driven mainly by domestic consumption and investment relative to the size of its trade flows.

Ví dụ mẫu · Calculating a trade-dependency ratio

"Nation A" records exports of $\$220$ billion and imports of $\$190$ billion in a year in which its GDP is $\$300$ billion. (a) Calculate Nation A's trade balance. (b) Calculate its trade-dependency ratio. (c) Interpret what this ratio implies about Nation A's exposure to global economic shocks.

(a) Trade balance $= 220 - 190 = +\$\mathbf{30}$ billion surplus.

(b) Trade-dependency ratio:

$$\frac{220+190}{300}\times 100\% = \frac{410}{300}\times 100\% \approx \mathbf{136.7}\%.$$

(c) A trade-dependency ratio above 100% shows that the total value of Nation A's trade (exports plus imports) actually *exceeds* the size of its entire domestic economy – a hallmark of a small, highly open, trade-oriented economy (broadly similar in structure to real small trading economies such as Singapore or Vietnam). This means a very large share of Nation A's economic activity depends directly on international demand and supply chains, so a global recession, a collapse in a key export market, or a disruption to shipping networks would transmit very quickly and severely into Nation A's domestic economy, output and employment.

VN **GIẢI THÍCH TIẾNG VIỆT**

Phân biệt hai chỉ số: **cán cân thương mại** (trade balance) = xuất khẩu − nhập khẩu, cho biết quốc gia **thặng dư** hay **thâm hụt**. **Tỉ lệ phụ thuộc thương mại** (trade-dependency ratio) = (xuất khẩu + nhập khẩu) ÷ GDP $\times 100\%$, cho biết mức độ **mở cửa/phụ thuộc** của nền kinh tế vào thương mại quốc tế nói chung, bất kể cán cân đó cân bằng hay không. Tỉ lệ càng cao, nền kinh tế càng dễ bị tổn thương trước các cú sốc kinh tế toàn cầu (suy thoái, gián đoạn chuỗi cung ứng, biến động giá hàng hoá).

Ví dụ mẫu · Comparing trade-dependency ratios across two economies

"Nation B" (a small, trade-oriented economy) has exports of \$$90$ billion, imports of \$$75$ billion, and GDP of \$$120$ billion. "Nation C" (a large, continental economy) has exports of \$$1.6$ trillion, imports of \$$1.4$ trillion, and GDP of \$$21$ trillion. Calculate each country's trade-dependency ratio and explain which economy is more exposed to a global trade shock.

Nation B:

$$\frac{90+75}{120}\times 100\% = \frac{165}{120}\times 100\% \approx \mathbf{137.5}\%.$$

Nation C:

$$\frac{1.6+1.4}{21}\times 100\% = \frac{3.0}{21}\times 100\% \approx \mathbf{14.3}\%.$$

Despite Nation C having a far larger absolute volume of trade (\$$3.0$ trillion versus Nation B's \$$165$ billion), its trade-dependency ratio is roughly *one-tenth* that of Nation B, because Nation C's total domestic economy is so much larger that trade forms only a modest share of it. **Nation B is far more exposed** to a global trade shock: a given percentage fall in world trade would translate into a much larger relative shock to Nation B's total economic output than to Nation C's, even though Nation C's economy would still feel the shock in absolute dollar terms. This is a key reason why small, open, trade-dependent economies often pursue economic diversification and build larger financial reserves as a buffer against global volatility.

VN **GIẢI THÍCH TIẾNG VIỆT**

So sánh hai nền kinh tế minh hoạ rõ: dù Nation C có tổng giá trị thương mại tuyệt đối lớn hơn nhiều, tỉ lệ phụ thuộc thương mại của Nation C lại thấp hơn nhiều vì nền kinh tế nội địa của họ rất lớn. **Nation B, nền kinh tế nhỏ và mở**, dễ tổn thương hơn nhiều trước biến động thương mại toàn cầu – đây là lý do các nền kinh tế nhỏ, phụ thuộc thương mại thường theo đuổi đa dạng hoá kinh tế và tích luỹ dự trữ ngoại hối lớn hơn để phòng ngừa rủi ro từ bên ngoài.

(!) Lỗi thường gặp: Students very frequently confuse the **trade balance** with the **trade-dependency ratio**. The trade balance (exports minus imports) tells you only whether a country runs a surplus or deficit – it says nothing about how large trade is relative to the size of the economy. A country can run a small, roughly balanced trade position (trade balance near zero) while still having an extremely high trade-dependency ratio, if both its exports *and* its imports are each very large relative to GDP. Always check which of the two questions is actually being asked: "is trade balanced?" (trade balance) versus "how exposed is this economy to trade generally?" (trade-dependency ratio).

8.6.3 Remittances

Remittances are the money that international migrant workers send back to family and communities in their country of origin. For many labour-exporting countries, remittance inflows are a very substantial source of foreign currency earnings and household income, often rivalling or exceeding export earnings or foreign direct investment as a share of GDP. Remittances are typically calculated and compared as a percentage of the receiving country's GDP, providing another quantitative indicator of a country's particular mode of integration into the global economy – in this case, integration primarily through the export of labour rather than goods or capital.

Ví dụ mẫu · Remittances as a share of GDP

"Nation R" has a large diaspora of migrant workers abroad. In a given year, Nation R receives $\$8$ billion in remittance inflows, and its GDP is $\$35$ billion. (a) Calculate remittances as a percentage of GDP. (b) Interpret what this implies about Nation R's position in the global economy.

(a)

$$\frac{8}{35} \times 100\% \approx \mathbf{22.9}\%.$$

(b) Remittances equivalent to nearly a quarter of GDP indicate that Nation R's economy is heavily integrated into the global system primarily through the **export of labour** rather than through exporting manufactured goods or attracting large FDI inflows. In real economies with comparably high remittance dependence – such as Nepal, Tajikistan, or the Philippines, where remittance inflows have at times reached a fifth or more of GDP – this pattern brings clear domestic benefits (foreign currency earnings, poverty reduction, household consumption) but also exposes the country to risks: an economic downturn or restrictive migration policy change in the destination countries where its migrants work can sharply reduce this income, with an impact transmitted directly into household incomes and the wider domestic economy.

VN **GIẢI THÍCH TIẾNG VIỆT**

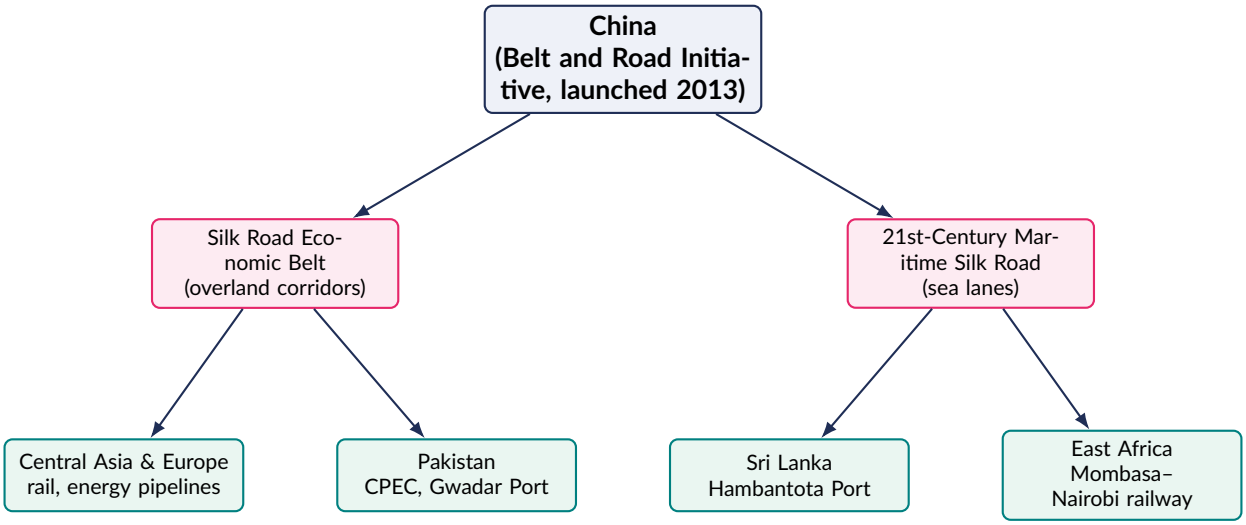
Kiều hối (remittances) là tiền người lao động di cư quốc tế gửi về gia đình ở nước gốc. Với nhiều quốc gia xuất khẩu lao động, kiều hối là nguồn thu ngoại tệ và thu nhập hộ gia đình rất lớn, có khi vượt cả kim ngạch xuất khẩu hoặc FDI tính theo % GDP. Tỉ lệ kiều hối/GDP cao (như ở Nepal, Tajikistan, Philippines trong thực tế) cho thấy một quốc gia hội nhập vào kinh tế toàn cầu chủ yếu qua **xuất khẩu lao động**, mang lại lợi ích (ngoại tệ, giảm nghèo) nhưng cũng dễ bị tổn thương nếu nước tiếp nhận lao động gặp suy thoái hoặc thắt chặt chính sách di trú.

8.7 Case Study: China's Belt and Road Initiative

8.7.1 Scale and aims of the BRI

Launched by China in **2013**, the **Belt and Road Initiative (BRI)** is a large-scale, ongoing programme of overseas infrastructure investment and financing, encompassing two broad components: the over-

land "**Silk Road Economic Belt**" (railways, roads, energy pipelines connecting China through Central Asia toward Europe) and the maritime "**21st-Century Maritime Silk Road**" (port development and shipping-lane investment through Southeast Asia, South Asia, East Africa and beyond). Through the BRI, Chinese state-owned banks (such as the China Development Bank and the Export-Import Bank of China) have financed and Chinese state-owned construction firms have built ports, railways, roads, power plants and other infrastructure across dozens of participating countries in Asia, Africa, Europe and Latin America. China's stated aims include expanding trade connectivity for itself and partner countries, addressing a genuine global infrastructure investment gap in many developing countries, securing access to resources and markets, and extending China's economic and diplomatic influence internationally.



A schematic node-and-arrow representation of the Belt and Road Initiative (this is *not* a geographic map): Chinese state investment channelled through two broad corridors – an overland "Belt" and a maritime "Road" – reaching named infrastructure projects in Central Asia, Europe, Pakistan, Sri Lanka and East Africa, among the many other participating countries not shown here.

VN **GIẢI THÍCH TIẾNG VIỆT**

Được Trung Quốc khởi động năm **2013**, **Sáng kiến Vành đai và Con đường (BRI)** là chương trình đầu tư hạ tầng quy mô lớn gồm hai phần: **"Vành đai kinh tế Con đường Tơ lụa"** (đường bộ, đường sắt, đường ống năng lượng nối Trung Quốc qua Trung Á tới châu Âu) và **"Con đường Tơ lụa trên biển thế kỷ 21"** (đầu tư cảng biển và tuyến hàng hải qua Đông Nam Á, Nam Á, Đông Phi). Các ngân hàng nhà nước Trung Quốc tài trợ và các công ty xây dựng nhà nước Trung Quốc xây dựng cảng, đường sắt, đường bộ, nhà máy điện tại hàng chục quốc gia. Mục tiêu: mở rộng kết nối thương mại, giải quyết khoảng trống đầu tư hạ tầng ở nhiều nước đang phát triển, tiếp cận tài nguyên/thị trường, và mở rộng ảnh hưởng kinh tế–ngoại giao của Trung Quốc.

8.7.2 The debt-trap diplomacy debate: Hambantota Port

A major controversy surrounding the BRI concerns what critics call **"debt-trap diplomacy"**: the concern that China extends large infrastructure loans to lower-income countries for projects with uncertain commercial viability, and that when a borrowing country subsequently struggles to service that debt, China can gain long-term strategic control over the resulting asset. The most widely cited example is **Hambantota Port** in southern Sri Lanka. The port was built substantially with loans from Chinese state banks, but from an early stage struggled to attract the volume of shipping traffic needed to generate revenue sufficient to service its debt. As Sri Lanka's broader external debt difficulties deepened, the Sri Lankan government, in **2017**, agreed to grant a **99-year lease** over

Hambantota Port's operations to **China Merchants Port Holdings**, a Chinese state-owned company, in exchange for debt relief and additional investment. This transaction became one of the most widely cited cautionary examples of the potential risks of large-scale infrastructure borrowing from a single foreign creditor: a sovereign state effectively transferring long-term operational control of a strategic asset in the face of debt distress. It is important to note, however, that this narrative is also **contested by some analysts**, who argue that Sri Lanka's broader debt crisis stemmed mainly from a wider accumulation of international sovereign bond debt (owed largely to private, non-Chinese bondholders) and domestic macroeconomic mismanagement, rather than from the Hambantota loan specifically, and that characterising the case as a deliberate Chinese strategy of "debt-trap diplomacy" oversimplifies a more complex set of causes.

VN **GIẢI THÍCH TIẾNG VIỆT**

Một tranh cãi lớn quanh BRI là khái niệm **"ngoại giao bẫy nợ" (debt-trap diplomacy)** – lo ngại rằng Trung Quốc cho các nước thu nhập thấp vay để xây hạ tầng có khả năng sinh lời thương mại không chắc chắn, và khi nước vay gặp khó khăn trả nợ, Trung Quốc có thể giành quyền kiểm soát chiến lược lâu dài đối với tài sản đó. Ví dụ được trích dẫn nhiều nhất là **cảng Hambantota** (Sri Lanka): xây dựng chủ yếu bằng vốn vay từ ngân hàng nhà nước Trung Quốc, nhưng lưu lượng tàu bè không đủ để trả nợ; năm **2017**, chính phủ Sri Lanka đã cho **China Merchants Port Holdings** (công ty nhà nước Trung Quốc) thuê vận hành cảng trong **99 năm** để đổi lấy giảm nợ và đầu tư thêm. Tuy nhiên, một số nhà phân tích **tranh cãi** cách diễn giải này, cho rằng khủng hoảng nợ của Sri Lanka chủ yếu đến từ nợ trái phiếu quốc tế (chủ yếu do các chủ nợ tư nhân, không phải Trung Quốc, nắm giữ) và quản lý kinh tế vĩ mô trong nước, chứ không chỉ từ khoản vay Hambantota.

8.8 Unequal Power in Global Trade Rules

Global trade governance does not always operate on a level playing field between high-income and lower-income countries. A clear illustration is **agricultural subsidies**: government payments that many high-income countries (notably the United States and the member states of the European Union, through mechanisms such as the EU's Common Agricultural Policy) provide to their domestic farmers, on top of whatever price the farmer receives from selling a crop on the open market. These subsidies allow farmers in subsidising countries to sell their produce internationally at prices that do not reflect their true underlying cost of production, since the subsidy covers part of that cost regardless of the market price obtained. When such artificially cheap, subsidised agricultural exports (for example, cotton, sugar, or grain) enter world markets, they can **undercut smallholder farmers** in developing countries who receive no comparable government support and who consequently cannot compete on price, even where their own production costs are genuinely lower. A well-documented real example is the long-running dispute over **cotton subsidies**: heavily subsidised cotton production in high-income countries has been argued, including by the group of West African cotton-producing states informally known as the "Cotton Four" (Benin, Burkina Faso, Chad and Mali) in negotiations at the WTO, to depress world cotton prices and directly harm the livelihoods of millions of smallholder cotton farmers across West Africa who receive no equivalent subsidy. This example shows that global trade governance, even where formal rules (such as WTO agreements) apply nominally to all member states, can still produce outcomes that systematically favour economically and politically more powerful members over less powerful ones.

VN **GIẢI THÍCH TIẾNG VIỆT**

Quản trị thương mại toàn cầu không phải lúc nào cũng công bằng. **Trợ cấp nông nghiệp** ở các nước thu nhập cao (Hoa Kỳ, các nước EU qua Chính sách Nông nghiệp Chung – CAP) cho phép nông dân nước họ bán nông sản ra thị trường quốc tế với giá thấp hơn chi phí sản xuất thực tế (vì phần chênh lệch được chính phủ trợ cấp), từ đó **lấn át nông dân nhỏ lẻ** ở các nước

đang phát triển – những người không nhận được trợ cấp tương tự và không thể cạnh tranh về giá dù chi phí sản xuất của họ thực sự có thể thấp hơn. Ví dụ thực tế nổi bật: tranh chấp về **trợ cấp bông** – nhóm "Cotton Four" (Benin, Burkina Faso, Chad, Mali) ở Tây Phi từng nêu vấn đề này tại WTO, cho rằng trợ cấp bông ở các nước giàu làm giảm giá bông thế giới và gây thiệt hại trực tiếp cho hàng triệu nông dân trồng bông nhỏ lẻ ở Tây Phi.

Two further mechanisms illustrate the same underlying asymmetry. **Tariff escalation** refers to a common pattern in the tariff schedules of high-income importing countries whereby the tariff rate charged rises with the degree of processing of a good: raw, unprocessed commodities (raw cocoa beans, raw cotton, unroasted coffee) typically enter duty-free or at very low tariff rates, while the equivalent processed product (chocolate, textiles, roasted/packaged coffee) faces a substantially higher tariff. This structure gives developing-country producers a strong incentive to keep exporting low-value raw commodities rather than moving up the value chain into processing and manufacturing, since the processed version of their own product would face a tariff penalty in the very markets they are trying to sell into — entrenching many developing economies in a role as raw-material suppliers rather than processors or manufacturers. A second mechanism concerns **intellectual property (IP) rules**: international agreements such as the WTO's **TRIPS Agreement** (Trade-Related Aspects of Intellectual Property Rights) require member states to enforce patent, copyright and trademark protections that were negotiated by, and are predominantly held by, firms based in high-income countries (pharmaceuticals, technology, agricultural seed patents). Critics argue that strict IP enforcement can raise the cost of accessing patented medicines, agricultural technology, or software in lower-income countries, since local producers cannot legally manufacture cheaper generic versions without a licence, even though supporters argue IP protection is necessary to fund the research and innovation that produces such technologies in the first place.

VN **GIẢI THÍCH TIẾNG VIỆT**

Hai cơ chế khác cũng minh hoạ sự bất cân xứng trong quản trị thương mại toàn cầu. **Thuế quan luỹ tiến theo mức chế biến (tariff escalation)**: các nước nhập khẩu thu nhập cao thường đánh thuế thấp hoặc miễn thuế với nguyên liệu thô (hạt ca cao thô, bông thô, cà phê chưa rang), nhưng đánh thuế cao hơn nhiều với sản phẩm đã qua chế biến tương ứng (sô-cô-la, vải sợi, cà phê rang đóng gói) – điều này khiến các nước đang phát triển có động lực tiếp tục xuất khẩu nguyên liệu thô giá trị thấp thay vì phát triển ngành chế biến/sản xuất giá trị cao hơn, vì sản phẩm chế biến của chính họ sẽ bị đánh thuế cao hơn khi vào các thị trường đó. **Quy định sở hữu trí tuệ (IP)**: các hiệp định như **Hiệp định TRIPS** của WTO buộc các nước thành viên thực thi bảo hộ bằng sáng chế, bản quyền, thương hiệu – phần lớn do các công ty ở nước thu nhập cao nắm giữ (dược phẩm, công nghệ, giống cây trồng). Điều này có thể làm tăng chi phí tiếp cận thuốc, công nghệ nông nghiệp, hoặc phần mềm có bằng sáng chế ở các nước thu nhập thấp, dù người ủng hộ cho rằng bảo hộ sở hữu trí tuệ là cần thiết để tài trợ cho hoạt động nghiên cứu và đổi mới.

8.9 Towards Core and Periphery: A Forward Link

Khái niệm mở đầu: Lõi và ngoại vi

The patterns examined throughout this unit – concentrated nodes in transport and information networks, uneven value capture along TNC supply chains, unequal hard/soft/economic/political power, and asymmetric trade governance – can be summarised through the **core–periphery** concept: the idea that the global economy can usefully be described as a dominant **core** of wealthy, high-power regions (concentrating capital, decision-making, high-value production, and political influence) and a **periphery** of lower-power regions that chiefly

supply resources, labour and low-value manufacturing to the core, typically on less favourable terms. This unit has introduced the building blocks – flows, networks, TNCs, power, governance – that make the core–periphery pattern possible; the following unit develops the core–periphery model itself in depth, including its semi-periphery variant and how individual places and countries can shift position within it over time.

VN **GIẢI THÍCH TIẾNG VIỆT**

Các mô hình đã học trong Unit này – các nút tập trung trong mạng lưới vận tải/thông tin, sự phân bổ giá trị không đồng đều trong chuỗi cung ứng TNC, quyền lực cứng/mềm/kinh tế/chính trị không đồng đều, và quản trị thương mại bất cân xứng – đều có thể tóm gọn qua khái niệm **lõi–ngoại vi (core–periphery)**: nền kinh tế toàn cầu có thể được mô tả như một **lõi** (core) giàu có, quyền lực cao (tập trung vốn, quyền quyết định, sản xuất giá trị cao, ảnh hưởng chính trị) và một **ngoại vi** (periphery) quyền lực thấp hơn, chủ yếu cung cấp tài nguyên, lao động và sản xuất giá trị thấp cho lõi, thường với điều kiện kém thuận lợi hơn. Unit tiếp theo sẽ phát triển đầy đủ mô hình lõi–ngoại vi này, bao gồm cả khái niệm "bán ngoại vi" (semi-periphery) và cách một quốc gia/nơi chốn có thể thay đổi vị trí theo thời gian.

8.10 Practice Questions

Câu 1 – Trắc nghiệm

Which of the following best defines globalisation?

(A) The process by which one single global government replaces national governments

(B) The increasing interconnectedness of places through growing flows of capital, labour, goods and information

(C) The exclusive spread of a single dominant culture to all other cultures worldwide

(D) A recent phenomenon that began only with the invention of the internet

Lời giải chi tiết

Correct answer: (B). Globalisation is defined precisely as the increasing interconnectedness and interdependence of places driven by growing flows of capital (FDI), labour (migration), goods (trade) and information (internet/media). (A) is wrong – globalisation does not create a single world government; national governments and borders persist. (C) is wrong – globalisation involves flows and exchange in multiple directions, not a one-way cultural takeover, even though cultural globalisation is one real dimension of the process. (D) is wrong – globalisation has deep historical roots (e.g. colonial-era trade networks, telegraph cables) that long predate the internet, even though its pace has accelerated dramatically in recent decades.

Câu 2 – Trắc nghiệm

"Time–space compression" refers to:

(A) Physical distances between places becoming literally shorter in kilometres

(B) The falling relative time and cost of moving people, goods, capital and information across a given distance

(C) A decline in the total volume of international trade and travel

(D) The introduction of time zones to standardise international schedules

Lời giải chi tiết

Correct answer: (B). Time–space compression describes how technological change (containerisation, jet travel, digital communication) has reduced the *relative* time and cost of covering a given distance – not the distance itself, which is unchanged (ruling out A). It describes a dramatic long-term *increase*, not decrease, in the volume of global movement (ruling out C), and it is unrelated to the administrative concept of time zones (ruling out D).

Câu 3 – Bài tập tính toán

"Nation Meridia" records an FDI inflow of $\$26$ billion and an FDI outflow of $\$64$ billion in a given year. Calculate the net FDI flow and classify the country as a net capital importer or net capital exporter.

Lời giải chi tiết

$$\text{Net FDI} = 26 - 64 = -\$\mathbf{38}\text{ billion.}$$

Because the result is negative, Nation Meridia is a **net capital exporter**: its firms invested $\$38$ billion more abroad than foreign firms invested within Meridia. This suggests Meridia has internationally active firms actively seeking growth, resources, or markets overseas, rather than being primarily a destination for inward foreign investment.

Câu 4 – Bài tập tính toán

"Nation Thalassa" records an FDI inflow of $\$71$ billion and an FDI outflow of $\$18$ billion. (a) Calculate the net FDI flow. (b) Explain why net FDI is a different measure from the trade balance, even though both are calculated as a difference between an inflow-type and outflow-type figure.

Lời giải chi tiết

(a)

$$\text{Net FDI} = 71 - 18 = +\$\mathbf{53}\text{ billion.}$$

Because net FDI is positive, Nation Thalassa is a **net capital importer**: it received $\$53$ billion more in foreign direct investment than its own firms invested abroad – the opposite position from a net capital exporter such as Republic of Kestrel above.

(b) Although both net FDI and the trade balance are calculated as an inflow-type figure minus an outflow-type figure, they measure fundamentally different things. **Net FDI** is a **capital/financial-account** concept: it records long-term investment and ownership decisions by firms and individuals – building a factory, acquiring a stake in a foreign company, financing infrastructure – reflecting judgements about where productive assets should be located over years or decades. The **trade balance**, by contrast, is a **current-account** concept: it records the flow of goods and services actually exchanged in a given year, driven by consumer demand, comparative advantage in production, and relative prices. Because these two accounts respond to different underlying decisions, a country can be a net capital importer while simultaneously running a trade surplus, or a net capital exporter while running a trade deficit – there is no necessary link between the sign of one and the sign of the other. In fact the two are often connected in the opposite direction to what intuition might suggest: countries running large and persistent trade deficits (importing far more goods and services than they export) are frequently also large net recipients of FDI and other capital inflows, because for-

eign capital inflows are precisely what allows a country to finance a trade deficit; conversely, countries that are large net capital *exporters* often generate the surplus domestic savings to invest abroad partly because they run trade surpluses. Net FDI and the trade balance should therefore always be treated as two separate, complementary indicators of a country's global economic position, not as two versions of the same measurement.

Câu 5 – Trắc nghiệm

Which of the following best describes a maritime "chokepoint" such as the Strait of Malacca?

(A) A deep-water port capable of handling the largest container ships afloat

(B) A narrow, geographically constrained sea passage through which a disproportionately large volume of global maritime trade must pass

(C) A regional trade bloc that restricts shipping between member states

(D) An international agreement setting minimum safety standards for container ships

Lời giải chi tiết

Correct answer: (B). A chokepoint is a narrow strait or canal (the Strait of Malacca, the Suez Canal, the Panama Canal) that concentrates an enormous share of global shipping into a physically constrained corridor, making it strategically critical and vulnerable to blockage or disruption. (A) is wrong – that describes a large container port (a node), not a narrow passage (a link constraint). (C) is wrong – a chokepoint is a physical geographic feature, not an institutional trade agreement. (D) is wrong – safety regulation is unrelated to the geographic concept of a chokepoint.

Câu 6 – Bài tập tính toán

In 2010, the Port of Shanghai handled approximately 29.0 million TEU (twenty-foot equivalent units) of containers. By 2023, it handled approximately 49.2 million TEU. (a) Calculate the absolute increase in TEU handled. (b) Calculate the percentage increase over the period. (c) Suggest one driver of globalisation that could plausibly help explain this growth.

Lời giải chi tiết

(a) Absolute increase $= 49.2 - 29.0 =$ **20.2** million TEU.

(b) Percentage increase:

$$\frac{20.2}{29.0} \times 100\% \approx \textbf{69.7}\%.$$

(c) Any well-justified driver is acceptable, for example: the continued expansion of **containerisation** and container-ship capacity lowering unit shipping costs; the growth of **global production networks** routing components and finished goods through Shanghai as a manufacturing and export hub; or the effect of **trade liberalisation** (falling tariffs, China's 2001 WTO accession) increasing the volume of Chinese manufactured exports moving through its ports.

Câu 7 – Tự luận

Explain how trade liberalisation and financial deregulation, alongside containerisation and information and communication technology (ICT), have acted as drivers of globalisation since the mid-twentieth century.

Lời giải chi tiết

Trade liberalisation – the progressive reduction of tariffs and other trade barriers, first through the General Agreement on Tariffs and Trade (GATT) and then its successor the WTO, together with the formation of regional trade blocs (EU, ASEAN, NAFTA/USMCA) – has made it cheaper and administratively easier for firms to buy and sell across borders, directly increasing the volume of the "goods" flow of globalisation. **Financial deregulation** – the relaxation, from the 1970s–1980s onward, of government controls on cross-border movements of capital, bank lending, and currency exchange – has allowed the "capital" flow (FDI, portfolio investment, bank lending) to move far more freely and in far larger volumes between countries than under the more tightly capital-controlled system that prevailed after 1945. These two policy-driven changes reinforced, and were reinforced by, the physical and technological drivers already discussed: **containerisation** cut the cost of physically shipping the goods that liberalised trade rules now made cheaper to trade, while **ICT** (the internet, mobile networks, electronic financial trading systems) allowed the huge volumes of capital freed by deregulation to be transferred, tracked and invested internationally within seconds. Together, policy liberalisation (trade and financial) and technological change (containerisation and ICT) are mutually reinforcing: falling barriers created the incentive to trade and invest internationally, while falling technological costs made acting on that incentive practically possible at a far larger scale than before.

Câu 8 – Trắc nghiệm

What is the main advantage of a hub-and-spoke airline network compared with a point-to-point network connecting the same number of cities?

(A) It requires far fewer total routes, allowing airlines to consolidate passengers onto larger, more fully-booked long-haul flights

(B) It always provides a shorter total journey time for every individual passenger

(C) It eliminates the need for any transfer or layover between flights

(D) It requires every city in the network to have an equally large population

Lời giải chi tiết

Correct answer: (A). By routing traffic through a small number of hubs, an airline needs only $n-1$ routes to connect n cities, rather than $n(n-1)/2$ for full point-to-point coverage, letting it fill fewer, larger aircraft on the busiest trunk routes and achieve economies of scale. (B) is wrong – passengers whose true origin and destination are not the hub itself typically face a *longer* total journey than a direct point-to-point flight would offer. (C) is wrong – hub-and-spoke journeys between two non-hub cities require passengers to change planes at the hub, the opposite of eliminating layovers. (D) is wrong – hub-and-spoke networks are specifically designed to serve smaller "spoke" cities that could not individually support a direct route, so equal population size is neither required nor typical.

Câu 9 – Bài tập tính toán

An airline wants to connect 10 cities. (a) Calculate the number of direct routes required for a pure point-to-point network. (b) Calculate the number of direct routes required for a hub-and-spoke network with one hub and 9 spokes. (c) Calculate how many times more routes the point-to-point network requires compared with the hub-and-spoke network.

Lời giải chi tiết

(a) Point-to-point:

$$\frac{n(n-1)}{2} = \frac{10 \times 9}{2} = \mathbf{45} \text{ routes.}$$

(b) Hub-and-spoke:

$$n - 1 = 10 - 1 = \mathbf{9} \text{ routes.}$$

(c)

$$\frac{45}{9} = \mathbf{5}.$$

The point-to-point network requires exactly 5 times as many direct routes as the hub-and-spoke network to connect the same 10 cities, illustrating why hub-and-spoke structures scale far more efficiently as the number of served cities grows.

Câu 10 – Trắc nghiệm

The "digital divide" refers to:

(A) The gap in internet/broadband access and digital device ownership between and within countries

(B) The physical distance between submarine fibre-optic cable landing stations

(C) The difference in standard time zones between two countries

(D) The declining total number of internet users worldwide

Lời giải chi tiết

Correct answer: (A). The digital divide is precisely the persistent inequality in access to the internet, broadband infrastructure and digital devices, both between countries and within them (urban/rural, rich/poor, young/old). (B) is wrong – cable landing-station geography is a physical network detail, not the definition of the divide itself. (C) is wrong – time zones are an administrative convention unrelated to digital access. (D) is wrong – global internet use has risen dramatically for decades, not declined; the divide concerns unequal *access*, not a shrinking total.

Câu 11 – Tự luận

Discuss the factors that influence where a transnational corporation chooses to locate different stages of its production, using the concept of a "footloose" industry in your answer.

Lời giải chi tiết

TNCs weigh several locational factors when deciding where to place each stage of production. **Labour cost** favours locating labour-intensive stages (assembly) in countries with lower wages; **market access** favours locating final assembly or distribution close to large consumer markets to reduce shipping cost and time; **specialised skills or technology clusters** favour locating high-value stages (component fabrication, R&D) in countries with the relevant expertise (for example, Taiwan for advanced semiconductor fabrication); and **regulatory environment** (tax incentives, labour law, environmental standards) can make some countries more attractive hosts than others for a given stage. The concept of a **footloose industry** is central to understanding why some stages relocate far more readily than others: footloose activities (such as electronics assembly) are not tied to a specific raw-material source, energy supply, or local

market, so a TNC can and often does move them relatively quickly to whichever country currently offers the best combination of low labour cost, incentives and logistics – as illustrated by the periodic shifting of assembly contracts between contract manufacturers and countries in the Apple supply chain. By contrast, some stages are inherently *not* footloose: an aluminium smelter must remain near cheap, abundant electricity, and a mining or agricultural processing operation must remain near the resource itself, regardless of labour costs elsewhere. Overall, the more footloose a stage of production is, the more its location is determined by cost and policy factors that can change quickly, and the more vulnerable a host country's employment in that stage is to being relocated elsewhere in future.

Câu 12 – Bài tập tính toán

A garment retailer sells a T-shirt for $\$40$ at retail. Based on typical industry cost breakdowns, suppose: raw cotton and fabric cost approximately $\$5$; cutting, sewing and assembly labour (paid in a low-wage garment-exporting country) costs approximately $\$3$; freight and logistics cost approximately $\$2$. (a) Calculate the total manufacturing and logistics cost. (b) Calculate the value captured by the brand-owning/retailing company. (c) Express the assembling country's labour share and the brand/retailer's share as percentages of the retail price.

Lời giải chi tiết

(a) Total manufacturing and logistics cost $= 5 + 3 + 2 = \$\mathbf{10}$.

(b) Value captured by the brand/retailer $= 40 - 10 = \$\mathbf{30}$.

(c) Assembling country's labour share $= \dfrac{3}{40} \times 100\% = \mathbf{7.5}\%$. Brand/retailer's share $= \dfrac{30}{40} \times 100\% = \mathbf{75}\%$.

As with the smartphone example earlier in this unit, the country performing the physically visible, labour-intensive assembly work captures only a small share (7.5%) of the final retail value, while the brand-owning, design and retail company – typically based in a high-income country – captures the large majority (75%) through its control of design, marketing and distribution channels rather than physical production.

Câu 13 – Trắc nghiệm

Which statement correctly distinguishes "outsourcing" from "offshoring"?

(A) Outsourcing always involves moving production to another country, while offshoring never does

(B) Outsourcing means contracting a stage of production out to an independently-owned company, while offshoring means relocating a stage of production to a different country, which may still be carried out in-house

(C) Outsourcing and offshoring are simply two different names for exactly the same process

(D) Offshoring applies only to service-sector jobs, while outsourcing applies only to manufacturing jobs

Lời giải chi tiết

Correct answer: (B). Outsourcing concerns *ownership* (contracting work to a separate company, domestic or foreign), while offshoring concerns *location* (moving a stage abroad, whether

kept in-house within the same TNC or simultaneously outsourced) – the two describe different, independent dimensions of a sourcing decision, so a stage of production can be offshored without being outsourced (an in-house foreign subsidiary) or outsourced without being offshored (a domestic contractor). (A) is wrong – outsourcing does not require crossing a border at all. (C) is wrong – conflating the two obscures the important distinction between ownership and location. (D) is wrong – both terms apply equally to manufacturing and to services (for example, offshored/outsourced customer-service call centres).

Câu 14 – Tự luận

Using the concepts of backward and forward linkages, explain why some host countries benefit more than others from hosting the same amount of TNC investment.

Lời giải chi tiết

The economic benefit a host country gains from TNC investment depends heavily on how well that investment connects to the rest of the domestic economy, not merely on the size of the investment itself. A **backward linkage** exists where the TNC's local operation sources inputs, components or services from domestic suppliers; strong backward linkages mean local firms grow, gain technical know-how and employment expands beyond the TNC's own payroll, multiplying the investment's economic impact across the host economy. A **forward linkage** exists where the TNC's output becomes an input for other domestic firms further down the value chain; strong forward linkages allow domestic industries to develop around processing or using what the TNC produces, again spreading benefit beyond the TNC itself. Where a TNC investment has *weak* backward and forward linkages – for example, an assembly plant that imports nearly all its components from abroad and exports its entire output directly, with minimal purchase from or sale to domestic firms – it functions as an economic "enclave": it may still generate direct employment and export revenue, but comparatively little of its economic activity spills over into the wider domestic economy, and the host country's development benefit is correspondingly limited compared with an equivalent investment that is deeply linked to local suppliers and downstream users.

Câu 15 – Trắc nghiệm

A country provides substantial military aid to an ally, on condition that the ally supports its foreign-policy positions in international forums. This is best classified as:

(A) Soft power, because it is conducted through diplomatic channels

(B) Hard power, because it relies on a conditional material inducement rather than genuine attraction

(C) Neither hard nor soft power, since no military force is actually used

(D) Purely economic power, unrelated to the hard/soft power distinction

Lời giải chi tiết

Correct answer: (B). What determines the category is the *mechanism* of influence, not the setting in which it occurs: conditional military aid is a material inducement (a "carrot" tied to compliance) exactly of the kind Joseph Nye classifies as hard power, even though it is negotiated through diplomatic channels. (A) is wrong – being conducted diplomatically does not make a conditional, coercive-style inducement into soft power; soft power requires attraction, not conditionality. (C) is wrong – hard power includes the threat, promise or provision of mil-

itary and economic inducements, not only the direct use of force. (D) is wrong – while it has an economic dimension (aid), its defining feature here is the coercive/inducement mechanism, which places it squarely within the hard-power category.

Câu 16 – Tự luận / Thảo luận

To what extent can China's Belt and Road Initiative be considered primarily an exercise of soft power rather than hard power? Refer to the Hambantota Port case study in your answer.

Lời giải chi tiết

There is a genuine case for both readings, and a strong answer should weigh them rather than assert one side only. **The case for soft power:** the BRI funds infrastructure – ports, railways, power plants – that many partner countries want and could not otherwise easily afford, generating goodwill, diplomatic access, and a positive association with China as a development partner; to that extent it functions like a large-scale, attraction-based influence campaign, not unlike the soft-power effect of cultural exports, operating instead through the appeal of tangible development assistance. **The case for hard/economic power:** critics of "debt-trap diplomacy" argue that when a BRI-financed project (such as Hambantota Port) cannot generate enough revenue to service its debt, China can extract a material, coercive-style outcome – as happened when Sri Lanka ceded a 99-year operating lease over the port to a Chinese state-owned company in 2017 – which resembles conditional economic leverage (a material outcome extracted from a position of financial strength) more than attraction-based soft power. On balance, the BRI is best understood as a mixed instrument: its public framing and much of its day-to-day operation function as soft power (attracting partners through infrastructure provision), while the debt dynamics exposed in cases like Hambantota reveal an economic-power dimension that can shade into outcomes usually associated with harder forms of influence – consistent with the observation, noted earlier in this unit, that real-world diplomacy frequently blends hard and soft power ("smart power") rather than falling cleanly into one category. A complete answer should also note the contested counter-view that Hambantota's outcome reflected Sri Lanka's broader debt mismanagement rather than a deliberate Chinese strategy, which would weaken the "hard power/coercion" reading.

Câu 17 – Bài tập tính toán

A UN Security Council resolution receives 13 votes in favour and 2 against, out of 15 members; one of the "no" votes is cast by France (a P5 member) and the other by a non-permanent member. (a) Does the resolution pass? Explain. (b) Suppose instead that only the non-permanent member had voted against, with France voting in favour. Would the resolution then pass? State the general voting rule that applies in the absence of any P5 veto.

Lời giải chi tiết

(a) The resolution **fails**, despite a 13-to-2 majority in favour, because France, as one of the five permanent members, can **veto** any substantive resolution with a single "no" vote, regardless of how large the majority in favour is.

(b) If France instead voted in favour, no P5 member would have vetoed the resolution. In that case the general rule applies: a UNSC resolution on substantive matters passes if it receives at least 9 **affirmative votes out of** 15, *provided* none of the five permanent members casts a "no" vote. With 13 (or, in this revised scenario, 14) votes in favour and no P5 veto, the threshold of 9 affirmative votes is comfortably met, so the resolution **would pass**. This illustrates that

Security Council decision-making requires *both* a numerical majority (at least 9 of 15) *and* the absence of any P5 veto – satisfying only one of these two conditions is not sufficient.

Câu 18 – Trắc nghiệm

Which of the following is a core function of the WTO that is not typically performed by the G7 or the G20?

(A) Coordinating informal policy dialogue among the leaders of major economies

(B) Adjudicating formal trade disputes between member states through a binding dispute-settlement process

(C) Providing an annual forum for cultural exchange between nations

(D) Enforcing United Nations Security Council resolutions

Lời giải chi tiết

Correct answer: (B). The WTO's dispute-settlement process is a formal, rules-based mechanism through which a member state can bring a case against another member and obtain a binding ruling with authorised remedies – a function neither the G7 nor the G20 perform, since both are informal forums without treaty-based binding authority. (A) is wrong – informal leader-level policy coordination is precisely what the G7 and G20 do, not a distinctive WTO function. (C) is wrong – neither the WTO, G7 nor G20 has cultural exchange as a stated function. (D) is wrong – enforcing UNSC resolutions falls under the UN system, not the WTO, G7 or G20.

Câu 19 – Tự luận

Compare the G7 and the G20 in terms of their membership, their formal authority, and how representative each is of the global economy as a whole.

Lời giải chi tiết

Membership: the G7 comprises seven major advanced economies (the United States, the United Kingdom, France, Germany, Italy, Japan and Canada, with the EU also participating), while the G20 includes all G7 members plus major emerging economies (China, India, Brazil, Indonesia, Mexico, South Africa, Saudi Arabia, Turkey, South Korea, Argentina, Australia and Russia) together with the EU – a substantially larger and more economically diverse membership. **Formal authority:** neither forum has a treaty basis or binding legal authority (unlike the WTO or a UNSC resolution); both rely entirely on political consensus among their members and on those members' own subsequent domestic implementation, meaning neither can compel non-member compliance or enforce its own decisions. **Representativeness:** because it includes major emerging economies alongside the traditional advanced-economy grouping, the G20 collectively represents a substantially larger share of world GDP, population and trade than the G7 alone, and better reflects a global economy in which emerging economies (especially China and India) now account for a large and growing share of world output – which is precisely why the G20 was elevated to leaders'-level status after the 2008 financial crisis, reflecting the recognition that the G7 alone could no longer credibly coordinate global economic policy.

Câu 20 – Bài tập tính toán

"Nation D" records exports of $\$55$ billion and imports of $\$80$ billion in a year in which its GDP is $\$500$ billion. (a) Calculate Nation D's trade balance. (b) Calculate its trade-dependency ratio. (c) Interpret both results together.

Lời giải chi tiết

(a) Trade balance $= 55 - 80 = -\$\mathbf{25}$ billion (a trade deficit).

(b) Trade-dependency ratio:

$$\frac{55 + 80}{500} \times 100\% = \frac{135}{500} \times 100\% = \mathbf{27}\%.$$

(c) Nation D runs a moderate trade deficit (importing $\$25$ billion more than it exports) but has a comparatively *low* trade-dependency ratio of 27%, meaning trade (exports plus imports combined) makes up only just over a quarter of the value of its total economy. This combination suggests a large, relatively diversified economy in which international trade, while giving rise to a deficit, is not the dominant driver of overall economic activity – a global trade shock would affect Nation D far less severely, in relative terms, than a small, highly trade-dependent economy with a similar trade balance.

Câu 21 – Bài tập tính toán

"Nation E" receives $\$12$ billion in remittance inflows in a year in which its GDP is $\$60$ billion. (a) Calculate remittances as a percentage of GDP. (b) Explain one benefit and one risk this level of remittance dependence creates for Nation E.

Lời giải chi tiết

(a)

$$\frac{12}{60} \times 100\% = \mathbf{20}\%.$$

(b) Benefit: remittances equivalent to a fifth of GDP represent a very large, relatively stable inflow of foreign currency and household income, which can reduce poverty, fund household consumption, education and small-business investment, without requiring Nation E to attract FDI or expand exports of goods. **Risk:** because this income depends on economic and policy conditions in the *destination* countries where Nation E's migrants work, an economic downturn, rise in unemployment, or restrictive migration policy change abroad can sharply reduce remittance inflows with little warning, transmitting an external shock directly into Nation E's household incomes and domestic economy – a vulnerability distinctive to labour-export-based integration into the global economy, as opposed to trade- or FDI-based integration.

Câu 22 – Trắc nghiệm

Which regional trade bloc has achieved the deepest level of economic integration, including a genuine single market and free movement of labour among member states?

(A) ASEAN
(B) USMCA
(C) The European Union
(D) The G20

Lời giải chi tiết

Correct answer: (C). The EU's single market is built on the "four freedoms" – free movement of goods, services, capital *and labour* – across internal borders, a depth of integration no other bloc listed has achieved. (A) is wrong – ASEAN promotes regional economic cooperation and reduced internal tariffs but with looser integration than the EU, and without a single market or free movement of labour on the EU model. (B) is wrong – USMCA is a free trade agreement eliminating most tariffs among the US, Mexico and Canada, but it does not create a single market or free movement of labour between the three countries. (D) is wrong – the G20 is an informal policy-coordination forum, not a regional trade bloc at all, and has no internal free-trade or free-movement provisions.

Câu 23 – Tự luận / Thảo luận

Evaluate the extent to which the concept of "debt-trap diplomacy" accurately describes the case of Hambantota Port.

Lời giải chi tiết

Evidence supporting the debt-trap diplomacy reading: Hambantota Port was built substantially with loans from Chinese state banks for a project that struggled from an early stage to attract sufficient shipping traffic to generate revenue for debt servicing; when Sri Lanka's broader external debt difficulties deepened, it ceded a 99-year operating lease over the port to China Merchants Port Holdings, a Chinese state-owned company, in exchange for debt relief – an outcome that, on its face, matches the "debt-trap" narrative of a lower-income borrower losing long-term strategic control of an asset it could not afford to service. **Evidence complicating this reading:** some analysts argue that Sri Lanka's debt crisis stemmed mainly from a much larger accumulation of international sovereign bond debt, owed largely to private, non-Chinese bondholders, and from domestic macroeconomic mismanagement, rather than from the Hambantota loan specifically, which formed only a modest share of Sri Lanka's total external debt; on this reading, the port lease was one negotiated response to a much broader debt crisis rather than proof of a deliberate Chinese strategy of extracting strategic assets through lending. **Evaluation:** the Hambantota case does demonstrate a real and important risk of concentrated infrastructure borrowing from a single foreign creditor – the possibility of losing long-term control of a strategic asset under debt distress – and this risk is a legitimate, generalisable lesson for other BRI recipient countries. However, treating it as clear proof of a deliberate, premeditated Chinese "debt-trap" strategy overstates what the evidence shows, since the underlying causes of Sri Lanka's debt crisis were broader than this single loan and the immediate purpose of the original loan (port development) does not, by itself, establish strategic intent. A balanced answer should conclude that the case illustrates a genuine structural risk of BRI-style lending, while treating the strongest "debt-trap diplomacy" framing as a contested rather than settled interpretation.

Câu 24 – Tự luận

Using the examples of agricultural subsidies and tariff escalation, explain how global trade rules can systematically disadvantage developing countries even when formal WTO rules apply equally to all member states.

Lời giải chi tiết

Formal equality of rules does not guarantee equality of outcomes, because the same rules can interact very differently with economies that have different starting positions. **Agricultural subsidies:** high-income countries (the US, EU members under the Common Agricultural Policy) are permitted, within WTO rules, to subsidise their domestic farmers; this allows those farmers to sell into world markets at prices below their true cost of production, undercutting smallholder farmers in developing countries who receive no comparable subsidy and cannot compete on price, as in the long-running cotton dispute raised by the West African "Cotton Four" at the WTO. **Tariff escalation:** many high-income countries apply low or zero tariffs to raw commodities but substantially higher tariffs to the processed version of the same commodity; because developing countries disproportionately export raw commodities, this structure discourages them from developing higher-value domestic processing and manufacturing industries, since the processed product would face a tariff penalty in the very markets it would need to access. In both cases, the formal WTO rule (permitting subsidies within limits; permitting each country to set its own external tariff schedule) applies equally on paper to every member state, yet the *practical effect* systematically favours high-income countries – which have the fiscal capacity to subsidise farmers and the established processing industries the tariff structure protects – over developing countries, which typically lack that fiscal capacity and are structurally discouraged from moving up the value chain. This illustrates a general principle in global governance: rules that are procedurally neutral can still produce substantively unequal outcomes when the parties subject to them start from very different economic positions.

Câu 25 – Trắc nghiệm

Which of the following best characterises a "peripheral" region within the core–periphery framework?

(A) A region that concentrates high-value decision-making, finance and political power

(B) A region that primarily supplies raw materials, low-cost labour and low-value manufacturing to more powerful regions, often on unfavourable terms

(C) A region defined solely by having a large total population

(D) A region that holds a veto at the UN Security Council

Lời giải chi tiết

Correct answer: (B). A peripheral region, in the core–periphery framework, chiefly supplies resources, labour and low-value production to the dominant core, typically on less favourable terms than the core enjoys, and holds comparatively little decision-making power over the terms of that exchange. (A) is wrong – concentrating high-value decision-making, finance and political power describes the **core**, not the periphery, and is the direct opposite of the correct answer. (C) is wrong – population size alone does not determine core or peripheral status; a peripheral region can be large or small in population. (D) is wrong – holding a UNSC veto is a marker of concentrated political power characteristic of core states, not peripheral ones.

Câu 26 – Tự luận / Thảo luận

Evaluate the claim that globalisation, on balance, reduces inequalities of power between countries. Refer to at least three of the following in your answer: TNC value capture along global

production networks, hard/soft/economic/political power, global governance institutions, and unequal global trade rules.

Lời giải chi tiết

The case that globalisation reduces power inequalities: globalisation has allowed some previously peripheral economies to industrialise rapidly by attracting TNC investment and inserting themselves into global production networks (as with the manufacturing-led growth of several East and Southeast Asian economies), has given a wider range of countries a voice in global economic coordination through the elevation of the G20 (which includes major emerging economies) alongside the G7, and has allowed emerging economies to build the economic power (measured by rising GDP and trade shares) that underlies greater influence in institutions such as the WTO and IMF than they held several decades ago. **The case that globalisation entrenches or worsens power inequalities:** value capture along TNC global production networks remains highly uneven, with design, branding and intellectual property (concentrated overwhelmingly in high-income countries) capturing the large majority of value, while assembly and raw-material-producing countries capture only a small share, as shown by the smartphone and T-shirt value-chain calculations earlier in this unit; formal political power remains concentrated in a small number of states through mechanisms such as the UNSC veto, held by only five countries regardless of the scale of economic change elsewhere; and global trade governance can produce systematically unequal outcomes even under formally equal rules, as shown by agricultural subsidies and tariff escalation, which continue to disadvantage developing-country producers within a rules-based system that nominally applies to all WTO members alike. **Evaluation:** the evidence supports a nuanced conclusion rather than a simple yes/no answer – globalisation has measurably shifted *economic* power toward some previously peripheral states (most clearly emerging Asian economies), but has done comparatively little to redistribute the *political* power embedded in institutions such as the UNSC, and the *value-capture* and *trade-rule* evidence suggests that much of the core–periphery structure described in this unit persists even as absolute living standards rise in many peripheral and semi-peripheral regions. A strong answer should therefore distinguish between different *types* of power (economic, political, hard, soft) and argue that globalisation's effect on inequality is uneven across these types, rather than claiming it straightforwardly increases or decreases power inequality overall.

Global Interactions II: Human Development, Diversity and Global Risks and Resilience

HIGHER LEVEL (HL) EXTENSION

Mục tiêu Unit: Sau khi hoàn thành Unit 9, học sinh có thể: phân biệt các thước đo phát triển kinh tế cơ bản (GDP, GNI bình quân đầu người theo ngang giá sức mua — PPP) và những hạn chế của chúng; giải thích cách tính Chỉ số Phát triển Con người (HDI) qua trung bình nhân của ba chỉ số thành phần (y tế, giáo dục, thu nhập); mô tả Chỉ số Bất bình đẳng Giới (GII) và Chỉ số Nghèo Đa chiều (MPI) cùng các chiều đo lường của từng chỉ số; trình bày và phê phán Đường Brandt (1980) như một cách phân chia Bắc–Nam mang tính lịch sử, nay đã lỗi thời; giải thích Lý thuyết Hệ thống Thế giới của Wallerstein với ba nhóm quốc gia lõi — bán ngoại vi — ngoại vi và khái niệm trao đổi không ngang giá; phân tích cuộc tranh luận giữa đồng nhất hoá văn hoá (cultural homogenisation) và hiện tượng glocalisation trong bối cảnh toàn cầu hoá, cùng vai trò của các phong trào quyền bản địa; đánh giá bất bình đẳng trong tiếp cận thị trường và công nghệ qua khoảng cách số, tình trạng không tiếp cận dịch vụ tài chính, và rào cản thuế quan; định nghĩa rủi ro toàn cầu (global risk) và phân tích các trường hợp cụ thể (đại dịch COVID-19, khủng hoảng tài chính toàn cầu 2007–2008, sự cố kênh đào Suez 2021, dịch Ebola Tây Phi 2014–2016); và áp dụng khung khái niệm khả năng chống chịu (resilience) — phơi nhiễm, tính dễ tổn thương, năng lực thích ứng — cùng các chiến lược xây dựng khả năng chống chịu cho tương lai.

9.1 Measuring Development

9.1.1 GDP and GNI per Capita at Purchasing Power Parity

Gross Domestic Product (GDP) is the total market value of all final goods and services produced within a country's borders in a given period, usually one year, regardless of who owns the factors of production that generated that output. **Gross National Income (GNI)** — the successor to the older term Gross National Product (GNP) — instead measures the total income earned by a country's own residents and firms wherever in the world that income is earned: GNI is calculated as GDP plus net income received from abroad (wages, profits, interest and dividends earned by residents on overseas investments and employment) minus the equivalent income paid abroad to foreign owners of factors of production located within the country. Dividing either measure by total population produces a simple, widely available average figure, **GDP per capita** or **GNI per capita**, that is routinely used as a first, headline indicator of a country's average economic output or income.

Raw GDP or GNI figures are conventionally converted between national currencies using market **exchange rates**, but exchange rates fluctuate for reasons that have little to do with the relative cost of living inside each country — capital flows, interest-rate differentials, and speculative currency trading can all move an exchange rate independently of how much a unit of local currency actually buys locally. **Purchasing power parity (PPP)** adjustment corrects for this distortion: GNI (or GDP) per capita PPP is expressed in a common unit, the **international dollar**, defined so that it has the same purchasing power over a broadly comparable basket of goods and services in every country, rather than simply reflecting the prevailing market exchange rate. Because the prices of many non-traded

goods and services (local transport, housing, personal services, unskilled labour) tend to be considerably lower in lower-income countries than in high-income countries, PPP-adjusted GNI per capita figures for lower-income countries are typically substantially higher than their exchange-rate-based equivalents. PPP conversion is now the standard basis on which international organisations such as the World Bank, the IMF, and the UNDP present cross-country income comparisons, including as the income component of the Human Development Index discussed below.

Despite their convenience as a single-number summary of the overall scale of a country's economic activity, GDP and GNI per capita carry several well-documented limitations. First, without PPP adjustment, headline exchange-rate-based figures can substantially overstate or understate a country's real purchasing power, and even PPP conversion itself rests on an internationally standardised basket of goods and services (compiled through the International Comparison Program) that is necessarily an approximation, since the relative importance and local availability of specific goods varies from country to country. Second, GDP and GNI are **value-neutral**: every measure simply totals the market value of final output, with no distinction between output that reflects genuine improvement and output that is merely a costly response to a prior loss — reconstruction spending after a natural disaster, clean-up spending following an industrial accident, and rising healthcare expenditure on a growing burden of chronic illness all register as positive additions to GDP in exactly the same way as the production of a new hospital or a new factory. Third, these measures place no value on the depletion of a country's natural-resource base: a country that draws down its forests, fisheries, soils, or mineral reserves at an unsustainable rate can post strong short-term GDP growth even while its underlying long-run productive capacity is quietly being eroded. Finally, GDP and GNI estimates depend on the statistical capacity of each country's national accounts office, and that capacity varies considerably around the world, so headline figures — particularly for countries with less-developed statistical systems — are best treated as informed estimates rather than exact, error-free values.

VN **GIẢI THÍCH TIẾNG VIỆT**

GDP là tổng giá trị thị trường của hàng hoá và dịch vụ cuối cùng sản xuất *trong biên giới* một quốc gia; **GNI** (trước đây gọi là GNP) đo tổng *thu nhập* mà công dân và doanh nghiệp của quốc gia đó kiếm được ở bất kỳ đâu trên thế giới (GDP cộng thu nhập ròng từ nước ngoài). Vì tỉ giá hối đoái thị trường biến động vì nhiều lý do không liên quan đến mức giá sinh hoạt thực tế, các tổ chức quốc tế thường quy đổi GNI/GDP bình quân đầu người theo **ngang giá sức mua (PPP)** — dùng đơn vị "đô la quốc tế" có sức mua tương đương ở mọi quốc gia — để so sánh công bằng hơn giữa các nước có mức giá sinh hoạt khác nhau. Hạn chế của GDP/GNI: (1) nếu không quy đổi PPP, số liệu theo tỉ giá thị trường có thể sai lệch nghiêm trọng; (2) các chỉ số này **trung lập về giá trị** — không phân biệt sản lượng "tốt" hay "xấu" (chi phí tái thiết sau thiên tai cũng được cộng vào GDP như một khoản đầu tư mới); (3) không phản ánh việc khai thác cạn kiệt tài nguyên thiên nhiên hay suy thoái môi trường; (4) phụ thuộc vào năng lực thống kê quốc gia, vốn không đồng đều giữa các nước.

Ví dụ mẫu · Nominal versus PPP-adjusted GNI per capita

Country M has a nominal (market exchange-rate) GNI per capita of \$2 800, but its PPP-adjusted GNI per capita is \$7 900. Country N has a higher nominal GNI per capita of \$3 400, but a PPP-adjusted figure of only \$6 100. (a) Calculate the ratio of PPP-adjusted to nominal GNI per capita for each country. (b) Explain why PPP adjustment reverses the ranking between the two countries, and what this implies about relative price levels.

(a) Country M: $7\,900 \div 2\,800 \approx$ **2.82**. Country N: $6\,100 \div 3\,400 \approx$ **1.79**.

(b) Under market exchange rates, Country N looks richer per capita (\$3 400 vs. \$2 800). Once incomes are converted to reflect what they can actually buy locally, Country M overtakes

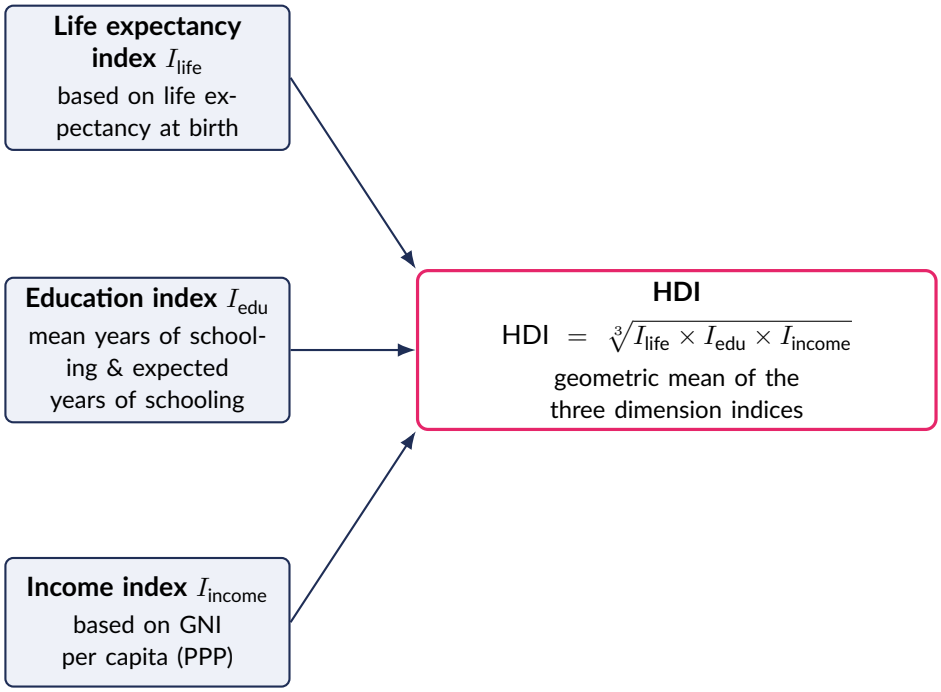
Country N ($7 900 vs. $6 100). The much larger PPP-to-nominal ratio for Country M (2.82 versus 1.79) indicates that the general price level for non-traded goods and services in Country M is considerably lower relative to Country N — a nominal unit of Country M's currency converts, at the market exchange rate, into far less purchasing power than it actually commands inside Country M's own economy. This is a common pattern for many lower- and middle-income economies, and it is exactly the distortion that PPP conversion is designed to correct before cross-country comparisons (such as the income component of the HDI) are made.

9.1.2 The Human Development Index (HDI)

Recognising that GDP and GNI per capita capture only the economic-output dimension of a country's development, the United Nations Development Programme (UNDP) introduced the **Human Development Index (HDI)** in its first Human Development Report in 1990, explicitly built on the premise that development should be judged by the range of opportunities and freedoms available to people, not by economic output alone. The HDI is a **composite index** combining three dimension indices, each first normalised onto a scale from 0 to 1 using a fixed minimum and maximum reference value for that dimension: a **life expectancy index** (I_{life}), built from life expectancy at birth; an **education index** (I_{edu}), built from an equally-weighted average of two separate measures — **mean years of schooling** (the average number of years of education actually completed by adults aged 25 and over) and **expected years of schooling** (the number of years of schooling a child entering school today could expect to receive, given current enrolment patterns); and a **GNI-per-capita index** (I_{income}), built from GNI per capita at PPP, using a logarithmic transformation to reflect the fact that an additional dollar of income tends to matter less to overall well-being at high income levels than at low income levels. The three dimension indices are then combined not by a simple arithmetic average but by their **geometric mean**:

$$\text{HDI} = \sqrt[3]{I_{\text{life}} \times I_{\text{edu}} \times I_{\text{income}}}\,.$$

Using the geometric mean rather than an arithmetic average has an important consequence: a very low score in any single dimension pulls the overall HDI down more severely than an arithmetic average would, because the three dimensions are treated as only **partially substitutable** for one another — a country cannot fully compensate for very poor health or very poor education outcomes simply by having a high income. Published HDI values are conventionally grouped into four bands: **very high human development** (HDI ≥ 0.800), **high human development** (0.700–0.799), **medium human development** (0.550–0.699), and **low human development** (below 0.550).



The Human Development Index combines a life expectancy index, an education index (itself an average of mean years of schooling and expected years of schooling), and a GNI-per-capita income index, using the geometric mean rather than a simple average — so a very low score in any one dimension cannot be fully offset by high scores in the other two.

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HDI (UNDP, lần đầu công bố năm 1990) là chỉ số tổng hợp gồm ba chỉ số thành phần đã chuẩn hoá về thang 0–1: **chỉ số tuổi thọ** (dựa trên tuổi thọ trung bình khi sinh), **chỉ số giáo dục** (trung bình của số năm đi học bình quân thực tế và số năm đi học kỳ vọng), và **chỉ số thu nhập** (dựa trên GNI bình quân đầu người theo PPP, có biến đổi logarit). Ba chỉ số này được kết hợp bằng **trung bình nhân (geometric mean)** chứ không phải trung bình cộng: $\text{HDI} = \sqrt[3]{I_{\text{life}} \times I_{\text{edu}} \times I_{\text{income}}}$. Vì dùng trung bình nhân, một chỉ số thành phần quá thấp sẽ kéo HDI tổng thể xuống mạnh hơn nhiều so với trung bình cộng — thu nhập cao không thể "bù đắp hoàn toàn" cho y tế hay giáo dục quá yếu kém. Bốn mức phân loại: rất cao (≥ 0.800), cao (0.700–0.799), trung bình (0.550–0.699), thấp (< 0.550).

Ví dụ mẫu · Calculating HDI from given dimension indices

A hypothetical country has a life expectancy index of $I_{\text{life}} = 0.850$, an education index of $I_{\text{edu}} = 0.720$, and an income index of $I_{\text{income}} = 0.790$. Calculate its HDI and state its human development category.

Apply the geometric mean formula. First find the product of the three indices:

$$I_{\text{life}} \times I_{\text{edu}} \times I_{\text{income}} = 0.850 \times 0.720 \times 0.790 = 0.483.$$

Then take the cube root:

$$\text{HDI} = \sqrt[3]{0.483} \approx \mathbf{0.785}.$$

Since $0.700 \leq 0.785 < 0.800$, this country falls into the **high human development** category — close to, but just below, the "very high" threshold of 0.800.

Ví dụ mẫu · Building the HDI from raw indicator data

A country reports the following raw data: life expectancy at birth $= 72$ years; mean years of schooling $= 8.2$ years; expected years of schooling $= 13.5$ years; GNI per capita (PPP) $= \$9\,500$. Using the standard UNDP reference (minimum/maximum) values — life expectancy: 20 to 85 years; mean years of schooling: 0 to 15 years; expected years of schooling: 0 to 18 years; GNI per capita: $\$100$ to $\$75\,000$ (logarithmic scale) — calculate the country's HDI.

Life expectancy index:

$$I_{\text{life}} = \frac{72 - 20}{85 - 20} = \frac{52}{65} = 0.800.$$

Education index (average of the two normalised schooling measures):

$$\frac{8.2}{15} = 0.547, \qquad \frac{13.5}{18} = 0.750, \qquad I_{\text{edu}} = \frac{0.547 + 0.750}{2} = 0.648.$$

Income index (logarithmic transformation):

$$I_{\text{income}} = \frac{\ln(9\,500) - \ln(100)}{\ln(75\,000) - \ln(100)} = \frac{9.159 - 4.605}{11.225 - 4.605} = \frac{4.554}{6.620} \approx 0.688.$$

Combine by geometric mean:

$$\text{HDI} = \sqrt[3]{0.800 \times 0.648 \times 0.688} = \sqrt[3]{0.357} \approx \mathbf{0.709}.$$

This places the country just inside the **high human development** band, only narrowly above the boundary with "medium human development" (0.700) — illustrating how a country's overall HDI category can be sensitive to modest changes in any one underlying indicator, and why single-indicator comparisons (e.g., income alone) can be misleading about a country's broader development position.

(!) Lỗi thường gặp: Nhiều học sinh nhầm lẫn **GDP/GNI bình quân đầu người** với **HDI** — hai khái niệm hoàn toàn khác nhau. GDP/GNI bình quân đầu người chỉ là *một* thước đo kinh tế đơn lẻ (đôi khi là một trong ba thành phần cấu tạo nên HDI thông qua chỉ số thu nhập), trong khi HDI là chỉ số *tổng hợp* kết hợp thu nhập với tuổi thọ và giáo dục qua trung bình nhân. Một quốc gia có thể có GNI bình quân đầu người cao nhưng HDI chỉ ở mức trung bình nếu tuổi thọ hoặc giáo dục yếu kém — do đó không được viết "GDP bình quân đầu người cao nghĩa là HDI cao" trong bài thi, mà phải luôn nêu rõ cả ba thành phần.

9.1.3 The Gender Inequality Index (GII)

The **Gender Inequality Index (GII)**, also produced by the UNDP, reflects the loss in human development that results from disparities between men and women across three dimensions: **reproductive health** (measured through the maternal mortality ratio — deaths per $100\,000$ live births from causes related to pregnancy and childbirth — and the adolescent birth rate); **empowerment** (measured through the share of parliamentary seats held by women, and the share of adult men and women who have attained at least a secondary level of education); and **labour-market participation** (measured through the labour force participation rate for men compared with women). The GII ranges from 0 (women and men fare equally across all three dimensions) to 1 (women fare as poorly as possible relative to men across all three dimensions), so unlike the HDI, a *higher* GII value indicates *greater* gender inequality, not better performance. Because it is built from gaps between male and female outcomes rather than from absolute income or output, the GII can highlight substantial gender disparities even in countries with comparatively high overall HDI scores, and conversely can

show relatively modest gender gaps in some countries with lower overall HDI — the two indices measure genuinely different things and do not necessarily move together.

VN **GIẢI THÍCH TIẾNG VIỆT**

GII (UNDP) đo mức độ **bất bình đẳng giới** qua ba chiều: **sức khoẻ sinh sản** (tỉ suất tử vong mẹ, tỉ suất sinh ở tuổi vị thành niên), **trao quyền** (tỉ lệ ghế trong quốc hội do phụ nữ nắm giữ, tỉ lệ đạt trình độ trung học trở lên), và **tham gia thị trường lao động** (tỉ lệ tham gia lực lượng lao động của nam so với nữ). GII chạy từ 0 (bình đẳng hoàn toàn) đến 1 (bất bình đẳng tối đa) — **lưu ý ngược với HDI**: GII *càng cao* nghĩa là bất bình đẳng giới *càng nghiêm trọng*. GII và HDI đo hai khía cạnh khác nhau của phát triển nên không nhất thiết tương quan cùng chiều — một quốc gia có HDI cao vẫn có thể có GII cao nếu tồn tại khoảng cách giới lớn.

Ví dụ mẫu · Comparing two countries' gender-inequality profiles

The table below gives simplified GII-related indicators for two countries.

Indicator	Country P	Country Q
Maternal mortality ratio (per $100\,000$ live births)	550	12
Adolescent birth rate (per $1\,000$ women aged 15–19)	90	8
Women's share of parliamentary seats	12%	38%
Secondary-education attainment (female vs. male)	25% vs. 45%	88% vs. 90%
Labour force participation (female vs. male)	48% vs. 78%	58% vs. 68%

Identify which country is likely to record the higher (worse) GII, and justify your answer using all three GII dimensions.

Reproductive health: Country P's maternal mortality ratio (550) is over 45 times higher than Country Q's (12), and its adolescent birth rate is over ten times higher — a substantially worse reproductive-health outcome.

Empowerment: Country P has far fewer women in parliament (12% vs. 38%) and a much larger secondary-education gender gap (20 percentage points, vs. only 2 points in Country Q).

Labour-market participation: Country P's female-to-male participation gap (48% vs. 78%, a 30-point gap) is considerably wider than Country Q's (58% vs. 68%, a 10-point gap).

Conclusion: Country P performs worse than Country Q on all three GII dimensions, so Country P would be expected to record a substantially **higher (worse) GII value** than Country Q.

9.1.4 The Multidimensional Poverty Index (MPI)

The **Multidimensional Poverty Index (MPI)** was developed jointly by the UNDP and the **Oxford Poverty and Human Development Initiative (OPHI)** at the University of Oxford, first published in 2010, to measure poverty as a condition of **overlapping deprivations** experienced by a household, rather than as a single measure of income or consumption. The MPI assesses each surveyed household across ten indicators grouped into three equally weighted dimensions.

Dimension (weight)	Indicator	Indicator weight
Health ($1/3$)	Nutrition	$1/6$
	Child mortality	$1/6$
Education ($1/3$)	Years of schooling	$1/6$
	School attendance	$1/6$
Living standards ($1/3$)	Cooking fuel	$1/18$
	Sanitation	$1/18$
	Drinking water	$1/18$
	Electricity	$1/18$
	Housing	$1/18$
	Assets	$1/18$

The Multidimensional Poverty Index (UNDP/OPHI): three equally weighted dimensions (health, education, living standards), each built from a small number of household-level indicators. Health and education indicators each carry a weight of $1/6$; the six living-standards indicators each carry a weight of $1/18$, so that each dimension still totals $1/3$ of the overall weighted score.

A household's **weighted deprivation score** is the sum of the weights of all indicators in which it is deprived; a household is classified as **multidimensionally poor** if its weighted deprivation score is at least $1/3$ (i.e., it is deprived in at least one-third of the weighted indicators). From this, two further quantities are calculated across the surveyed population: the **headcount ratio** (H), the proportion of the population who are multidimensionally poor, and the **intensity of poverty** (A), the average proportion of weighted indicators in which poor households (only) are deprived. The MPI itself is the product of the two: MPI $= H \times A$. This construction means the MPI rises both when *more* households fall into poverty and when poor households are deprived across a *larger share* of indicators — capturing both the incidence and the depth of multidimensional poverty in a single figure, and directly identifying which dimension (health, education, or living standards) is driving deprivation for a given population, information a purely income-based poverty line cannot provide.

VN **GIẢI THÍCH TIẾNG VIỆT**

MPI (UNDP/OPHI, từ năm 2010) đo nghèo như tình trạng **thiếu hụt chồng chéo** của hộ gia đình trên 10 chỉ báo thuộc 3 chiều có trọng số bằng nhau ($1/3$ mỗi chiều): **y tế** (dinh dưỡng, tử vong trẻ em — mỗi chỉ báo trọng số $1/6$), **giáo dục** (số năm đi học, đi học đúng độ tuổi — mỗi chỉ báo $1/6$), và **mức sống** (nhiên liệu nấu ăn, vệ sinh, nước uống, điện, nhà ở, tài sản — mỗi chỉ báo $1/18$). Một hộ được coi là **nghèo đa chiều** nếu điểm thiếu hụt có trọng số $\geq 1/3$. H (headcount ratio) là tỉ lệ dân số nghèo đa chiều; A (intensity) là mức độ thiếu hụt trung bình của riêng nhóm hộ nghèo; MPI $= H \times A$ — vừa phản ánh *có bao nhiêu* hộ nghèo, vừa phản ánh nghèo *sâu* đến mức nào, và cho biết chính xác chiều nào (y tế/giáo dục/mức sống) đang "kéo" nghèo đa chiều lên cao — điều mà một ngưỡng nghèo thu nhập đơn thuần không thể hiện được.

Ví dụ mẫu · Comparing MPI profiles of two countries

A small household survey (five households sampled per country) gives the following weighted deprivation scores.

Country	Household weighted deprivation scores	Poor households ($\geq 1/3$)
Country A	$0.10,\ 0.40,\ 0.55,\ 0.05,\ 0.72$	HH2, HH3, HH5
Country B	$0.15,\ 0.20,\ 0.38,\ 0.45,\ 0.10$	HH3, HH4

In Country A, the poor households (HH2, HH3, HH5) are deprived mainly in **living-standards** indicators (no electricity, unimproved sanitation, dirt-floor housing) together with child mortality. In Country B, the poor households (HH3, HH4) are deprived mainly in **education** indicators (low school attendance) together with cooking-fuel deprivation. Calculate H, A, and MPI for each country, and state which dimension appears to drive multidimensional poverty in each.

Country A: $H = 3/5 = 0.60$. $A = \dfrac{0.40 + 0.55 + 0.72}{3} = \dfrac{1.67}{3} \approx 0.557$. $\text{MPI}_A = 0.60 \times 0.557 \approx$ **0.334**.

Country B: $H = 2/5 = 0.40$. $A = \dfrac{0.38 + 0.45}{2} = 0.415$. $\text{MPI}_B = 0.40 \times 0.415 \approx$ **0.166**.

Interpretation. Country A's MPI (0.334) is roughly double Country B's (0.166), driven by both a higher headcount ratio (60% vs. 40% of households poor) and a greater average intensity of deprivation among the poor (55.7% vs. 41.5% of weighted indicators). The underlying deprivation profiles also differ qualitatively: Country A's multidimensional poverty is concentrated in **living standards** (infrastructure-related deprivations that often require large capital investment — grid electricity, piped water, sanitation networks — to resolve), whereas Country B's is concentrated in **education**, suggesting different policy priorities would most efficiently reduce each country's MPI.

9.2 Global Patterns of Development: The Brandt Line

In 1980, an independent commission chaired by the former West German Chancellor **Willy Brandt** published a report titled *North–South: A Programme for Survival*, examining the growing economic divide between wealthier and poorer nations and proposing greater international cooperation to reduce it. The report is best remembered today for popularising a single cartographic device — the **Brandt Line** — a line drawn across a world map, running roughly along $30°$N latitude across most of the globe but dipping south to place Australia and New Zealand within the wealthier grouping despite their southern-hemisphere location. Countries above the line were grouped as the relatively wealthy, industrialised **"Global North"**; countries below the line were grouped as the relatively poorer **"Global South"**.

The Brandt Line has become one of the most widely reproduced images in introductory development geography, but it is equally widely criticised today as an **oversimplified, outdated binary**. It was drawn using economic data from the late 1970s, and the global economy has changed enormously since then: the rapid industrialisation of a number of **newly industrialised countries (NICs)** and **emerging economies** — South Korea, and later China, India, Brazil, and others — has produced levels of manufacturing output, trade integration, and per-capita income for some "South" countries that now rival or exceed those of some "North" countries, blurring the very distinction the line was drawn to represent. The line also treats each side as internally homogeneous, when in reality both groupings contain enormous internal variation: within the notional "South," oil-rich Gulf states and some East Asian economies have per-capita incomes far above the global average, while some countries nominally on the "North" side of earlier lines have faced serious economic difficulty; conversely, considerable poverty and inequality persist within many wealthy "North" countries. For these reasons, the Brandt Line today is best understood as a historically significant, simplified snapshot of the world economy circa 1980, useful for introducing the general idea of a global development divide, rather than as a scientifically precise or currently valid classification of countries.

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Đường Brandt xuất phát từ Báo cáo Brandt năm 1980 (chủ trì bởi cựu Thủ tướng Tây Đức Willy Brandt), vẽ một đường gần vĩ tuyến $30°$Bắc (uốn xuống phía nam để xếp Úc và New

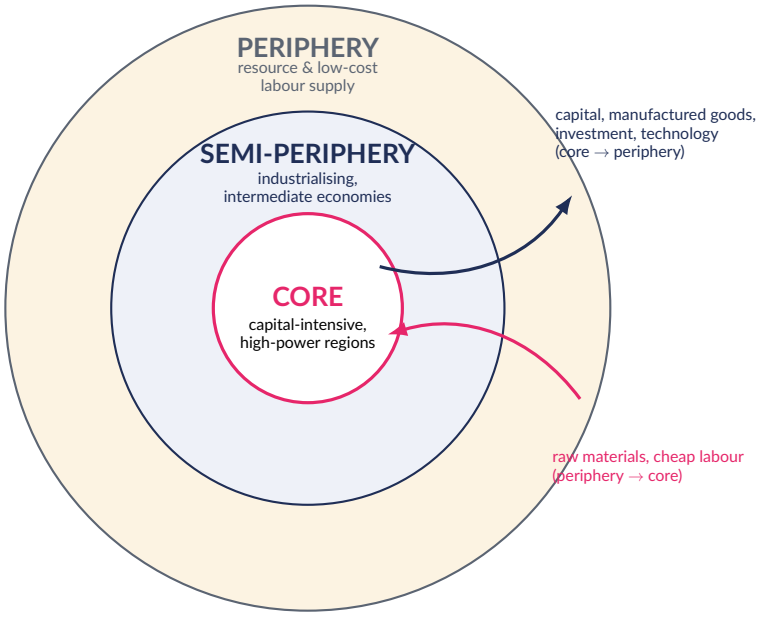
Zealand vào nhóm giàu) chia thế giới thành **"Bắc"** (giàu, công nghiệp hoá) và **"Nam"** (nghèo hơn). Đây là hình ảnh kinh điển trong địa lý phát triển nhưng bị phê phán là **quá đơn giản và đã lỗi thời**: (1) không phản ánh sự trỗi dậy của các nền kinh tế công nghiệp mới (NICs) và nền kinh tế mới nổi (Hàn Quốc, Trung Quốc, Ấn Độ, Brazil...) khiến ranh giới Bắc–Nam mờ nhạt; (2) coi mỗi bên là đồng nhất trong khi thực tế có sự khác biệt rất lớn bên trong cả hai nhóm (các nước vùng Vịnh giàu dầu mỏ thuộc "Nam" về mặt vị trí nhưng thu nhập rất cao; nghèo đói vẫn tồn tại ở nhiều nước "Bắc"). Đường Brandt nên được xem như một ảnh chụp lịch sử đơn giản hoá của nền kinh tế thế giới năm 1980, không phải một ranh giới khoa học chính xác và vẫn còn hiệu lực ngày nay.

(!) Lỗi thường gặp: Đừng viết trong bài thi rằng Đường Brandt là một ranh giới "chính xác về mặt khoa học" hay "vẫn còn đúng cho đến ngày nay". Đây là một công cụ minh hoạ mang tính lịch sử từ báo cáo năm 1980, dựa trên số liệu kinh tế đã hơn bốn thập kỷ tuổi. Khi đề bài yêu cầu đánh giá (evaluate/examine) Đường Brandt, luôn phải nêu rõ hạn chế của nó — đặc biệt là việc bỏ sót các nền kinh tế công nghiệp mới và sự đa dạng nội tại trong mỗi nhóm — thay vì chỉ mô tả đường này như một sự thật địa lý cố định.

9.3 The Core-Periphery Model and World Systems Theory

Where the Brandt Line offers only a simple binary snapshot, **World Systems Theory**, most closely associated with the American sociologist **Immanuel Wallerstein** (writing from the 1970s onward), offers a more structural and dynamic account of global economic inequality. Wallerstein described the modern global economy as a single interconnected **world-system** organised into three broad zones. The **core** comprises wealthy, high-power regions with capital-intensive, high-technology, high-value manufacturing and service economies, strong institutions, and disproportionate influence over global trade rules and financial systems — historically Western Europe, North America, and Japan. The **periphery** comprises lower-power regions that supply raw materials, agricultural commodities, and low-cost labour to the world economy, typically with less-diversified economies, weaker bargaining power in international trade negotiations, and greater dependence on core-region capital, technology, and export markets. Between these two lies the **semi-periphery**: industrialising economies exhibiting characteristics of both — often exporting manufactured goods (sometimes as low-cost assembly or export-processing activity for core-region firms) while remaining dependent on core-region capital, technology, or markets for their most advanced production, and sometimes acting as an intermediary or "sub-core" in relation to peripheral regions within their own trading area.

A central claim of World Systems Theory is that of **unequal exchange**: the theory holds that the terms of trade and investment between core and periphery are structured such that the core systematically captures a disproportionate share of the value generated within the world-system, while the periphery — despite supplying essential raw materials and labour — receives comparatively little of that value in return. On this view, the relationship between core and periphery is not simply a historical accident but is actively reproduced and maintained through ongoing patterns of trade, investment, and institutional power, so that periphery regions face structural obstacles (rather than merely a temporary developmental lag) to closing the gap with the core. The semi-periphery plays an important role in this account by absorbing some of the political pressure that might otherwise arise from a purely two-tier global order, and by providing at least the possibility of upward mobility within the world-system over time, as some semi-peripheral economies (historically Japan, more recently a number of East Asian and other emerging economies) have moved closer to core status.



Wallerstein's World Systems Theory: a nested core – semi-periphery – periphery structure. Raw materials, agricultural commodities and low-cost labour flow inward, from periphery toward core; capital, manufactured goods, investment and technology flow outward, from core toward periphery – a pattern of *unequal exchange* that the theory holds systematically favours the core.

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VN

Lý thuyết Hệ thống Thế giới (World Systems Theory) của nhà xã hội học Immanuel Wallerstein chia nền kinh tế toàn cầu thành ba vùng: **lõi (core)** — giàu có, quyền lực cao, kinh tế thâm dụng vốn và công nghệ cao; **ngoại vi (periphery)** — quyền lực thấp, cung cấp nguyên liệu thô và lao động giá rẻ, phụ thuộc vào vốn/công nghệ/thị trường xuất khẩu của lõi; và **bán ngoại vi (semi-periphery)** — nền kinh tế đang công nghiệp hoá, mang đặc điểm của cả hai (vừa xuất khẩu hàng chế tạo, vừa phụ thuộc vốn/công nghệ từ lõi). Luận điểm trung tâm là **trao đổi không ngang giá (unequal exchange)**: lõi liên tục chiếm phần giá trị lớn hơn từ hệ thống thế giới so với những gì ngoại vi nhận lại, và mối quan hệ bất bình đẳng này được duy trì một cách có hệ thống qua thương mại, đầu tư và quyền lực thể chế — chứ không đơn thuần là "chậm phát triển tạm thời".

Ví dụ mẫu · Classifying countries into core, semi-periphery and periphery

Using the indicators below, classify each country as core, semi-periphery, or periphery, and justify each classification.

Country	GNI per capita (PPP)	Economic profile
W	\$58 000	Global financial/headquarters hub; high-tech and service-based economy; net exporter of capital and advanced manufactured goods
X	\$16 500	Rapidly growing manufacturing sector (28% of GDP), major exporter of electronics and vehicles, but still reliant on foreign capital and licensed technology
Y	\$2 100	Primary commodities (cocoa, unprocessed minerals) make up 80% of export earnings; manufacturing only 6% of GDP; heavy reliance on foreign aid

Country W: CORE. Very high GNI per capita, a globally central, capital- and technology-intensive economy, and a net exporter (rather than importer) of capital and advanced manufactured goods — the defining features of a core economy.

Country X: SEMI-PERIPHERY. Middle-income GNI per capita and a substantial, export-oriented manufacturing base show clear industrialisation, but continued dependence on foreign capital and licensed (rather than home-grown) technology indicates the economy has not yet achieved full core status — the hallmark combination of a semi-peripheral economy.

Country Y: PERIPHERY. Low GNI per capita, an export base dominated by unprocessed primary commodities, a very small manufacturing sector, and dependence on foreign aid all indicate low bargaining power and structural dependence on core and semi-peripheral economies for manufactured imports, capital, and export markets.

9.4 Cultural Diversity in a Globalising World

9.4.1 Cultural Homogenisation and Erosion

One influential view of globalisation's cultural effects holds that the accelerating global circulation of media, brands, consumer goods, and popular culture — much of it historically originating from, or heavily influenced by, the United States and other Western economies — tends to spread a increasingly dominant **global culture** at the expense of local languages, traditions, and identities. This process is often termed **cultural homogenisation** or **cultural erosion**: as global chains, streaming platforms, and social media come to occupy an ever-larger share of everyday cultural life in many places, distinctive local practices, dress, cuisine, and especially minority **languages** can be displaced, particularly among younger generations who may increasingly favour globally dominant languages and cultural forms for economic and social advancement. **Language extinction** — a language falling entirely out of daily use, eventually surviving nowhere as anyone's first or only language — is widely cited as one of the most visible and measurable symptoms of this process: of the several thousand languages spoken worldwide today, a substantial proportion are considered endangered, with especially small, undocumented, indigenous, and minority languages most at risk, since a language's ordinary transmission from one generation to the next can break down within a single generation once a dominant alternative language becomes essential for education, employment, and social mobility.

VN **GIẢI THÍCH TIẾNG VIỆT**

Một quan điểm về ảnh hưởng văn hoá của toàn cầu hoá cho rằng sự lan toả nhanh chóng của truyền thông, thương hiệu, hàng tiêu dùng và văn hoá đại chúng toàn cầu (phần lớn có

nguồn gốc hoặc chịu ảnh hưởng mạnh từ phương Tây, đặc biệt là Hoa Kỳ) đang tạo ra một **nền văn hoá toàn cầu** ngày càng chiếm ưu thế, làm xói mòn ngôn ngữ, truyền thống và bản sắc địa phương — gọi là **đồng nhất hoá văn hoá (cultural homogenisation)** hay **xói mòn văn hoá (cultural erosion)**. **Sự tuyệt chủng ngôn ngữ** — một ngôn ngữ hoàn toàn không còn ai sử dụng — thường được xem là biểu hiện rõ ràng nhất của quá trình này: nhiều ngôn ngữ nhỏ, ngôn ngữ bản địa và ngôn ngữ thiểu số đang có nguy cơ biến mất trong vòng chỉ một thế hệ, khi ngôn ngữ toàn cầu chiếm ưu thế trở thành điều kiện bắt buộc để tiếp cận giáo dục, việc làm và cơ hội thăng tiến xã hội.

9.4.2 Cultural Diffusion, Glocalisation and Indigenous Rights

An alternative and increasingly influential view emphasises that global cultural products are rarely adopted unchanged; instead they are actively selected, reinterpreted, and blended with existing local culture to create genuinely new **hybrid** cultural forms. This process is often described using the portmanteau term **glocalisation** — the deliberate adaptation of a global product, brand, or cultural practice to fit local tastes, languages, and traditions, so that the same global brand or format can appear meaningfully different from one country or region to the next. Rather than passively erasing local culture, on this view globalisation is better understood as a two-way process of **cultural diffusion**, in which global and local cultural elements continuously interact and reshape one another, producing new combinations (in cuisine, music, fashion, and language) that did not previously exist in either the "global" or the "local" culture alone. Local culture, in this account, is not simply a passive victim of outside forces but an active participant in selecting, resisting, and remixing what circulates globally.

Concerns about cultural erosion have also fuelled a rise in organised **indigenous-rights movements** around the world, asserting land rights, cultural and linguistic preservation, and rights to self-determination for indigenous peoples whose distinct cultures, languages, and traditional livelihoods are often especially exposed to the homogenising pressures described above, as well as to loss of ancestral land through resource extraction, agricultural expansion, or urban growth. International recognition of these claims has grown significantly, most visibly through instruments such as the **UN Declaration on the Rights of Indigenous Peoples (UNDRIP)**, adopted in 2007, which affirms indigenous peoples' rights to self-determination, to their own languages and cultural practices, and to the lands and resources they have traditionally occupied. Such movements represent an active, organised form of resistance to cultural erosion, reasserting the value and durability of local and indigenous identity even within an increasingly interconnected global system.

VN **GIẢI THÍCH TIẾNG VIỆT**

Quan điểm ngược lại nhấn mạnh rằng sản phẩm văn hoá toàn cầu hiếm khi được tiếp nhận nguyên vẹn — chúng được chọn lọc, diễn giải lại và pha trộn với văn hoá địa phương để tạo ra các hình thức **lai (hybrid)** mới, gọi là **glocalisation** (thuật ngữ ghép "global" + "local"): một thương hiệu hay sản phẩm toàn cầu được điều chỉnh để phù hợp khẩu vị, ngôn ngữ, truyền thống địa phương. Thay vì xoá bỏ văn hoá địa phương một chiều, đây là quá trình **khuếch tán văn hoá (cultural diffusion)** hai chiều, trong đó văn hoá địa phương chủ động tham gia chọn lọc và biến đổi những gì lan toả từ bên ngoài. Song song đó, các **phong trào quyền bản địa** ngày càng phát triển nhằm khẳng định quyền đất đai, bảo tồn văn hoá — ngôn ngữ, và quyền tự quyết của người bản địa, được công nhận rộng rãi qua **Tuyên ngôn Liên Hợp Quốc về Quyền của Người bản địa (UNDRIP, 2007)** — một hình thức phản kháng có tổ chức trước nguy cơ xói mòn văn hoá.

9.5 Unequal Access to Markets and Technology

9.5.1 The Digital Divide

At a global development scale, the **digital divide** refers to persistent inequality in access to broadband internet connections, mobile data networks, and internet-capable devices (smartphones, computers) between wealthier and lower-income countries, and between wealthier and lower-income populations within countries. Despite rapid growth in global mobile-phone ownership over the past two decades, a substantial share of the world's population — heavily concentrated in lower-income countries, and within those countries in rural and remote areas — remains offline or has only limited, low-bandwidth access, according to data regularly published by the International Telecommunication Union (ITU). This gap matters for development because an ever-larger share of economic opportunity, education, financial services, and government services is increasingly delivered digitally: without reliable, affordable connectivity, people and firms in lower-income regions can be effectively excluded from participating fully in the global digital economy, potentially widening — rather than narrowing — existing development gaps over time.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khoảng cách số (digital divide) ở quy mô toàn cầu là sự bất bình đẳng dai dẳng trong khả năng tiếp cận internet băng rộng, mạng dữ liệu di động và thiết bị kết nối internet giữa các quốc gia giàu và nghèo, cũng như giữa các nhóm dân cư trong cùng một quốc gia (đặc biệt là nông thôn so với thành thị). Một bộ phận lớn dân số thế giới — tập trung ở các nước thu nhập thấp — vẫn chưa được kết nối internet hoặc chỉ có kết nối hạn chế. Vì ngày càng nhiều cơ hội kinh tế, giáo dục và dịch vụ tài chính được cung cấp qua kênh số, việc thiếu kết nối khiến người dân và doanh nghiệp ở các khu vực này có nguy cơ bị **loại khỏi nền kinh tế số toàn cầu**, khiến khoảng cách phát triển có thể ngày càng rộng ra thay vì thu hẹp lại.

9.5.2 Financial Exclusion and Mobile Money

Closely related to the digital divide is **financial exclusion**: the lack of access to basic formal financial services — a bank account, savings products, credit, or insurance — that remains widespread in many developing regions, where physical bank branches are often sparse outside major cities, and where many people lack the formal documentation, credit history, or minimum balances that traditional banks typically require. Financial exclusion limits people's ability to save securely, borrow to invest in a business or education, insure against shocks, and receive wages or remittances safely, reinforcing wider development disadvantages. A major recent development addressing this gap is the rise of **mobile money** services, which allow users to store, send, and receive money using a basic mobile phone and a local network of registered agents, without requiring a conventional bank account. The best-known example is **M-Pesa**, launched in Kenya in 2007 by the mobile network operator Safaricom, which rapidly achieved very high adoption and is widely credited with substantially expanding formal and semi-formal financial access across Kenya and, through similar services, in a number of other countries — demonstrating how a digital innovation can partially bypass a physical infrastructure gap (the shortage of bank branches) that had long constrained financial inclusion.

VN **GIẢI THÍCH TIẾNG VIỆT**

Tình trạng không tiếp cận dịch vụ tài chính (financial exclusion) — thiếu tài khoản ngân hàng, tiết kiệm, tín dụng hay bảo hiểm chính thức — vẫn phổ biến ở nhiều khu vực đang phát triển do chi nhánh ngân hàng thưa thớt ngoài các thành phố lớn và yêu cầu giấy tờ/số dư tối thiểu mà nhiều người không đáp ứng được. **Tiền di động (mobile money)** — điển hình là dịch vụ **M-Pesa** ra mắt tại Kenya năm 2007 bởi nhà mạng Safaricom — cho phép lưu trữ, gửi và nhận tiền chỉ bằng điện thoại di động cơ bản và mạng lưới đại lý địa phương, không cần tài khoản ngân hàng truyền thống, giúp mở rộng đáng kể khả năng tiếp cận tài chính ở những nơi thiếu hạ tầng ngân hàng vật lý.

9.5.3 Tariffs and Trade Barriers

A further structural obstacle facing many developing-country producers is the system of **tariffs** (taxes imposed on imported goods) and other **trade barriers** (quotas, subsidies to domestic producers, and complex product standards) maintained by wealthier importing countries, particularly on agricultural products and processed goods in which developing countries might otherwise hold a comparative advantage. Such barriers can make it substantially harder for developing-country producers to access the most lucrative export markets on competitive terms, and can also encourage a pattern in which developing countries continue to export mostly unprocessed raw materials (which often face lower tariffs) rather than more valuable processed or manufactured goods (which more often face higher **tariff escalation**) — reinforcing, rather than helping to overcome, a peripheral role in global trade of the kind described by World Systems Theory above.

VN **GIẢI THÍCH TIẾNG VIỆT**

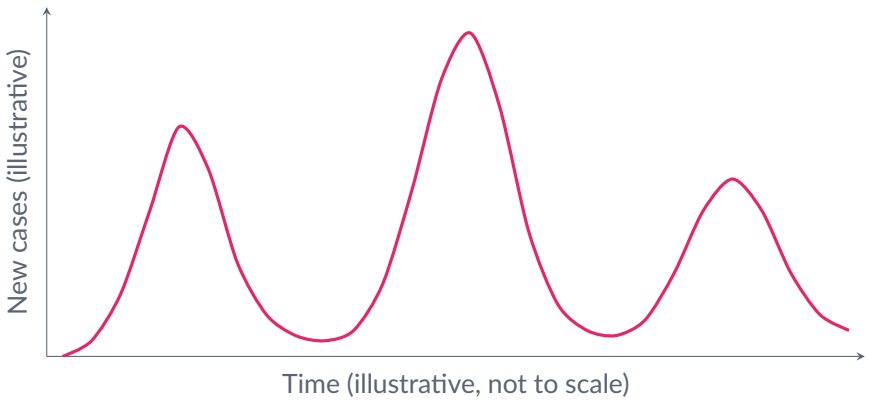
Thuế quan (tariffs) và các rào cản thương mại khác (hạn ngạch, trợ cấp cho nhà sản xuất trong nước, tiêu chuẩn sản phẩm phức tạp) mà các nước nhập khẩu giàu có áp đặt — đặc biệt với nông sản và hàng đã qua chế biến — khiến nhà sản xuất ở các nước đang phát triển khó tiếp cận các thị trường xuất khẩu sinh lời cao. Vì thuế thường tăng dần theo mức độ chế biến (**tariff escalation**), các nước đang phát triển có xu hướng tiếp tục chỉ xuất khẩu nguyên liệu thô (chịu thuế thấp hơn) thay vì hàng chế tạo giá trị cao hơn — càng củng cố vai trò "ngoại vi" của họ trong thương mại toàn cầu.

9.6 Global Risks

A **global risk** is a shock — an event or unfolding process — that has the potential to produce widespread, cross-border social, economic, and/or environmental impact, often propagating rapidly through the same networks of trade, finance, travel, and communication that drive everyday globalisation. Because the modern world economy is so densely interconnected, a shock originating in one country or sector can transmit rapidly to seemingly unrelated countries and sectors elsewhere, and the same global shock frequently produces very different outcomes in different places, depending on each country's exposure, vulnerability, and capacity to respond.

9.6.1 Pandemics: The COVID-19 Pandemic

A **pandemic** is an epidemic of infectious disease that has spread across multiple countries or continents, typically affecting a large number of people. The **COVID-19 pandemic** is caused by the novel coronavirus **SARS-CoV-2**, first identified in **Wuhan, China, in December 2019**. As the outbreak spread internationally, the World Health Organization (WHO) declared it a **Public Health Emergency of International Concern (PHEIC)** on **30 January 2020**, and subsequently characterised it as a **pandemic** on **11 March 2020**, once sustained community transmission was occurring on multiple continents. National policy responses varied enormously in speed and severity, ranging from strict, extended lockdowns and international travel restrictions in some countries to far lighter interventions in others, reflecting differences in governance, health-system capacity, and public risk tolerance. Vaccine development proceeded at unprecedented speed, but initial global access to vaccines was highly unequal, with high-income countries securing the large majority of early supply through direct advance-purchase agreements with manufacturers, while many lower-income countries faced severe shortages. This inequality was partly addressed through **COVAX**, an international vaccine-sharing mechanism co-led by the WHO together with Gavi, the Vaccine Alliance, and the Coalition for Epidemic Preparedness Innovations (CEPI), which pooled funding and purchasing power to distribute vaccine doses to participating lower-income countries, though it fell well short of achieving equal global access in the pandemic's early phase.



Schematic illustration only, *not* real epidemiological data, of the general pattern by which a pandemic can arrive in successive "waves" – periods of rising case counts followed by decline (through a mix of immunity, behavioural change, and public health measures), followed later by renewed growth (often linked to a new variant, seasonal effects, or the relaxation of control measures).

Ví dụ mẫu · Exponential growth and doubling time in an early-stage outbreak

During the early, largely unmitigated stage of an outbreak, daily confirmed cases are observed to grow at a constant rate of 20% per day, starting from 100 confirmed cases on day 0. (a) Calculate the projected number of cases after 10 days. (b) Calculate the approximate doubling time of the outbreak. (c) Comment on why even a seemingly modest daily growth rate can compound into a large problem within a few weeks.

(a) Using $N_t = N_0(1+r)^t$ with $N_0 = 100$, $r = 0.20$, $t = 10$:

$$N_{10} = 100 \times (1.20)^{10} = 100 \times 6.19 \approx \textbf{619} \text{ cases.}$$

(b) The doubling time is $t_{\text{double}} = \dfrac{\ln 2}{\ln(1+r)} = \dfrac{0.693}{\ln(1.20)} = \dfrac{0.693}{0.182} \approx$ **3.8** days (roughly 4 days) — broadly consistent with the fast early doubling times reported in a number of unmitigated early COVID-19 outbreak settings.

(c) Because growth compounds on an ever-larger base rather than adding a fixed number of new cases each day, a constant daily growth rate produces **exponential**, not linear, growth: case counts roughly double every 3–4 days in this scenario, so starting from just 100 cases, the outbreak reaches roughly 600 within 10 days and could exceed $10\,000$ within about a month if left completely unchecked. This is precisely why early, rapid public-health intervention — before exponential growth has compounded for many doubling periods — has a disproportionately large effect on the eventual total scale of an outbreak, and why apparently small early case counts should not be read as a sign that a fast-growing outbreak is not yet a serious concern.

VN GIẢI THÍCH TIẾNG VIỆT

Virus **SARS-CoV-2** được xác định lần đầu tại **Vũ Hán, Trung Quốc, tháng 12/2019**; WHO công bố **Tình trạng khẩn cấp y tế công cộng gây quan ngại quốc tế (PHEIC)** vào **30/01/2020**, và chính thức gọi đây là **đại dịch** vào **11/03/2020**. Các quốc gia phản ứng chính sách rất khác nhau (phong toả, hạn chế đi lại, chương trình tiêm chủng), và khả năng tiếp cận vắc-xin ban đầu rất bất bình đẳng giữa các nước giàu và nghèo — một phần được khắc phục qua cơ chế chia sẻ vắc-xin quốc tế **COVAX** (WHO, Gavi, CEPI đồng dẫn dắt). Vì số ca bệnh tăng theo cấp số nhân (compound theo tỉ lệ tăng trưởng hằng ngày chứ không phải cộng dồn số cố định), một tỉ lệ tăng trưởng hằng ngày dù nhỏ vẫn có thể khiến số ca tăng vọt chỉ sau vài tuần — đây

là lý do can thiệp y tế công cộng sớm có tác động rất lớn.

9.6.2 Financial Crises: The 2007–2008 Global Financial Crisis

A **financial crisis** is a severe disruption to a country's (or the world's) financial system — typically involving a sharp loss of confidence in financial institutions, a collapse in asset prices, and a contraction in the availability of credit — that can rapidly spill over into the wider "real" economy of production, employment, and trade. The **2007–2008 Global Financial Crisis** originated in the **United States subprime mortgage market**, where large volumes of high-risk home loans had been issued to borrowers with weak creditworthiness and then repackaged into complex financial securities sold to investors worldwide. When large numbers of these mortgages began to default as US house prices fell, the value of the associated securities collapsed, exposing many banks and other financial institutions — in the US and internationally — to unexpectedly large losses. The crisis intensified sharply with the collapse of the major US investment bank **Lehman Brothers**, which filed for bankruptcy in **September 2008**, triggering a rapid, near-global loss of confidence in the financial sector and a severe contraction in interbank lending and credit availability. Because major financial institutions around the world were tightly interconnected through cross-border lending, investment, and derivative contracts, the shock transmitted rapidly beyond the US financial sector into a broad global recession, affecting trade, investment, and employment in countries with little direct exposure to the original US subprime mortgages. Governments and central banks responded with large, often internationally coordinated, interventions: substantial fiscal stimulus packages, emergency interest-rate cuts, and direct support for distressed financial institutions, coordinated in part through summits of the **G20** group of major economies and supported by emergency lending from the **International Monetary Fund (IMF)** to a number of countries whose external finances came under acute strain.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khủng hoảng tài chính toàn cầu 2007–2008 bắt nguồn từ thị trường **cho vay thế chấp dưới chuẩn (subprime mortgage)** tại Hoa Kỳ; khi giá nhà giảm và các khoản vay rủi ro cao vỡ nợ hàng loạt, các chứng khoán phái sinh liên quan sụp đổ giá trị. Sự sụp đổ của ngân hàng đầu tư **Lehman Brothers vào tháng 9/2008** châm ngòi cho một cuộc khủng hoảng niềm tin lan nhanh khắp hệ thống tài chính toàn cầu vốn liên kết chặt chẽ, đẩy nền kinh tế thế giới vào suy thoái sâu rộng — ngay cả những nước không trực tiếp liên quan đến thị trường thế chấp Mỹ. Các chính phủ và ngân hàng trung ương phản ứng bằng các gói kích thích tài khoá lớn, cắt giảm lãi suất khẩn cấp, và hỗ trợ định chế tài chính gặp khó khăn, phối hợp qua các hội nghị thượng đỉnh **G20** và các khoản vay khẩn cấp từ **IMF**.

9.6.3 Systemic and Supply-Chain Risk: The Suez Canal Blockage

Beyond pandemics and financial crises, global risk can also arise from a single, highly localised physical event that disrupts a critical node in the tightly interconnected networks of global trade. In **March 2021**, the large container ship **Ever Given** ran aground and turned sideways within the **Suez Canal**, one of the world's most important maritime shipping routes linking the Mediterranean and Red Seas, completely blocking the canal to traffic in both directions for approximately **six days** before it was successfully refloated. Because the Suez Canal normally carries a very substantial share of global east–west maritime trade, the blockage rapidly produced a large backlog of waiting vessels at both ends of the canal and forced some shipping companies to reroute vessels around the much longer Cape of Good Hope route, adding significant delay and fuel cost. The episode is widely cited as a clear illustration of how a single, localised, and relatively short-lived disruption can cascade through tightly interconnected global supply chains, delaying the delivery of goods, components, and raw materials far beyond the immediate vicinity of the disruption itself, and highlighting the systemic risk created by the concentration of so much global trade through a small number of critical geographic chokepoints.

Ví dụ mẫu · Estimating the scale of the Suez Canal disruption

Assume the Suez Canal normally handles an average of 50 vessel transits per day, carrying cargo with a combined value of approximately $9.6 billion per day (a figure consistent with contemporaneous estimates of the value of trade passing through the canal). The canal was completely blocked for 6 days in March 2021. (a) Estimate the number of vessel transits delayed by the blockage. (b) Estimate the approximate value of cargo whose transit was delayed. (c) State one supply-chain consequence of this disruption beyond the canal itself.

(a) Vessels delayed ≈ 50 vessels/day $\times 6$ days $=$ **300** vessels (an order-of-magnitude estimate; actual reported queue lengths by the end of the blockage were broadly consistent with this scale).

(b) Value of delayed cargo $\approx \$9.6$ billion/day $\times 6$ days $\approx \$$**58** billion.

(c) Beyond the roughly 58 billion dollars of cargo whose delivery was delayed, the backlog of vessels took additional time to clear even after the canal reopened (causing knock-on port congestion), some cargo owners faced higher freight and insurance costs, and some shipping companies rerouted vessels around the Cape of Good Hope, adding one to two weeks of extra transit time and substantial extra fuel cost for those voyages — illustrating how the consequences of a single localised blockage extend well beyond the canal itself and beyond the six days of the blockage.

VN **GIẢI THÍCH TIẾNG VIỆT**

Vào **tháng 3/2021**, tàu container **Ever Given** mắc cạn và chắn ngang **kênh đào Suez** — một trong những tuyến hàng hải quan trọng nhất thế giới — trong khoảng **6 ngày**. Vì kênh Suez đảm nhận một tỉ trọng lớn thương mại hàng hải Đông–Tây toàn cầu, sự cố này nhanh chóng gây ùn tắc tàu ở cả hai đầu kênh và buộc một số hãng tàu phải đi vòng qua Mũi Hảo Vọng, kéo dài thời gian và chi phí vận chuyển. Sự kiện này minh hoạ rõ cách một sự cố cục bộ, tương đối ngắn có thể lan toả (cascade) qua chuỗi cung ứng toàn cầu vốn liên kết chặt chẽ, làm chậm trễ hàng hoá ở phạm vi vượt xa khu vực xảy ra sự cố.

9.6.4 Overwhelmed Health Systems: The West African Ebola Outbreak

The **West African Ebola virus disease outbreak of 2014–2016** — concentrated primarily in **Guinea, Liberia, and Sierra Leone** — was, at the time, by far the largest and most geographically extensive Ebola outbreak on record, resulting in tens of thousands of confirmed and probable cases and a substantial number of deaths across the region. The outbreak is widely cited in the study of global risk not primarily as an example of geographically extensive cross-border spread (although limited exported cases did occur outside the three main affected countries), but as a stark illustration of how a severe infectious-disease outbreak can **overwhelm health systems** that were already significantly under-resourced — with too few trained health workers, hospital beds, and basic infection-control supplies — even before the crisis began. As case numbers rose faster than the affected health systems' capacity to isolate, treat, and trace them, routine health services for unrelated conditions (childbirth, malaria, vaccination programmes) were also severely disrupted in the three worst-affected countries, compounding the outbreak's overall public-health toll well beyond deaths directly attributable to Ebola itself, and illustrating why pre-existing health-system strength is such a critical determinant of how well a country can withstand an infectious-disease shock.

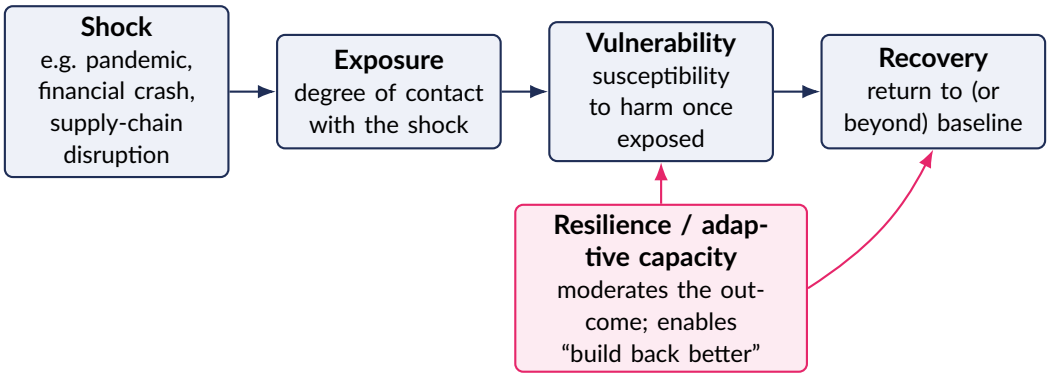
VN **GIẢI THÍCH TIẾNG VIỆT**

Dịch Ebola Tây Phi 2014–2016, tập trung chủ yếu tại **Guinea, Liberia và Sierra Leone**, là đợt bùng phát Ebola lớn nhất và lan rộng nhất từng ghi nhận vào thời điểm đó. Sự kiện này thường được nhắc đến không chỉ vì quy mô lây lan mà còn vì minh hoạ rõ cách một dịch bệnh nghiêm

trọng có thể **làm quá tải hệ thống y tế** vốn đã thiếu nguồn lực từ trước (thiếu nhân viên y tế, giường bệnh, vật tư kiểm soát nhiễm khuẩn) — khiến các dịch vụ y tế thông thường khác (sinh sản, sốt rét, tiêm chủng) cũng bị gián đoạn nghiêm trọng, làm gia tăng thiệt hại y tế công cộng tổng thể vượt xa số ca tử vong trực tiếp do Ebola.

9.7 Resilience: Absorbing, Recovering and Adapting

Resilience, in the context of global risk, is the capacity of a system, economy, or society to **absorb** a shock without complete collapse, and subsequently to **recover and adapt**, ideally emerging with an **improved** capacity to withstand and respond to future shocks of a similar kind — an aspiration frequently summarised by the phrase **"build back better."** Analysing resilience requires distinguishing several related concepts that are frequently confused. **Exposure** describes the degree to which a system or population comes into contact with a given hazard or shock in the first place (for example, how internationally connected a country's trade and travel networks are, which shapes how quickly an imported disease or an external financial shock can reach it). **Vulnerability** describes how susceptible that system or population is to being harmed *once* exposed — shaped by factors such as poverty, health-system capacity, infrastructure quality, and governance — and is a fundamentally different concept from exposure: a country can be highly exposed to a global shock (extensively connected internationally) yet have relatively low vulnerability (strong institutions and resources to cope), or conversely can have low exposure yet very high vulnerability if a shock does eventually reach it.



A shock translates into harm only through a system's exposure and vulnerability; resilience (adaptive capacity) moderates both the severity of the impact on vulnerability and the speed and completeness of the eventual recovery.

Resilience is not a fixed, given property of a country but can be actively built through deliberate strategies. **Economic diversification** — reducing a country's dependence on any single export commodity, industry, or trading partner — reduces vulnerability to a shock affecting one particular sector or market, spreading risk across a broader economic base. **Social safety nets** — unemployment insurance, cash-transfer programmes, public health coverage — cushion households against income loss during a shock, preventing a temporary shock from causing lasting damage to health, education, or livelihoods. **Early-warning and surveillance systems** — for infectious disease, extreme weather, or financial-sector stress — allow a faster, better-targeted response before a shock fully escalates, reducing both its ultimate severity and the time needed to recover. Finally, **international cooperation** through multilateral institutions plays a central role in building resilience at a global scale: the **World Health Organization (WHO)** coordinates disease surveillance, technical guidance, and (as with COVAX) equitable access to medical countermeasures across borders, while the **International Monetary Fund (IMF)** provides emergency financing and coordinates policy responses to preserve financial stability during crises that individual countries cannot manage alone.

VN **GIẢI THÍCH TIẾNG VIỆT**

Khả năng chống chịu (resilience) là năng lực của một hệ thống, nền kinh tế hay xã hội **hấp thụ** một cú sốc mà không sụp đổ hoàn toàn, rồi **phục hồi và thích ứng**, lý tưởng là trở nên vững vàng hơn trước các cú sốc tương lai — khái niệm thường gọi là **"xây dựng lại tốt hơn" (build back better)**. **Phơi nhiễm (exposure)** là mức độ một hệ thống tiếp xúc với hiểm hoạ (ví dụ mức độ kết nối quốc tế); **tính dễ tổn thương (vulnerability)** là mức độ dễ bị tổn hại *sau khi* đã phơi nhiễm (phụ thuộc nghèo đói, năng lực y tế, hạ tầng, quản trị) — đây là hai khái niệm hoàn toàn khác nhau: một quốc gia có thể phơi nhiễm cao (kết nối quốc tế sâu rộng) nhưng tính dễ tổn thương thấp (thể chế và nguồn lực mạnh), hoặc ngược lại. Các chiến lược xây dựng khả năng chống chịu: **đa dạng hoá kinh tế** (giảm phụ thuộc vào một ngành/thị trường xuất khẩu duy nhất), **mạng lưới an sinh xã hội**, **hệ thống cảnh báo sớm & giám sát**, và **hợp tác quốc tế** qua các tổ chức như **WHO** (y tế) và **IMF** (ổn định tài chính).

Ví dụ mẫu · Export diversification and vulnerability to a commodity-price shock

Country R earns 85% of its export revenue from a single mineral commodity. Country S earns export revenue from a broad range of goods and services, with no single commodity exceeding 15% of total exports. A sudden 50% fall in the world price of the mineral commodity occurs. (a) Explain which country is more vulnerable to this shock, and why. (b) Suggest one resilience-building strategy that would most directly reduce Country R's vulnerability to a repeat of this type of shock.

(a) Country R is far more vulnerable. Because 85% of its export revenue depends on a single commodity, a 50% price fall in that commodity translates directly into an extremely large shock to national export earnings, government revenue (if the commodity is taxed or state-owned), foreign-exchange reserves, and potentially the exchange rate and import capacity. Country S's much more diversified export base means the same global commodity-price shock affects, at most, a small fraction of its total export revenue, leaving the remainder of its economy comparatively insulated.

(b) Economic diversification — deliberately developing additional export industries and sectors (manufacturing, services, alternative commodities) so that no single commodity dominates export earnings — would most directly reduce Country R's structural vulnerability to future price shocks in this one commodity market, though this typically requires sustained investment and cannot be achieved quickly.

(!) Lỗi thường gặp: Trong khung khái niệm chống chịu (shock → exposure → vulnerability → resilience → recovery), học sinh thường nhầm lẫn **phơi nhiễm (exposure)** với **tính dễ tổn thương (vulnerability)**. Phơi nhiễm chỉ đơn thuần là mức độ *tiếp xúc* với hiểm hoạ (ví dụ một quốc gia có sân bay quốc tế lớn sẽ phơi nhiễm cao hơn với một dịch bệnh lây qua đường hàng không); tính dễ tổn thương là mức độ *dễ bị tổn hại sau khi* đã phơi nhiễm, quyết định bởi năng lực y tế, nghèo đói, hạ tầng và quản trị. Hai quốc gia có thể phơi nhiễm như nhau nhưng chịu thiệt hại rất khác nhau nếu tính dễ tổn thương khác nhau — vì vậy khi phân tích "tại sao một cú sốc toàn cầu ảnh hưởng không đồng đều giữa các nước", bài làm cần tách rõ hai khái niệm này thay vì gộp chung.

9.8 Practice Bank

Bài tập luyện tập

Q1. GNI per capita is typically expressed "at purchasing power parity (PPP)" when comparing countries mainly in order to:

(A) Increase the reported GDP of wealthy countries

(B) Correct for differing price levels between countries, so income is compared in terms of what it can actually buy locally

(C) Eliminate the need for national statistical offices

(D) Convert GNI into a measure of gender inequality

Lời giải chi tiết

Market exchange rates do not reflect differing local price levels; PPP conversion expresses income in "international dollars" with comparable purchasing power in every country. **(B)**.

Bài tập luyện tập

Q2. The Human Development Index (HDI) combines its three dimension indices using:

(A) A simple arithmetic average

(B) A weighted sum with health weighted most heavily

(C) The geometric mean (cube root of the product of the three indices)

(D) Whichever single index is highest

Lời giải chi tiết

$\text{HDI} = \sqrt[3]{I_{\text{life}} \times I_{\text{edu}} \times I_{\text{income}}}$ — the geometric mean, not an arithmetic average, so a very low score in one dimension cannot be fully offset by high scores in the others. **(C)**.

Bài tập luyện tập

Q3. A country has a life expectancy index of $I_{\text{life}} = 0.910$, an education index of $I_{\text{edu}} = 0.650$, and an income index of $I_{\text{income}} = 0.700$. Calculate its HDI and state its human development category.

Lời giải chi tiết

Product: $0.910 \times 0.650 \times 0.700 = 0.414$. $\text{HDI} = \sqrt[3]{0.414} \approx \boxed{0.745}$. Since $0.700 \leq 0.745 < 0.800$, this is **high human development**.

Bài tập luyện tập

Q4. The Gender Inequality Index (GII) reflects disparities between men and women across which three dimensions?

(A) Income, education, health care spending

(B) Reproductive health, empowerment, and labour-market participation

(C) Life expectancy, mean years of schooling, GNI per capita

(D) Nutrition, sanitation, and housing

Lời giải chi tiết

Choice (C) describes the HDI's dimensions, and (D) describes MPI living-standards indicators — both are distractors from other indices covered in this unit. The GII's own three dimensions are reproductive health, empowerment, and labour-market participation. **(B)**.

Bài tập luyện tập

Q5. A village survey of four households gives weighted MPI deprivation scores of 0.50, 0.12, 0.38, and 0.05. Household 1 (score 0.50) is deprived mainly in health indicators (child mortality and nutrition); household 3 (score 0.38) is deprived mainly in living-standards indicators (no electricity, unimproved sanitation). Calculate H (headcount ratio), A (intensity), and the MPI for this village, and state which two dimensions are driving multidimensional poverty here.

Lời giải chi tiết

Poverty threshold is a weighted score $\geq 1/3 \approx 0.333$. Poor households: HH1 (0.50) and HH3 (0.38); HH2 and HH4 are below the threshold and not counted as poor. $H = 2/4 = 0.50$. $A = \dfrac{0.50 + 0.38}{2} = 0.44$. MPI $= H \times A = 0.50 \times 0.44 = \boxed{0.22}$. The two dimensions driving poverty in this village are **health** (HH1: child mortality, nutrition) and **living standards** (HH3: electricity, sanitation).

Bài tập luyện tập

Q6. The 1980 Brandt Report divided the world along a line running roughly near:

(A) The Equator

(B) $30°$N latitude, dipping south to place Australia and New Zealand in the wealthier grouping

(C) The Tropic of Capricorn

(D) The international date line

Lời giải chi tiết

The Brandt Line runs approximately along $30°$N across most of the world but dips south around Australia and New Zealand, placing them in the "North" grouping despite their southern-hemisphere location. **(B)**.

Bài tập luyện tập

Q7. State two criticisms of using the Brandt Line to classify countries today.

Lời giải chi tiết

(1) It does not capture the rise of newly industrialised and emerging economies (e.g., South Korea, China, India, Brazil) since 1980, whose income and manufacturing output now blur the original North–South distinction. (2) It treats "North" and "South" as internally homogeneous, ignoring wide variation within each grouping — for example, wealthy oil-exporting Gulf states are geographically "South" of the line but have very high incomes, while poverty persists within many "North" countries.

Bài tập luyện tập

Q8. World Systems Theory, describing the global economy as a core – semi-periphery – periphery structure, is most closely associated with which scholar?

(A) Walt Rostow
(B) Immanuel Wallerstein
(C) Amartya Sen
(D) Thomas Malthus

Lời giải chi tiết

Immanuel Wallerstein developed World Systems Theory from the 1970s onward. **(B)**.

Bài tập luyện tập

Q9. Classify each country below as core, semi-periphery, or periphery, and justify your answer. Country J: GNI per capita (PPP) $62 000, a global financial and corporate headquarters hub, high-tech/service economy, net capital exporter. Country K: GNI per capita (PPP) $4 300, economy dependent on raw timber and agricultural exports (75% of export earnings), low industrial base, reliant on imported manufactured goods and foreign aid. Country L: GNI per capita (PPP) $13 800, rapidly expanding automotive and electronics manufacturing for export, growing services sector, but still substantial technological dependence on core-country firms.

Lời giải chi tiết

Country J: core. Very high GNI per capita, a globally central financial/service economy, and net exporter of capital — the defining features of a core economy.

Country K: periphery. Low GNI per capita, exports dominated by unprocessed raw commodities, minimal manufacturing, and dependence on imported manufactures and foreign aid indicate low bargaining power and structural dependence on core/semi-peripheral economies.

Country L: semi-periphery. Middle-income GNI per capita with a substantial, growing export-manufacturing base shows real industrialisation, but continued technological dependence on core-country firms shows the economy has not yet achieved full core status.

Bài tập luyện tập

Q10. "Unequal exchange," as used in World Systems Theory, refers to:

(A) Periphery regions receiving full and fair market value for the raw materials and labour they supply
(B) Core regions systematically capturing a disproportionate share of value generated within the world-system relative to what periphery regions receive
(C) Perfectly equal terms of trade between all countries in the world-system
(D) Direct barter trade between neighbouring periphery countries

Lời giải chi tiết

World Systems Theory holds that trade and investment relationships are structured so the core systematically captures more value than it returns to the periphery, reproducing dependency rather than simply reflecting a temporary developmental lag. **(B)**.

Bài tập luyện tập

Q11. Give one concrete example of "glocalisation" and briefly explain why it illustrates cultural blending rather than pure cultural replacement.

Lời giải chi tiết

Example: a global fast-food or beverage franchise that reformulates its menu in different national markets to include locally popular flavours, ingredients, or dishes alongside its standard global offering. This illustrates glocalisation rather than pure replacement because the global brand does not simply impose an identical product everywhere; it actively adapts to local taste and culture, producing a genuinely new, hybrid version of the product in each market rather than erasing local culinary preference.

Bài tập luyện tập

Q12. Language extinction — a language falling entirely out of use — is most commonly cited as evidence for which globalisation-related process?

(A) Glocalisation
(B) Cultural homogenisation / erosion
(C) Unequal exchange
(D) Semi-peripheral industrialisation

Lời giải chi tiết

Language extinction is widely cited as one of the clearest, most measurable symptoms of cultural homogenisation/erosion — the displacement of local languages and traditions by an increasingly dominant global culture. **(B)**.

Bài tập luyện tập

Q13. Briefly explain the role that indigenous-rights movements play in response to concerns about cultural erosion.

Lời giải chi tiết

Indigenous-rights movements organise to assert land rights, preserve indigenous languages and cultural practices, and claim rights to self-determination, resisting the homogenising pressures of globalisation and loss of ancestral land. Their claims have gained increasing international recognition, notably through the UN Declaration on the Rights of Indigenous Peoples (UNDRIP), adopted in 2007, which affirms indigenous peoples' rights to their own culture, language, and traditionally occupied lands and resources.

Bài tập luyện tập

Q14. At a development scale, the "digital divide" refers primarily to:

(A) Differences in internet speed between two neighbourhoods in the same wealthy city
(B) Unequal access to broadband/mobile internet and digital devices that limits participation in the global digital economy, disproportionately affecting lower-income countries and populations
(C) A rivalry between two competing technology companies
(D) A generational gap in social-media use

Lời giải chi tiết

At the global development scale, the digital divide refers to unequal connectivity between (and within) countries that constrains participation in an increasingly digital global economy, with lower-income countries and populations most affected. **(B)**.

Bài tập luyện tập

Q15. Before a mobile-money service was introduced in a country, an estimated 23% of adults held an account at a formal financial institution. Five years after the mobile-money service launched, 68% of adults had access to a formal or mobile financial account. (a) Calculate the percentage-point increase in financial inclusion. (b) State one reason mobile money can reach populations that traditional banking could not.

Lời giải chi tiết

(a) Increase $= 68\% - 23\% = \boxed{45 \text{ percentage points}}$.

(b) Mobile money requires only a basic mobile phone and a local agent network rather than a physical bank branch, so it can reach rural or remote populations lacking nearby bank infrastructure, and it typically does not require the formal documentation or minimum balances that traditional banks often demand.

Bài tập luyện tập

Q16. Tariffs imposed by wealthier importing countries on agricultural or manufactured goods from developing countries tend to:

(A) Have no effect on developing-country producers

(B) Make it harder for developing-country producers to access lucrative export markets, reducing potential export revenue

(C) Automatically raise developing-country producers' incomes

(D) Only ever apply to trade between two wealthy countries

Lời giải chi tiết

Tariffs and related trade barriers raise the effective cost of developing-country exports in the importing market, reducing competitiveness and market access. **(B)**.

Bài tập luyện tập

Q17. Which of the following correctly orders the key milestones of the early COVID-19 pandemic in chronological order?

(A) Pandemic declared → PHEIC declared → virus first identified

(B) Virus first identified in Wuhan → WHO declares a PHEIC → WHO characterises the outbreak as a pandemic

(C) WHO declares a pandemic → virus identified → PHEIC declared

(D) PHEIC declared → virus identified → pandemic declared

Lời giải chi tiết

December 2019: virus first identified in Wuhan. 30 January 2020: WHO declares a PHEIC. 11 March 2020: WHO characterises COVID-19 as a pandemic. **(B)**.

Bài tập luyện tập

Q18. An outbreak's daily case count grows at a constant rate of 10% per day, starting from 200 cases on day 0. Calculate (a) the projected case count after 14 days, and (b) the approximate doubling time.

Lời giải chi tiết

(a) $N_{14} = 200 \times (1.10)^{14}$. Since $(1.10)^{14} \approx 3.80$: $N_{14} \approx 200 \times 3.80 = \boxed{759 \text{ cases}}$.

(b) $t_{\text{double}} = \dfrac{\ln 2}{\ln(1.10)} = \dfrac{0.693}{0.0953} \approx \boxed{7.3 \text{ days}}$.

Bài tập luyện tập

Q19. The 2007–2008 Global Financial Crisis is most closely associated with the collapse of which institution in September 2008, which triggered a rapid, near-global loss of confidence in credit markets?

(A) Bear Stearns
(B) Lehman Brothers
(C) Northern Rock
(D) Silicon Valley Bank

Lời giải chi tiết

The bankruptcy filing of the US investment bank Lehman Brothers in September 2008 is the single most widely cited trigger of the acute phase of the Global Financial Crisis. **(B)**.

Bài tập luyện tập

Q20. *Examine* the reasons why a global shock can affect different countries very unequally. Use one named example (COVID-19 or the 2007–2008 Global Financial Crisis) to support your answer.

Lời giải chi tiết

Essay plan (using COVID-19).

Introduction: Define a global risk/shock, and state the paradox to be examined: although COVID-19 was a near-universal global shock (WHO pandemic declaration, 11 March 2020), its measured health, economic, and social impacts varied enormously between countries — reflecting differences in exposure, vulnerability, and resilience/response capacity, rather than the underlying shock itself differing.

Point 1 – differing exposure: Countries with major international aviation and trade hubs experienced earlier, larger case importation than more isolated economies; high population density and crowded informal urban settlements increased transmission exposure relative to lower-density regions.

Point 2 – differing vulnerability (health-system capacity): Countries with well-resourced health systems and high hospital-bed/ICU capacity per capita could treat severe cases with-

out system collapse; countries with weaker, under-resourced systems (some already strained by prior epidemics, cf. the West African Ebola outbreak) faced disproportionate mortality and disruption to routine care.

Point 3 – differing fiscal/economic capacity to respond: High-income countries funded large fiscal stimulus and furlough schemes and secured early vaccine doses through advance-purchase agreements; many lower-income countries had far less fiscal space and relied on COVAX for vaccine access, producing markedly slower vaccination rollouts and prolonged economic disruption, especially for informal-sector workers with no safety net.

Point 4 – differing policy response and economic structure: Variation in lockdown speed/stringency shaped both health outcomes and the depth of economic contraction; economies highly dependent on a single exposed sector (e.g., international tourism) suffered disproportionate economic shocks regardless of their domestic case numbers.

Conclusion: The shock itself (the virus) was global and broadly uniform; its ultimate impact was mediated by each country's exposure, vulnerability, and resilience — showing that global risks nonetheless produce highly uneven geographical outcomes, and that resilience-building (health-system strengthening, fiscal buffers, international cooperation via WHO/IMF/COVAX) is what narrows this gap for future shocks.

Bài tập luyện tập

Q21. Which international mechanism was established to promote more equal global access to COVID-19 vaccines?

(A) IMF Special Drawing Rights

(B) COVAX

(C) The G20 Debt Service Suspension Initiative

(D) The WTO TRIPS Agreement alone

Lời giải chi tiết

COVAX, co-led by the WHO, Gavi, and CEPI, pooled funding and purchasing power to distribute vaccine doses to participating lower-income countries. **(B)**.

Bài tập luyện tập

Q22. The Suez Canal normally carries roughly 45 vessel transits per day. Assume a blockage lasts 4 days. (a) Estimate the number of vessels delayed, assuming none can be rerouted. (b) State one economic consequence of such a delay for globally interconnected supply chains.

Lời giải chi tiết

(a) Vessels delayed $\approx 45 \times 4 = \boxed{180 \text{ vessels}}$.

(b) Possible consequences include higher freight and insurance costs, delays to just-in-time manufacturing inputs (e.g., components arriving late to assembly lines), continued port congestion for some time after the canal reopens as the backlog clears, and added time and fuel cost for any vessels rerouted around the Cape of Good Hope.

Ôn tập nhanh

- Phân bố dân số phụ thuộc yếu tố tự nhiên (khí hậu, địa hình, nguồn nước) và kinh tế–xã hội; Mô hình quá độ dân số (DTM) mô tả các giai đoạn thay đổi tỉ suất sinh–tử; tỉ số phụ thuộc $= \dfrac{\text{dân số} < 15 + \text{dân số} > 64}{\text{dân số } 15\text{–}64} \times 100$.
- Tính dễ tổn thương trước biến đổi khí hậu = hàm của phơi nhiễm, độ nhạy cảm và năng lực thích ứng; **thích ứng (adaptation)** là điều chỉnh để sống chung với tác động khí hậu, **giảm thiểu (mitigation)** là cắt giảm phát thải khí nhà kính tại nguồn — hai chiến lược bổ sung, không thay thế nhau.
- An ninh tài nguyên lương thực – nước – năng lượng liên kết chặt chẽ qua "nexus" tài nguyên; mất an ninh một loại tài nguyên thường kéo theo mất an ninh loại khác.
- Hệ thống sông ngòi vận hành theo chu trình nước của lưu vực (drainage basin); các đập lớn (ví dụ đập Tam Hiệp, đập Aswan) mang lại thuỷ điện/tưới tiêu nhưng gây tranh cãi về di dời dân cư và tác động sinh thái hạ lưu.
- Quá trình bờ biển gồm xói mòn (thuỷ lực, mài mòn, va đập, hoà tan), vận chuyển bồi (long-shore drift), và bồi tụ; quản lý bờ biển gồm biện pháp cứng (kè, đê chắn sóng) và biện pháp mềm (nuôi bãi, trồng rừng ngập mặn).
- Kiến tạo mảng giải thích phân bố động đất/núi lửa dọc ranh giới mảng (hội tụ, phân kỳ, trượt ngang); rủi ro thiên tai $= \dfrac{\text{hiểm hoạ} \times \text{tính dễ tổn thương}}{\text{năng lực ứng phó}}$.
- Các mô hình cấu trúc đô thị (vành đai đồng tâm Burgess, hình quạt Hoyt) mô tả không gian đô thị; đảo nhiệt đô thị (UHI) do bề mặt bê tông/nhựa hấp thụ và giữ nhiệt; giao thông bền vững ưu tiên phương tiện công cộng, xe đạp, giảm phát thải.
- Toàn cầu hoá thể hiện qua dòng chảy vốn, hàng hoá, lao động và thông tin xuyên biên giới; công ty xuyên quốc gia (TNC) dịch chuyển sản xuất đến nơi chi phí thấp; quyền lực mềm (soft power) dựa trên sức hút văn hoá/ngoại giao, quyền lực cứng (hard power) dựa trên năng lực quân sự/kinh tế cưỡng chế.
- Đo lường phát triển vượt ra ngoài GDP/GNI bình quân đầu người (PPP) bằng các chỉ số tổng hợp: **HDI** (trung bình nhân của chỉ số y tế – giáo dục – thu nhập), **GII** (bất bình đẳng giới), **MPI** (nghèo đa chiều, MPI $= H \times A$).
- Đường Brandt (1980) chia thế giới thành Bắc giàu – Nam nghèo nhưng đã lỗi thời trước sự trỗi dậy của các nền kinh tế công nghiệp mới và mức độ đa dạng nội tại của cả hai nhóm.
- Lý thuyết Hệ thống Thế giới (Wallerstein) chia nền kinh tế toàn cầu thành lõi – bán ngoại vi – ngoại vi, với "trao đổi không ngang giá" giữa lõi và ngoại vi.
- Toàn cầu hoá vừa thúc đẩy đồng nhất hoá văn hoá (nguy cơ mai một ngôn ngữ, bản sắc địa phương) vừa tạo ra hiện tượng glocalisation — pha trộn văn hoá toàn cầu với bản địa; phong trào quyền bản địa (UNDRIP 2007) phản kháng xói mòn văn hoá.
- Khoảng cách số và tình trạng không tiếp cận dịch vụ tài chính cản trở các nước đang phát triển tham gia kinh tế số; tiền di động (mobile money, ví dụ M-Pesa) là một giải pháp; thuế quan của nước giàu hạn chế khả năng tiếp cận thị trường xuất khẩu của nước nghèo.
- Rủi ro toàn cầu là cú sốc có khả năng lan toả xuyên biên giới: đại dịch COVID-19 (Vũ Hán 12/2019, PHEIC 01/2020, đại dịch 03/2020), khủng hoảng tài chính toàn cầu 2008 (sụp đổ Lehman Brothers), sự cố kênh đào Suez (2021), dịch Ebola Tây Phi (2014–2016).
- Khả năng chống chịu (resilience) là năng lực hấp thụ cú sốc rồi phục hồi và thích ứng tốt hơn ("build back better"); phân biệt rõ phơi nhiễm (exposure) với tính dễ tổn thương (vulnerability); chiến lược xây dựng khả năng chống chịu gồm đa dạng hoá kinh tế, an sinh xã hội, cảnh báo sớm, và hợp tác quốc tế (WHO, IMF).

Đồng hành cùng 8020 English

Cảm ơn bạn đã học cùng bộ giáo trình quốc tế 8020. **Điểm thật · Thầy thật · Kết quả thật** — nhiều học viên chỉ cần 1–2 khoá để đạt kết quả mong muốn.

Chương trình đào tạo tại 8020 English

IELTS Academic/General · **SAT** · PTE · Duolingo · TOEFL | **AP** (College Board) · **IB** Diploma · **Cambridge** IGCSE / A-Level | săn học bổng du học.

Vì sao chọn 8020 English?

- **100% giáo viên** đạt tối thiểu 8.0 IELTS hoặc 1500 SAT — đội ngũ Giáo sư · Tiến sĩ · Thạc sĩ tốt nghiệp trường top đầu thế giới (Carnegie Mellon — #1 Hoa Kỳ về Khoa học Máy tính).
- **Kèm 1–1** mọi độ tuổi; lớp sĩ số nhỏ 2–5 bạn (đa số dưới 10 bạn/lớp).
- Lộ trình cá nhân hoá, theo sát tiến độ từng học viên; lớp OFFLINE tại TP.HCM & ONLINE toàn quốc.

Bảng vàng học viên

AP 5/5 — Calculus AB/BC	**AP** 4–5 — Biology, Chemistry	**IB** 90/100 — Economics
SAT 1590 / 1570 / 1550	**IELTS** 8.0–9.0	**Duolingo** 110 · **PTE** 90

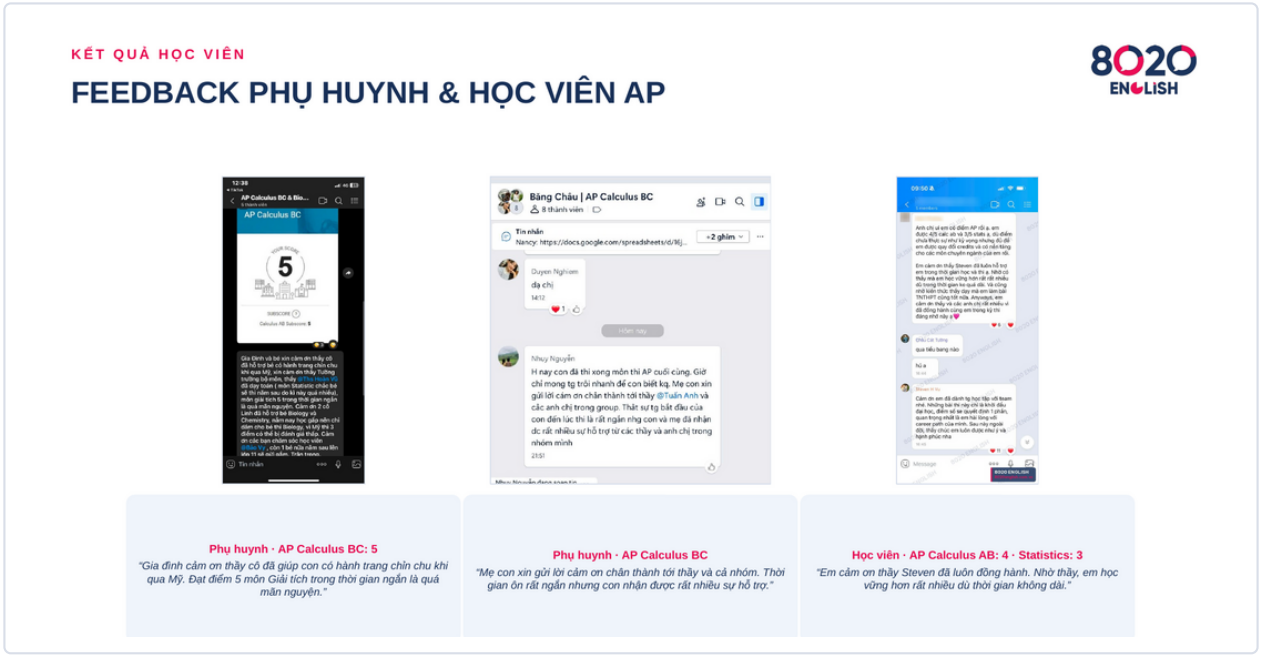
Cảm nhận học viên & phụ huynh

> *"Bạn đã cải thiện được tư duy Writing — kỹ năng từng là nỗi sợ lớn nhất — và cuối cùng đã đậu vào trường top như mong muốn. Thái độ học tập cực kỳ nghiêm túc; ngay cả khi nằm viện vẫn cố gắng học đều đặn."*
>
> — Phan Thị Thanh Hằng · IELTS Overall 8.5

> *"Cần tất cả kỹ năng trên 7.5 để xét vào trường top 1 Anh Quốc về Y học (chương trình UKFPO của NHS) — và đã đạt mục tiêu sau khi học Writing 1–1."*
>
> — Trần Hoàng Bảo Ngọc · IELTS Overall 8.0 (Writing 6.0 → 7.5)

> *"Gia đình và bé xin cảm ơn thầy cô đã giúp con có hành trang chỉn chu khi qua Mỹ. Đạt điểm 5 môn Giải tích trong thời gian ngắn là quá mãn nguyện."*
>
> — Phụ huynh · AP Calculus BC 5/5

> *"Em cảm ơn thầy đã luôn đồng hành. Nhờ thầy, em học vững hơn rất nhiều dù thời gian ôn không dài."*
>
> — Học viên · AP Calculus AB 4

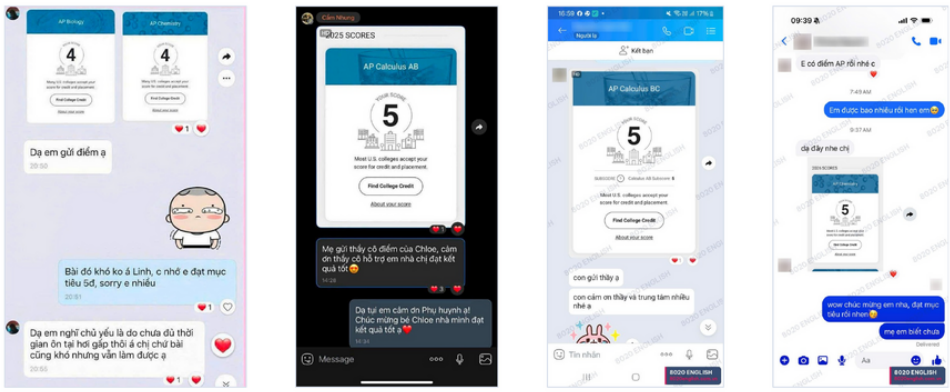


Feedback phụ huynh & học viên AP — nhiều môn đạt điểm 4 & 5

Điểm thi thật của học viên

KẾT QUẢ HỌC VIÊN

ĐIỂM SỐ AP



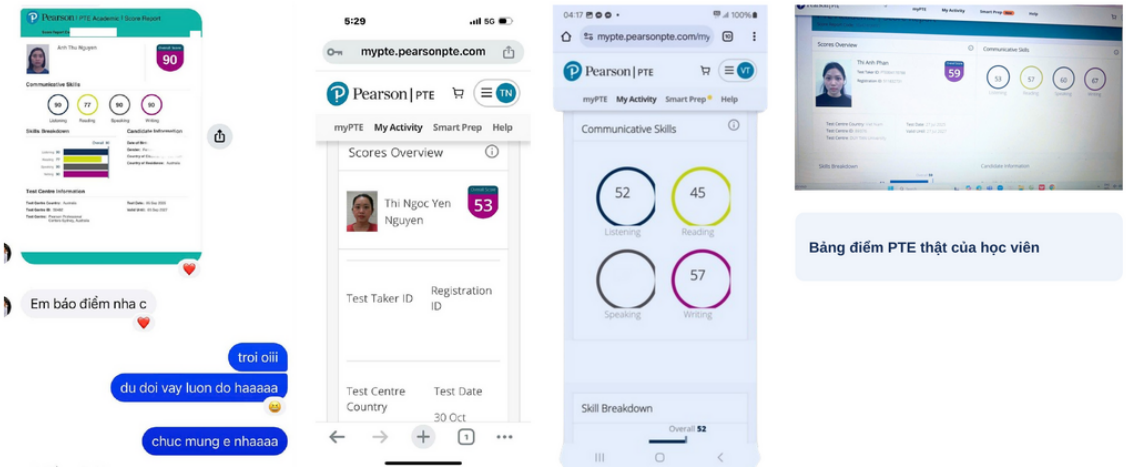
AP Biology: 4 · AP Chemistry: 4 | AP Calculus AB: 5 | AP Calculus BC: 5 | AP Chemistry: 5

Bảng điểm AP thật của học viên – nhiều môn đạt điểm 4 & 5

Bảng điểm AP thật — Calculus AB/BC 5/5 · Biology & Chemistry 4–5 (College Board)

KẾT QUẢ HỌC VIÊN

ĐIỂM SỐ PTE

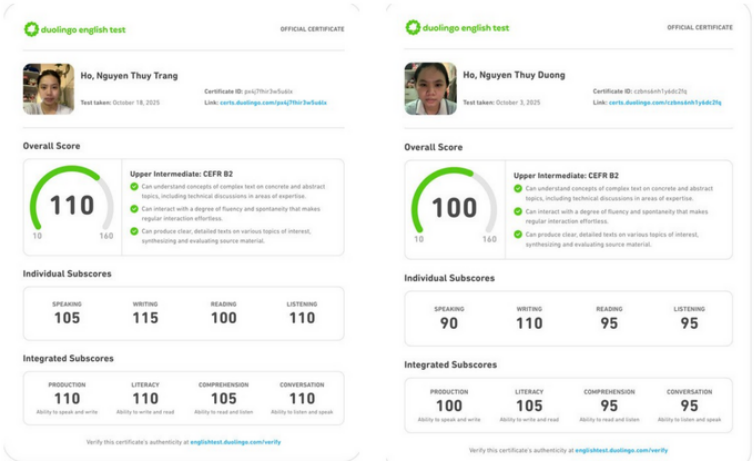


Bảng điểm PTE thật của học viên

Học viên 8020 — PTE Academic 90

KẾT QUẢ HỌC VIÊN

ĐIỂM SỐ DUOLINGO



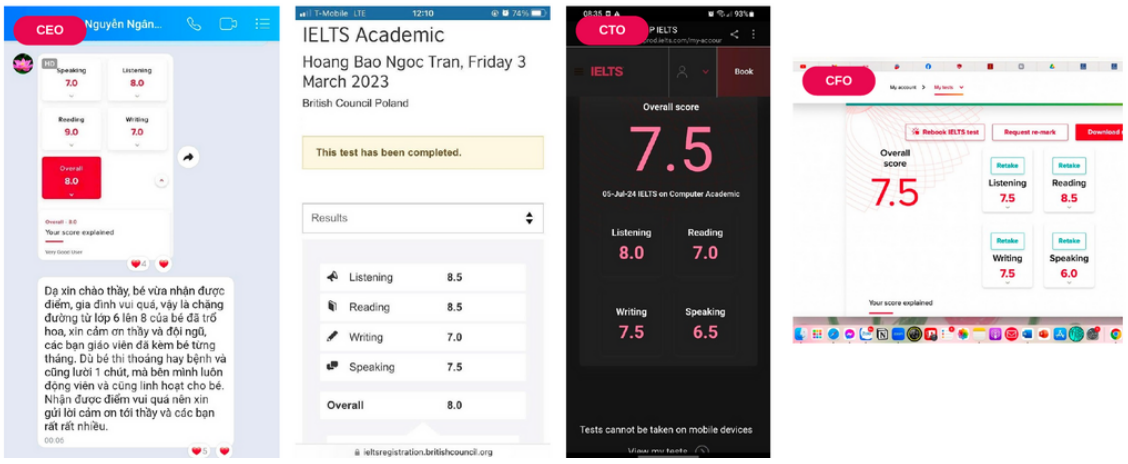
Duolingo English Test – 110 & 100

Học viên 8020 — Duolingo English Test 110 & 100

KẾT QUẢ HỌC VIÊN

THÀNH TÍCH HỌC VIÊN

Bảng điểm thi thật – chất lượng được giám sát nghiêm ngặt. Một số học viên chỉ cần 1–2 khóa để đạt kết quả mong muốn.



Học viên 8020 — IELTS 8.0 / 7.5 / 8.5 (báo điểm thật)