GENERAL BIOLOGY · STUDY GUIDE

Exam 7 Study Guide

This guide covers chapters 13 and 14. First you see how an animal body keeps its internal pond of fluid steady: feeding, moving blood and gases, fighting infection, cleaning the blood, signaling, moving and making the next generation. Then you zoom out to whole populations, communities, ecosystems and the planet. Both chapters reward numbers, so work every worked case with a pencil. Read the "what to know" paragraphs, copy the tables out by hand, then try each case with the steps covered. Finish each chapter with its ten self-test items. The cram sheet holds every value and equation.

WHAT THIS GUIDE COVERS

- Chapter 13 · the four tissues, surface area and diffusion, homeostasis and feedback, thermoregulation, digestion, open and closed circulation, the heart and cardiac output, gas exchange and hemoglobin, innate and adaptive immunity, osmoregulation and the nephron, hormones and the pituitary, action potentials, synapses, senses, muscle contraction, gametogenesis, reproductive hormones and early development.
- Chapter 14 · levels of ecology, climate and circulation cells, rain shadows, biomes and aquatic zones, mark recapture, survivorship, exponential and logistic growth, life histories, density dependence, species interactions, niches and competitive exclusion, keystone species and trophic cascades, succession, primary production, the 10 percent rule, biogeochemical cycles, threats to biodiversity, conservation and climate change.

CHAPTER 13

Animal Form, Function, Homeostasis, Reproduction and Development

Read it in full: **Chapter 13 in the textbook**. See it in motion: **Animal Form and Function Lab** and **Reproduction and Development Lab**.

What to know

Animal bodies use four tissues. **Epithelial** tissue covers and lines surfaces, is polarized and sits on a basement membrane. **Connective** tissue has scattered cells in a matrix (tendon, cartilage, bone, adipose, blood). **Muscle** tissue is skeletal, cardiac or smooth. **Nervous** tissue has neurons and glia. Diffusion time rises with the square of distance, and the surface area to volume ratio falls as size grows, so large animals use folded exchange surfaces (lungs, gills, villi) plus a circulatory system.

Homeostasis holds variables near set points (blood pH near 7.4, glucose, temperature). A control loop has a stimulus, sensor, control center and effector. **Negative feedback** opposes the change and stabilizes; it is almost universal (insulin lowering glucose). **Positive feedback** amplifies a change until an outside event ends it (oxytocin in childbirth).

Endotherms (birds, mammals) heat themselves with metabolism, costing about five to ten times more energy at rest. **Ectotherms** take heat from the environment. Heat moves by radiation, conduction (water conducts about 25 times better than air), convection and evaporation (which only removes heat). Animals adjust with insulation, vasodilation or vasoconstriction, countercurrent heat exchange, sweating or panting, behavior, shivering and brown fat with thermogenin. The hypothalamus is the thermostat; a fever resets the set point upward.

Food supplies energy, carbon skeletons and essential nutrients (essential amino acids, essential fatty acids, vitamins, minerals). Processing runs ingestion, digestion (hydrolysis), absorption and elimination. Salivary amylase starts on starch; stomach acid (pH about 2) and pepsin start on protein; in the small intestine, bile emulsifies fat (no enzymes), pancreatic enzymes and bicarbonate act, brush border enzymes finish, and villi absorb. Sugars and amino acids go to the liver by the hepatic portal vein; fats leave in chylomicrons through lacteals. The colon reabsorbs water and hosts the microbiome.

Arthropods and most molluscs have **open** circulation; annelids, cephalopods and vertebrates have **closed** circulation. Arteries carry blood away from the heart and veins carry it toward the heart, whatever its oxygen. Fishes have a two-chambered heart and single circulation; birds and mammals have four chambers and **double circulation** (pulmonary and systemic), which evolved separately in the two groups. The SA node sets the beat, the AV node delays it about 0.1 second,

and Purkinje fibers spread it. **Cardiac output** = heart rate × stroke volume, about 72 × 70 mL, or about 5 L per minute. Blood is about 55 percent plasma.

Gas exchange surfaces are moist, thin and large. Air at sea level has a PO_2 of about 160 mm Hg. Fish gills use **countercurrent exchange** to extract over 80 percent of the oxygen. Mammals breathe by negative pressure (the diaphragm contracts and flattens). Surfactant keeps alveoli open. The medulla drives breathing mainly by sensing CO_2 through pH. Hemoglobin binds O_2 cooperatively (S-shaped curve), and low pH shifts the curve right (**Bohr shift**), unloading more oxygen in active tissue. Carbon monoxide binds about 200 times more tightly than oxygen.

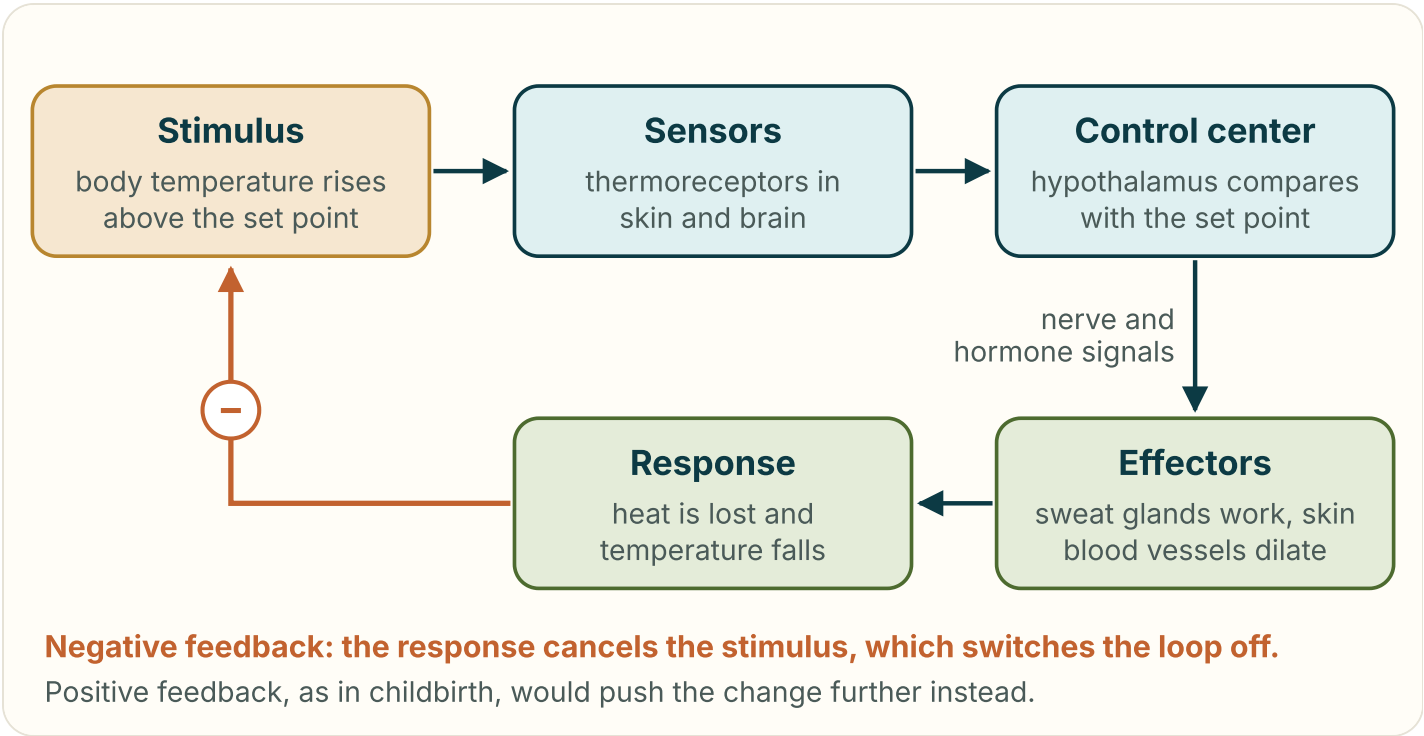
Innate immunity is fast and broad: barriers, lysozyme, Toll-like receptors, neutrophils, macrophages, natural killer cells and inflammation (histamine, cytokines). **Adaptive immunity** (vertebrates only) uses B cells (mature in marrow) and T cells (mature in thymus), each with one rearranged receptor. Antibodies have two heavy and two light chains. Class I MHC shows inside fragments to CD8 cytotoxic T cells; class II shows engulfed fragments to CD4 helper T cells. **Clonal selection** makes effector and memory cells; the primary response peaks in about 10 to 17 days, and the secondary response is faster and larger. Vaccines give active immunity; transferred antibodies give passive immunity that fades.

Marine bony fish drink seawater and excrete salt; freshwater fish make dilute urine and take up salt. Nitrogen leaves as **ammonia** (aquatic, cheapest, most water), **urea** (mammals) or **uric acid** (insects, reptiles and birds; least water, most energy). The **nephron** filters at the glomerulus (about 180 L a day), reabsorbs about 99 percent (only about 1.5 L of urine), secretes wastes and uses the loop of Henle to build a salty medulla. **ADH** inserts aquaporins in the collecting duct; the renin-angiotensin-aldosterone system raises sodium reabsorption and blood volume.

Water-soluble hormones (insulin, glucagon, epinephrine) bind surface receptors and act fast through second messengers. Lipid-soluble hormones (steroids, thyroid hormone) bind intracellular receptors and change gene expression slowly. The hypothalamus makes oxytocin and ADH (released from the posterior pituitary) and releasing hormones that control the anterior pituitary, as in TRH to TSH to thyroid hormone, with negative feedback. Insulin (beta cells) lowers glucose; glucagon (alpha cells) raises it.

A neuron rests at about −70 mV, set by the Na^+/K^+ pump and K^+ leak channels. At threshold (about −55 mV), voltage-gated Na^+ channels open in a positive feedback upswing to about +30 to +40 mV; Na^+ channels then inactivate and K^+ channels repolarize. The **action potential** is all or none; strength is coded by frequency. Myelin gives saltatory conduction. At a synapse, Ca^{2+} entry releases transmitter, causing EPSPs or IPSPs that are summed. In muscle, Ca^{2+} binds troponin, tropomyosin moves, and myosin heads pull actin in the **sliding filament** model; ATP cocks and releases the heads and powers the calcium pump.

Spermatogenesis gives four sperm per meiosis, continuously (about 100 million or more a day). Oogenesis starts before birth, arrests in prophase I, and gives one egg plus polar bodies, finishing meiosis II only if a sperm enters. GnRH drives FSH and LH; rising estradiol switches to positive feedback and causes the LH surge and ovulation around day 14; the corpus luteum makes progesterone; hCG from an embryo keeps it alive. Development runs cleavage, morula, blastula (blastocyst in mammals), **gastrulation** into ectoderm (skin, nervous system), mesoderm (muscle, bone, heart, kidneys) and endoderm (gut lining, liver, pancreas), then organogenesis: the notochord induces the neural tube, and somites form vertebrae and muscle.



Negative feedback keeps you near 37 °C. The loop runs until the response removes the stimulus, then it stops.

LOCK THESE IN

- Negative feedback stabilizes; positive feedback amplifies to completion.
- Four heat routes: radiation, conduction, convection, evaporation (only removes heat).
- Bile emulsifies; it has no enzymes. Most digestion and absorption happen in the small intestine.
- Artery = away from the heart; vein = toward it. Cardiac output = rate × stroke volume.
- Bohr shift: low pH, more O_2 unloaded. Breathing is driven mainly by CO_2.
- Class I with CD8; class II with CD4. Memory makes the secondary response fast.
- ADH adds aquaporins; about 99% of filtrate is reabsorbed.
- Action potential: threshold about −55 mV, all or none; Ca^{2+} on troponin starts contraction.

Numbers and formulas

Item	Value or formula	Note
Cardiac output	Heart rate × stroke volume	72 × 70 mL ≈ 5 L/min
Blood pressure	About 120/80 mm Hg	Systolic over diastolic
PO_2 at sea level	0.21 × 760 ≈ 160 mm Hg	Air about 21% O_2
Kidney filtrate	About 180 L/day	About 1.5 L urine; about 99% reabsorbed
Resting potential	About −70 mV	K^+ equilibrium about −90 mV
Threshold; peak	About −55 mV; +30 to +40 mV	All or none
AV node delay	About 0.1 s	Atria finish emptying
Diffusion time	Rises with distance squared	Double the distance, four times slower
Primary immune response	Peaks about 10 to 17 days	Secondary faster and larger
Ovulation	Around day 14 of about 28	LH surge

Key terms and comparisons

Pair	How to tell them apart
Innate vs adaptive	All animals, fast, broad, no memory; vertebrates, days, specific, memory.
Humoral vs cell-mediated	B cells and antibodies; cytotoxic T cells kill infected cells.
Active vs passive immunity	Own response with memory; transferred antibodies, temporary.
Ammonia, urea, uric acid	Most toxic and most water; middle; least water, most energy.
Water- vs lipid-soluble hormones	Surface receptor, fast; intracellular receptor, gene changes.
Posterior vs anterior pituitary	Releases hypothalamic oxytocin and ADH; makes its own tropic hormones.
EPSP vs IPSP	Na^+ in, toward threshold; Cl^- in or K^+ out, away.
Spermatogenesis vs oogenesis	Four sperm, continuous; one egg, arrests, unequal divisions.

Key terms and comparisons: germ layers

Layer	Gives rise to
Ectoderm	Epidermis, hair, nails, nervous system, eye lens, tooth enamel
Mesoderm	Notochord, muscle, bone, heart, blood vessels, blood, kidneys, gonads
Endoderm	Lining of gut and airways, liver, pancreas, thyroid

Worked cases

WORKED CASE 1 · CARDIAC OUTPUT AT REST AND IN EXERCISE

At rest a person has a heart rate of 80 beats per minute and a stroke volume of 60 mL. During exercise these rise to 150 and 100 mL. Find both cardiac outputs.

STEP 1 · REST

80 × 60 = 4,800 mL, or **4.8 L/min**.

STEP 2 · EXERCISE

150 × 100 = 15,000 mL, or **15 L/min**.

STEP 3 · COMPARE

15 ÷ 4.8 is a bit over **3 times** more blood per minute.

WHAT SPED IT UP

Sympathetic nerves and epinephrine speed the SA node pacemaker.

WORKED CASE 2 · HOW MUCH DOES THE KIDNEY SAVE?

The kidneys filter about 180 L a day and make about 1.5 L of urine. What share is reabsorbed? What happens to urine if ADH receptors are blocked?

STEP 1 · REABSORBED VOLUME

180 − 1.5 = 178.5 L.

STEP 2 · SHARE

178.5 ÷ 180 = 0.992, about **99 percent**.

STEP 3 · ADH BLOCKED

No aquaporins go into the collecting duct, so water stays in the filtrate: **large volumes of dilute urine**.

WORKED CASE 3 · TRACING AN ACTION POTENTIAL AND A CONTRACTION

A motor neuron fires and a skeletal muscle fiber contracts. List the main events in order.

STEP 1 · THRESHOLD

Depolarization at the hillock reaches about −55 mV; voltage-gated Na^+ channels open.

STEP 2 · SPIKE AND RECOVERY

Na^+ rushes in to about +30 mV; Na^+ channels inactivate and K^+ channels repolarize. Myelin lets the spike jump node to node.

STEP 3 · SYNAPSE

At the terminal, Ca^{2+} enters and acetylcholine is released at the neuromuscular junction.

STEP 4 · MUSCLE

The fiber fires, the signal runs down T tubules, the sarcoplasmic reticulum releases Ca^{2+}, Ca^{2+} binds troponin and tropomyosin moves.

STEP 5 · CROSS BRIDGES

Myosin heads bind actin and pull. New ATP releases each head; pumping Ca^{2+} back relaxes the muscle.

WORKED CASE 4 · FEEDBACK OR NOT?

Classify: (a) rising glucose leads to insulin, which lowers glucose; (b) the baby's head stretches the cervix, oxytocin rises, contractions strengthen; (c) rising estradiol triggers the LH surge; (d) thyroid hormone inhibits TRH and TSH.

STEP 1 · (A)

The response opposes the change: **negative**.

STEP 2 · (B)

The response strengthens the change until birth ends it: **positive**.

STEP 3 · (C)

High estradiol boosts LH, which drives ovulation: **positive**.

STEP 4 · (D)

The end product shuts down its own cascade: **negative**.

TRAPS PEOPLE FALL INTO

- **Saying bile digests fat.** Bile has no enzymes; it emulsifies so lipase can work.
- **Naming vessels by oxygen.** The pulmonary artery carries oxygen-poor blood; direction decides the name.
- **Thinking low O_2 is the main breathing signal.** Rising CO_2, sensed through pH, is the main driver.
- **Calling ectotherms "cold blooded."** A basking lizard can be warmer than a mammal; the terms are about heat source.
- **Saying antibodies kill pathogens directly.** They neutralize, opsonize, clump and activate complement.
- **Thinking a stronger stimulus makes a bigger spike.** Action potentials are all or none; frequency codes strength.
- **Saying actin and myosin filaments shorten.** They slide past each other; the sarcomere shortens.
- **Placing the nervous system in mesoderm.** It comes from ectoderm.

Chapter 13 self-test · ten items

1. A cell grows from 10 to 20 micrometers across. What happens to its surface area to volume ratio?

A. It rises fourfold
B. It stays the same
C. It doubles
D. It is cut in half

D. It is cut in half Surface rises fourfold but volume eightfold, so the ratio halves.

2. Which is an example of positive feedback?

A. Insulin lowering a high blood glucose
B. Sweating as body temperature rises
C. Oxytocin strengthening labor contractions
D. Thyroid hormone inhibiting TSH release

C. Oxytocin strengthening labor contractions The response amplifies the stimulus until delivery ends the loop.

3. Why does a person with a rising fever shiver?

A. The thermostat has stopped working
B. The hypothalamic set point was raised
C. Sweat glands have been switched on
D. Pyrogens block all heat production

B. The hypothalamic set point was raised The body is below its new set point, so heat-making responses switch on.

4. Which statement about bile is correct?

A. It emulsifies fat but contains no enzymes
B. It is made by the pancreas for proteins
C. It neutralizes acid with bicarbonate ions
D. It digests triglycerides into fatty acids

A. It emulsifies fat but contains no enzymes Bile acts like detergent; lipase does the hydrolysis.

5. Which vessel carries oxygen-rich blood to the heart?

A. The venae cavae
B. The aorta
C. The pulmonary veins
D. The pulmonary arteries

C. The pulmonary veins Veins carry blood toward the heart; the pulmonary veins bring oxygenated blood from the lungs.

6. Active muscle has a low pH. How does hemoglobin respond?

A. It releases more oxygen there
B. It switches to carry carbon monoxide
C. It binds oxygen more tightly
D. It stops carrying any oxygen

A. It releases more oxygen there The Bohr shift lowers oxygen affinity, unloading more O_2 where it is needed.

7. Which cells read antigen fragments on class I MHC?

A. Helper T cells (CD4)
B. Cytotoxic T cells (CD8)
C. Neutrophils (innate)
D. Plasma cells (from B)

B. Cytotoxic T cells (CD8) Class I MHC on nearly all nucleated cells is read by CD8 cytotoxic T cells.

8. A desert lizard excretes nitrogen as a paste. Which waste is this?

A. Ammonia
B. Urea
C. Creatine
D. Uric acid

D. Uric acid Uric acid needs very little water, which suits reptiles, birds and insects.

9. Why does cortisol act hours after release while epinephrine acts in seconds?

A. Epinephrine is a steroid like cortisol
B. Cortisol changes gene expression inside cells
C. Cortisol binds surface receptors more slowly
D. Epinephrine enters the nucleus faster

B. Cortisol changes gene expression inside cells Lipid-soluble cortisol binds intracellular receptors that alter transcription.

10. Damage to which germ layer would most directly block formation of the brain?

A. Ectoderm
B. Trophoblast
C. Mesoderm
D. Endoderm

A. Ectoderm The neural tube forms from ectoderm.

CHAPTER 14

Ecology: Populations, Communities, Ecosystems and Conservation

Read it in full: **Chapter 14 in the textbook**. See it in motion: **Populations and Communities Lab** and **Ecosystems Lab**.

What to know

Ecology studies interactions among organisms and their environment at the organism, population, community, ecosystem, landscape and global levels. It is experimental and quantitative, and it is not the same as environmentalism: ecology describes how nature works; deciding what to do also involves values.

The sun heats Earth unevenly: direct light at the equator, slanted light toward the poles. Seasons come from the 23.5 degree tilt, not distance from the sun. In the circulation cells, warm moist air rises at the equator, cools and drops rain (rain forests); dry air sinks near 30 degrees and warms (deserts); air rises again near 60 degrees. The Coriolis effect turns winds into trade winds and westerlies, which drive ocean currents such as the Gulf Stream. Oceans moderate coastal climate. Temperature falls about 6 °C per 1,000 m of elevation, and mountains cast **rain shadows** on their leeward sides.

Biomes on land are set mainly by temperature and precipitation: tropical rain forest, tropical dry forest, savanna, desert (under 30 cm rain), chaparral, temperate grassland, temperate broadleaf forest, taiga (the largest) and tundra. Aquatic biomes depend on light, depth, salinity and nutrients: the photic and aphotic zones, the benthic zone and the thermocline; oligotrophic versus eutrophic lakes; wetlands, streams, estuaries, intertidal zones, the open ocean, coral reefs and vent communities.

Populations are described by density and dispersion (clumped, uniform, random). **Mark recapture** estimates N = s × n ÷ x. Survivorship curves are type I (most die old: humans), type II (constant risk) and type III (most die young: oysters). **Exponential growth**, $dN/dt = r_{max}N$, gives a J curve. **Logistic growth**, $dN/dt = r_{max}N(K - N)/K$, gives an S curve that levels at the carrying capacity K and is fastest at K/2. Real populations can overshoot or oscillate, and some show an Allee effect at low density.

Life histories trade offspring number against investment: semelparous versus iteroparous; r-selected (many small offspring, early maturity, type III) versus K-selected (few large offspring, late maturity, type I). Density-independent factors (frost, floods) kill a similar fraction at any density; only **density-dependent** factors (competition, territoriality, disease, predation, toxic wastes, stress) regulate a population by negative feedback. Hare and lynx cycle about every 10 years. Humans passed 8 billion in the early 2020s; growth peaked near 2 percent a year in the 1960s and is now under 1 percent.

Interactions: competition (−/−), predation, herbivory and parasitism (+/−), mutualism (+/+) and commensalism (+/0). A species' **fundamental niche** is what it could use alone; its **realized niche** is what it uses with competitors (Connell's barnacles). Gause showed **competitive exclusion**; resource partitioning and character displacement let similar species coexist. Prey defenses include camouflage, warning colors, **Batesian mimicry** (harmless copies harmful) and **Müllerian mimicry** (harmful species look alike).

Diversity has species richness and relative abundance. A **keystone species** has an effect far larger than its numbers: removing Pisaster sea stars dropped richness from over 15 species to fewer than 5. Ecosystem engineers such as beavers reshape habitat. Control can be bottom up or top down; a **trophic cascade** follows the loss of sea otters (urchins boom, kelp collapses). The intermediate

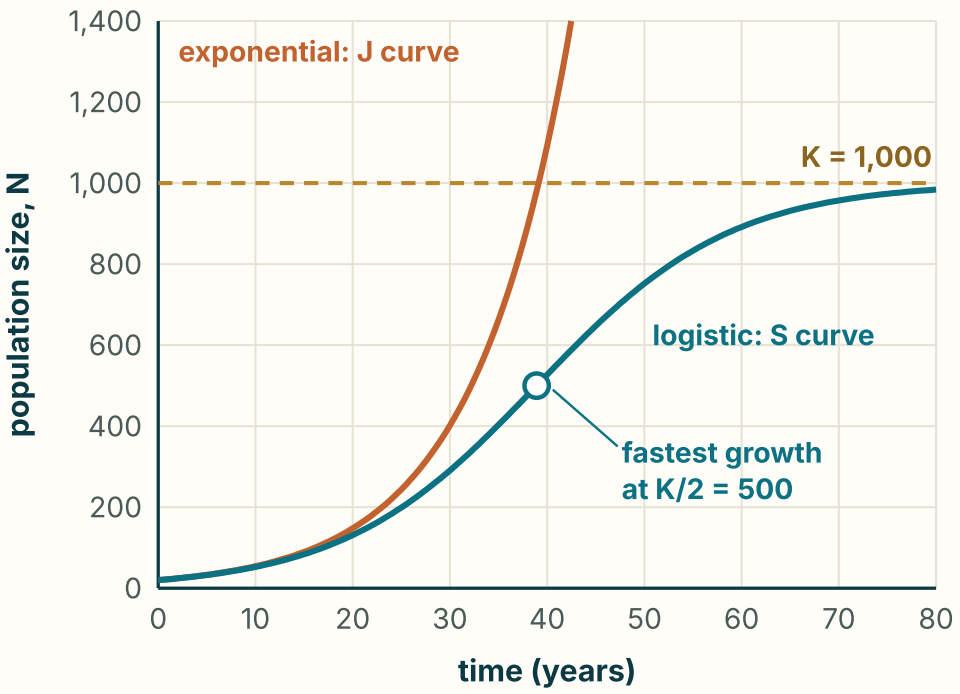
disturbance hypothesis says moderate disturbance gives the most diversity. **Primary succession** starts without soil (pioneers: lichens, mosses); **secondary succession** starts with soil left in place and is faster.

Energy flows one way and leaves as heat; matter cycles. Producers, consumers and detritivores form trophic levels. **NPP = GPP − R**, usually about half of GPP; only about 1 percent of visible light is captured. Rain forests, estuaries, wetlands and reefs are the most productive per area; the open ocean matches all land in total. Limiting nutrients: nitrogen in coastal seas, iron in parts of the open ocean, phosphorus in lakes. **Trophic efficiency** is about 10 percent (5 to 20), so food chains are short. Energy pyramids always narrow upward; some aquatic biomass pyramids are inverted.

Cycles: **water** (oceans about 97 percent), **carbon** (photosynthesis and respiration; fossil fuels raised CO_2 from about 280 to over 420 ppm, and about a quarter dissolves in the ocean, acidifying it), **nitrogen** (fixation, ammonification, nitrification, denitrification; Haber-Bosch now fixes as much as all natural land processes) and **phosphorus** (no gas phase; from rock; excess causes cultural eutrophication and dead zones).

Biodiversity exists at genetic, species and ecosystem levels; about 1.8 to 2 million species are named. Extinction now runs hundreds to a thousand times above background. Threats (HIPPO): habitat loss and fragmentation (the biggest), invasive species, pollution (with **biological magnification** of DDT, PCBs and methylmercury), population growth and consumption, and overharvesting. Small populations face an extinction vortex; managers watch the minimum viable population and effective population size. Tools include hot spots, corridors, reserves, restoration and island biogeography (large, near islands hold the most species).

The **greenhouse effect** keeps Earth at about 15 °C instead of about −18 °C. Added CO_2, methane and nitrous oxide have warmed the surface about 1.1 to 1.3 °C since the late 1800s. Effects include range shifts toward the poles and upslope, changes in phenology, coral bleaching, ocean acidification and thawing permafrost (a positive feedback). **Mitigation** reduces the cause; **adaptation** reduces the harm. The recovering ozone layer shows that coordinated action works.



Same start, same rate

N_o = 20, r_{max} = 0.1 per year

Exponential

$dN/dt = r_{max}N$

no limit, keeps speeding up

Logistic

$dN/dt = r_{max}N(K - N)/K$

slows as N nears K

At N = 900: $(K - N)/K = 0.1$, so growth is 10% of the exponential rate.

K is the carrying capacity, the most the habitat holds.

Exponential against logistic growth. Both curves come from the same numbers. Only the logistic one feels the limit of K.

LOCK THESE IN

- Rising air drops rain; sinking air dries the land. Deserts near 30 degrees.
- Mark recapture: N = s × n ÷ x.
- Exponential: $dN/dt = r_{max}N$. Logistic: multiply by $(K - N)/K$; fastest at K/2.
- Only density-dependent factors regulate populations.
- Realized niche is the same size or smaller than the fundamental niche.
- Keystone species and trophic cascades show top-down control.
- NPP = GPP − R. About 10% passes up each level. Energy flows; matter cycles.
- HIPPO threats; toxins magnify upward while energy shrinks upward.

Formulas and numbers

Item	Formula or value	Example
Mark recapture	$N = s \times n \div x$	$50 \times 40 \div 10 = 200$
Exponential growth	$dN/dt = r_{max}N$	J curve
Logistic growth	$dN/dt = r_{max}N(K - N)/K$	S curve; fastest at K/2
Net primary production	$NPP = GPP - R$	Usually about half of GPP
Trophic efficiency	About 10% (5 to 20%)	10,000 to 1,000 to 100 to 10 kcal
Light captured	About 1% of visible light	By producers
Elevation	About 6 °C cooler per 1,000 m	Like moving toward the poles
Axial tilt	About 23.5 degrees	Causes seasons
Atmospheric CO_2	About 280 to over 420 ppm	About a quarter dissolves in the ocean
Warming	About 1.1 to 1.3 °C since the late 1800s	Most at high northern latitudes
Greenhouse effect	About 15 °C with it; about −18 °C without	Natural plus enhanced

Key terms and comparisons: interactions and life histories

Item	Effect or trait	Example
Competition	−/−	Weeds and crops
Predation, herbivory, parasitism	+/−	Lynx and hares; urchins and kelp; ticks
Mutualism	+/+	Mycorrhizae; pollinators
Commensalism	+/0	Cattle egrets
Batesian mimicry	Harmless copies harmful	Scarlet kingsnake and coral snake
Müllerian mimicry	Harmful species look alike	Bees and wasps
r-selected	Many small offspring; type III	Weeds, insects, mice
K-selected	Few large offspring; type I	Elephants, whales, humans

Worked cases

WORKED CASE 1 · COUNTING BY MARK RECAPTURE

Biologists mark 80 frogs and release them. Later they catch 60 frogs, and 15 are marked. Estimate the population.

STEP 1 · WRITE THE FORMULA

$N = s \times n \div x$.

STEP 2 · PLUG IN

$N = 80 \times 60 \div 15 = 4{,}800 \div 15 =$ **320 frogs**.

ASSUMPTIONS

Marked frogs mix randomly, marks are not lost, and no births, deaths or migration happen between samples.

WORKED CASE 2 · LOGISTIC GROWTH AT THREE SIZES

A population has $K = 1{,}000$ and $r_{max} = 0.1$ per year. Find dN/dt at $N = 100$, 500 and 900.

STEP 1 · N = 100

0.1 × 100 × (900/1,000) = 0.1 × 100 × 0.9 = **9 per year**.

STEP 2 · N = 500

0.1 × 500 × (500/1,000) = **25 per year**, the fastest, at K/2.

STEP 3 · N = 900

0.1 × 900 × (100/1,000) = **9 per year**.

THE SHAPE

Small populations add few because N is small; crowded ones add few because little capacity is left.

WORKED CASE 3 · ENERGY UP A FOOD CHAIN

Producers in a grassland have a GPP of 24,000 kcal/m^2/yr and use 11,000 in respiration. Using 10 percent per step, how much reaches tertiary consumers?

STEP 1 · FIND NPP

24,000 − 11,000 = **13,000 kcal/m^2/yr**.

STEP 2 · PRIMARY CONSUMERS

13,000 × 0.1 = 1,300.

STEP 3 · SECONDARY CONSUMERS

1,300 × 0.1 = 130.

STEP 4 · TERTIARY CONSUMERS

130 × 0.1 = **13 kcal/m^2/yr**, which is why top predators are rare.

WORKED CASE 4 · FOLLOWING AIR OVER A MOUNTAIN

Moist ocean air blows east over a north to south mountain range. Predict rainfall and vegetation on each side.

STEP 1 · WINDWARD (WEST)

Air rises, cools and drops rain: **wet** slopes, often forest.

STEP 2 · LEEWARD (EAST)

Air sinks, warms and absorbs moisture: **dry** rain shadow, often desert.

SAME RULE, BIGGER SCALE

Rising air at the equator gives rain forests; sinking air near 30 degrees gives the great deserts.

TRAPS PEOPLE FALL INTO

- **Blaming seasons on distance from the sun.** The 23.5 degree tilt causes seasons; Earth is closest to the sun in January.
- **Calling frost a regulator.** Density-independent factors do not regulate; only density-dependent ones do.
- **Expecting the fastest growth near K.** Logistic growth is fastest at K/2.
- **Making the realized niche bigger than the fundamental niche.** It is the same size or smaller, unless a mutualist expands it.
- **Saying energy cycles.** Energy flows through and leaves as heat; matter cycles.
- **Mixing up Batesian and Müllerian mimicry.** Batesian: a harmless mimic. Müllerian: harmful species share a look.
- **Thinking biomass pyramids are always upright.** Some aquatic ones invert because phytoplankton turn over fast.
- **Confusing biological magnification with the energy pyramid.** Energy shrinks upward; persistent toxins concentrate upward.

Chapter 14 self-test · ten items

1. Why are many great deserts found near 30 degrees latitude?

A. Ocean currents bring polar air there
B. The sun is most direct there
C. Dry air sinks there and warms
D. Moist air rises there and cools

C. Dry air sinks there and warms Air that dropped its rain at the equator descends near 30 degrees, warming and drying the land.

2. Researchers mark 40 birds, then catch 50, of which 8 are marked. What is the estimate?

A. 160 birds
B. 400 birds
C. 2,000 birds
D. 250 birds

D. 250 birds N = 40 × 50 ÷ 8 = 250.

3. A population has K = 600. At what size does logistic growth add the most individuals?

A. 600
B. 300
C. 450
D. 150

B. 300 Growth is fastest at K/2.

4. Oysters release millions of eggs, and nearly all larvae die. Which pattern fits?

A. Type III survivorship, r-selected
B. Type I survivorship, r-selected
C. Type I survivorship, K-selected
D. Type II survivorship, K-selected

A. Type III survivorship, r-selected Huge numbers of offspring with little care and very high early death fit type III and r selection.

5. Which factor regulates a population by negative feedback?

A. A drought that hits sparse and dense alike
B. A flood that sweeps away the area
C. A late frost that kills a fixed share
D. Disease that spreads faster when crowded

D. Disease that spreads faster when crowded Only density-dependent factors grow stronger with density.

6. When barnacle A is removed, barnacle B spreads into the space. What does this show?

A. A was B's mutualist
B. Competition with A limited B
C. B evolved a new niche fast
D. B's fundamental niche grew

B. Competition with A limited B Competition had kept B out of part of the habitat it can tolerate, so its realized niche was smaller than its fundamental niche.

7. A harmless fly looks like a stinging wasp. What is this?

A. Cryptic coloration
B. Aposematic coloration
C. Batesian mimicry
D. Müllerian mimicry

C. Batesian mimicry A harmless species copying a harmful one is Batesian mimicry.

8. Sea otters disappear from a kelp forest. What happens next?

A. Urchins boom and kelp declines
B. Nothing changes in the forest
C. Kelp booms and urchins decline
D. Urchins and kelp both increase

A. Urchins boom and kelp declines Losing the predator releases urchins, which overgraze kelp: a trophic cascade.

9. Producers make 20,000 kcal/m^2/yr of NPP. About how much reaches secondary consumers?

A. 10,000 kcal/m^2/yr
B. 20 kcal/m^2/yr
C. 2,000 kcal/m^2/yr
D. 200 kcal/m^2/yr

D. 200 kcal/m^2/yr About 10 percent passes each step: 2,000 to primary consumers, 200 to secondary.

10. Soil lacks nitrifying bacteria. Which form of nitrogen builds up?

A. Ammonium
B. N_2 gas
C. Nitrite
D. Nitrate

A. Ammonium Without nitrification, ammonium cannot be oxidized to nitrite and nitrate.

Cram sheet

Everything from chapters 13 and 14 in one place. Cover the right column and see if you can rebuild each row.

Numbers and formulas

Item	Value	Note
Cardiac output	Rate × stroke volume	About 5 L/min at rest
PO_2, sea level	About 160 mm Hg	21% of 760
Kidney	180 L filtered, 1.5 L urine	About 99% reabsorbed
Neuron	Rest −70; threshold −55; peak +30 to +40 mV	All or none
CO binding	About 200 times O_2	Falsely normal pulse oximetry
Endothermy cost	About 5 to 10 times ectothermy	At rest
Mark recapture	$N = s \times n \div x$	Closed population
Logistic	$dN/dt = r_{max}N(K - N)/K$	Peak at K/2
NPP	GPP − R	About half of GPP
Trophic efficiency	About 10%	5 to 20%
CO_2	About 280 to over 420 ppm	Ocean takes about a quarter
Warming	About 1.1 to 1.3 °C	Since the late 1800s
Named species	About 1.8 to 2 million	True total far higher

Key terms and comparisons

Pair	How to tell them apart
Negative vs positive feedback	Opposes change; amplifies change.
Open vs closed circulation	Hemolymph bathes organs; blood stays in vessels.
Innate vs adaptive immunity	Fast and broad; specific with memory.
Exponential vs logistic	J curve, no limit; S curve, levels at K.
Density dependent vs independent	Regulates; does not.
Fundamental vs realized niche	Alone; with competitors.
Primary vs secondary succession	No soil; soil left.
GPP vs NPP	Total fixed; minus producer respiration.
Mitigation vs adaptation	Reduce the cause; reduce the harm.

Rules that win points

Topic	The rule
Vessels	Name by direction, not oxygen.
Hormones	Solubility tells receptor location and speed.
Germ layers	Ecto outside and nerves, meso muscle, endo inner tubes.
Rainfall	Follow the air: rising wet, sinking dry.
Food chains	Multiply by 0.1 for each step up.
Toxins	Persistent fat-soluble toxins concentrate upward.

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