

Unit 3: Populations

Unit 3 covers how populations grow and what stops them. It includes generalist and specialist species, r-selected and K-selected reproductive strategies, survivorship curves, carrying capacity and overshoot, limiting factors, age structure diagrams, fertility rates, human population dynamics, and the demographic transition model.

AP Environmental Science

Populations

About 15 minutes to read

How to use this guide

Read it in order the first time because the topics build on each other. Reproductive strategies explain survivorship curves, survivorship and resource limits shape the growth models, and the growth models are what the human population topics apply to people. Exam questions often give a description or a graph and ask you to name the pattern and predict what happens next.

After the first read, use the trap boxes and the tables to review the distinctions that exam questions test most often. Finish with the practice questions, then complete the recall check on the last page out loud and note any items you cannot explain yet.

What this unit is worth. Populations is about 10 to 15 percent of the AP Environmental Science exam. Its tools also show up everywhere else. The Rule of 70, exponential and logistic growth, and carrying capacity reappear in land use, energy consumption, and pollution questions. A shaky grasp of population models here makes later units harder than they need to be.

3.1 Generalist and Specialist Species

A **specialist species** has a narrow niche. It depends on a small set of resources or a particular habitat, so it tends to do well where conditions stay constant. A **generalist species** has a broad niche. It eats many foods, tolerates many habitats, and tends to do well where conditions are changing. Pandas and koalas are classic specialists. Raccoons, rats, cockroaches, and humans are generalists.

This matters for extinction risk. When a habitat changes suddenly, specialists have nowhere to go, so they are more vulnerable. Generalists can shift to a new food or a new area. That is why generalists often thrive in human-disturbed landscapes while specialists decline.

Trap. Being a specialist is not a weakness in itself. In a stable habitat, specialists usually outcompete generalists because they use their narrow resource set so efficiently. The vulnerability only appears when conditions change. Questions that ask which species survives a disturbance want the generalist, but questions about who wins in an undisturbed habitat often want the specialist.

3.2 r-Selected and K-Selected Species

Species face a tradeoff between having many offspring with little care or few offspring with heavy care. An **r-selected species** takes the first path. It is small, matures early, produces many offspring with minimal energy invested in each one, lives a short time, and often reproduces once. Competition for resources is usually low in its habitat. Insects, weeds, and rodents are examples.

A **K-selected species** takes the second path. It is large, matures late, produces few offspring with heavy parental investment in each, lives a long time, and reproduces many times. Competition for resources is usually high. Elephants, whales, and primates are examples.

The name comes from the population growth equation. The letter r stands for the intrinsic growth rate, which r-selected species maximize. The letter K stands for carrying capacity, which K-selected species live near and compete for.

TRAIT	R-SELECTED	K-SELECTED
Body size	Small	Large
Offspring per reproduction	Many	Few
Parental care	Little or none	Heavy investment per offspring
Maturation and lifespan	Early maturation, short life	Late maturation, long life
Reproductive events	Often one	Multiple
Habitat competition	Usually low	Usually high

Trap. The r/K split is a spectrum, not two boxes. Many species fall in between, and some shift strategies with conditions. If a question describes a species with mixed traits, the honest answer is an intermediate strategy, not whichever endpoint is closer.

3.2 continued: Biotic Potential and Invasive Species

Biotic potential is the maximum reproductive rate of a population under ideal conditions. It is the ceiling a population would hit if nothing limited it, and r-selected species have the highest biotic potential. Real populations rarely reach it because conditions are rarely ideal.

Most invasive species are r-selected. They arrive in a new habitat, reproduce fast with little parental care, and overwhelm the natives. **K-selected native species** are hit hardest by invasions because they reproduce slowly and cannot recover quickly. This is why an invasive weed or insect can drive a slow-breeding native toward extinction in a few generations.

Trap. High biotic potential does not guarantee a large population. It only describes what would happen under ideal conditions. A high-biotic-potential species in a harsh environment can still be rare, and a low-biotic-potential species in a rich one can still be abundant. Questions testing this phrase want the ceiling, not the reality.

3.3 Survivorship Curves

A **survivorship curve** tracks one cohort from birth to the age of the oldest member, showing what fraction survives at each age. There are three types, and each one lines up with a reproductive strategy.

TYPE	SHAPE OF THE CURVE	WHO FOLLOWS IT
Type I	Most individuals survive to old age, then die off steeply at the end.	Humans, elephants. Typically K-selected.
Type II	Mortality is roughly constant at every age, so the curve falls in a straight line.	Many birds, squirrels, some reptiles. Often K-selected or intermediate.
Type III	Most offspring die very young, but the survivors live long.	Fish, insects, plants. Typically r-selected.

Read the curve by where the deaths happen. A steep drop at the start is Type III. A flat line through the middle is Type I. A steady diagonal is Type II.

Trap. Type III does not mean the species is failing. The survivors still live long enough to produce thousands of offspring, so the population holds steady or grows. Questions that describe mass early death and ask whether the population is doomed want "no, this is normal for Type III."

3.4 Carrying Capacity

Carrying capacity, written K , is the maximum population size an environment can sustain over time. A population grows fast while resources are plentiful, then growth slows as it approaches K . This S-shaped pattern is called **logistic growth**. The J-shaped pattern, where growth keeps accelerating because nothing limits it, is **exponential growth**. Real populations often follow the logistic curve, growing exponentially at first and leveling off near K .

Populations do not always stop politely at K . **Overshoot** happens when a population grows past its carrying capacity, usually because abundant resources hide the limit for a while. The damage follows: depleted resources, polluted habitat, and crowding. The crash that follows overshoot is called **dieback**. Resources run scarce, and famine, disease, and conflict cut the population back down, sometimes catastrophically.

Trap. Carrying capacity is not a fixed number. It shifts as conditions change. A new food source, better shelter, or a change in climate can raise K , and resource depletion or habitat loss can lower it. Questions that ask what happens after a lasting habitat improvement want " K increases," not "the population stays at the old K ."

3.5 Population Growth and Resource Availability

Limiting factors are the environmental pressures that cap population growth, chiefly available resources and space. The resource base is finite at every scale of time. When resources are abundant, growth usually accelerates. When the resource base shrinks, distribution gets unequal, mortality rises, and birth rates fall, so growth declines to or below carrying capacity.

Put the two directions together and you get the full picture. Abundance pushes populations up toward and sometimes past K . Scarcity pulls them back down. The population tracks the resources, not the other way around.

Trap. A population does not have to land exactly on K and stay there. It can overshoot and crash in a dieback, or it can hover below K if some other factor limits it first. "Limited by resources" describes the mechanism, not a guaranteed landing point.

3.6 Age Structure Diagrams

An **age structure diagram** stacks a population by age group, usually pre-reproductive at the bottom, reproductive in the middle, and post-reproductive at the top. The shape tells you where the population is heading.

SHAPE	WHAT IT MEANS
Wide base, narrow top (pyramid)	Many young people entering reproductive age soon. Rapid growth.
Straight sides (column)	Births roughly match deaths. Stable population.
Narrow base, wider top (inverted)	Few young people. Declining population.

A rapidly growing population has a higher proportion of younger people than a stable or declining one. That is the whole read: compare the base to the top.

Trap. The diagram shows the future, not the present. A wide base does not mean the population is already large, it means a large cohort is about to start reproducing, so growth is coming. Questions that pair a pyramid shape with a policy choice are testing whether you can see that future.

3.7 Total Fertility Rate

The **total fertility rate (TFR)** is the average number of children a woman is expected to have in her lifetime. It is shaped by the age of first birth, female educational opportunities, access to family planning, and government acts and policies. A country with high TFR grows fast, all else equal.

Replacement-level fertility is the TFR at which a population stays roughly stable. It is about 2.1 children per woman, not exactly 2, because some children do not survive to reproductive age and the sex ratio is not exactly even. Below replacement level, the population declines over time. Above it, the population grows.

Infant mortality tracks how many babies die before their first birthday, and it responds to mothers' access to healthcare and nutrition. When those improve, infant mortality falls, and fewer births are needed to reach the same family size, which eventually pushes TFR down too.

Trap. Replacement level is not exactly two children per woman. The standard value is about 2.1. A question that gives a TFR of 2.0 and asks about stability wants "slight decline," not "stable."

3.8 Human Population Dynamics

Human population change comes down to four numbers: **births, deaths, immigration, and emigration**. Birth and death rates are shaped by access to education, family planning, healthcare, and nutrition. Migration adds or subtracts people on top of that. There is no mystery to the accounting, just four terms.

Growth has limits. The Earth's **carrying capacity** caps the global population, and Malthusian theory gives the classic warning: human populations can grow faster than the food supply can expand. Technology keeps pushing the limit outward, but the limit is still there.

Two kinds of factors act on populations. **Density-dependent factors** get stronger as density rises: competition for food and water, disease transmission, territory fights. **Density-independent factors** hit regardless of density: storms, fires, heat waves, droughts. A hurricane does not check how crowded the town is before it arrives.

Trap. Disease is density-dependent, not density-independent. It spreads faster through a crowded population, so its bite grows with density. Students often file it with storms and fires because it feels like a disaster, but the test classifies by the mechanism, and disease scales with crowding.

3.8 continued: Rate of Natural Increase and the Rule of 70

The **rate of natural increase (RNI)** measures population growth from births and deaths alone, ignoring migration. It is the crude birth rate minus the crude death rate, usually expressed as a percentage. A country with 20 births and 8 deaths per 1,000 people has an RNI of 12 per 1,000, or 1.2 percent. A negative RNI means the population is shrinking even before migration is counted.

The **Rule of 70** turns that rate into a doubling time. Divide 70 by the annual growth rate as a percent, and the answer is roughly how many years it takes the population to double. At 2 percent growth, doubling time is $70 / 2 = 35$ years. At 1.4 percent, it is $70 / 1.4 = 50$ years. The rule is an estimate, but it is close enough for exam work.

The math underneath is exponential. A constant growth rate compounds like interest, so the population doubles in a fixed number of years. Higher rates double faster, which is why a small difference in RNI produces a large difference in doubling time.

Trap. The Rule of 70 needs the rate as a whole-number percent. If you are given 0.014 as a decimal, convert to 1.4 percent first. Dividing 70 by 0.014 gives 5,000 years, which is the classic wrong answer when the units slip.

3.9 Demographic Transition

The **demographic transition** describes how birth and death rates shift as a country develops from a pre-industrial to an industrialized economy. The four-stage model is the standard version.

STAGE	BIRTH AND DEATH RATES	POPULATION GROWTH
1	High birth, high death	Slow, roughly stable
2	High birth, falling death	Rapid
3	Falling birth, low death	Slowing
4	Low birth, low death	Stable or declining

Death rates fall first, usually from better food, sanitation, and medicine. Birth rates fall later, usually from education, family planning, and urbanization. The gap between the two curves is where the fast growth happens. **Developing countries** typically sit in stages 2 and 3, and they still show higher infant mortality rates and more children in the workforce than developed countries.

Trap. The model describes a typical path, not a law. Countries can stall in a stage, and some move through faster than others. A question that asks what stage a country is in wants you to match its birth and death rates to the table, not to assume every country is marching neatly through all four.

Practice Questions

Original questions written for this guide in the style of the AP exam. Answers and explanations are on the next page, so complete the questions before checking them.

- 1.** A country's population is growing at an annual rate of 1.4 percent. Using the Rule of 70, the estimated doubling time is closest to
 - A. 35 years
 - B. 50 years
 - C. 70 years
 - D. 98 years

- 2.** A marine biologist studies a fish species in which most individuals die within the first few weeks of life, but the small number that survive live for many years. Which survivorship curve and reproductive strategy best describe this species?
 - A. Type I curve, K-selected
 - B. Type II curve, intermediate strategy
 - C. Type III curve, r-selected
 - D. Type III curve, K-selected

- 3.** Which of the following best describes an r-selected species?
 - A. Large body size, few offspring per reproduction, heavy parental investment, long lifespan
 - B. Small body size, many offspring per reproduction, minimal parental investment, short lifespan
 - C. Large body size, many offspring per reproduction, minimal parental investment, short lifespan
 - D. Small body size, few offspring per reproduction, heavy parental investment, long lifespan

- 4.** A country's age structure diagram has a very wide base and a narrow top. Which of the following is the best prediction?
 - A. The population is stable and will remain so
 - B. The population is declining because of low birth rates
 - C. The population will grow rapidly as the large young cohort reaches reproductive age
 - D. The population has already finished growing

Answer Key

- 1. B.** The Rule of 70 says doubling time is 70 divided by the growth rate as a percent: $70 / 1.4 = 50$ years. A divides 70 by 2 instead of 1.4, confusing the 2 percent example with this rate. C forgets to divide at all and just answers 70. D multiplies 70 by 1.4, reversing the operation entirely.
- 2. C.** Heavy early mortality with long-lived survivors is the Type III curve, and it pairs with the r-selected strategy of many offspring with little care. A misreads the early deaths as a Type I pattern, but Type I has most deaths late in life. B invents a Type II fit, but the mortality is not constant across ages here. D gets the curve right but attaches the wrong strategy, since K-selected species show Type I or II curves.
- 3. B.** r-selected species are small, produce many offspring with minimal investment in each, mature early, and live short lives. A describes a K-selected species exactly, the most common confusion. C and D mix traits from both strategies, which makes them tempting but wrong, since the strategies are defined by the full package, not individual traits.
- 4. C.** A wide base means a large pre-reproductive cohort. When those young people reach reproductive age, births rise and the population grows rapidly. A misreads the pyramid shape as the column shape of a stable population. B reads the shape backward, since a declining population has a narrow base, not a wide one. D confuses the present with the future: the diagram predicts growth to come, not growth already finished.

One-Page Recall Check

- Explain why specialists are vulnerable to habitat change while generalists are not.
- List the traits of r-selected and K-selected species and name one example of each.
- Define biotic potential and explain why invasive species tend to be r-selected.
- Describe each survivorship curve type and match it to a reproductive strategy.
- Define carrying capacity, overshoot, and dieback in your own words.
- Sketch the logistic and exponential growth curves and explain how they differ.
- Explain how resource abundance and scarcity push a population toward and away from K.
- Read an age structure diagram and predict whether the population is growing, stable, or declining.
- Define total fertility rate and state the approximate replacement level.
- Name two factors that affect infant mortality and two that affect TFR.
- List the four components of human population change.
- Give an example of a density-dependent factor and a density-independent factor, and explain the difference.
- Calculate the rate of natural increase from a crude birth rate and a crude death rate.
- Use the Rule of 70 to find the doubling time for a 2 percent growth rate.
- Describe the four stages of the demographic transition and where developing countries typically fall.

Where to go next. Turn every missed item above into flashcards and drill them spaced out over several days rather than in one sitting. In Rycal, open the AP Environmental Science deck and work the Unit 3 cards. If you have a test date, add it in the Test Planner so your review is paced to the exam. You can also start your next review with a Brain Dump, then check what you missed against this guide.

Key terms for this unit

Generalist vs. specialist species, K-selected species, r-selected species, Biotic potential, Intermediate reproductive strategies, r-selected invasive species, Survivorship curve, Survivorship curves by reproductive strategy, Carrying capacity and overshoot, Dieback, Limiting factors on population growth, Finite resource base, Resource abundance and growth, Resource scarcity and population decline, Age structure diagrams, Age structure of growing populations, Total fertility rate (TFR), Replacement-level fertility, Infant mortality factors, Components of human population change, Limits to human population growth, Density-dependent vs. density-independent factors, Rate of natural increase (RNI), Rule of 70, Demographic transition, Developing-country demographics.

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