BIOZONE

SHOWCASE

BIOZONE

Introducing:

Richard Allan

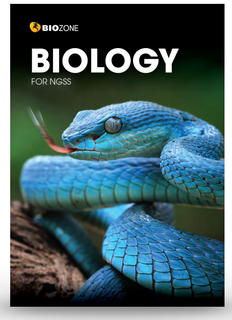
President

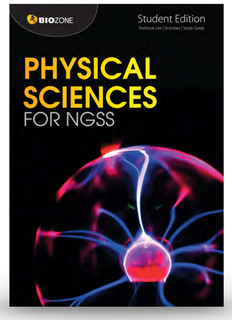
BIOZONE Corporation

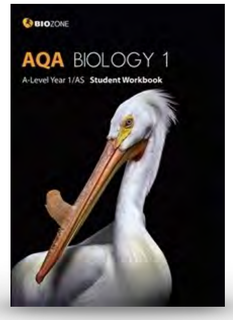
What Will be Covered:

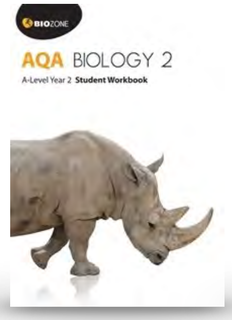
- Key programs and latest titles:
    - NGSS Biology Programs
    - AP Programs
    - IB Biology *NEW*
    - Anatomy & Physiology
    - Environmental Science *NEW*
    - Biology for Texas *NEW*
- **BIOZONE** WORLD

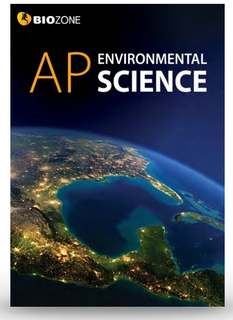
Our range of resources reflects our diverse market

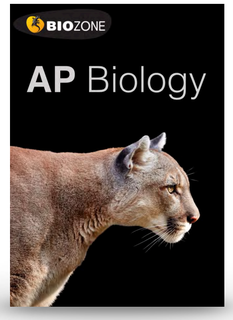


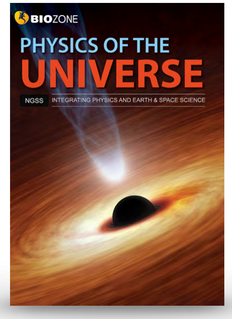


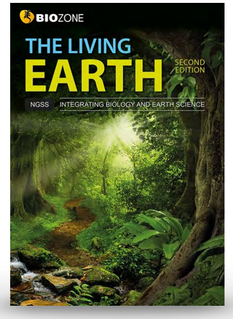


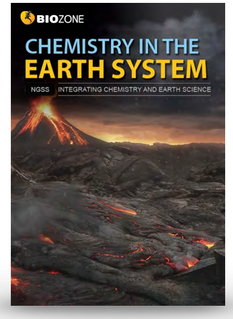


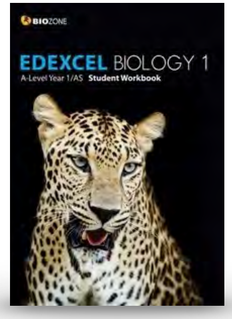


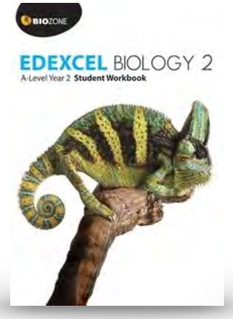


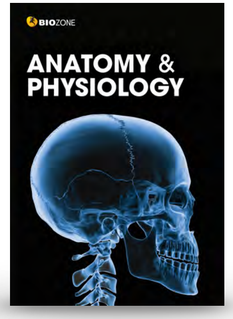


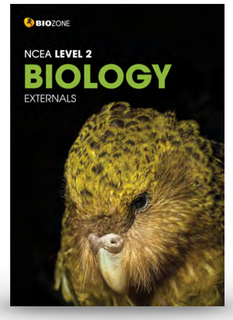


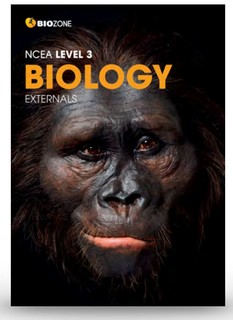


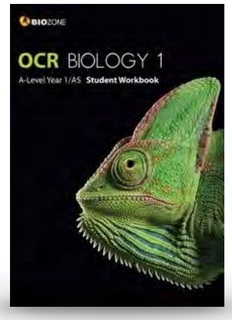


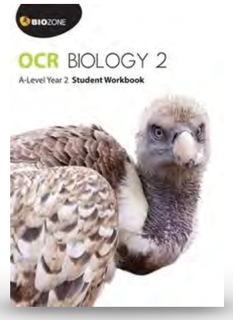


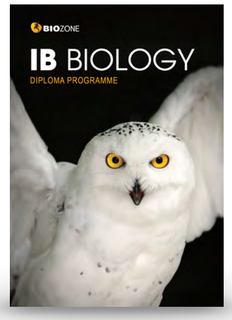


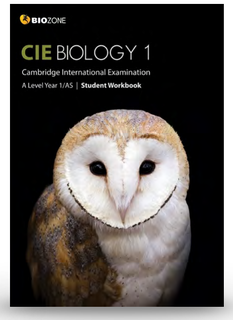








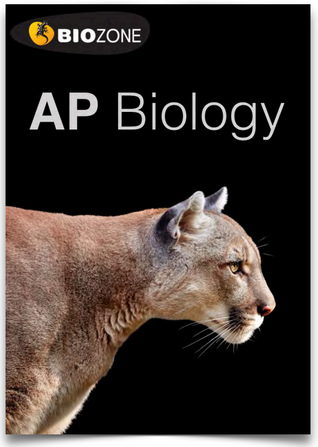


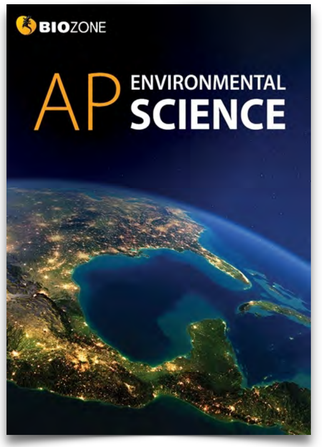


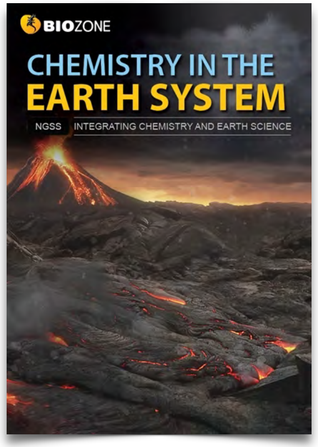
BIOZONE

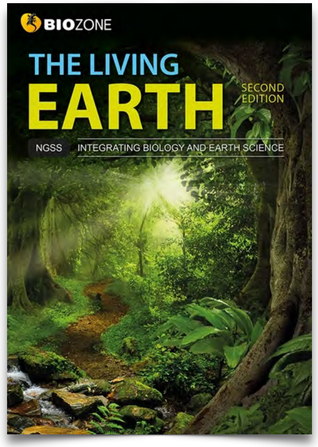
SCIENCE

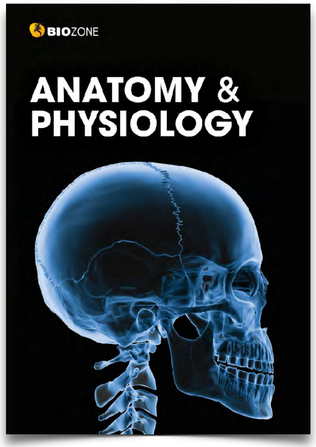
US PROGRAMS

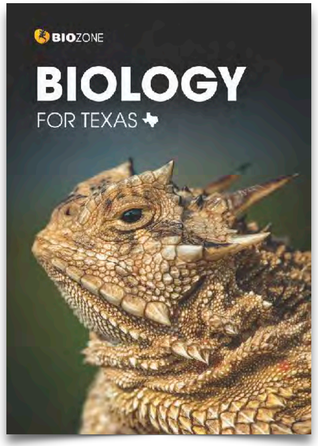


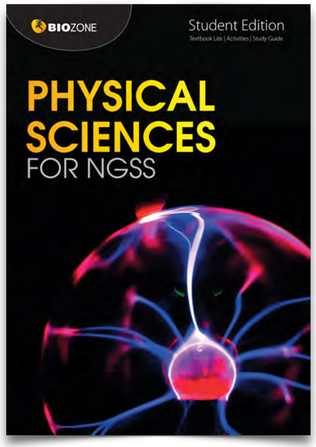


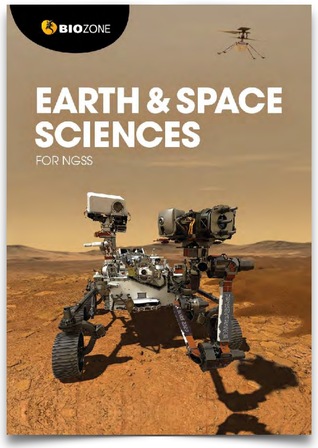


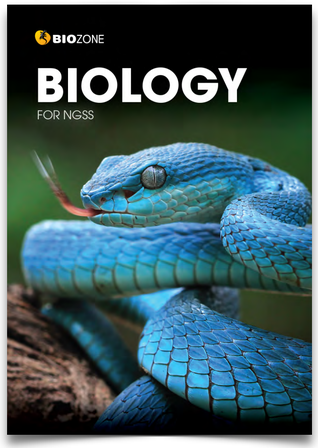


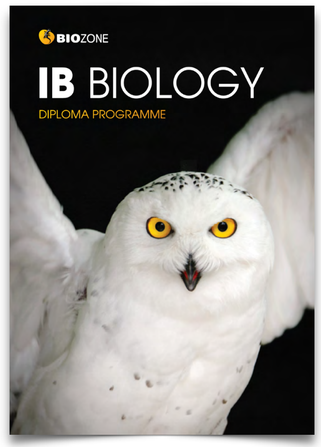


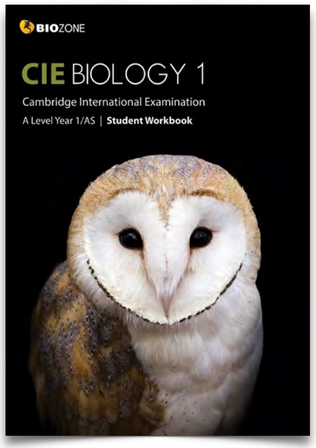


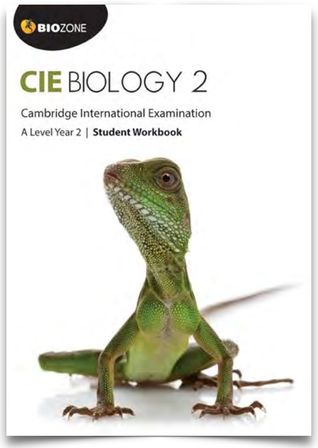








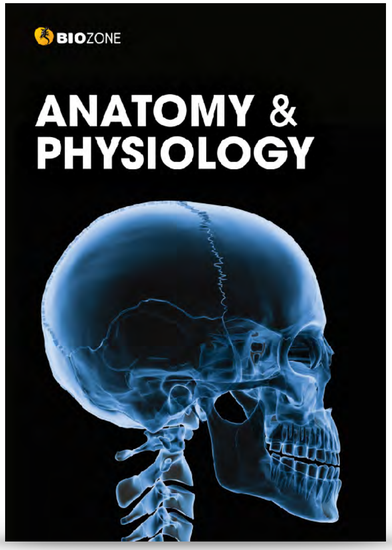


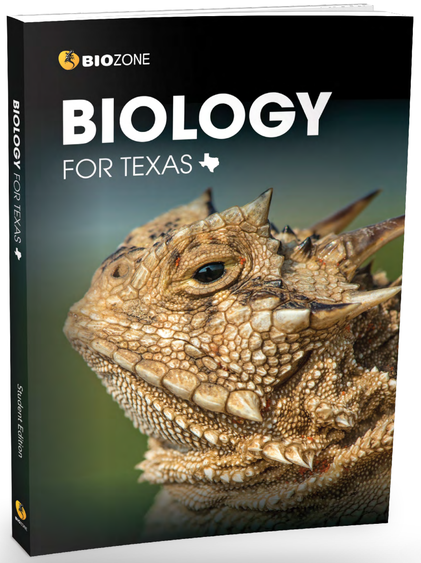


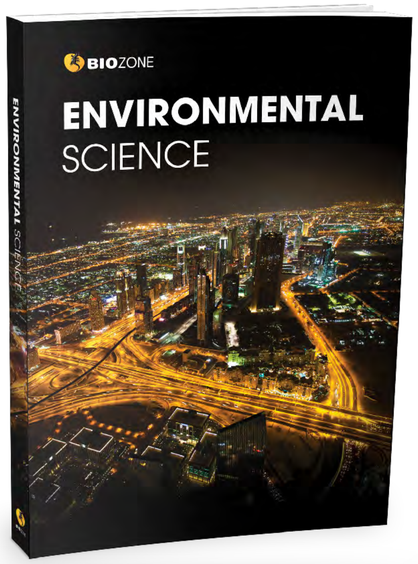
Meet the BIOZONE Authors

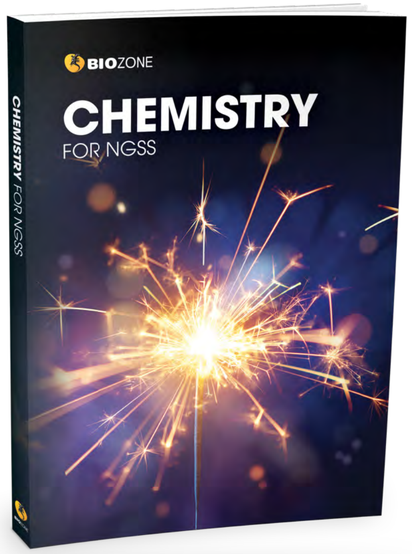
Questions? Author Hotline: authors@biozone.com

Recent & New Editions

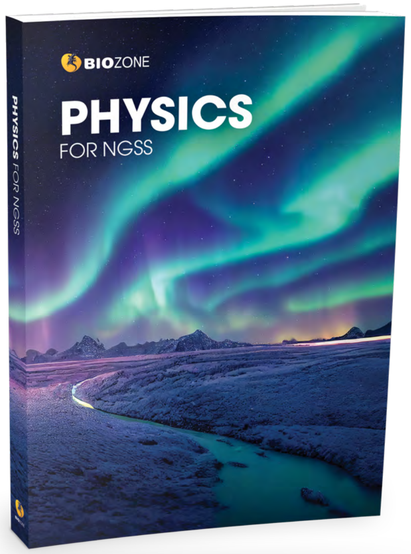








2025



2026

BIOZONE Worktexts

Combine the very best features of a **textbook** ....

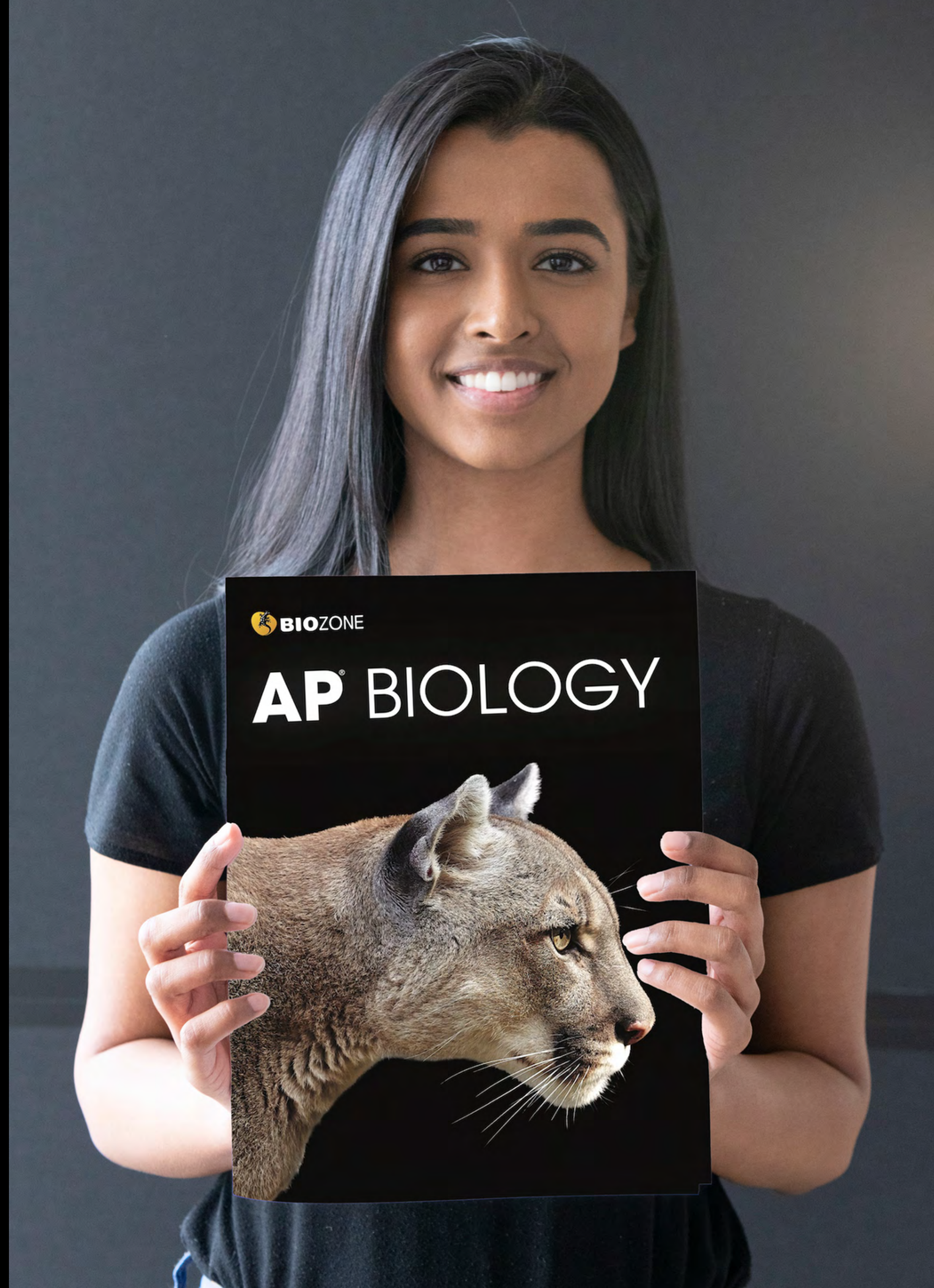
.... with the utility of **workbook**

Student-Owned **Worktext**

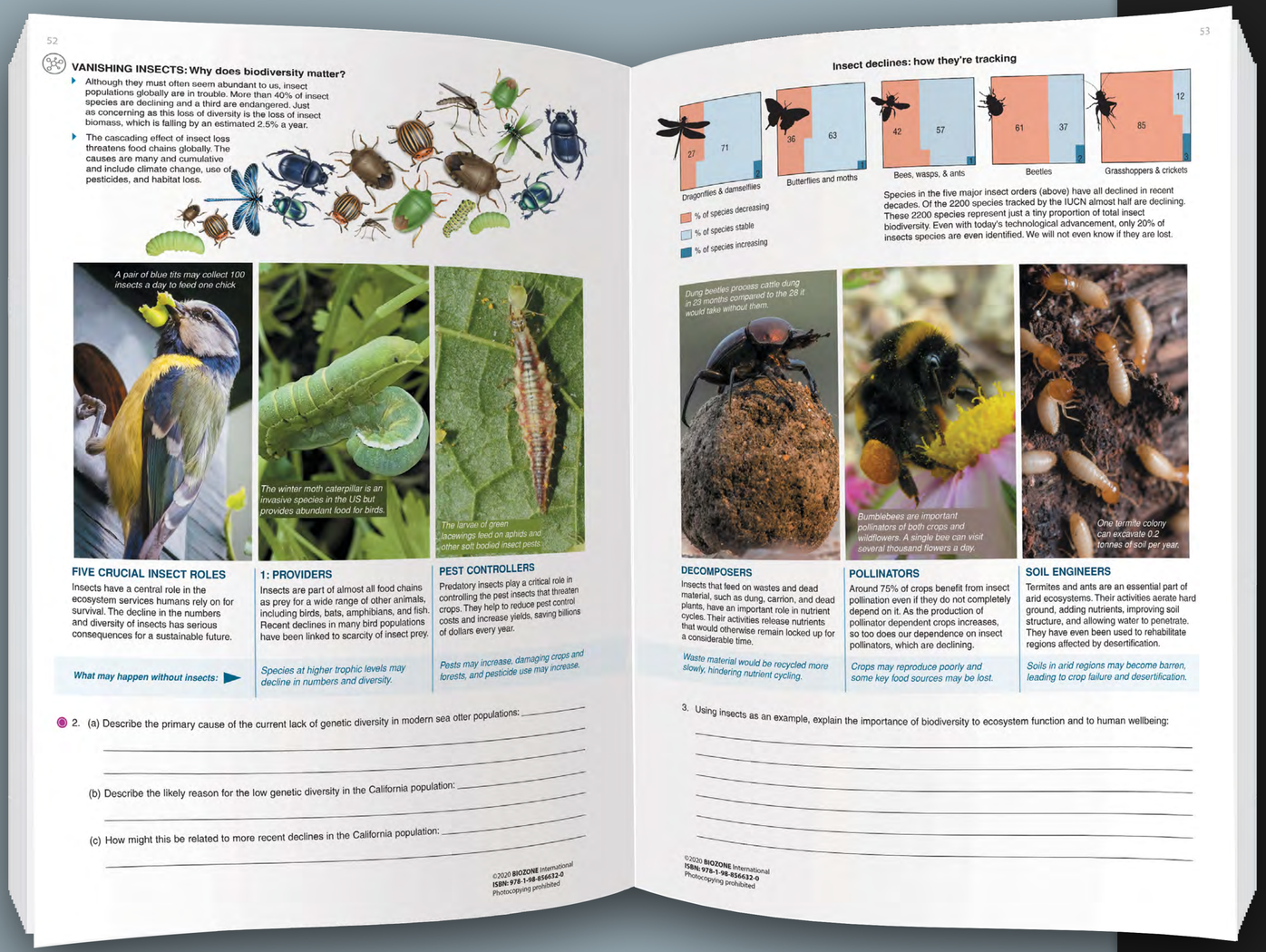
– *not* a traditional basal textbook

Our worktexts are designed to be consumable:

- **Combines** the *very best features* of a textbook with function and utility of a workbook
- Requires direct student interaction with content
- Students write answers directly onto the page that forms a **record of work**
- Engaging graphics with chunked text for accessibility
- Many data driven activities



What is the **BIOZONE solution?**



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VANISHING INSECTS: Why does biodiversity matter?

- Although they must often seem abundant to us, insect populations globally are in trouble. More than 40% of insect species are declining and a third are endangered. Just as concerning as this loss of diversity is the loss of insect biomass, which is falling by an estimated 2.5% a year.
- The cascading effect of insect loss threatens food chains globally. The causes are many and cumulative and include climate change, use of pesticides, and habitat loss.

A pair of blue tits may collect 100 insects a day to feed one chick

The winter moth caterpillar is an invasive species in the US but provides abundant food for birds.

The larvae of green lacewings feed on aphids and other soft bodied insect pests.

FIVE CRUCIAL INSECT ROLES

Insects have a central role in the ecosystem services humans rely on for survival. The decline in the numbers and diversity of insects has serious consequences for a sustainable future.

1: PROVIDERS

Insects are part of almost all food chains as prey for a wide range of other animals, including birds, bats, amphibians, and fish. Recent declines in many bird populations have been linked to scarcity of insect prey.

PEST CONTROLLERS

Predatory insects play a critical role in controlling the pest insects that threaten crops. They help to reduce pest control costs and increase yields, saving billions of dollars every year.

What may happen without insects:

Species at higher trophic levels may decline in numbers and diversity.

Pests may increase, damaging crops and forests, and pesticide use may increase.

2. (a) Describe the primary cause of the current lack of genetic diversity in modern sea otter populations: _____

(b) Describe the likely reason for the low genetic diversity in the California population: _____

(c) How might this be related to more recent declines in the California population: _____

ISBN: 978-1-98-856632-0

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Insect declines: how they're tracking

Species in the five major insect orders (above) have all declined in recent decades. Of the 2200 species tracked by the IUCN almost half are declining. These 2200 species represent just a tiny proportion of total insect biodiversity. Even with today's technological advancement, only 20% of insects species are even identified. We will not even know if they are lost.

Dung beetles process cattle dung in 23 months compared to the 28 it would take without them.

Bumblebees are important pollinators of both crops and wildflowers. A single bee can visit several thousand flowers a day.

One termite colony can excavate 0.2 tonnes of soil per year.

DECOMPOSERS

Insects that feed on wastes and dead material, such as dung, carrion, and dead plants, have an important role in nutrient cycles. Their activities release nutrients that would otherwise remain locked up for a considerable time.

POLLINATORS

Around 75% of crops benefit from insect pollination even if they do not completely depend on it. As the production of pollinator dependent crops increases, so too does our dependence on insect pollinators, which are declining.

SOIL ENGINEERS

Termites and ants are an essential part of arid ecosystems. Their activities aerate hard ground, adding nutrients, improving soil structure, and allowing water to penetrate. They have even been used to rehabilitate regions affected by desertification.

Waste material would be recycled more slowly, hindering nutrient cycling.

Crops may reproduce poorly and some key food sources may be lost.

Soils in arid regions may become barren, leading to crop failure and desertification.

3. Using insects as an example, explain the importance of biodiversity to ecosystem function and to human wellbeing: _____

ISBN: 978-1-98-856632-0

It is a unique *3-in-1 hybrid* resource:

- ☑ **Part textbook**
- ☑ **Part study guide**
- ☑ **Part activity workbook**

Supported by the

Teacher Toolkit

Professor John Hattie

Researcher | Professor | Author

Professor John Hattie is a researcher in education.

He holds a Ph.D. from the *University of Toronto, Canada*.

The design of BIOZONE's solution has been strongly influenced by the research published by Prof. Hattie.

His book: ***Visible Learning*** is a synthesis of more than 1,500 meta-studies over 90,000 studies involving more than 300 million students (the result of nearly 30 years of research about what works best for learning in schools).

Director of the **Melbourne Educational Research Institute** at the *University of Melbourne, Australia*, since March 2011.

Before, he was project director of **asTTle** and professor of education at the *University of Auckland, New Zealand*.

Visible Learning™ 250+ Influences on Student Achievement

STUDENT	ES
Prior knowledge and background	
Field independence	0.94
Non-standard dialect use	-0.29
Piagetian programs	1.28
Prior ability	0.98
Prior achievement	0.59
Relating creativity to achievement	0.35
Relating high school to university achievement	0.60
Relating high school achievement to career performance	0.38
Self-reported grades	1.33
Working memory strength	0.66
Beliefs, attitudes and dispositions	
Attitude to content domains	0.46
Concentration/persistence/ engagement	0.54
Grit/incremental vs. entity thinking	0.25
Mindfulness	0.28
Morning vs. evening	0.12
Perceived task value	0.46
Positive ethnic self-identity	0.12
Positive self-concept	0.47
Self-efficacy	0.71
Stereotype threat	-0.33
Student personality	0.30
Motivational approach, orientation	
Achieving motivation and approach	0.42
Boredom	-0.47
Deep motivation and approach	0.57
Depression	-0.26
Lack of stress	0.17
Mastery goals	0.06
Motivation	0.38
Performance goals	-0.01
Anxiety	-0.44
Surface motivation and approach	-0.14
Physical influences	
ADHD	-0.90
ADHD – treatment with drugs	0.32
Breastfeeding	0.04
Deafness	-0.61
Exercise/relaxation	0.21
Gender on achievement	0.08
Illness	-0.44
Lack of sleep	-0.05
Full compared to pre-term/low birth weight	0.57
Relative age within a class	0.45
Bullying	-0.20

CURRICULA	ES
Reading, writing and the arts	
Comprehensive instructional programs for teachers	0.72
Comprehension programs	0.55
Drama/arts programs	0.42
Exposure to reading	0.43
Music programs	0.30
Phonics instruction	0.60
Repeated reading programs	0.75
Reading Recovery	0.53
Sentence combining programs	0.15
Spelling programs	0.58
Visual-perception programs	0.55
Vocabulary programs	0.63
Whole language approach	0.06
Writing programs	0.46
Math and sciences	
Manipulative materials on math	0.30
Mathematics programs	0.59
Science programs	0.56
Use of calculators	0.27
Other curricula programs	
Bilingual programs	0.36
Career interventions	0.38
Chess instruction	0.34
Conceptual change programs	0.99
Creativity programs	0.64
Diversity courses	0.09
Extra-curricula programs	0.20
Integrated curricula programs	0.47
Juvenile delinquent programs	0.12
Motivation/character programs	0.35
Outdoor/adventure programs	0.43
Perceptual-motor programs	0.08
Play programs	0.50
Social skills programs	0.37
Tactile stimulation programs	0.58

HOME	ES
Family structure	
Adopted vs non-adopted care	0.25
Engaged vs disengaged fathers	0.21
Intact (two-parent) families	0.22
Other family structure	0.16
Home environment	
Corporal punishment in the home	-0.33
Early years' interventions	0.44
Home visiting	0.29
Moving between schools	-0.30
Parental autonomy support	0.12
Parental involvement	0.45
Parental military deployment	-0.16
Positive family/home dynamics	0.52
Television	-0.18
Family resources	
Family on welfare/state aid	-0.12
Non-immigrant background	0.01
Parental employment	0.03
Socio-economic status	0.52

SCHOOL	ES
Leadership	
Collective teacher efficacy	1.39
Principals/school leaders	0.37
School climate	0.43
School resourcing	
External accountability systems	0.20
Finances	0.21
Types of school	
Charter schools	0.04
Religious schools	0.24
Single-sex schools	0.08
Summer school	0.19
Summer vacation effect	0.02
School compositional effects	
College halls of residence	0.05
Desegregation	0.28
Diverse student body	0.10
Middle school interventions	0.18
Out-of-school curricula experiences	0.07
School choice programs	0.12
School size (600-900 students at secondary)	0.43
Other school factors	
Counseling effects	0.35
Modifying school calendars/ timetables	0.09
Pre-school programs	0.28
Suspension/expelling students	-0.20

The Visible Learning™ research synthesises findings from **1,600+** meta-analyses of **95,000+** studies involving **300** million students, into what works best in education.

Key for rating

- Potential to considerably accelerate student achievement
- Potential to accelerate student achievement
- Likely to have positive impact on student achievement
- Likely to have small positive impact on student achievement
- Likely to have a negative impact on student achievement

ES Effect size calculated using Cohen's *d*

CORWIN Visible Learning^plus

visiblelearningplus.com
corwin.com/visiblelearning

Visible Learning™ 250+ Influences on Student Achievement

CLASSROOM	ES
Classroom composition effects	
Detracking	0.09
Mainstreaming/inclusion	0.25
Multi-grade/age classes	0.04
Open vs. traditional classrooms	0.01
Reducing class size	0.15
Retention (holding students back)	-0.32
Small group learning	0.47
Tracking/streaming	0.12
Within class grouping	0.18
School curricula for gifted students	
Ability grouping for gifted students	0.30
Acceleration programs	0.68
Enrichment programs	0.48
Classroom influences	
Background music	0.10
Behavioral intervention programs	0.62
Classroom management	0.35
Cognitive behavioral programs	0.29
Decreasing disruptive behavior	0.34
Mentoring	0.12
Positive peer influences	0.53
Strong classroom cohesion	0.53
Students feeling disliked	-0.19

TEACHER	ES
Teacher attributes	
Average teacher effects	0.32
Teacher clarity	0.75
Teacher credibility	1.09
Teacher estimates of achievement	1.29
Teacher expectations	0.43
Teacher personality attributes	0.24
Teacher performance pay	0.05
Teacher verbal ability	0.22
Teacher-student interactions	
Student rating of quality of teaching	0.45
Teachers not labeling students	0.44
Teacher-student relationships	0.48
Teacher education	
Initial teacher training programs	0.10
Micro-teaching/video review of lessons	0.88
Professional development programs	0.37
Teacher subject matter knowledge	0.23

STUDENT LEARNING STRATEGIES	ES
Strategies emphasizing student meta-cognitive/ self-regulated learning	
Elaboration and organization	0.75
Elaborative interrogation	0.56
Evaluation and reflection	0.75
Meta-cognitive strategies	0.55
Help seeking	0.72
Self-regulation strategies	0.52
Self-verbalization and self-questioning	0.59
Strategy monitoring	0.58
Transfer strategies	0.86
Student-focused interventions	
Aptitude/treatment interactions	0.11
Individualized instruction	0.23
Matching style of learning	0.32
Student-centered teaching	0.36
Student control over learning	0.02
Strategies emphasizing student perspectives in learning	
Peer tutoring	0.51
Volunteer tutors	0.51
Learning strategies	
Deliberate practice	0.79
Effort	0.77
Imagery	0.51
Interleaved practice	0.47
Mnemonics	0.80
Note taking	0.51
Outlining and transforming	0.66
Practice testing	0.46
Record keeping	0.52
Rehearsal and memorization	0.73
Spaced vs. mass practice	0.65
Strategy to integrate with prior knowledge	0.93
Study skills	0.45
Summarization	0.74
Teaching test taking and coaching	0.30
Time on task	0.44
Underlining and highlighting	0.44

TEACHING STRATEGIES	ES
Strategies emphasizing learning intentions	
Appropriately challenging goals	0.59
Behavioral organizers	0.42
Clear goal intentions	0.51
Cognitive task analysis	1.29
Concept mapping	0.64
Goal commitment	0.40
Learning goals vs. no goals	0.51
Learning hierarchies-based approach	0.19
Planning and prediction	0.76
Setting standards for self-judgement	0.75
Strategies emphasizing success criteria	
Mastery learning	0.61
Worked examples	0.37
Strategies emphasizing feedback	
Classroom discussion	0.82
Different types of testing	0.12
Feedback	0.66
Formative evaluation	0.34
Questioning	0.48
Response to intervention	1.09
Teaching/instructional strategies	
Adjunct aids	0.35
Collaborative learning	0.34
Competitive vs. individualistic learning	0.24
Cooperative learning	0.40
Cooperative vs. competitive learning	0.53
Cooperative vs. individualistic learning	0.55
Direct instruction	0.59
Discovery-based teaching	0.21
Explicit teaching strategies	0.57
Humor	0.04
Inductive teaching	0.44
Inquiry-based teaching	0.46
Jigsaw method	1.20
Philosophy in schools	0.43
Problem-based learning	0.35
Problem-solving teaching	0.67
Reciprocal teaching	0.74
Scaffolding	0.58
Teaching communication skills and strategies	0.43

TECHNOLOGY, SCHOOL, & OUT-OF-SCHOOL STRATEGIES	ES
Implementations using technologies	
Clickers	0.22
Gaming/simulations	0.34
Information communications technology (ICT)	0.48
Intelligent tutoring systems	0.51
Interactive video methods	0.54
Mobile phones	0.43
One-on-one laptops	0.16
Online and digital tools	0.26
Programmed instruction	0.23
Technology in distance education	0.01
Technology in mathematics	0.33
Technology in other subjects	0.55
Technology in reading/literacy	0.29
Technology in science	0.23
Technology in small groups	0.21
Technology in writing	0.42
Technology with college students	0.42
Technology with elementary students	0.44
Technology with high school students	0.30
Technology with learning needs students	0.57
Use of PowerPoint	0.26
Visual/audio-visual methods	0.22
Web-based learning	0.33
Implementations using out-of-school learning	
After-school programs	0.40
Distance education	0.14
Home-school programs	0.16
Homework	0.29
Service learning	0.58
Implementations that emphasize school-wide teaching strategies	
Co- or team teaching	0.19
Interventions for students with learning needs	0.77
Student support programs – college	0.21
Teaching creative thinking	0.37
Whole-school improvement programs	0.28

Key for rating

- Potential to considerably accelerate student achievement
- Potential to accelerate student achievement
- Likely to have positive impact on student achievement
- Likely to have small positive impact on student achievement
- Likely to have a negative impact on student achievement

ES Effect size calculated using Cohen's *d*

The Visible Learning™ research synthesises findings from **1,600+** meta-analyses of **95,000+** studies involving **300** million students, into what works best in education.

CORWIN Visible Learning^plus

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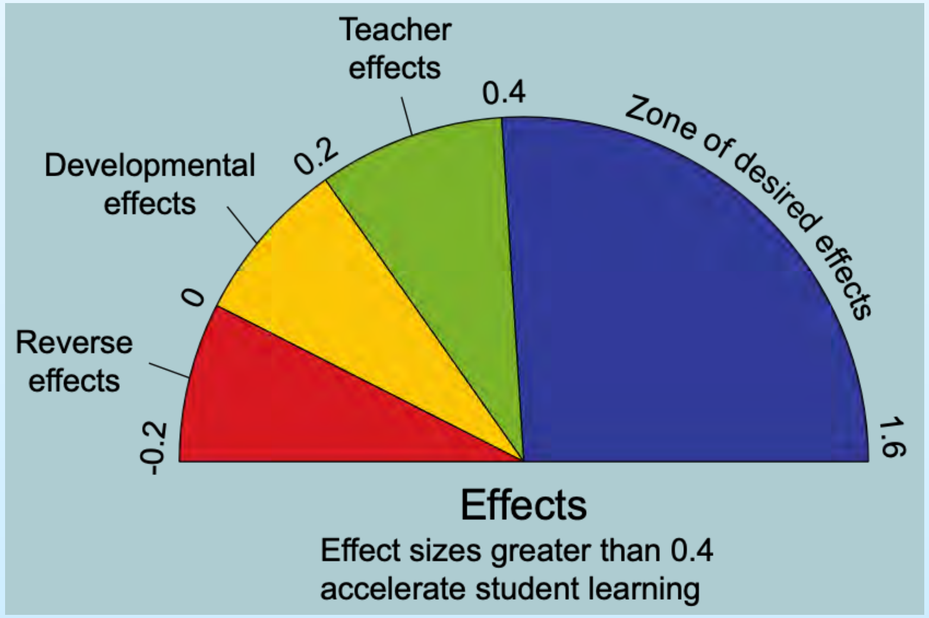
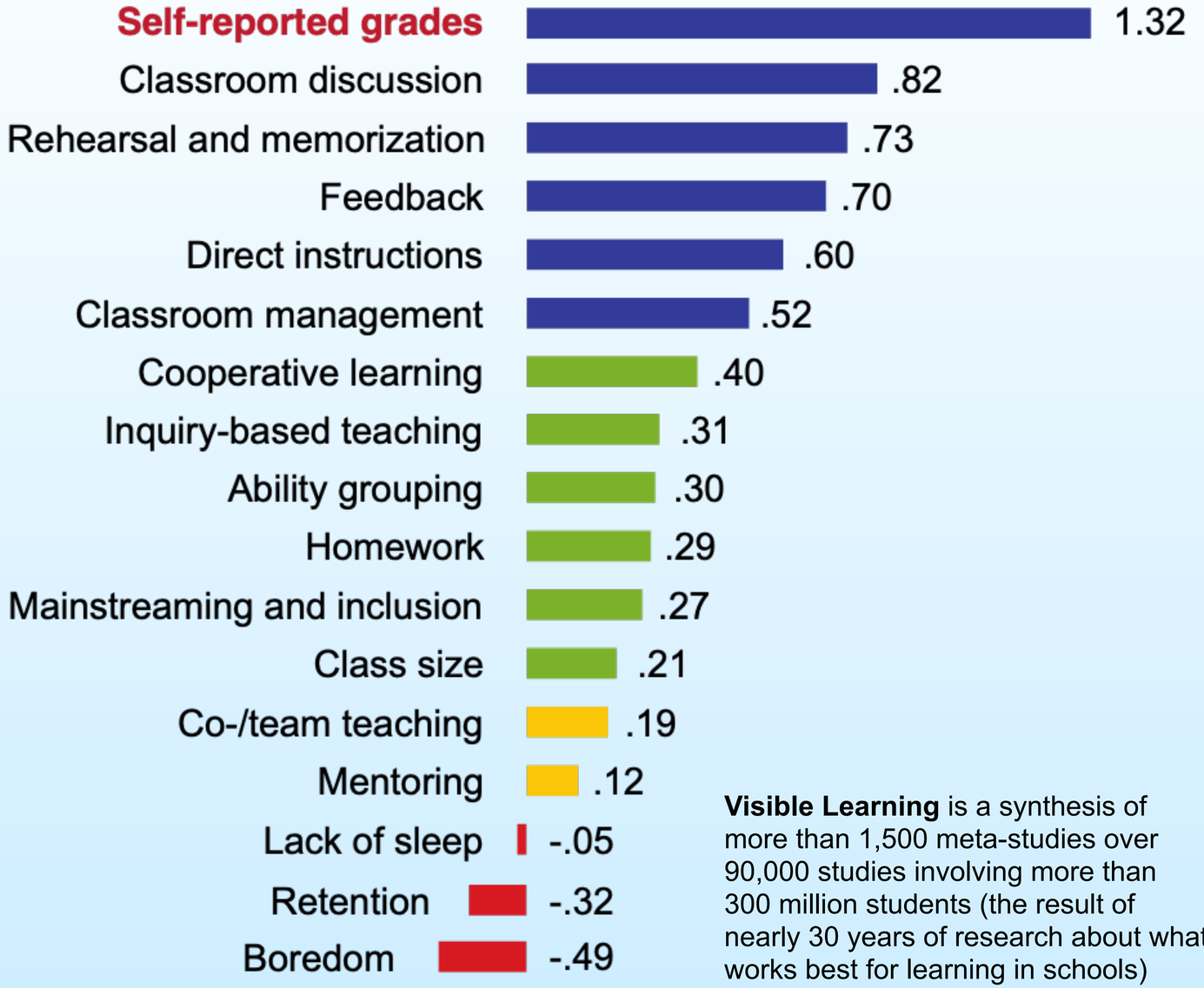
Self-Reported Grades

According to educational research, one of the most successful pedagogical tools leading to student academic achievement is **self-reported grades**.

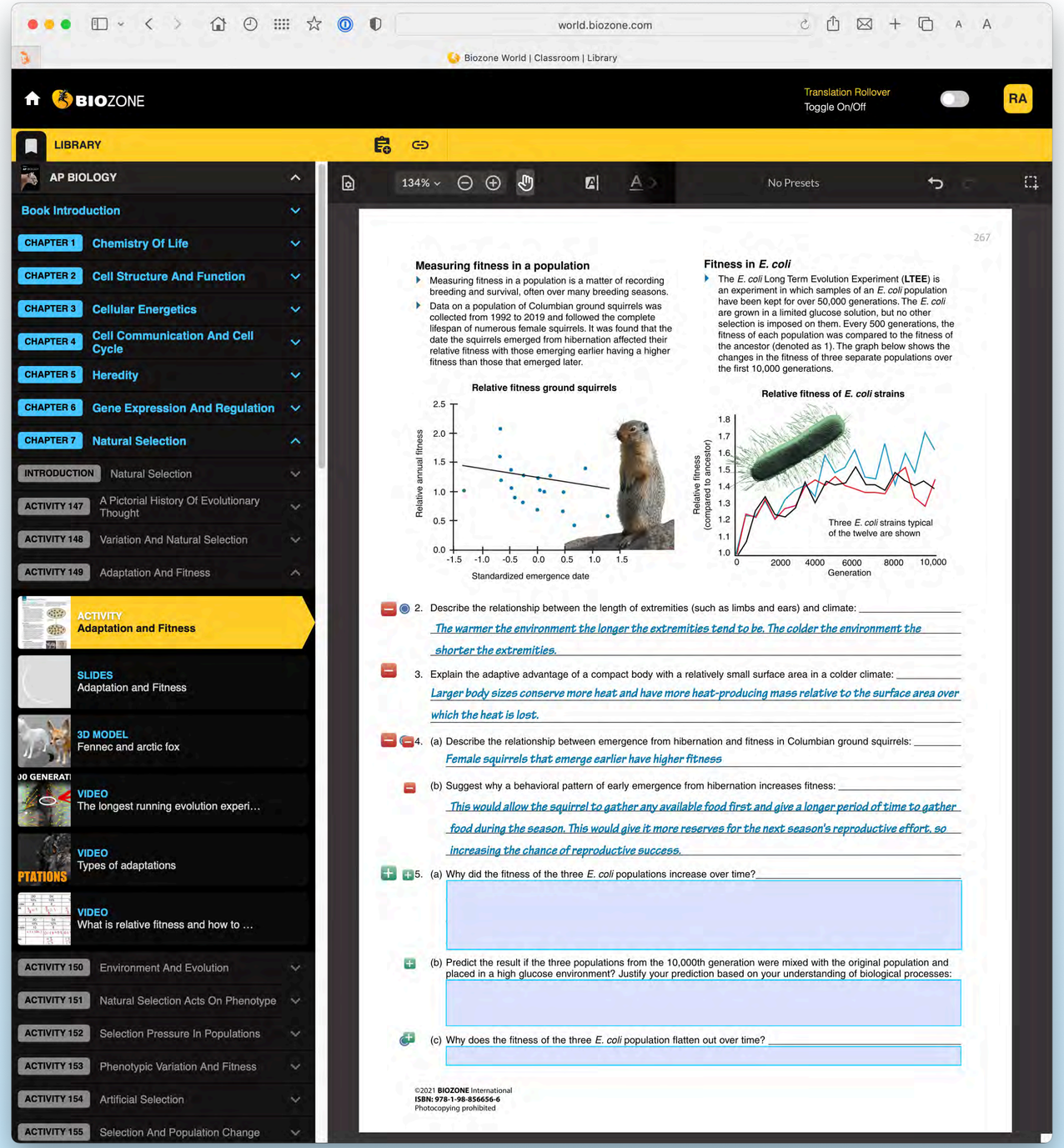
(Hattie, J. (2009) Visible Learning)



Influences on student achievement



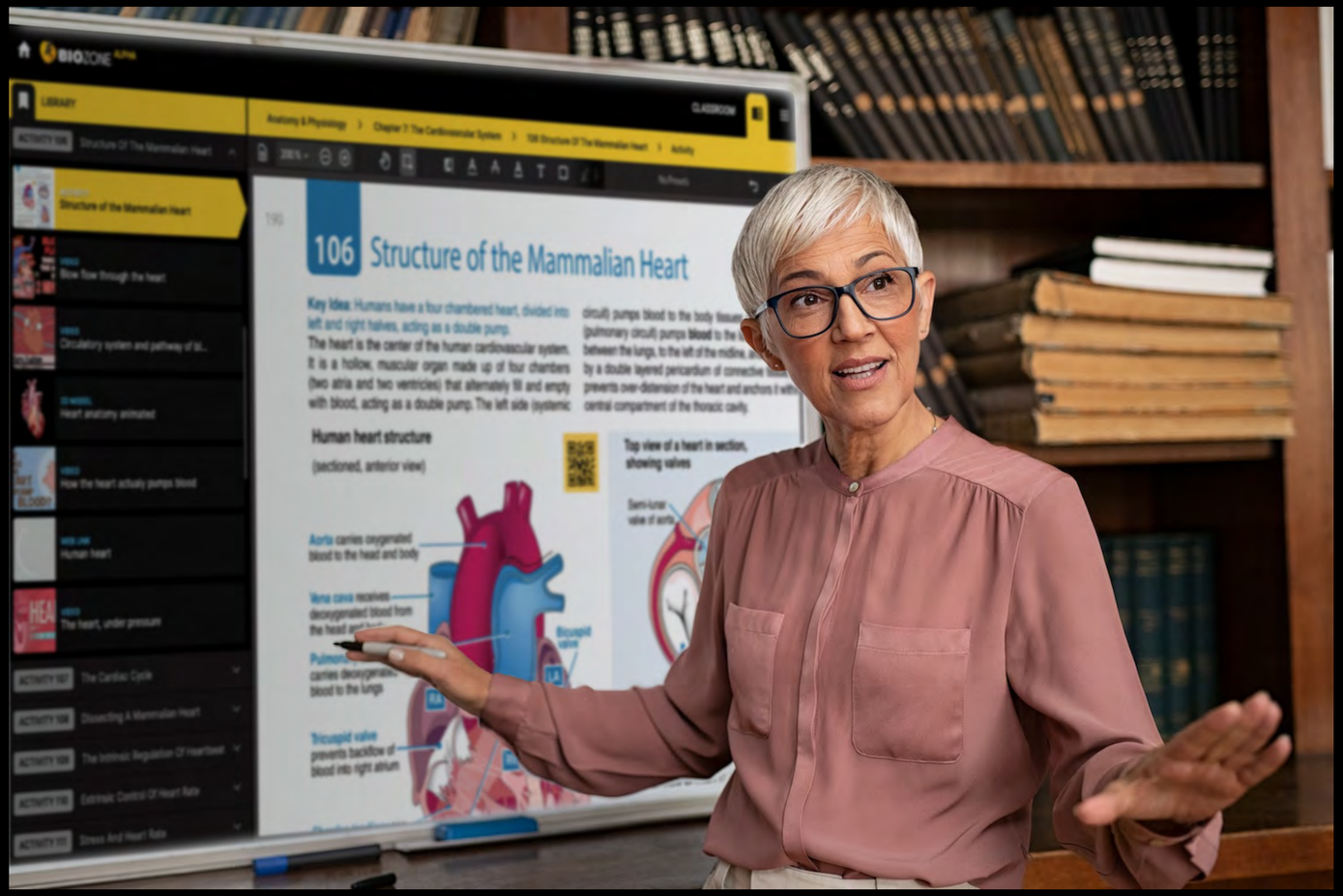
Visible Learning is a synthesis of more than 1,500 meta-studies over 90,000 studies involving more than 300 million students (the result of nearly 30 years of research about what works best for learning in schools)



How can students self-grade with BIOZONE?

- **Suggested answers** are provided via teacher access to **BIOZONE World**
- With *teacher guidance*, answers can be displayed to the class.
- Students can refine their own answers and strengthen their understanding.
- This provides a **powerful additional learning moment**.

Streamline classroom-based **Collaborative Learning**



Teacher
introduces Activity

Brief class discussion
to “unpack” the Activity’s
infographic or **data**

Breakout into small student groups

Student Group A
Discuss, then create consensus answers

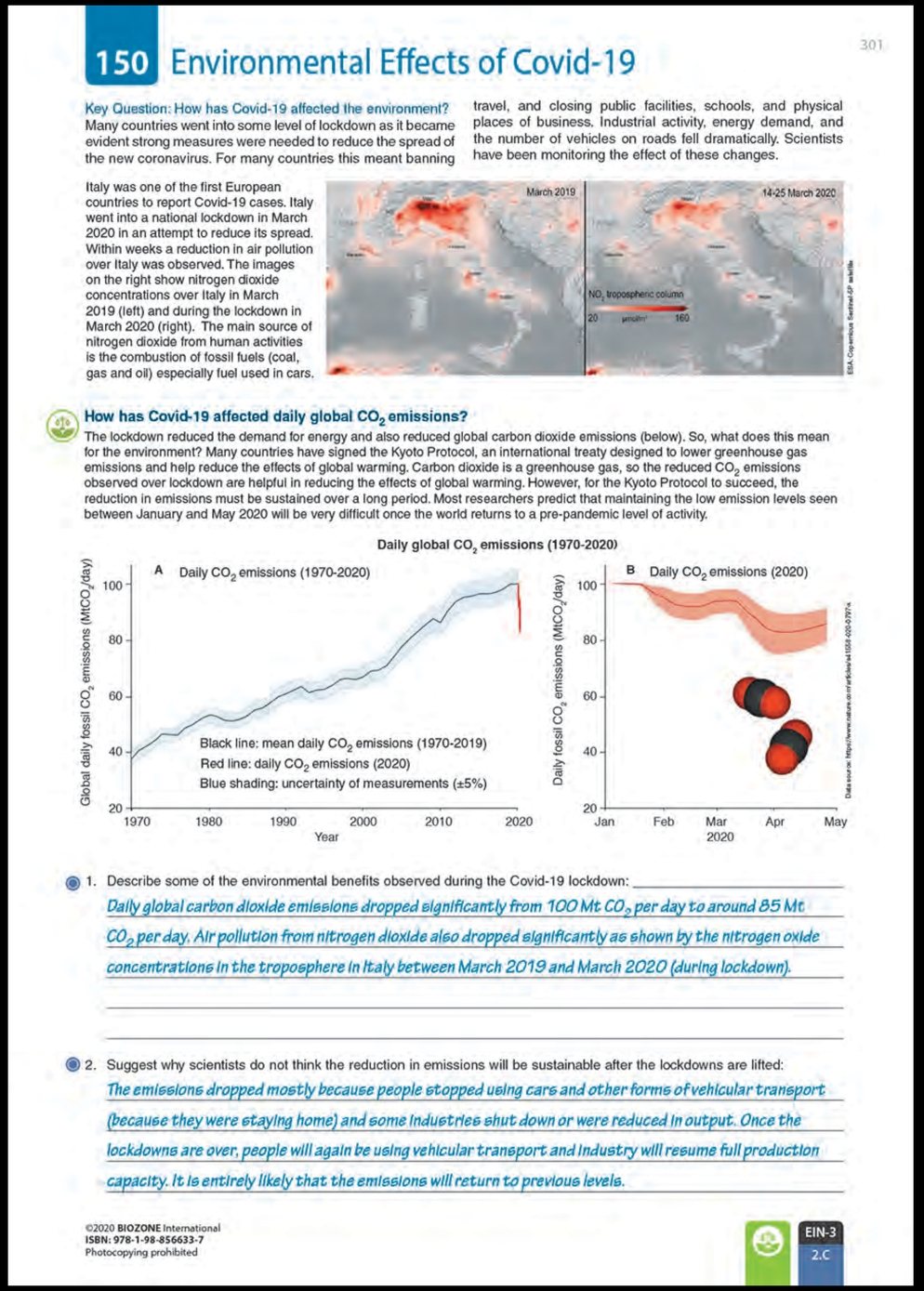
Student Group B
Discuss, then create consensus answers

Student Group C
Discuss, then create consensus answers

Students **quickly report back** via **teacher-led discussion** then **Self-grade** and **improve answers**

The Powerful 2nd Learning Moment

- Students write their **answers directly onto page** - thereby forming a **record of work**
- Having students **self-grade** their work, and possibly **correct** and **improve** their answers is a **powerful second learning moment**
- The **reference material**, questions and **answers** are all in one place - making for **easy revision**



150 Environmental Effects of Covid-19

301

Key Question: How has Covid-19 affected the environment?
Many countries went into some level of lockdown as it became evident strong measures were needed to reduce the spread of the new coronavirus. For many countries this meant banning travel, and closing public facilities, schools, and physical places of business. Industrial activity, energy demand, and the number of vehicles on roads fell dramatically. Scientists have been monitoring the effect of these changes.

Italy was one of the first European countries to report Covid-19 cases. Italy went into a national lockdown in March 2020 in an attempt to reduce its spread. Within weeks a reduction in air pollution over Italy was observed. The images on the right show nitrogen dioxide concentrations over Italy in March 2019 (left) and during the lockdown in March 2020 (right). The main source of nitrogen dioxide from human activities is the combustion of fossil fuels (coal, gas and oil) especially fuel used in cars.

How has Covid-19 affected daily global CO_2 emissions?

The lockdown reduced the demand for energy and also reduced global carbon dioxide emissions (below). So, what does this mean for the environment? Many countries have signed the Kyoto Protocol, an international treaty designed to lower greenhouse gas emissions and help reduce the effects of global warming. Carbon dioxide is a greenhouse gas, so the reduced CO_2 emissions observed over lockdown are helpful in reducing the effects of global warming. However, for the Kyoto Protocol to succeed, the reduction in emissions must be sustained over a long period. Most researchers predict that maintaining the low emission levels seen between January and May 2020 will be very difficult once the world returns to a pre-pandemic level of activity.

Daily global CO_2 emissions (1970-2020)

1. Describe some of the environmental benefits observed during the Covid-19 lockdown:
Daily global carbon dioxide emissions dropped significantly from 100 Mt CO_2 per day to around 85 Mt CO_2 per day. Air pollution from nitrogen dioxide also dropped significantly as shown by the nitrogen oxide concentrations in the troposphere in Italy between March 2019 and March 2020 (during lockdown).

2. Suggest why scientists do not think the reduction in emissions will be sustainable after the lockdowns are lifted:
The emissions dropped mostly because people stopped using cars and other forms of vehicular transport (because they were staying home) and some industries shut down or were reduced in output. Once the lockdowns are over, people will again be using vehicular transport and industry will resume full production capacity. It is entirely likely that the emissions will return to previous levels.

ISBN: 978-1-98-856633-7

Curricula-specific Titles

Content, delivery, and assessment

Titles are written “from the ground up” to meet the requirements of a **specific program:**

- NGSS frameworks
- **State standards**
- **College Board CEDs**

Program specific coding identifies key components:

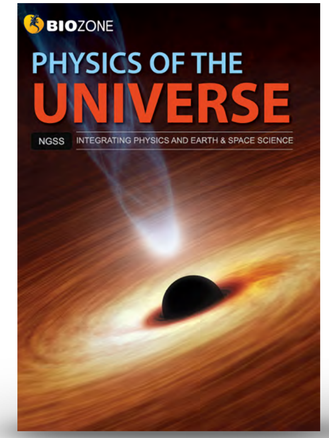
- Program specific content, examples, case studies
- **Practical** components and **investigations**
- Curricula specific **assessment tools**

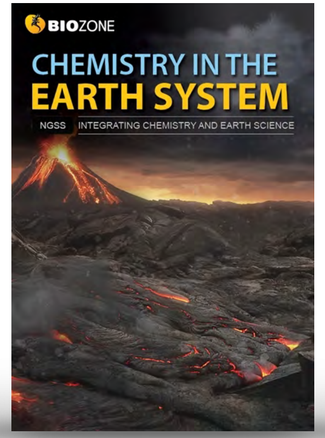
BIOZONE Programs

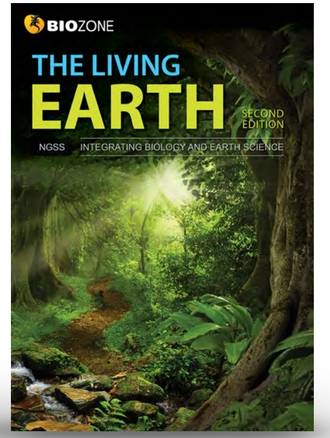
BIOZONE

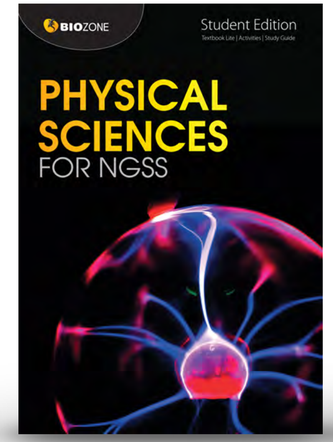
BIOZONE has two NGSS series

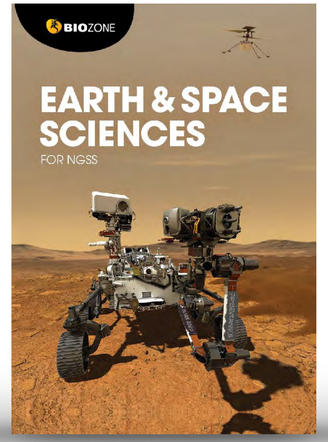
- Both series have been specifically written for NGSS
- Both series are **fully three dimensional** (DCIs, CCCs, SEPs)
- Both series scaffold delivery of material using the **5Es instructional model**

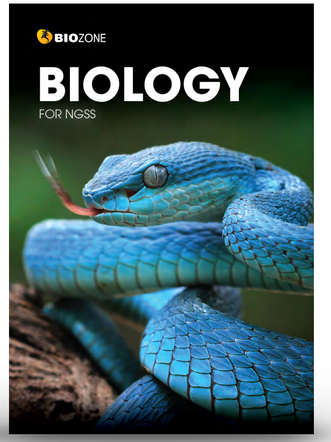








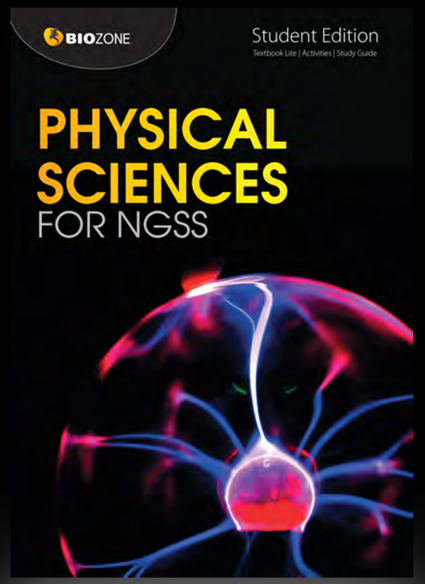


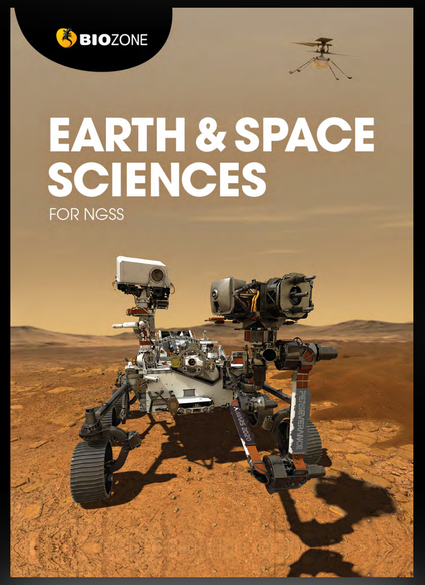


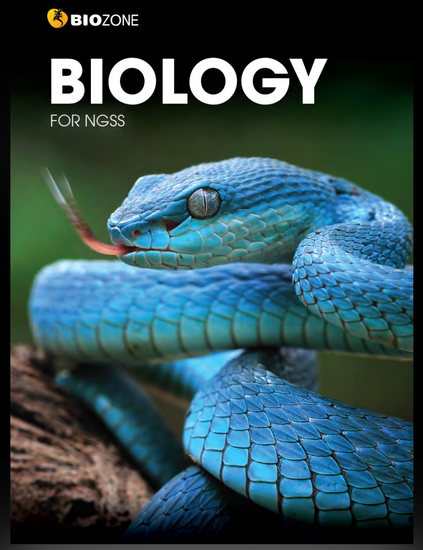
Integrated NGSS series	Standard NGSS series
Integrates Earth & Space with 3 other sciences	Traditional approach - No integration with ESS
Longer activities, several concepts (5Es)	Shorter activities, one concept
Concept understanding is developed within an activity	Concept understanding is developed over a series of related activities

Standard NGSS Series

- Written for the standard **high school NGSS framework** (not integrated).
- Structured and organized on the **Disciplinary Core Ideas** (DCIs) of the NGSS framework.
  - Allows **flexible content delivery** deliver the material in an order which best suits you
  - **Phenomena** focused and driven







136 Eat or be Eaten

Key Question: How did energy and matter move through ecosystems when dinosaurs were the dominant species?

- Over the time dinosaurs existed, from the Triassic period, 252 million years ago, to the end of the Cretaceous period, 65 million years ago, 66 species of carnivorous dinosaur and 185 species of herbivorous dinosaur were known to have existed in North America.
- *Tyrannosaurus rex* was an apex (top) predator of the late Cretaceous period, ending 65 million years ago. It was one of the largest land predators to have ever existed, measuring 12.3 meters long and weighing 8.4 tonnes.
- *T. rex* obtained its food by hunting herbivorous dinosaurs, and sometimes members of its own species. The herbivorous dinosaurs dominated the landscape and obtained food by eating a wide variety of plant-based materials such as ferns, horsetails, club-mosses, conifers, cycads, and ginkgos.

1. (a) How do you think we could represent the feeding relationships between the plants, herbivorous dinosaurs, and the carnivorous *T. rex* described above by a simple diagram?

(b) All life on Earth needs energy to survive. If animals obtain energy from the food they eat, either from plants or by eating other animals, where do you think plants obtain their energy from?

2. What do you think would happen to the Cretaceous ecosystem described above if the number of plants fell significantly?

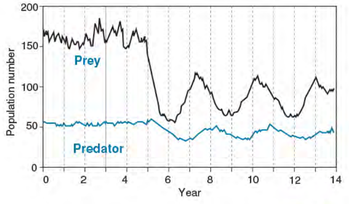
124 Predator-Prey Relationships

Key Question: Are the populations of predators and prey related and how do they change over time?

Do predators limit prey numbers?

- It was once thought that predators always limited the numbers of their prey populations. While this is often true for invertebrate predator-prey systems, prey species are very often regulated more by factors, such as climate and the availability of food, than by **predation**.
- In contrast, predator populations can be strongly affected by the availability of prey, especially when there is little opportunity for prey switching, i.e hunting another prey if the preferred one becomes scarce.
- Predator and prey populations may settle into a stable oscillations, where the predator numbers follow those of the prey, with a time lag (right).

Fluctuations in hypothetical populations of predator and prey



A case study in predator-prey numbers

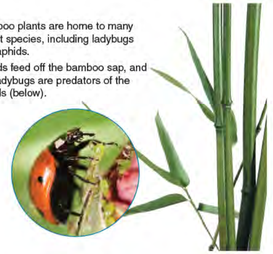
In some areas of Northeast India, a number of woolly aphid species colonize and feed off bamboo plants. The aphids can damage the bamboo so much that it is no longer able to be utilized by the local people for construction and textile production.

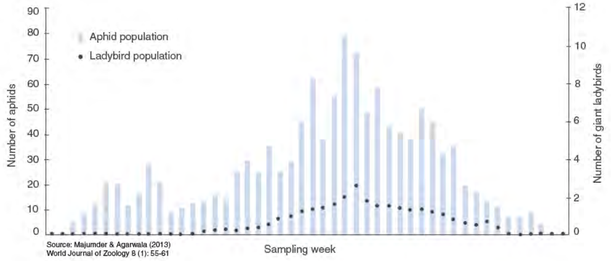
Giant ladybug beetles (*Anisolemnia dilatata*) feed exclusively off the woolly aphids of bamboo plants. There is some interest in using them as biological control agents to reduce woolly aphid numbers, and limit the damage woolly aphids do to bamboo plants.

The graph below shows the relationship between the giant ladybug beetle and the woolly aphid, when grown in controlled laboratory conditions.

Bamboo plants are home to many insect species, including ladybugs and aphids.

Aphids feed off the bamboo sap, and the ladybugs are predators of the aphids (below).





Source: Majumder & Agarwala (2013) World Journal of Zoology 8 (1): 55-61

1. (a) On the graph above, mark the two points (using different colored pens) where the peak numbers of woolly aphids and giant ladybugs occur.

202 Modeling Meiosis

Key Question: How is variation introduced into the gametes formed during meiosis?

Modeling meiosis using popsicle sticks can help to understand how meiosis creates variation. Each of your somatic (body) cells contains 46 chromosomes: 23 maternal and 23 paternal. Therefore, you have 23 **homologous pairs**. For simplicity, the number of chromosomes studied in this exercise has been reduced to four, i.e. two homologous pairs.

Investigation 11.2 Modelling meiosis using popsicle sticks

See appendix for equipment list.

To study the effect of crossing over on genetic variation, you will work in pairs to simulate the inheritance of two of your own traits: ability to tongue roll and handedness. This activity will take 25–45 minutes.

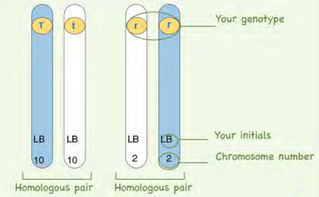
Chromosome number	Phenotype	Genotype
10	Tongue roller	TT, Tt
10	Non-tongue roller	tt
2	Right handed	RR, Rr
2	Left handed	rr

1. Record your phenotype and genotype for each trait in the table (right). If you have a dominant trait, you will not know if you are heterozygous or homozygous for that trait, so you can choose either genotype.
2. Before you start the simulation, partner up with a classmate. Your gametes will combine with theirs (fertilization) at the end of the activity to produce a "child". Decide who will be female, and who will be male. You will need to work with this person again at step 7.
3. Collect four popsicle sticks. These represent four chromosomes. Color two sticks blue or mark them with a P. for paternal chromosomes. The plain sticks are the maternal chromosomes. Write your initials on each of the four sticks. Label each chromosome with its number. Label four sticky dots with alleles to describe your phenotype and stick each onto the appropriate chromosome. In the example shown (right), the person is heterozygous for tongue rolling so sticky dots with alleles T and t are placed on chromosome 10. The person is also left handed, so alleles r and r are placed on chromosome 2.
4. Randomly drop the chromosomes onto a table. This represents a cell in either the testes or ovaries. Duplicate your chromosomes by adding four more identical popsicle sticks to the table (right). What are you simulating with this action?

Step 1

Trait	Phenotype	Genotype
Handedness		
Tongue rolling		

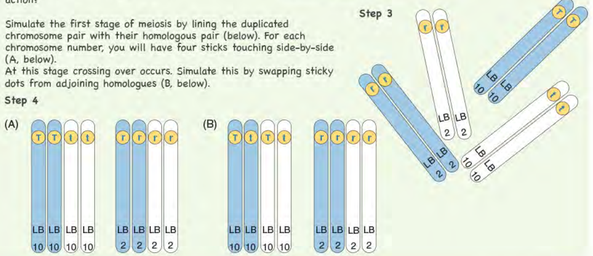
Step 2

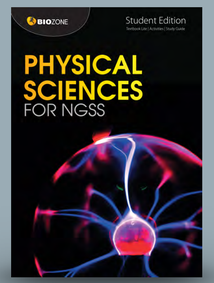


Step 3

Simulate the first stage of meiosis by lining the duplicated chromosome pair with their homologous pair (below). For each chromosome number, you will have four sticks touching side-by-side (A, below).
At this stage crossing over occurs. Simulate this by swapping sticky dots from adjoining homologues (B, below).

Step 4





26 Bonding

Key Question: What are some of the ways atoms bind together?

Sticking together

- Apart from a small group of elements called the "noble gases", elements are never found in nature as singular free-floating atoms. Their atoms are always found bonded to other atoms. These can be either the same kind of atom (as in hydrogen gas) or they can be different atoms (as in carbon dioxide).

In its pure form, the element sodium is a silvery metal. Its atoms share their mobile electrons and are held together by **metallic bonds**. It is a very reactive metal.

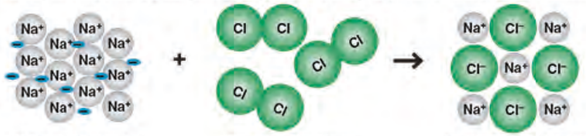
Chlorine is a gaseous element with a yellow tinge. In its pure form, the atoms are found **covalently** bonded together in pairs. Chlorine is highly toxic and reactive.

Sodium chloride (table salt) is a highly stable crystal made of sodium and chloride ions held together by **ionic** bonds.

- Atoms without full valence shells are reactive because having unpaired electrons and vacant orbitals is energetically unfavorable. Vacant orbitals can be filled by either sharing electrons (e.g. covalent bonding) or by gaining or losing electrons. When an atom gains or loses an electron (or electrons) it becomes an **ion**.
- In the example above of sodium and chlorine, both elements are highly reactive in their pure form. Although their atoms are sharing electrons, it is energetically more favorable for sodium atoms to lose an electron and chlorine atoms to gain an electron and form ions. When sodium and chlorine react, a large amount of thermal energy is released. The resulting product, sodium chloride, is stable and unreactive.

Sodium reacting with chlorine in the presence of water (which "kick starts" the reaction).

- The diagram below shows the changes in bonding that occurs during the reaction between sodium and chlorine.



Metallic bonds in sodium | Covalent bonds in chlorine | Ionic bonds in sodium chloride

1. (a) What has happened to the charge on the chlorine after it became a chloride ion? _____

   _____

   (b) How has this happened? _____

   (c) Where did this charge come from? _____

2. Compare the positions of sodium and chlorine on the periodic table. What does this say about their electronegativity and the reaction between them?

   _____

   _____

PS1.A P

ISBN: 978-1-927309-79-7

29 Molecular Shape

Key Question: How does the sharing of electrons in molecules affect a molecule's shape?

Spontaneous orientations

- Sometimes objects orientate themselves into certain shapes without any apparent input of energy. In fact by orientating themselves in such shapes the objects are in their most stable and least energetic form.
- For example the spring in the photo below right, has been placed under tension and is bent. Work must be done to bend the spring like this. In other words, energy is needed.
- If the person removes their fingers the energy in the spring will be released and the spring will instantly return to its normally straight shape (and probably go flying across the room as some of the energy it converted into movement).
- But note that the spring will remain in its straight unbent shape as long as no one puts energy into it by bending, stretching, or compressing it. Why doesn't the spring spontaneously bend, or compress, or stretch?
- The reason is because its normal straight shape is the least energetic. To transform its shape energy most be put into it.

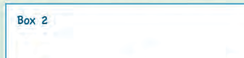
INVESTIGATION 2.1: Repulsion theory

See appendix for equipment list.

1. Inflate a balloon and tie it closed. Draw a dot at the top and bottom of the balloon with a marker.
2. Imagine a line connecting the dots you have drawn. Box 1 below shows a simple drawing of the two dots and the line connecting them.
3. Inflate a second balloon and tie it closed. Draw a dot on the top. Tie the end of the second balloon to the end of the first balloon.
4. In box 2 draw a diagram (similar to box 1) to show how the three dots are connected.
5. Bend the balloons at the point where they are joined. What happens when you let them go?
6. Inflate a third balloon and tie it closed. Again draw a dot on the top and tie it to the join of the first and second balloons.
7. In box 3 draw a diagram to show how the four dots (the top of three balloons and the one at the bottom of the first balloon) are connected.
8. Repeat this procedure with a fourth balloon and draw the diagram of the shape connecting all five dots in box 4.

Box 1

Box 2



Box 3

Box 4

PS1.A P

ISBN: 978-1-927309-82-7

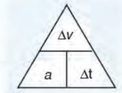
67 Acceleration

Key Question: How do we use what we know about constant acceleration to solve unknown values of displacement, time, and velocity?

Acceleration

- **Acceleration** occurs when velocity changes. Acceleration can be changed by altering speed or direction (or both). It is defined as the change in velocity over the time elapsed.

Acceleration (a) = change in velocity (Δv) ÷ change in time (Δt)



- In everyday language, we talk about accelerating (speeding up) and decelerating (slowing down) as would describe the skiers below.

- In physics, acceleration can be positive and negative.
- Positive acceleration acts in the direction of an object's movement. Negative acceleration acts in the direction opposite to the object's movement. Thus negative acceleration, if it persists, means that an object will not only slow down, but stop and eventually travel backwards in the opposite direction as shown in the diagrams (1-4) below.

- Acceleration is measured in meters per second per second (m/s^2). A car accelerating from a stationary start at 5 m/s^2 will increase its velocity by 5 meters per second every second.

1. For the car mentioned above, what will its velocity be after:

   (a) 1 second: _____ (b) 2 seconds: _____ (c) 3 seconds: _____

2. Two cars compete in a straight-line race. The velocities of each car are shown in the table below:

Time (s)	Velocity of car 1 (m/s)	Velocity of car 2 (m/s)
0	0	0
1	10	7.5
2	20	15.0
3	30	22.5
4	40	30.0

   (a) Calculate the average acceleration of car 1: _____

   (b) Calculate the average acceleration of car 2: _____

   (c) Calculate the average velocity of car 1: _____

   (d) Calculate the average velocity of car 2: _____

   (e) How far did car 1 travel in the 4 second race? _____

   (f) How far did car 2 travel in the 4 second race? _____

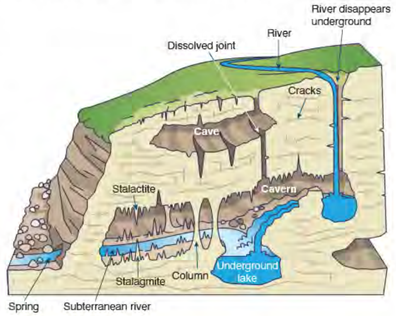
PS2.A CE

ISBN: 978-1-927309-79-7

76 Lets Go Spelunking!

Key Question: What processes helped to form the Mammoth Caves?

- At Mammoth Cave National Park in Kentucky there is an underground limestone cave system, with around 640 km mapped out, and over 1000 km yet to be discovered by spelunkers, a term for cave explorers.
- The cave system started to form around 10 million years ago. It sits within the large Green River drainage basin, so was exposed to river water, along with slightly acidic rainwater, and ground water seeping through the rock.
- The cave system contains huge caverns, underground lakes, and sinkholes in which streams suddenly disappear into caves containing underground lakes.
- Mammoth Caves have stalactites, mineral formations that hang from the cave's ceilings, and stalagmites extending from the ground upwards.
- The oldest rocks that form the deep cave structure were laid down around 320 million years ago, on the site of a huge inland sea. On top of that are three other layers, or formations, that are successively younger.



1. In groups, discuss what type of rock you think the big open caverns, containing the stalactites and stalagmites, in Mammoth Caves are made from, and how might you know that? Record a summary of your group's ideas below:

2. How do you think the Mammoth Caves might have formed? Use the space below to develop a flow chart of the processes you think might be involved in forming Mammoth Caves (you may not decide to use all four steps):

ISBN: 978-1-98-856693-1

59 Structure of the Earth

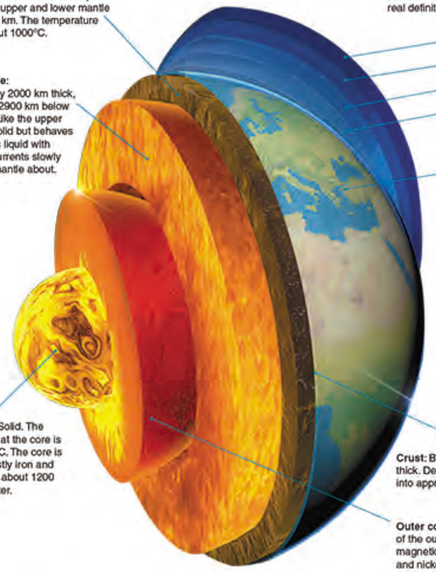
Key Question: What are the characteristics of each of the Earth's layers?

The Earth is layered due to the density of different materials in it. The Earth's crust has a density of about 3 g/cm^3 while the core has a density of about 12 g/cm^3. Movement of convection currents in the mantle shifts the plates of the Earth's crust, while movement of the outer core produces the Earth's magnetic field.

Upper mantle: Solid layer about 400 km thick with a transition layer between the upper and lower mantle of about 300 km. The temperature reaches about 1000°C.

Lower mantle: Approximately 2000 km thick, extending to 2900 km below the surface. Like the upper mantle it is solid but behaves like a viscous liquid with convection currents slowly moving the mantle about.

Inner core: Solid. The temperature at the core is about 4700°C. The core is made of mostly iron and nickel and is about 1200 km in diameter.



The atmosphere is about 700 km thick in total, although there is no real definition of the outer edge.

Exosphere

Thermosphere

Mesosphere

Stratosphere: Includes the ozone layer which absorbs UV light.

Troposphere: The lowest layer of the Earth's atmosphere. Most of the weather occurs here.

Crust: Between 5 and 70 km thick. Density ~3 g/cm^3. Divided into approximately 16 large plates.

Outer core: Liquid. The movement of the outer core produces Earth's magnetic field. Made mostly of iron and nickel the outer core is 2200 km thick and reaches 4000°C.

1. Why does the Earth have different internal layers? _____

2. Identify whether each of the following is liquid or solid:

   (a) Mantle: _____ (b) Outer core _____ (c) Inner core _____

3. What produces the Earth's magnetic field? _____

ESS2.A EM

ISBN: 978-1-98-856693-1

85 Modeling Erosion

Key Question: What role does water play in erosion?

Stream trays or tables are a simple way of modeling and observing how rivers develop and change the land by erosion and deposition of sediment. Any long tray can be used as long as there is a water supply and an outlet for the water is drilled at the lower end.

You will use your stream tray set-up to explore how water affects the landscape and what features of the landscape influence the landforms that result.

Investigation 7.1 Using stream trays to model erosion

See appendix for equipment list.

1. You may work in groups. Set up the tray by placing it on a slight angle with the outlet at the lower end. Place your substrate, e.g. gravel, silt, or sand in the tray and work the sediment so that it becomes thinner near the lower end.

   The simplest set up is to make a sediment "mountain" near the upper end of the tray to initially block water flow, forming a "lake". See photo (right) for set up.

   Answer question 3 on the next page and then begin your investigation. Record your results over the page.

2. With your stream tray now operating, observe the effect of the lake overflowing (A).

   Experiment with making different mountain shapes the repeat the overflow scenario.

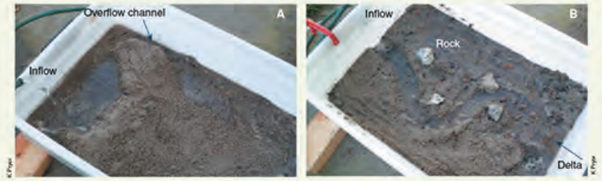
   Experiment with different materials (e.g. gravel, sand, clay) to simulate different rock types.

3. What factors influence how the channel will form? _____

4. Now create a river meander (sinuous track) and observe how it changes over time as water moves at different velocities around the bends, depositing and eroding material at different places (B).

5. Add larger rocks and vegetation to observe their effects on erosion and river channel formation (B).

6. Investigate the effect of increasing water velocity when banks are already undercut by erosion.

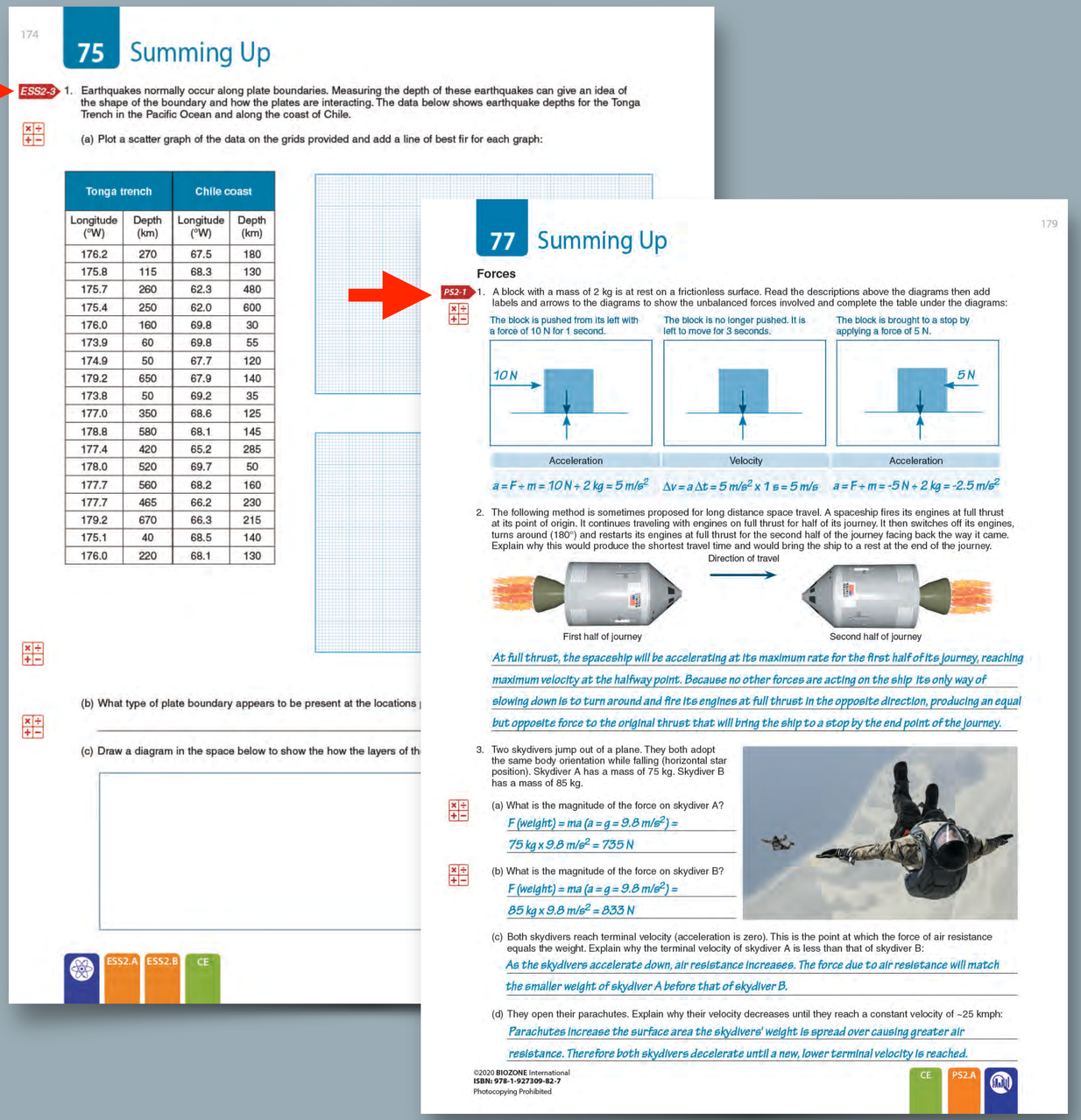


ISBN: 978-1-98-856693-1

SC CE ESS2.C

Assessment

- Each chapter concludes with a **Summative Assessment**.
- The **Performance Expectations** being assessed are identified in the Teacher's Edition.



174

75 Summing Up

ESS2-3 1. Earthquakes normally occur along plate boundaries. Measuring the depth of these earthquakes can give an idea of the shape of the boundary and how the plates are interacting. The data below shows earthquake depths for the Tonga Trench in the Pacific Ocean and along the coast of Chile.

(a) Plot a scatter graph of the data on the grids provided and add a line of best fir for each graph:

Tonga trench		Chile coast	
Longitude (°W)	Depth (km)	Longitude (°W)	Depth (km)
176.2	270	67.5	180
175.8	115	68.3	130
175.7	260	62.3	480
175.4	250	62.0	600
176.0	160	69.8	30
173.9	60	69.8	55
174.9	50	67.7	120
179.2	650	67.9	140
173.8	50	69.2	35
177.0	350	68.6	125
178.8	580	68.1	145
177.4	420	65.2	285
178.0	520	69.7	50
177.7	560	68.2	160
177.7	465	66.2	230
179.2	670	66.3	215
175.1	40	68.5	140
176.0	220	68.1	130

(b) What type of plate boundary appears to be present at the locations

(c) Draw a diagram in the space below to show the how the layers of th

ESS2.A ESS2.B CE

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77 Summing Up

Forces

PS2-1 1. A block with a mass of 2 kg is at rest on a frictionless surface. Read the descriptions above the diagrams then add labels and arrows to the diagrams to show the unbalanced forces involved and complete the table under the diagrams:

The block is pushed from its left with a force of 10 N for 1 second.

The block is no longer pushed. It is left to move for 3 seconds.

The block is brought to a stop by applying a force of 5 N.

Acceleration	Velocity	Acceleration
$a = F \div m = 10\ N \div 2\ kg = 5\ m/s^2$	$\Delta v = a\,\Delta t = 5\ m/s^2 \times 1\ s = 5\ m/s$	$a = F \div m = -5\ N \div 2\ kg = -2.5\ m/s^2$

2. The following method is sometimes proposed for long distance space travel. A spaceship fires its engines at full thrust at its point of origin. It continues traveling with engines on full thrust for half of its journey. It then switches off its engines, turns around (180°) and restarts its engines at full thrust for the second half of the journey facing back the way it came. Explain why this would produce the shortest travel time and would bring the ship to a rest at the end of the journey.

Direction of travel

First half of journey — Second half of journey

At full thrust, the spaceship will be accelerating at its maximum rate for the first half of its journey, reaching maximum velocity at the halfway point. Because no other forces are acting on the ship its only way of slowing down is to turn around and fire its engines at full thrust in the opposite direction, producing an equal but opposite force to the original thrust that will bring the ship to a stop by the end point of the journey.

3. Two skydivers jump out of a plane. They both adopt the same body orientation while falling (horizontal star position). Skydiver A has a mass of 75 kg. Skydiver B has a mass of 85 kg.

(a) What is the magnitude of the force on skydiver A?

F (weight) = ma (a = g = 9.8 m/s²) =
75 kg x 9.8 m/s² = 735 N

(b) What is the magnitude of the force on skydiver B?

F (weight) = ma (a = g = 9.8 m/s²) =
85 kg x 9.8 m/s² = 833 N

(c) Both skydivers reach terminal velocity (acceleration is zero). This is the point at which the force of air resistance equals the weight. Explain why the terminal velocity of skydiver A is less than that of skydiver B:

As the skydivers accelerate down, air resistance increases. The force due to air resistance will match the smaller weight of skydiver A before that of skydiver B.

(d) They open their parachutes. Explain why their velocity decreases until they reach a constant velocity of ~25 kmph:

Parachutes increase the surface area the skydivers' weight is spread over causing greater air resistance. Therefore both skydivers decelerate until a new, lower terminal velocity is reached.

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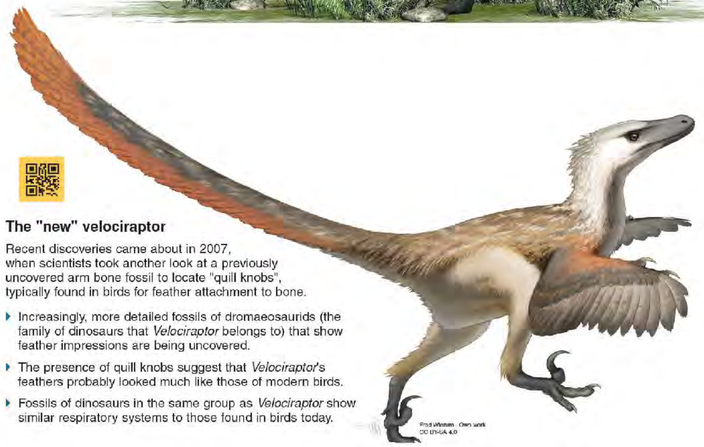
CE PS2.A

220 Dinosaur or Bird?

Anchoring Phenomenon: How does scientific evidence allow us to continually build ideas of what dinosaurs looked like?

The "old" velociraptor

The *Velociraptor* genus of dinosaurs is well known, thanks to movies such as Jurassic Park. These sleek, hairless hunters lived in packs and had a distinctly reptilian, featherless scaly skin. What evidence allowed us to form an impression of these dinosaurs? Fossil remains of a damaged skull and a toe claw were found in the Mongolian dessert in 1923. This was the first piece of the puzzle.



The "new" velociraptor

Recent discoveries came about in 2007, when scientists took another look at a previously uncovered arm bone fossil to locate "quill knobs", typically found in birds for feather attachment to bone.

- Increasingly, more detailed fossils of dromaeosaurids (the family of dinosaurs that *Velociraptor* belongs to) that show feather impressions are being uncovered.
- The presence of quill knobs suggest that *Velociraptor*'s feathers probably looked much like those of modern birds.
- Fossils of dinosaurs in the same group as *Velociraptor* show similar respiratory systems to those found in birds today.

1. How do you think evidence causes a change to scientific ideas?

2. Some scientists believe that birds should be classified as dinosaurs. What evidence might they use for their claim?

ISBN: 978-1-98-856692-4

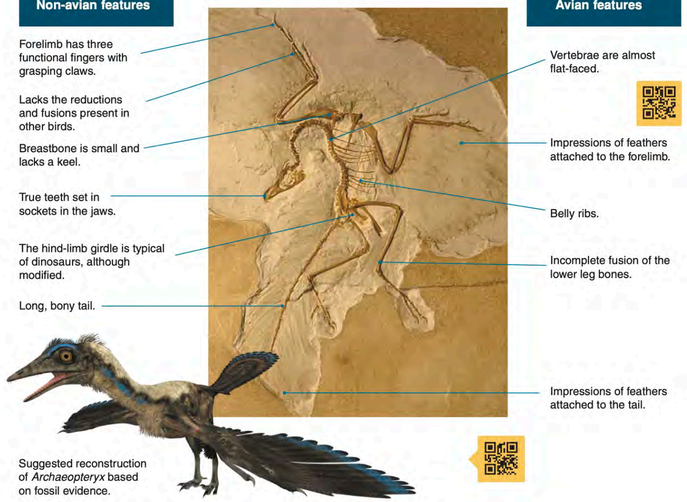
225 Transitional Fossils

Key Question: How do transitional fossils provide important links in the fossil record?

Transitional fossils are **fossils** which have a mixture of features, showing intermediate states, that are found in two different, but related, groups. Transitional fossils provide important links in the fossil record and provide evidence to support how one group may have given rise to the other by evolutionary processes.

Important examples of transitional fossils include horses, whales, and *Archaeopteryx* (below), a transitional form between birds and non-avian dinosaurs.

Archaeopteryx was crow-sized (50 cm length) and lived about 150 million years ago. It had a number of birdlike (avian) features, including feathers. However, it also had many non-avian features, which it shared with theropod dinosaurs of the time. Although not a direct ancestor of birds, the *Archaeopteryx* and birds shared a common ancestor.



Suggested reconstruction of *Archaeopteryx* based on fossil evidence.

1. (a) What is a transitional fossil?

(b) Why are transitional fossils important in understanding evolution?

LS4.A P

ISBN: 978-1-98-856692-4

231 Review Your Understanding

Anchoring Phenomenon Revisited: How does scientific evidence allow us to continually build on our ideas of what dinosaurs looked like?

125 MYA feathered fossil of *Zhenyuanlong* fossil is a close relative of the velociraptor.

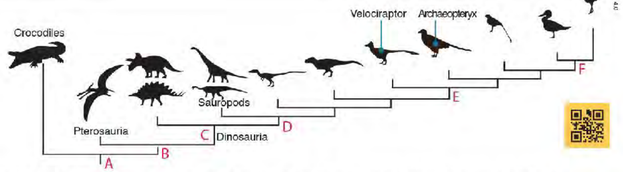
A dinosaur and a bird?

Scientific theory is developed through observation that is rigorously checked and repeated by the scientific community to confirm its validity. However, if new evidence arises, then the theory must be changed to accommodate it.

Birds are now classified by scientists as belonging to a group of dinosaurs called theropods. Birds have been on Earth for at least 150 million years.

1. What types of evidence could scientists have used to determine that birds belong to the (avian) dinosaur group?

2. (a) Scientists identify the *Archaeopteryx* as a transitional species between birds and dinosaurs, but not likely a direct ancestor. Refer to the phylogenetic tree below and explain why this might be:



(b) At what point in the phylogenetic tree would we expect to find the last common ancestor between birds and velociraptors? Explain your reasoning:

(c) Which of the above points are fossils likely to share with some features of birds? Explain your reasoning:

(d) Why is the ability to fly not an appropriate indicator of bird and dinosaur classification?

3. The foot bones of *Tyrannosaurus rex* and a chicken look similar (right). What is a probable explanation for this?

ISBN: 978-1-98-856692-4

Anchoring Phenomenon Activities explore concepts **Phenomenon Revisited**

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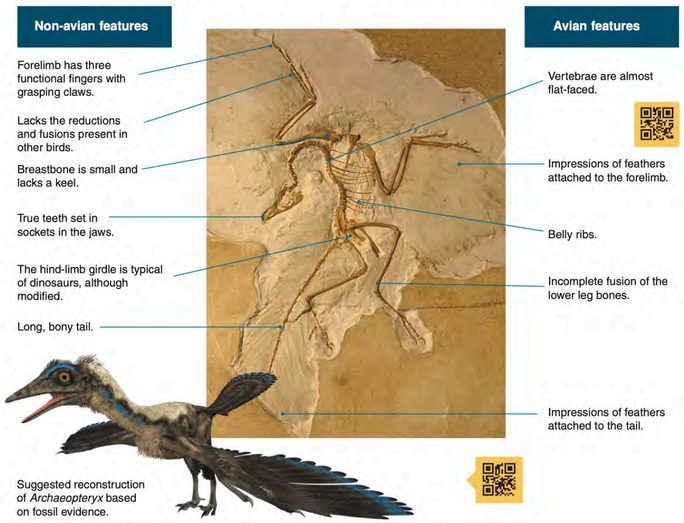

Suggested reconstruction of *Archaeopteryx* based on fossil evidence.

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LS4.A P

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_____

_____

_____

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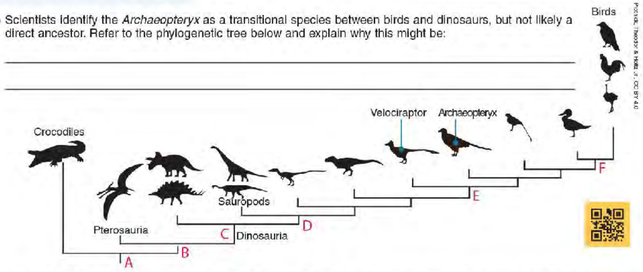
_____

_____



(b) At what point in the phylogenetic tree would we expect to find the last common ancestor between birds and velociraptors? Explain your reasoning:

_____

_____

(c) Which of the above points are fossils likely to share with some features of birds? Explain your reasoning:

_____

_____

(d) Why is the ability to fly not an appropriate indicator of bird and dinosaur classification?

_____

_____

_____

3. The foot bones of *Tyrannosaurus rex* and a chicken look similar (right). What is a probable explanation for this?

_____

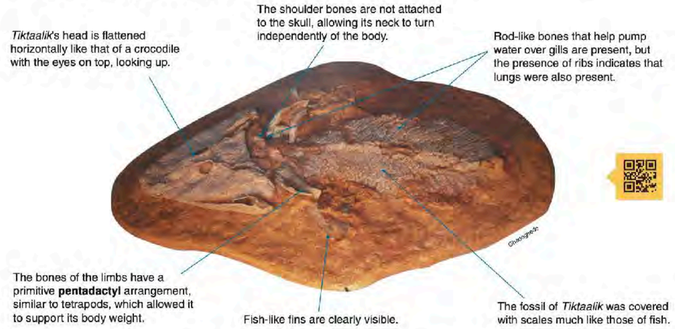
_____

_____

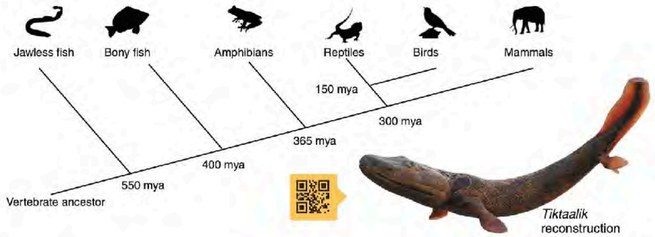
ISBN: 978-1-98-856692-4

232 Summing Up

In 2004, a **fossil** of an unknown vertebrate was discovered in northern Canada and subsequently called *Tiktaalik roseae*. The *Tiktaalik* fossil was quite well preserved and many interesting features could be identified. These are shown in the photograph of the fossil below.



1. Use the information above to place *Tiktaalik* on the time line of vertebrate evolution. Discuss the evidence for your decision.



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ISBN: 978-1-98-856692-4

P LS4.A

Activities explore concepts

Phenomenon Revisited

Problem-solving

Non-avian features

Avian features

Forelimb has three functional fingers with grasping claws.

Lacks the reductions and fusions present in other birds.

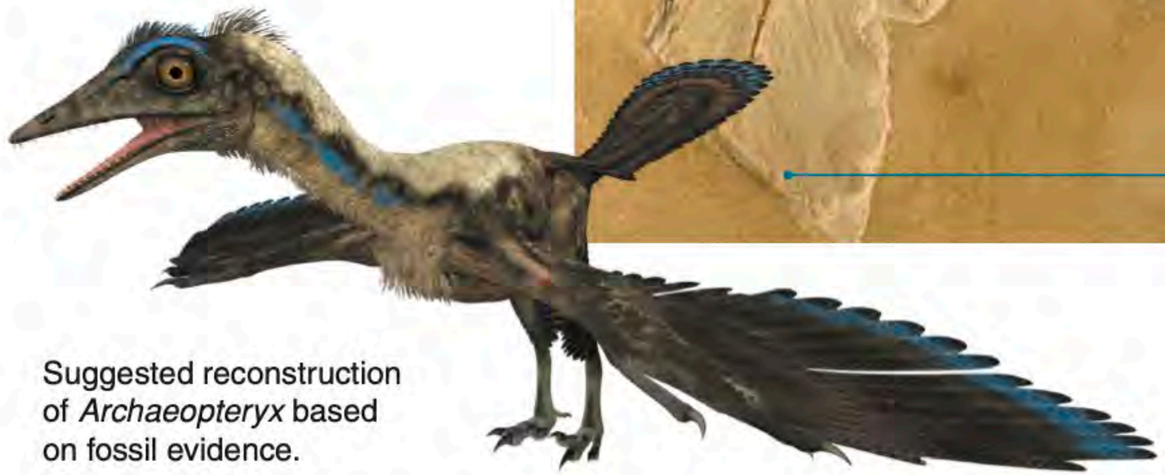
Breastbone is small and lacks a keel.

True teeth set in sockets in the jaws.

The hind-limb girdle is typical of dinosaurs, although modified.

Long, bony tail.

Impressions of feathers attached to the tail.



Suggested reconstruction of *Archaeopteryx* based on fossil evidence.

147 Investigating Ecological Pyramids

Key Question: What patterns do we see in ecological pyramids of real-world examples?

Investigation 7.1 Exploring biomass pyramids

See appendix for equipment list.

1. You can work individually or in pairs for this investigation. It makes use of HHMI's online interactive module "Exploring **Biomass Pyramids**". The module is based on real research from an aquatic ecosystem in Panama (Mary Power, 1984). The work examined the ecology of armored catfish (Ancistris sp.) in the Rio Frijoles. These small fish browse algae growing on the substrate. In this investigation, you will collect and analyze data from a virtual river to construct pyramids of energy and biomass. The investigation includes embedded questions, which you will answer in order to proceed.
2. Access the interactive module via BIOZONE's Resource Hub or by typing www.biointeractive.org/classroom-resources/exploring-biomass-pyramids.
3. Launch the interactive from the button on the left hand corner of the screen. Read through the introduction, then click the LAUNCH FIELD STUDY button.
4. The next screen will invite you to explore the pools of the Rio Frijoles. Once you have done that, you can commit to a pool using COMMIT TO POOL button at the bottom of the screen.
5. Follow the on-screen instructions to make a prediction about the shape of the biomass pyramid for this ecosystem. Once you have done this, move on to sample the algal community and quantify its biomass, and then count the catfish and quantify their biomass.

Aquarium specimen of armored catfish (*Ancistris* species) showing suckered mouth

1. Do your calculations from the investigation support your original prediction? Explain: _____

2. Continue with the interactive to run the trophic simulator and examine the productivity of algae over a longer period of time. What does the pyramid of biomass look like now?

3. You will be asked to summarize your findings. Paraphrase your summary below: _____

4. If you wish, continue the interactive session to explore how algal productivity is affected by the amount of sunlight reaching the pond and how this affects the number of consumers that can be supported. At the end of the interactive session, you can generate a report. Attach your report to this page.

ISBN: 978-1-98-856692-4

EM LS2.B

33 Studying Cells

Key Question: What techniques are used to prepare and view cells under a light microscope?

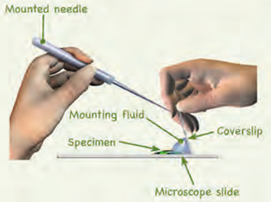
Specimens are usually prepared in some way before viewing in order to highlight features and reveal details. A wet mount is a temporary preparation in which a specimen and a drop of fluid are trapped under a thin coverslip. Wet mounts improve a sample's appearance and enhances visible detail. Sections must be made very thin.

Investigation 2.1 Preparing an onion slide

See appendix for equipment list.

Caution is required when using scalpels or razors. Iodine stains skin and clothes, and irritates the eyes. You should wear protective eyewear.

1. Onions make good subjects for preparing a simple wet mount. Cut a square segment from a thick leaf of the bulb using a razor or scalpel.
2. Bend the segment towards the upper epidermis (upper cell layer) until the lower epidermis and inner leaf tissue (the parenchyma) snaps, leaving the upper epidermis attached.
3. Carefully peel off the parenchyma from one side of the snapped leaf and then the other, leaving a peel of just the upper epidermis.
4. Place the peel in the centre of a clean glass microscope slide and cover it with a drop of water.
5. Carefully lower a coverslip over the peel. A mounted needle can be used for better precision. This avoids including air in the mount.
6. Use a small piece of tissue or filter paper to remove any excess water.
7. Place the slide on the microscope tray. Locate the specimen or region of interest at the lowest magnification. Focus using the lowest magnification first (remembering to move the lens away from the slide) before switching to the higher magnifications.
8. After viewing the slide under various magnifications, remove the slide and place it on the bench.
9. At the edge of the coverslip, place a small drop of iodine stain.
10. On the opposite side of the coverslip use a piece of tissue or filter paper to draw the water out from under the coverslip. The iodine will be drawn under the coverslip.
11. Replace the slide on the microscope and view the stained onion peel.



1. Why must sections viewed under a microscope be very thin? _____

2. Why do you think the specimen is covered with a coverslip? _____

3. Why would no chloroplasts be visible in an onion epidermis cell slide? _____

ISBN: 978-1-98-856692-4

LS1.A

202 Modeling Meiosis

Key Question: How is variation introduced into the gametes formed during meiosis?

Modeling meiosis using popsicle sticks can help to understand how meiosis creates variation. Each of your somatic (body) cells contains 46 chromosomes: 23 maternal and 23 paternal. Therefore, you have 23 **homologous pairs**. For simplicity, the number of chromosomes studied in this exercise has been reduced to four, i.e. two homologous pairs.

Investigation 11.2 Modelling meiosis using popsicle sticks

See appendix for equipment list.

To study the effect of crossing over on genetic variation, you will work in pairs to simulate the inheritance of two of your own traits: ability to tongue roll and handedness. This activity will take 25–45 minutes.

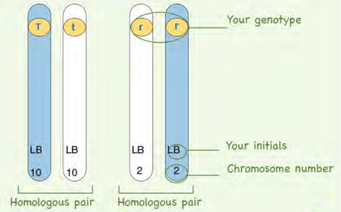
Chromosome number	Phenotype	Genotype
10	Tongue roller	TT, Tt
10	Non-tongue roller	tt
2	Right handed	RR, Rr
2	Left handed	rr

1. Record your phenotype and genotype for each trait in the table (right). If you have a dominant trait, you will not know if you are heterozygous or homozygous for that trait, so you can choose either genotype.
2. Before you start the simulation, partner up with a classmate. Your gametes will combine with theirs (fertilization) at the end of the activity to produce a "child". Decide who will be female, and who will be male. You will need to work with this person again at step 7.
3. Collect four popsicle sticks. These represent four chromosomes. Color two sticks blue or mark them with a P, for paternal chromosomes. The plain sticks are the maternal chromosomes. Write your initials on each of the four sticks. Label each chromosome with its number. Label four sticky dots with alleles to describe your phenotype and stick each onto the appropriate chromosome. In the example shown (right), the person is heterozygous for tongue rolling so sticky dots with alleles T and t are placed on chromosome 10. The person is also left handed, so alleles r and r are placed on chromosome 2.

Step 1

Trait	Phenotype	Genotype
Handedness		
Tongue rolling		

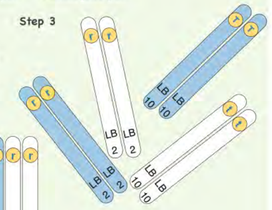
Step 2



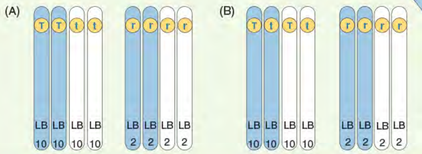
4. Randomly drop the chromosomes onto a table. This represents a cell in either the testes or ovaries. Duplicate your chromosomes by adding four more identical popsicle sticks to the table (right). What are you simulating with this action?

Simulate the first stage of meiosis by lining the duplicated chromosome pair with their homologous pair (below). For each chromosome number, you will have four sticks touching side-by-side (A, below). At this stage crossing over occurs. Simulate this by swapping sticky dots from adjoining homologues (B, below).

Step 3



Step 4



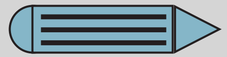
ISBN: 978-1-98-856692-4

LS3.B

Investigative phenomena

Teacher Codes

What do they mean?

				
Material supported on Resource Hub	Collaboration opportunity	Performance Expectation covered	CCSS ELA/ ELD connection covered	Support in Science Practices chapter
				
Extension material	Computer required	ETS DCI covered	CCSS math connection covered	

Pacing Guide

Biology for NGSS

- Suggested **delivery**
- Highlights **vocabulary**
- Highlights **investigations**
- Highlights **assessment**

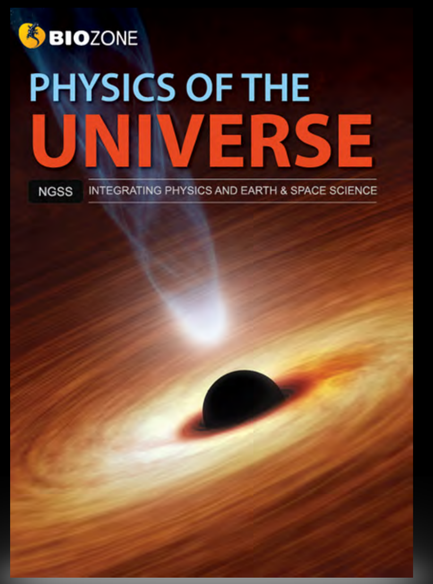
Biology for NGSS (3rd edition) SUGGESTED PACING GUIDE BIOZONE

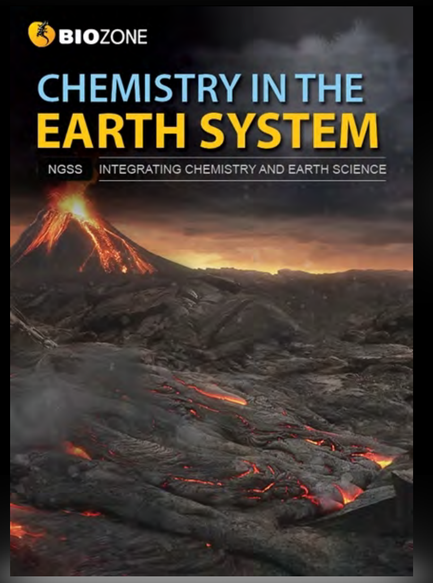
Unit 2 Title: **Cell Specialization and Organization**

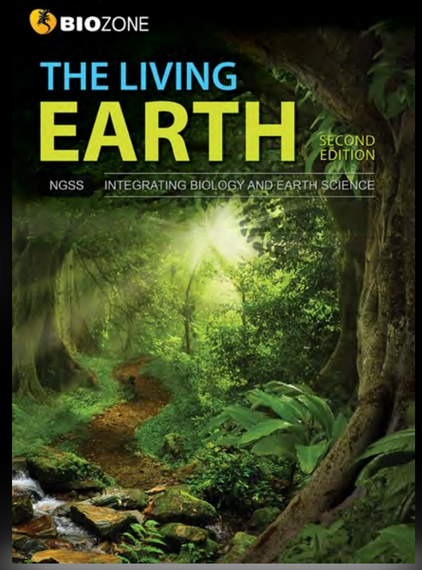
Date	Duration Time / No. of periods	Activity numbers	Notes	Lab / Practical activity	Formative or Summative Assessment
	1	29 – 30	How does freezing typically damage living tissue? Hierarchy of life **Vocab**: organelle, cell, tissue, organ, organ system		• Explain 2 mechanisms that the wood frog uses to survive freezing.
	4	31 - 36	**Vocab**: prokaryotic, eukaryotic, enzyme, magnification, resolution, organelle, chloroplast, mitochondrion, vacuole, ER, nucleus, ribosome, Golgi apparatus, amyloplast, cytoplasm, cell wall, plasma membrane, smooth ER, rough ER, lysosome, centrioles, microvilli	Calculate amount of magnification Calculate actual size of object **Inv 2.1**: Prepare a wet mount and observe	• Explain why it is important to start at the lowest magnification. • Using the TEM images, identify organelles and describe their function
	6	37 – 46 *17	**Vocab**: phospholipid, glycolipid, channel protein, carrier protein, glycoprotein, hydrophilic, hydrophobic, diffusion, facilitated diffusion, osmosis, solute, solvent, solution, osmolarity, surface area – to – volume ratio, active transport, ion pumps, specialized cell,	Build a paper model of the plasma membrane **Inv 2.2**: Simple diffusion across a membrane **Inv 2.3**: Estimating osmolarity **Inv 2.4**: How cell shapes affect diffusion **Inv 2.5**: Effect of temperature on membrane permeability	• What is the function / role of the plasma membrane?
	4	47 – 50	**Vocab**: DNA, proteins, nucleotide, adenine, guanine, cytosine, thymine, uracil, purine, pyrimidine, N-base, phosphate, RNA, ribose, deoxyribose	**Inv 2.6**: Extracting DNA Build a paper model of DNA	• Why is DNA vital to the survival and function of a cell?
	3	51 – 54	**Vocab**: gene, transcription, translation, amino acid, polypeptide, denature, hydrogen bonding, disulfide bond	**Inv 2.7**: Modeling protein structure	• What makes proteins so important? • How can there be so many different kind of proteins?
	4	55 – 59 *6 *23 *24	**Vocab**: microtubules, anabolic, catabolic, enzyme, catalyst, catalase	Match examples of proteins to their functions and pictograms **Inv 2.8**: Effect of temperature on enzyme activity	• What do enzymes do? • Is life possible without enzymes? Defend your answer.

Integrated NGSS Series

- Written for an integrated 3-course **high school NGSS framework**.
- Ideal for courses integrating **Earth & Space Sciences** with traditional sciences.
- Deliver the content in the order it is provided due to the iterative nature of the framework.
  - **5Es** sequencing
  - **Phenomena** introduced at the beginning of each chapter
  - **Phenomena revisited** at the conclusion of each chapter





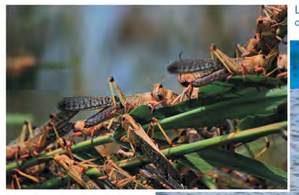


1 An Endless Swarm

ANCHORING PHENOMENON: The high density and swarming of migratory locusts

A swarm of locusts is one of nature's most incredible animal events. So astonishing and destructive are these swarms they are recorded in many historical accounts, including those of Greek and Roman historians. Plagues of desert locusts have historically been particularly catastrophic in North Africa, where they are associated with famine.

Under certain environmental conditions, particular species of normally solitary shorthorned grasshoppers may form vast swarms (dense aggregations) that migrate across the country eating everything in their path. Swarms have been known to contain billions of locusts (the swarming form of grasshoppers) and last multiple generations and many years. As at February 2020, Africa's largest locust outbreak in decades has created food emergencies in Ethiopia, Somalia, Kenya, with neighboring countries also threatened.



Locusts are the swarming form of certain grasshopper species.

Locust swarms may contain up to 80 million individuals per km^2

1. Identify a species in your local area that:

   (a) Swarms: _____

   (b) Migrates: _____

2. Divide the class into groups of three or four to discuss the following points:

   (a) What factors in the environment might cause a normally solitary species to suddenly form a voracious giant swarm?

   _____

   _____

   _____

   (b) Swarming occurs regularly, which suggests the behavior has advantages. What might these be? _____

   _____

   _____

   _____

   (c) How might human activities be involved with or affected by swarming locusts: _____

   _____

   _____

   _____

   _____

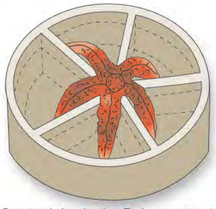
ISBN: 978-1-98-856628-3

3 Abiotic Factors Influence Distribution

ENGAGE: Distribution of the common sea star

The common sea star is a marine invertebrate (an animal without a backbone). It is found throughout the Atlantic at a wide range of depths between 0-400 m where it experiences large variations in abiotic factors.

Scientists collected adult sea stars from two populations in the White Sea (off the Northwest coast of Russia) and the Barentz Sea (off the Northern coasts of Norway and Russia). They exposed them to a range of salinities (amount of dissolved salt in parts per thousand) within a five-compartment chamber (right) and recorded the number of animals found in different salinities. The animal was placed in the center of the chamber with each arm experiencing water of different salinity. The animal then crawled into the compartment with the preferred salinity. All other factors were kept constant. The results are shown below.



Sea star choice chamber. Each compartment contains water of a different salinity.

Salinity (‰)	Frequency of choice (%)	
	White Sea	Barentz Sea
15.0	0	0
17.5	3	0
20.0	12	1.2
22.5	36	7.5
25.0	42	3.4
27.5	31	6.2
30.0	18	30.2
32.5	9	39.6
35.0	8	42.1
37.5	0	29.6
40.0	0	14
42.5	0	9.8

1. (a) Plot the two sets of data from the table above on the grid provided.

   (b) What do the plots show? _____

   _____

   _____

   (c) What was the preferred salinity for each of the sea star populations? _____

   _____

   (d) What do these results suggest about the salinity of the two areas of collection? _____

   _____

   _____

   (e) Describe the abiotic conditions the common sea star as a species can tolerate: _____

   _____

   _____

   _____

ISBN: 978-1-98-856628-3

CE LS2.A

EXPLORE: Modeling the effect of insulation

A thermos can keep food and drink hot or cold for many hours after you fill it. It doesn't have a heating or cooling unit, so how does it work? A thermos is a double-walled container (think of it like a bottle inside a bottle). When it is made, the air between the two walls is sucked out, creating a vacuum. The vacuum reduces the amount of heat transfer between the thermos and the outside environment. This insulates the contents and keeps them hot or cold for a long time.

We saw on the previous page that some animals use insulation to help thermoregulate. Common insulating materials in nature are fat, feathers, fur (or hair), and wool.

15. Can you think of animals that have the following types of insulation?

   (a) Fat: _____

   (b) Feathers: _____

   (c) Fur (or hair): _____

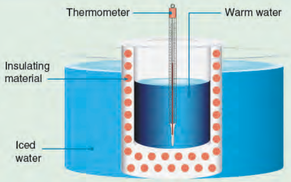
   (d) Wool: _____

INVESTIGATION 5.8: Exploring insulation See appendix for equipment list.

You will work in small groups or pairs. Your teacher may ask you to test all of the materials listed below, or only some. You can compare your results with the other groups. Four insulating materials will be studied: fat (lard), feathers, wool, and cotton balls.

Predict the best insulator: _____

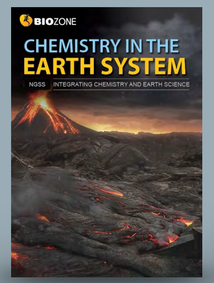
Predict the worst insulator: _____



1. Set up the control by placing a 100 mL beaker directly inside a 250 mL beaker (no insulation).
2. Set up your test by packing your chosen insulating material into a 250 mL beaker. Leave space to insert a 100 mL beaker.
3. Pour warm water (~45°C) into both 100 mL beakers then place each set up into separate containers of iced water (above).
4. Place a thermometer into each of the 100 mL beakers. You may need to tape or weigh the beakers down to stop them floating and tipping over.
5. Start a stop watch and record the temperature every two minutes for 20 minutes in the table below.

	Temperature (°C)				
Minutes	Control	Fat	Feathers	Wool	Cotton balls
2					
4					
6					
8					
10					
12					
14					
16					
18					
20					

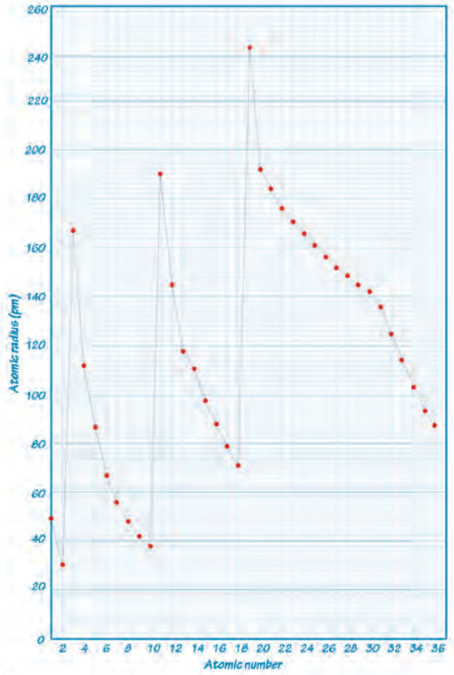
ISBN: 978-1-98-856628-3



EXPLORE: Trends in the periodic table

- It is useful to now explore more subtle details in the periodic table. The table below shows the atomic radius of the atoms from atomic number 1 (hydrogen) to 36 (krypton). This includes the first four rows of the periodic table (three short rows and one long row).
- The atomic radius at is simplest definition the distance from the nucleus to the edge of the electron cloud. Since the electron cloud has no fixed edge, a more definitive measure of the atomic radius is half the distance between two identical atoms in a covalent bond (the covalent radius).

Atomic number	Atomic radius (pm)
1	53
2	31
3	167
4	112
5	87
6	67
7	56
8	48
9	42
10	38
11	190
12	145
13	118
14	111
15	98
16	88
17	79
18	71
19	243
20	194
21	184
22	176
23	171
24	166
25	161
26	156
27	152
28	149
29	145
30	142
31	136
32	125
33	114
34	103
35	94
36	88



8. Plot the data on the grid provided:
9. Describe any trends or patterns you can see in the data: Atomic radius decreases within the elements of a period. It increases from periods higher on the table to those lower on the table (low number periods to high number periods).

ISBN: 978-1-927309-74-2

36 Fuels and People

ENGAGE: What fuels do you use?

- Fuel is what allows our industrial world to work. Without it, the factories stop, food production of farms would plummet, and what little food was produced could not be cooked or processed. The amount of fuel you use every day is enormous, but most of this use is indirect. You don't personally use the fuel, but manufacturers or producers of things you use or need use the fuel on your behalf.
- A simple example might be the shirt you are wearing. If it is made from cotton then diesel fuel was used to run the machinery that planted, irrigated, sprayed, and harvested the cotton. Diesel was used in the trucks that took the cotton to the mill where it was spun into thread. The factory used electricity, but that may have been generated by coal, or gas, or solid uranium pellets fueling a nuclear power station. Diesel fueled trucks would have transported the materials to factories were the shirt was made and then again to the shop were you bought it. Don't forget the processes that made the dyes that color the shirt. Or made the tractor, or any of the dozens of other implements used to make the shirt. All these stages in manufacture were powered by fuels. A large proportion of these fuels would be fossil fuels consisting of short chain alkane derivatives.

The harvester and tractor run on diesel fuel.

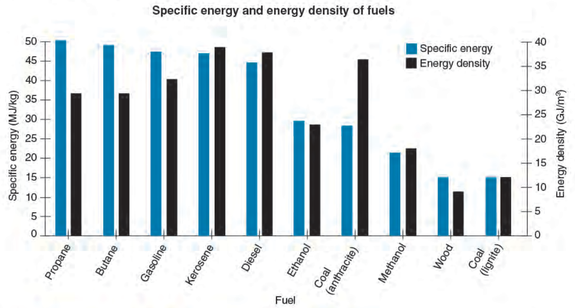
1. Think of two things that you do or use every day and make a list of how fuels (of any kind) are used in the process of getting them to you. Compare your ideas and list with others in your class:

(a) Student's answer

(b) Student's answer

EXPLORE: Fuels and energy density

- The amount of energy in a fuel can be measured in two important ways: its **specific energy** and its **energy density**.
- **Specific energy** is the amount of energy per unit of mass of the fuel.
- **Energy density** is the amount of energy per unit of volume of the fuel. The graph below shows the specific energy and energy density of a selection of fuels:



PS1.A PS3.D ESS3.A CE EM

ISBN: 978-1-927309-74-2

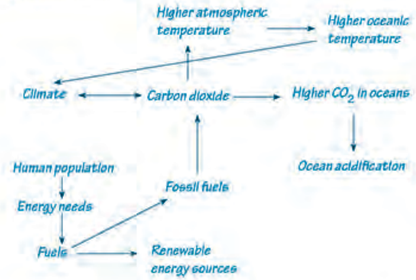
41 It's Heating Up Revisited

In this chapter you have been shown several lines of evidence for global warming and climate change and some of its possible causes. You should now be able to better describe the complex phenomenon of climate change and the evidence that supports it. You should also be able to explain the possible causes of climate change.

1. Write a short essay on the evidence for climate change, the possible effects of climate change, and humanity's role in enhancing or reducing these effects. Publish your work in a shared forum so that others can comment or critique your work and you can develop or strengthen your writing as needed. Use the space below to create a mind map (network of connected ideas) to help you plan your essay:

Student's answer will depend on their research, sources, and method of publishing.

A simple mind map is shown below.



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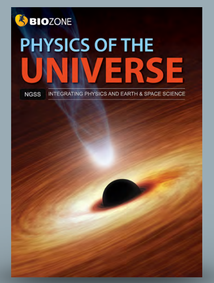
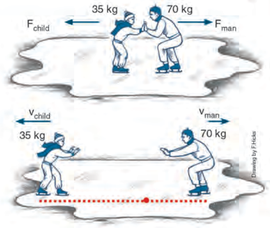


EXPLAIN: Explosions are collisions in reverse

Why are explosions, like the fireworks right, spherical? Where is the center of the explosion? Assuming all the fragments within the firework are all the same, how does this explain the shape of the firework?

- Explosions throw objects in all directions, but they still obey the law of conservation of momentum. Imagine the firework shown right has been fired straight up and has reached the highest point of its flight. Its momentum in that instant is zero.
- At that exact moment, it explodes. What is the momentum of all the fragments now? Conservation of momentum states that they must add up to zero.
- Consider the simplified diagram below:

- The momentum of fragment A is exactly opposite the momentum of fragment B.
- The drawing right shows a man (mass 70 kg) and a child (mass 35 kg) standing together on smooth ice (friction is negligible). The two push each other apart and the man moves away with a speed 0.3 m/s relative to the ice.



13. (a) Calculate the velocity of the child relative to the ice:

    _____

    _____

    (b) Determine how far apart the man and the child are after 5 seconds. Show your working:

    _____

    _____

- Now consider the cannon and cannon ball below:

- The explosion of the powder charge pushes the cannon and the cannon ball apart in opposite directions. The mass of the cannon is much larger than the cannon ball. As a result the cannon ball flies out of the barrel at high speed while the cannon itself rocks back on its wheels less than a meter or so at a much lower speed.

14. Considering the cannon above, the cannon has a mass of 900 kg and is at rest before firing. The cannon ball weighs 5 kg. When fired, the cannon ball exits the barrel at 230 m/s.

    Calculate the velocity of the cannon after it is fired: _____

    _____

15. An object at rest explodes into two equal parts, A and B. Part A flies off at 20 m/s. What is the velocity of part B?

    _____

16. A 12 kg object at rest has two parts, C and D. C has a mass of 4 kg and moves off at 6 m/s. What is the velocity of D?

    _____

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14 Electrostatic Force

ENGAGE: Zap!

- Ever got out of a car, gone to close the door and received an electric shock? What about taking off a polar fleece sweater or jacket? Try it in a darkened room and you will see sparks flash as the jersey rubs against the material of your shirt. What about lightning? What causes that? Study the photo of the little girl's hair (right) What's causing that to happen?

1. What do you think is causing these phenomena? Where does the electricity come from? Discuss your ideas with others in your class and write down a summary of these ideas:

    _____

    _____

    _____

    _____

    _____

    _____

EXPLORE: Balloon electrostatics

- Balloons are well known for producing some interesting electrostatic effects:

INVESTIGATION 2.5: Balloon electrostatics

See appendix for equipment list.

1. In a still, warm room, fully inflate a balloon and hang it from the ceiling or an insulated support with nylon thread or fishing line.
2. Rub the balloon with a piece of wool/synthetic material or a sweater so that it becomes charged.
3. Predict what will happen if you bring the material or sweater used to rub the balloon near the balloon.

    _____

    _____

4. Carry out step 3 and record your observations: _____

    _____

5. Fully inflate a second balloon and hang it from the ceiling with more nylon fishing line near the first balloon.
6. Rub both balloons with the same material (wool/synthetic fabric or a sweater). This should give the balloons a charge of the same sign and a similar amount.
7. Predict what will happen to these similarly charged balloons as they hang near each other.

    _____

    _____

8. Carry out step 7 and record your observations: _____

    _____

9. Leave the balloons hanging near each other for a few minutes. Record any changes that take place:

    _____

    _____

PS2.B P SPQ SSM

ISBN: 978-1-927309-75-9

EXPLORE: Orbits

- Our solar system consists of the Sun, eight planets, numerous dwarf planets, and almost uncountable numbers of comets and asteroids. Many of these objects orbit the Sun in elliptical orbits that are roughly circular, with the Sun near the center of the circle. However many do not. The most well known of these are comets, but many of the dwarf planets, (especially those in the outer solar system) also orbit with highly elongated orbits.
- How an object orbits depends on many things. These include how it formed, where it formed, the gravitational force from nearby objects, and its velocity during an encounter with any other object.

Orbits and escape velocity

The velocity required for a circular orbit can be calculated using the equation:

$$v_C = \sqrt{\frac{GM}{r}}$$

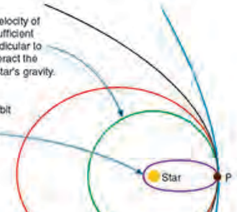
Escape velocity is the velocity required to escape the gravitational pull of an object at a particular distance from it. It can be calculated using the formula:

$$v_E = \sqrt{\frac{2GM}{r}}$$

The diagram right shows the orbit of a planet around a star of mass M based on the planet's actual velocity (v) compared to its escape velocity (v_E) and the velocity needed for the planet to orbit in a perfect circle (v_C). All orbits start at point P.

Circle: $v = v_C$. The velocity of the planet gives it sufficient momentum, perpendicular to the radius, to counteract the inwards pull of the star's gravity.

Ellipse 1: $v < v_C$. The planet will orbit in a small ellipse as the velocity is not fast enough to prevent the gravity of the star pulling it back before a circular orbit forms.

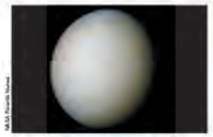


Ellipse 2: $v_C < v < v_E$. The planet will orbit in a large ellipse as it is travelling faster than the velocity required for a circle, but not fast enough to escape the pull of the star.


Comets have a highly elliptical orbit

Parabola: $v = v_E$. The planet will coast away from the star at an ever decreasing relative velocity but will never actually return.

Hyperbola: $v > v_E$. The planet will escape the pull of the star.



Venus has the most circular orbit in the solar system, being less than 1% off a perfect circle. At its closest approach to the Sun Venus is 0.716 AU away from the Sun, while at its furthest away it is 0.726 AU from the Sun. One AU (astronomical unit) is the average distance from the Sun to the Earth, about 150 million km.

Sedna is one of the most distant dwarf planets. It has a dramatically elongated orbit compared to the planets of the solar system. At its closest approach to the Sun, Sedna closes to 72 AU, but then swings back out to 936 AU from the Sun. Its orbit takes over 11,400 years to complete.

In 2017 the interstellar object 'Oumuamua' entered the solar system. Its trajectory brought it close to the orbit of Mars. Oumuamua was travelling at such a high speed that although the Sun's gravity bent its path it was not captured, and it has since travelled back out past the outer planets on its way out of the solar system.

6. (a) Of the five orbits shown in the diagram top right, which most likely matches the orbit of Oumuamua?

    The hyperbola

    (b) What would happen to the shape of Venus's orbit if it gained velocity as it moved along its orbit? _____

    Venus' orbit would become elliptical.

    (c) How would the size of the escape velocity be affected if a planet orbits closer to a star? _____

    The shorter the distance between the planet and the star, the greater the escape velocity.

ISBN: 978-1-927309-78-0

Instructional Segment 1

Ecosystem Interactions and Energy

Richard Ling cc2.5,3.0

Activity number

Anchoring Phenomenon

An endless swarm: The high density and swarming of migratory locusts. 1 19

What factors affect the size of populations within an ecosystem?

- ☐ 1 Identify the various abiotic and biotic components of ecosystems. Analyze and interpret data to describe how these different components influence one another. 3 4
- ☐ 2 In what way is the Earth a system of systems? Describe the general groupings of Earth materials and processes (atmosphere, hydrosphere, biosphere, geosphere, anthrosphere) each of which is shaped by its own processes and interactions with other systems. Develop a model to show how the spheres interact. 2
- ☐ 3 What is a population? Describe different patterns of population growth and explain the role of carrying capacity in limiting population growth. Use mathematical and computational thinking and modeling to predict the effect of chosen interdependent factors on the size of a population over time. 5-8
- ☐ 4 Conduct investigations to test how different parameters change population size. Analyze your findings and describe the population changes mathematically. Use mathematical models to support and revise evidence-based explanations about factors affecting populations and diversity in ecosystems of different scale. How well does an ecosystem model at one scale relate to a model at another scale? 6 7 8 11 20
- ☐ 5 Categorize factors influencing population growth as density dependent (DD) or density independent (DI) and describe how they are different. Analyze and interpret data to explain how DD and DI factors affect the flow of energy and matter and that this is how they affect population size. 8-11
- ☐ 6 Describe the ways organisms obtain and store energy. Explain how this energy is transferred in ecosystems through food chains and food webs. Use the conceptual model of an energy pyramid and calculate energy fluxes to explain the energy available at each successive trophic level in an ecosystem. 13 14
- ☐ 7 Use a simulation to investigate energy or biomass transfers in an ecosystem and explain these using ecological pyramids. 14
- ☐ 8 Use predictive models of predator-prey population cycles to support claims about the relative amounts of energy at different trophic levels. 10 14
- ☐ 9 Explain how nutrients (matter) cycle within and between ecosystems including between abiotic and biotic components. Use mathematical representations to show that matter and energy are conserved as matter cycles and energy flows through ecosystems. 15 20
- ☐ 10 How do populations behave as a system with many interacting parts (members)? Evaluate the evidence for the role of group behavior in the survival and reproductive success of individuals and populations. 17 18 20

What are common threats to remaining natural ecosystems and biodiversity? How can these threats be reduced?

- ☐ 11 Explain how humans might cause density dependent and density independent changes to ecosystems by altering the availability of resources and changing the landscape (including through climate change). Describe how these changes might affect the size and diversity of populations. 12
- ☐ 12 Obtain information to summarize the various positive and negative ways in which humans influence ecosystem resources and disrupt the usual nutrient cycles. Use mathematical representations to explain how humans affect populations and diversity in ecosystems of different scales. 16

1 An Endless Swarm

ANCHORING PHENOMENON: The high density and swarming of migratory locusts

A swarm of locusts is one of nature's most incredible animal events. So astonishing and destructive are these swarms they are recorded in many historical accounts, including those of Greek and Roman historians. Plagues of desert locusts have historically been particularly catastrophic in North Africa, where they are associated with famine.

Under certain environmental conditions, particular species of normally solitary shorthorned grasshoppers may form vast swarms (dense aggregations) that migrate across the country eating everything in their path. Swarms have been known to contain billions of locusts (the swarming form of grasshoppers) and last multiple generations and many years. As at February 2020, Africa's largest locust outbreak in decades has created food emergencies in Ethiopia, Somalia, Kenya, with neighboring countries also threatened.

Locusts are the swarming form of certain grasshopper species.

Locust swarms may contain up to 80 million individuals per km^2

1. Identify a species in your local area that:
   (a) Swarms: _____
   (b) Migrates: _____
2. Divide the class into groups of three or four to discuss the following points:
   (a) What factors in the environment might cause a normally solitary species to suddenly form a voracious giant swarm?
   _____
   _____
   _____
   (b) Swarming occurs regularly, which suggests the behavior has advantages. What might these be? _____
   _____
   _____
   _____
   (c) How might human activities be involved with or affected by swarming locusts: _____
   _____
   _____
   _____
   _____

2 The Earth's Systems

Hydrosphere: all liquid and surface water. Ice is sometimes called the cryosphere.

USDA

Geosphere: the Earth itself.

Biosphere: all living things.

ENGAGE: The Earth is made up of spheres

The model above shows the Earth's four spheres. These interact as a complex system that maintains life on Earth. The anthrosphere is part of the biosphere but is sometimes classified as a fifth sphere because of the impact that humans have on all other systems.

1. Observe the environment around you and identify elements of each of the five spheres:
   (a) Biosphere: _____
   (b) Anthrosphere: _____
   (c) Hydrosphere: _____
   (d) Geosphere: _____
   (e) Atmosphere: _____
2. Interactions between spheres involve movement of energy and/or matter between them. Lo the spheres present and briefly describe any interactions that could be occurring between t

3. The anthrosphere can have significant impacts on the other four spheres. Using your local describe a way in which human activity can affect the other spheres:
   _____
   _____
   _____

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Locusts are the swarming form of certain grasshopper species.

EXPLORE: Ecosystems have many components

Ecosystems are natural units made up of the living organisms (biotic factors) and the physical conditions (abiotic factors) in an area. **Abiotic factors** include non-living factors associated with the geosphere, hydrosphere, and atmosphere (below). **Biotic factors** include all the living organisms and their activities.

The interactions of living organisms with each other and with the physical environment help determine the features of an ecosystem. The components of an ecosystem are linked to each other (and to other ecosystems) through nutrient cycles and energy flows.

Biotic factors

These are all the living organisms in the environment, including their interactions.
- Plants
- Animals
- Microorganisms (e.g. bacteria)
- Fungi
- Protists (e.g. algae and protozoans)

Atmosphere (air)
- Wind speed
- Wind direction
- Humidity
- Light intensity/quality
- Precipitation
- Temperature

Hydrosphere (water)
- Dissolved nutrients
- pH
- Salinity
- Dissolved oxygen
- Precipitation
- Temperature

Geosphere (rock/soil)
- Nutrient availability
- Soil moisture
- pH
- Composition
- Temperature
- Depth

4. (a) Which spheres are represented in the savanna ecosystem model above? _____

_____

_____

(b) Activities in one sphere can affect other spheres and may cause changes at the ecosystem level. Develop a model, e.g. a diagram or mind map, of interactions within and between the biotic and abiotic components of an ecosystem.

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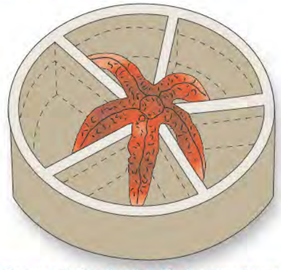
3 Abiotic Factors Influence Distribution

ENGAGE: Distribution of the common sea star

The common sea star is a marine invertebrate (an animal without a backbone). It is found throughout the Atlantic at a wide range of depths between 0-400 m where it experiences large variations in abiotic factors.

Scientists collected adult sea stars from two populations in the White Sea (off the Northwest coast of Russia) and the Barentz Sea (off the Northern coasts of Norway and Russia). They exposed them to a range of salinities (amount of dissolved salt in parts per thousand) within a five-compartment chamber (right) and recorded the number of animals found in different salinities. The animal was placed in the center of the chamber with each arm experiencing water of different salinity. The animal then crawled into the compartment with the preferred salinity. All other factors were kept constant. The results are shown below.



Sea star choice chamber. Each compartment contains water of a different salinity.

Salinity (‰)	Frequency of choice (%)	
	White Sea	Barentz Sea
15.0	0	0
17.5	3	0
20.0	12	1.2
22.5	36	7.5
25.0	42	3.4
27.5	31	6.2
30.0	18	30.2
32.5	9	39.6
35.0	8	42.1
37.5	0	29.6
40.0	0	14
42.5	0	9.8

1. (a) Plot the two sets of data from the table above on the grid provided.

(b) What do the plots show? _____

_____

_____

(c) What was the preferred salinity for each of the sea star populations? _____

_____

(d) What do these results suggest about the salinity of the two areas of collection? _____

_____

_____

(e) Describe the abiotic conditions the common sea star as a species can tolerate: _____

_____

_____

_____

ISBN: 978-1-98-856628-3

CE LS2.A

2. Based on the White Sea sea star population, draw a general diagram (model) to show how the numbers of individuals in a population change over an abiotic gradient. Label it to show the optimal (preferred), marginal, and unavailable habitat. Mark the tolerance range (the range for an abiotic factor outside of which no individuals can survive):

EXPLORE: Estuarine habitats


Estuary: high tide


Estuary: low tide

An estuary is a semi-enclosed coastal body of water, which has a free connection with the ocean and where marine and freshwater environments meet and mix. Estuarine water is brackish (it has more salt than fresh water but not as much as seawater) but salinity varies with tidal flows. Estuaries provide habitat for young fish and migratory bird populations. They are dynamic environments, meaning the abiotic conditions vary widely as the tide rises or falls to cover or expose tidal flats. Important abiotic factors include pH, salinity, temperature, and dissolved oxygen.

The estuarine habitat of the striped shore crab

The striped shore crab, right, is a widespread species along the west coast of North America. Its range extends high into the intertidal zone where it is exposed to air for about half of each day. It lives in hard mud and rocky substrates where it can easily burrow or hide. It cannot live in soft sand as its gills would clog up and it could suffocate. It will forage in and out of the water, feeding mostly at night on algae, limpets, and smaller crabs.


Peter D Tillman CC2.0

3. (a) Thinking about estuarine environments (above), what are some of the challenges faced by the striped shore crab living there?

(b) Suggest what physiological, structural, or behavioral features might be important to the striped shore crab's survival?

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SNAPSHOT: ELKHORN SLOUGH, CALIFORNIA

EXPLAIN: How do abiotic factors affect organisms?

- Elkhorn Slough National Estuarine Research Reserve (above) is a large (688 ha) tidal salt marsh and estuary located half way between Santa Cruz and Monterey. The estuary extends 11 km inland from the coast and provides habitat for over 700 species including plants, invertebrates, birds, marine mammals, and fish.
- The reserve is made up of several different areas, including South Marsh. Habitats range from oak woodlands and coastal chaparral to marshes and wetlands.
- The reserve is owned and managed by the California Department of Fish and Wildlife. Along with researchers from the National Oceanic and Atmospheric Administration (NOAA), they monitor the health of the reserve and carry out research in on-site field laboratories.
- Some of the research involves monitoring abiotic factors and the effect of their changes on the plants and animals within the reserve.
- Environmental tolerance factors for two organisms found at South Marsh are shown below. Chinook salmon is a migratory fish species, which moves into coastal streams to spawn. The Olympia oyster is a resident filter-feeding bivalve mollusk (shellfish).
- Selected physical data for South Marsh over two years (2016-2017) is presented on the next page.

CA EP&Cs I: The ecosystem services provided by natural systems are essential to human life (I b)

Wetlands like the Elkhorn Slough provide essential services to humans and the environment.

- The physical and biotic environment of the wetland acts as a natural filter for water before it enters the sea.
- The high productivity of wetlands also means they are able to remove and store large amounts of carbon dioxide from the atmosphere, slowing global warming.
- Monitoring protected coastal areas allows better management of resources to benefit both humans and wildlife.


Vitu Dagdag_CC2.0

Olympia oyster

- Salinity of 12-25 ppt (parts per thousand) is optimal for growth. Death occurs at salinities below 5 ppt or above 25 ppt.
  Brackish water is 5-30 ppt, seawater is ~35 ppt.
- More likely to spawn when salinity is over 20 ppt.
- Water temperature of 18°C for 4 hours is required for spawning.
- Need a dissolved oxygen (DO) of 4 mg/L or greater.
- Optimum temperature is 16°-19°C but temperatures up to 27°C are tolerated.
- pH range of 7.5-8.5 is required for optimal growth.


USGS Public Domain
Spawning coloration

Chinook salmon

- Salinity > 15 ppt. Tolerance depends on stage.
- Optimal temperature for adults is 14.5-17°C but they tolerate 3-20°C.
- Optimum temperature for fertilization and fry development is below 9-10°C and should not exceed 13.5-14.5°C.
- Spawn at temperatures below 14.5°C.
- Newly hatched salmon need a minimum DO of >10 mg/L. Adults prefer a DO of >7 mg/L.
- pH range 4.0-9.0 is required for survival. Optimum pH is narrow at 7.5-7.8.

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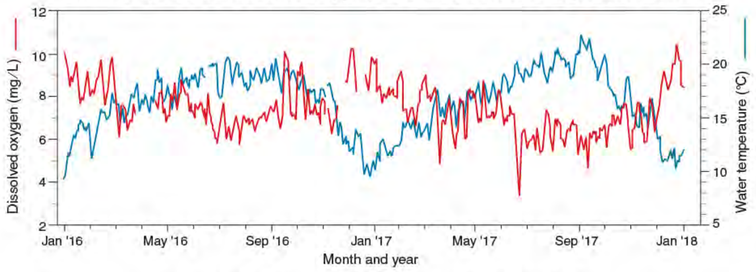
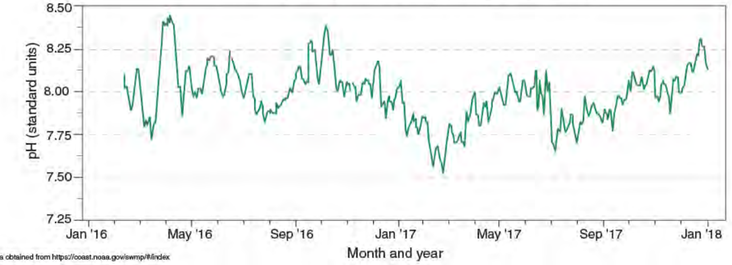
Water temperature and dissolved oxygen, South Marsh, Elkhorn Slough, 2016 - 2017



Water pH, South Marsh, Elkhorn Slough, 2016 - 2017



Data obtained from https://coast.noaa.gov/swmp/#/index

4. Explain the difference between the optimum range and the tolerance range for physical conditions. Use evidence from the data for the Chinook salmon or Olympia oyster on the previous page to support your answer:

5. Study the graph of water temperature and dissolved oxygen. Is there any relationship between the two? _____

6. (a) In what ways do humans benefit from an estuarine reserve such as Elkhorn Slough?_____

   (b) How do non-human species benefit from a protected estuarine areas such as Elkhorn Slough? _____

   (c) How does monitoring of the reserve's physical environment benefit its management and the species that live there?

ISBN: 978-1-98-856628-3

ELABORATE: Alien invaders and a system out of balance

USGS

USFW

- The alewife is a migratory species of herring found along the Atlantic Coast of North America. Like salmon, the adults move from the sea into freshwater streams to breed. Alewife have gained access to the four upper Great Lakes using the Welland Canal to bypass the natural barrier of the Niagara Falls (top photo).
- In the Great Lakes they are a nuisance species and have displaced many of the native Great Lakes fish species. Alewife in Lakes Huron and Michigan became so abundant in the 1960s that they made up most of the lakes' biomass. During these periods of very high abundance, unexplained massive alewife die-offs occurred, polluting shorelines and causing a public nuisance. The obvious native predator, the lake trout, had already declined as a result of another alien, the sea lamprey (seen left, feeding on a lake trout). Salmon were then introduced to control alewife instead.
- In the years since, an important salmon fishery has developed around alewife as a forage fish. Now, the alewife population is in decline, but the native forage fish species that the alewife displaced may not be able to recover.
- Adult alewife (image left) and their juveniles need a dissolved oxygen (DO) level >3.6 mg/L. The eggs and larvae need a DO >5 mg/L. Given its importance as a bait and forage fish, alewife introductions to California have been considered in the years before 1997. A related species, the American shad was successfully introduced to the Sacramento River in 1871 and now forms an important recreational fishery.

7. Based on information provided, the physical data for South Marsh on the opposite page, and the resources available through **BIOZONE's Resource Hub**, decide whether an alewife fishery is possible or desirable in Elkhorn Slough. As a group, argue a case either for or against its introduction to this region. What features of California's waterways could influence the success and risk of an introduction? What similarities are there to the Great Lakes scenario? What species would it compete with and potentially displace? Summarize your arguments below:

EVALUATE: Communicate your findings

8. As a group, present your arguments (as outlined above to the class), e.g. as a poster or oral presentation.

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4 The Ecological Niche

ENGAGE: The niche is the functional role of an organism

The **ecological niche** (or niche) of an organism describes its functional position in its environment. The full range of environmental conditions under which an organism can exist describes its **fundamental niche**.

- The fundamental niche is influenced by the physical environment and the organism's adaptations for exploiting it.
- The presence of other organisms may 'squeeze" an organism's niche so that the organism exploits only part of the niche 'space' available to it. The niche an organism actually occupies is called its **realized niche**.

The physical conditions influence the habitat. A factor may be well suited to the organism, or present it with problems to be overcome.

Physical conditions

- Substrate
- Humidity
- Sunlight
- Temperature
- Salinity
- pH
- Exposure
- Altitude
- Depth

Resources offered by the habitat

- Food sources • Shelter • Mating sites
- Nesting sites • Predator avoidance

Adaptations enable the organism to exploit the resources of the habitat. The adaptations take the form of structural, physiological and behavioral characteristics of the organism.

Adaptations for:

- Locomotion
- Activity pattern
- Tolerance to physical conditions
- Predator avoidance
- Defense
- Reproduction
- Feeding
- Competition

Resource availability is affected by the presence of other organisms and interactions with them: competition, predation, parasitism, and disease.

The habitat provides opportunities and resources for the organism. The organism may or may not have the adaptations to exploit them fully.

1. (a) Name an organism in your area and identify what type of environment it is commonly found in: _____

(b) List some adaptations its has that enable it to exploit certain resources or parts of the environment in which it lives (e.g. nocturnal, camouflage):

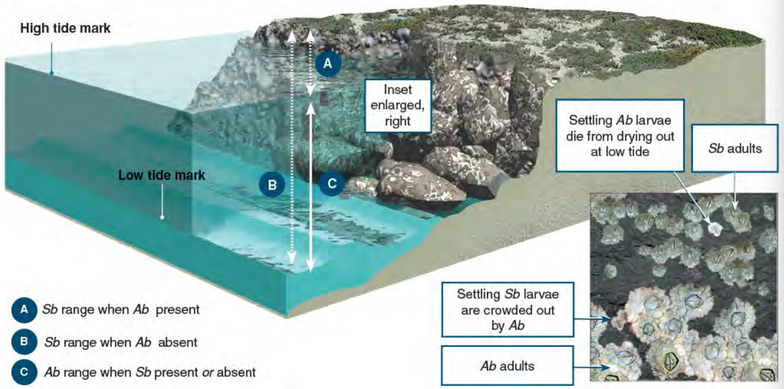
(c) What do you know of your organism's niche, i.e. its functional role in the environment? Describe what you know below:

LS2.A CE

ISBN: 978-1-98-856628-3

EXPLORE: Organisms can't always exploit all of their fundamental niche

- Barnacles are small suspension feeding crustaceans (related to crabs). The swimming larvae settle on rocks and once settled they do not move. On the Scottish coast, two barnacle species, the acorn barnacle (*Ab*) and Poli's stellate barnacle (*Sb*), coexist in the same general environment. The barnacles naturally show a layered distribution, with *Ab* concentrated on the lower region of the shore, and *Sb* on the upper shore.
- When *Ab* were experimentally removed from the lower shore, *Sb* spread into that area. However, when *Sb* were removed from the upper shore, *Ab* failed to move any further up than usual.



A *Sb* range when *Ab* present
B *Sb* range when *Ab* absent
C *Ab* range when *Sb* present *or* absent

2. (a) Which of the barnacles appeared to exploit its entire fundamental niche? _____

(b) What physical factor limited the range of this barnacle? _____

3. (a) Describe the range of the fundamental niche for *Sb*: _____

(b) Was this range realized (was it fully exploited)? _____

(c) Explain your answer: _____

(d) Based on this case study, what can you say about how the presence of other organisms might affect the distribution or population size of a species?

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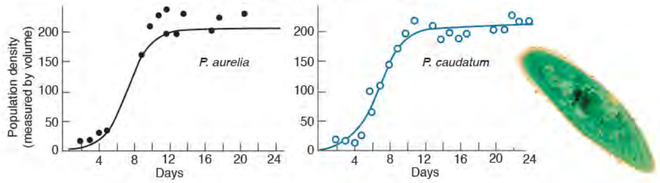
EXPLAIN: Making a prediction about niche

Can two species with the same fundamental niche coexist (live together) in the same environment? This question has been studied in many different situations. One of the more well known is the *Paramecium* experiment carried ou by G.F. Gause. First he grew two different separate populations of *Paramecium* with the same resource needs and recorded the growth of the populations over time. The graphs below show the results of this first experiment.

***Paramecium* grown in isolation**



In a second experiment Gause grew the two species together and recorded the growth of the populations over time

4. (a) Make a prediction about the result of this second experiment. Consider that the *Paramecium* species require the same resources (including type of food, depth of water, temperature, etc.)

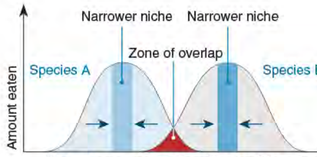
(b) Go **BIOZONE's resource hub** and read the page on Gause's experiment and the result of growing *P. aurelia* an *P. caudatum* together. Was your prediction correct? Can you explain the experiment's result?

Gause's law

The outcome of the second experiment led Gause to formulate the **competitive exclusion principle** (Gause's law) which states that two species that compete for exactly the same resources cannot coexist. Competition between species for the same resources narrows the niche of each species, producing the **realized niche** for each.

When different species exploit similar resources, we often see differences in particular characteristics (such as beak size). These differences help the species exploit a narrower range of resources more efficiently and so avoid direct competition with each other.

The phenomenon is well recorded in Darwin's finches, where different species have broadly similar and overlapping diets, but exploit some food resources more effectively because of their different beak sizes. Among the Galápagos ground finches, right, the medium ground finch can exploit larger, harder seeds than the small ground finch.



Small ground finch *Medium ground fin*

5. Explain why two species, competing for the same resources, cannot coexist. What evidence is there to support this?

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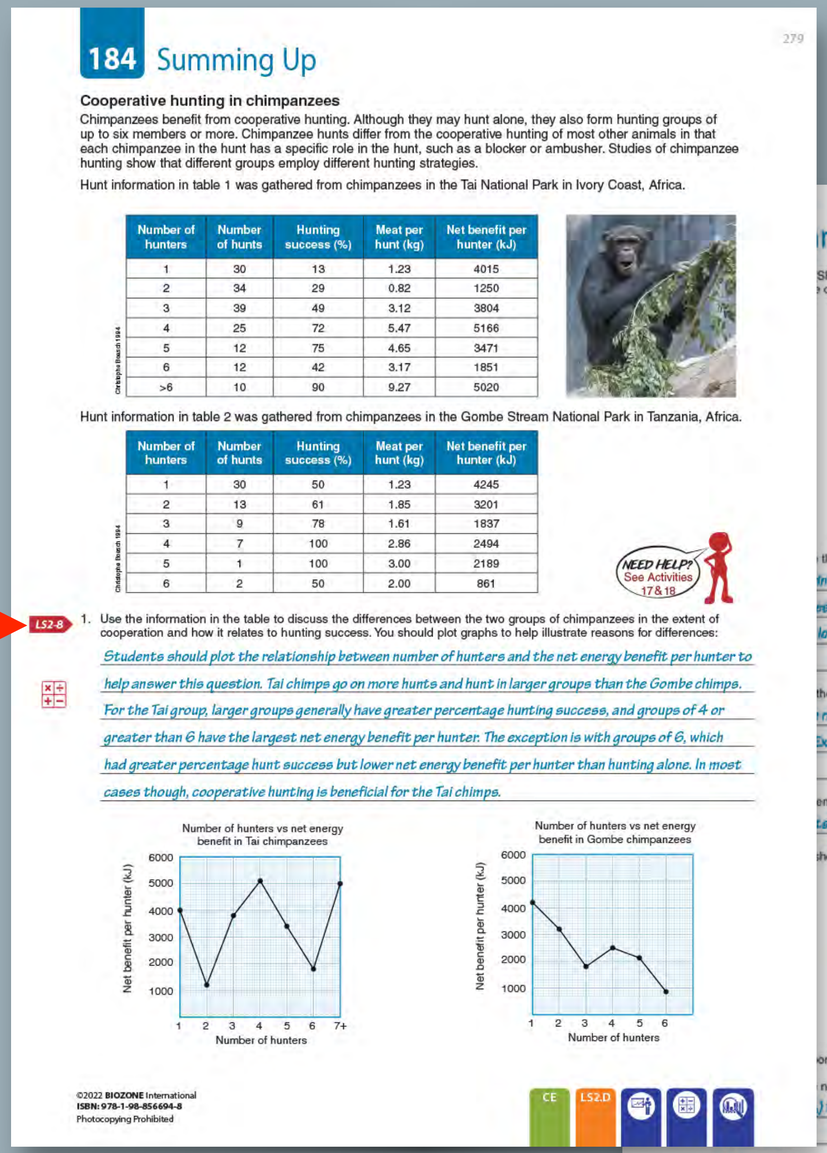
Assessment

- Each chapter concludes with a **Summative Assessment**.
- **Performance Expectations** being assessed are identified.



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184 Summing Up

Cooperative hunting in chimpanzees

Chimpanzees benefit from cooperative hunting. Although they may hunt alone, they also form hunting groups of up to six members or more. Chimpanzee hunts differ from the cooperative hunting of most other animals in that each chimpanzee in the hunt has a specific role in the hunt, such as a blocker or ambusher. Studies of chimpanzee hunting show that different groups employ different hunting strategies.

Hunt information in table 1 was gathered from chimpanzees in the Tai National Park in Ivory Coast, Africa.

Number of hunters	Number of hunts	Hunting success (%)	Meat per hunt (kg)	Net benefit per hunter (kJ)
1	30	13	1.23	4015
2	34	29	0.82	1250
3	39	49	3.12	3804
4	25	72	5.47	5166
5	12	75	4.65	3471
6	12	42	3.17	1851
>6	10	90	9.27	5020

Chimpanzee Watch 1994

Hunt information in table 2 was gathered from chimpanzees in the Gombe Stream National Park in Tanzania, Africa.

Number of hunters	Number of hunts	Hunting success (%)	Meat per hunt (kg)	Net benefit per hunter (kJ)
1	30	50	1.23	4245
2	13	61	1.85	3201
3	9	78	1.61	1837
4	7	100	2.86	2494
5	1	100	3.00	2189
6	2	50	2.00	861

Chimpanzee Watch 1994

NEED HELP? See Activities 17 & 18

LS2-8

1. Use the information in the table to discuss the differences between the two groups of chimpanzees in the extent of cooperation and how it relates to hunting success. You should plot graphs to help illustrate reasons for differences:

Students should plot the relationship between number of hunters and the net energy benefit per hunter to help answer this question. Tai chimps go on more hunts and hunt in larger groups than the Gombe chimps. For the Tai group, larger groups generally have greater percentage hunting success, and groups of 4 or greater than 6 have the largest net energy benefit per hunter. The exception is with groups of 6, which had greater percentage hunt success but lower net energy benefit per hunter than hunting alone. In most cases though, cooperative hunting is beneficial for the Tai chimps.

Number of hunters vs net energy benefit in Tai chimpanzees

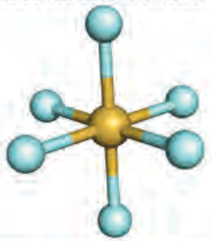
Number of hunters vs net energy benefit in Gombe chimpanzees

CE LS2.D

193

mative Assessment

SF6) is a molecule with a central sulfur surrounded by six covalently bonded fluorine atoms (single octahedral structure of the molecule is shown below:

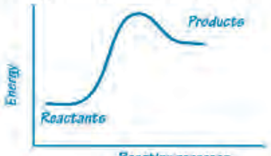


this shape? *Sulfur hexafluoride has an octahedral shape due to the repulsion of each ne bonding electrons. The bonding electrons repel each other and so spontaneously es into a position where they are as far away from each other is possible. In this shape the lowest possible potential energy.*

thermic and give an example of an exothermic reaction: *release of energy, usually through heat and light. An exothermic reaction therefore Examples include burning paper, or magnesium, or a hydrocarbon.*

endothermic: *Endothermic is the absorption of energy. An endothermic reaction absorbs its surroundings.*

howing the enthalpy change for an endothermic reaction:



on with oxygen is $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta_f H$ −393.5 kJ/mol

notation for the reaction means: *One mole of solid carbon (C) reacts with one mole of) to form one mole of carbon dioxide gas (CO_2). The reaction releases 393.5 kJ of energy*

(b) How much energy is released is 2.6 moles of carbon is reacted completely?

2.6 x 393.5 = 1023.1 kJ

EM P PS2.B PS1.B PS1.A

Environmental Science

- Written for a pre-AP program.
- Very up-to-date data on human issues and environmental impact (June 2024).
  - Some data sets provide time-sensitive environmental assessments and have blue **QR codes** that link to continuously updated sources.
- Provides a candid assessment of environmental challenges, but ....

  provides students with a sense of agency and possible solutions to solve problems.

Environmental Science

Chapters

1. The Earth's Systems
2. Ecosystems
3. Populations
4. Investigating Ecosystems
5. Land and Water
6. Energy
7. Pollution
8. Conservation
9. Climate Change
10. Scientific Skills and Practices

197 Megadroughts

Key Idea: Particularly severe, long-lasting, and widespread droughts are termed megadroughts. Climate change is projected to increase their occurrence.

Megadrought, as a term, was first coined in 1998. Colorado scientists have collected data from sediments, documents, and tree rings to identify historical megadroughts dating back over 2000 years, occurring on every continent except Antarctica. Some climate models are projecting that regions experiencing megadroughts in the past are more vulnerable to **climate change**-induced megadroughts or severe droughts in the future as the planet warms. Research suggests that the Western United States 2000-2023 megadrought was amplified by ~40-72% due to climate change, making what could have been a typical drought into a record breaker.

The Western US 23-year drought

- The megadrought experienced by the Western United States from 2000-2023 was the longest recorded dry spell in the area for least 1200 years. Data from annual tree rings, thinner in dry seasons, was able to verify the historical drought claims.
- The two largest lakes used as reservoirs on the Colorado River system, Lake Mead (right) and Lake Powell, reached their lowest water level in recorded history, at around 30% capacity. Authorities managing the Colorado River had to place almost total restrictions on water extraction from its remaining small flow during this time.
- Although heavy rainfall in 2023-24 alleviated most of the megadrought, 'patches' of severe (D3) drought are still present in areas such as western Texas.

At Lake Mead on the Colorado river, the white 'bathtub' ring (arrowed) on the cliff shows how high the water once sat. View from Hoover Dam at Nevada and Arizona border, USA.

What caused the megadrought?

- Scientists have partly linked the severity and length of this drought to environmental conditions caused by climate change. The drought was made more severe from higher-than-normal water loss from plants and early snowpack melting, both increased by warmer temperatures.
- The impacts of this exceptional drought included dead or dying crops, dry wells, harm to wildlife, loss of hydropower, and increased risk of intense wildfires.

United States drought monitor - May 31, 2022

Drought impact types:

S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:
- None
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

Data source

1. In late 2023, the El Niño Southern Oscillation (ENSO) caused higher than normal precipitation for the Western US region, relieving the megadrought. However, regions of the US are still experiencing drought.

   (a) Define a D3 and D4 drought: _____

   _____

   (b) What is the link between megadrought and climate change? _____

   _____

   _____

ISBN: 978-1-99-101409-2

GC

203 Tipping Point: West Antarctic Ice Sheet

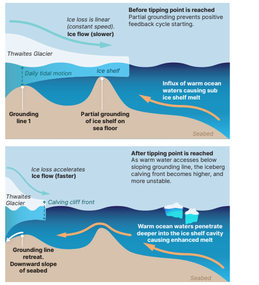
Key Idea: Climate change is accelerating the ice loss from the West Antarctic ice sheet, pushing the system towards a climate tipping point of collapse.

The ice in Antarctica sits on top of a continent and is the largest single **ice sheet** on the planet. Whereas the East Antarctic sheet sits on top of land, the West Antarctic ice sheet is mostly grounded on rock that is submerged to nearly 2.5km in some places, in marine basins. This difference influences the different rates of melt, with the West Antarctic ice sheet projected to reach the **tipping point** of collapse at a 1.5°C warming threshold, while the East Antarctic ice sheet is projected to maintain its current state until around a 7.5°C warming threshold. Antarctica sits directly over the South Pole, so temperatures tend to be lower than Greenland, reducing surface melt. Due to greater contact between ocean and ice at the ice sheet margins, ice shelves are formed, also called fast ice, which thin and melt rapidly. The ice that is supported behind will then accelerate forward to replace that lost in the ice shelves. The retreat of the ice grounding line due to warming oceans undercutting ice shelves acts as a destabilizing **positive feedback cycle**. After the tipping point, the ice sheet would continue to melt over 1000 years.

Collapse of Thwaites Glacier

Thwaites Glacier, situated in a marine basin in West Antarctica, is a large, fast retreating glacier. It has been termed the 'Doomsday Glacier,' due to its vulnerability and risk of collapse. Together with the neighboring and equally fast retreating Pine Island Glacier, a collapse could add up to a meter of **sea level rise**.

- Ice shelves extend from the base of the Thwaites Glacier into the ocean. The outer edge of the glacier that touches the sea floor is known as the grounding line (see right).
- Water can flow under the ice shelf and cause melting: the warmer the water, the faster the melt, and the more rapid the retreat of the glacier. Ice loss in Thwaites Glacier has been significant for several decades.
- As more of the ice shelf disappears, the warm water can access deeper under the ice, shifting the grounding line back. The cliff calving front (break off) above the grounding line becomes higher due to the downward, or retrograde, tilt of the sea floor further back. It is therefore more unstable: taller ice cliffs break off (calve) more easily.
- The loss of ice from Thwaites Glacier creates a positive feedback cycle: the more the glacier retreats, the faster the ice is lost. This type of feedback is called **marine ice sheet instability (MISI)** and evidence points to this process already starting at the Thwaites and Pine Island Glaciers.



1. The seabed under the Thwaites Glacier is sloping backwards. How does this contribute to a ice loss feedback cycle?

   _____

   _____

   _____

2. NASA Antarctica land mass changes data shows an average of 142 GT per year from the period of 2002-2022, with the most ice lost in the 2018-2022 period.

   (a) What is the total ice mass loss (GT) for 2002-2022? _____

   (b) Which Antarctic locations have the greatest mass ice loss and why? _____

   _____

   _____

   _____

ISBN: 978-1-99-101409-2

GC

204 Tipping Point: Boreal Permafrost

KeyIdea: Global warming could make large boreal ecosystems too warm and dry to maintain carbon-storing permafrost.

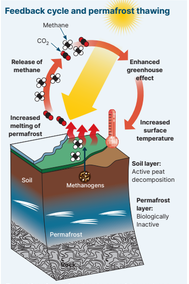
Cold temperate regions between northern polar regions and forested temperate regions are called boreal biomes; they include Siberia and Northern Europe. The soil is cold enough in most areas to maintain a permanently frozen ground called **permafrost** that locks away large quantities of carbon in peat. Increasingly warming temperatures, contributing to **climate change**, are thawing the permafrost and activating microbes that decompose the peat. **Greenhouse gases**, including **CO_2** and **CH_4** (methane), are products of peat decomposition and are being emitted at higher levels, leading to even more warming. Thus, a **positive feedback cycle** is being activated. Climate models have projected that specific regions such as Norway, Sweden, and Finland may have passed a **tipping point** already. Unless the world rapidly lowers greenhouse gas emissions, an inevitable collapse of the **boreal permafrost** regions, acting as net **carbon sinks** (taking in more carbon than releasing), is almost certain. However, recent research indicates the collapse will more likely occur at a regional or local level, and aggregation into runaway climate change is unlikely.

Exploding craters and climate change

- By April 2024, eight large craters up to 20 meters wide and nearly 50 meters deep had been identified in the Siberian permafrost. Local residents reported hearing loud explosions and seeing debris thrown across a large distance when craters formed.
- Scientists originally hypothesized that the built-up gas was due to decomposition of material in a trapped underground prehistoric lake. Microbial processes were 'reawakened' by climate change-induced ground warming, leading to the gas bursting through when enough pressure had built up.
- Another hypothesis for crater formation proposes that hot gases, built-up underground via geological processes, were able to escape rapidly through the permafrost which has thawed and weakened due to climate change.

Permafrost crater, Yamal peninsular, Russia

Feedback cycle and permafrost thawing



The melting of permafrost has the potential to produce a positive feedback cycle, producing even more heating.

1. Why does permafrost prevent greenhouse gases from being released?

   _____

   _____

   _____

2. Why might there be more than one hypothesis to explain the formation of the permafrost craters?

   _____

   _____

   _____

3. What is the link between the positive feedback cycle of permafrost melting and passing the tipping point of regional permafrost collapse?

   _____

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GC

218 Possibilities of Solar Radiation Modification

Key Idea: Solar radiation modification (SRM) is technology that reduces the amount of incoming solar radiation.

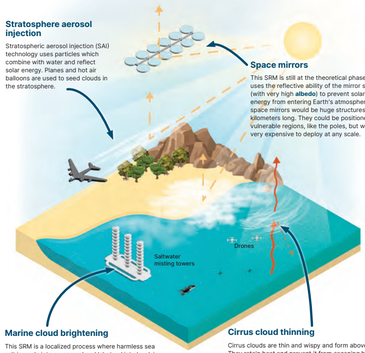
Solar radiation modification (SRM) or solar geoengineering, is a group of technologies that reflect or prevent incoming solar radiation, mostly light, from reaching Earth's surface. Although not a substitute for **climate change mitigation**, the appropriate use of this technology may temporarily reduce global temperatures ahead of the 1.5°C target until **CCS** and other **GHG emission** reductions are deployed at larger scale. Much of this technology is still in the initial development phase or at small scale, and would require strong cooperation between countries to begin use. The SRM that 'seeds' clouds with aerosols to increase reflectivity replicates a naturally occurring phenomenon during volcanic eruptions but the environmental impact of artificial SRM is still uncertain. **Solar radiation modification** (SRM) or solar geoengineering, is a group of technologies that reflect or prevent incoming solar radiation, mostly light, from reaching Earth's surface. Although not a substitute for **climate change mitigation**, the appropriate use of this technology may temporarily reduce global temperatures ahead of the 1.5°C target until **CCS** and other **GHG emission** reductions are deployed at larger scale. Much of this technology is still in the initial development phase or at small scale, and would require strong cooperation between countries to begin use. The SRM that 'seeds' clouds with aerosols to increase reflectivity replicates a naturally occurring phenomenon during volcanic eruptions but the environmental impact of artificial SRM is still uncertain. SRM does not reduce GHG emissions, therefore, effects related to climate change such as **ocean acidification** would not be reduced. Only technologies that remove GHG from the atmosphere are now classified as mitigation strategies by **IPCC**. Scientists propose that careful use of SRM, in tandem with CCS technology and **sequestration**, will allow peak **global warming** to be reduced in the near future. Research estimates each 1.0°C of global cooling from SRM could cost tens of billions (US dollars) each year. However, the technology may be an important last resort, where the need to temporarily reduce temperature outweighs risks and cost.

Stratosphere aerosol injection

Stratospheric aerosol injection (SAI) technology uses particles which combine with water and reflect solar energy. Planes and hot air balloons are used to seed clouds in the stratosphere.

Space mirrors

This SRM is still at the theoretical phase, and uses the reflective ability of the mirror surface (with very high **albedo**) to prevent solar energy from entering Earth's atmosphere. The space mirrors would be huge structures, many kilometers long. They could be positioned over vulnerable regions, like the poles, but would be very expensive to deploy at any scale.



Marine cloud brightening

This SRM is a localized process where harmless sea salt is made into an aerosol and 'shot up' into low lying marine clouds. The US conducted its first trials of this technology in April 2024. The clouds become temporarily brighter, increasing their albedo and enabling more solar energy to be reflected back into space. The equipment needs to be close to a source of salt water, so is likely to be fixed in place, and is limited to the height the sea salt can be shot up. Although considered a safer form of SRM, there are still concerns about unintended impacts to the climate.

Cirrus cloud thinning

Cirrus clouds are thin and wispy and form above 6km. They retain heat and prevent it from escaping higher into the atmosphere or space. The SRM process would 'seed' the clouds with aerosol particles to form ice crystals. Drones could be used to deliver the particles. The clouds would thin-out as a consequence and allow more heat to escape. This process would also allow more light to enter through them, but on balance they would induce more cooling than heating. Like all SRM, scientists are still unsure how deployment might impact the ozone layer and weather patterns, or if it might cause a harmful cooling overshoot.

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GC

46 Ecosystem Stability

Key Idea: The greater the species diversity in an ecosystem, the greater the stability of that ecosystem will be.

Ecological theory suggests that all species in an **ecosystem** contribute in some way to ecosystem function. Therefore, species loss past a certain point is likely to have a detrimental effect on the functioning of the ecosystem and on its ability to resist change (its **stability**). Although many species still await discovery, we do know that the rate of species extinction is increasing. This loss of biodiversity has serious implications for the long term stability of many ecosystems.

Rainforest

Deforestation

Rainforests (above left) represent the highest diversity systems on Earth. What they are generally resistant to disturbance, once degraded, (above right) they have little ability to recover. The diversity of ecosystems at low latitudes is generally higher than that at high latitudes, where climates are harsher, niches are broader, and systems may be dependent on a small number of key species.

Monoculture of soy beans

Natural grassland

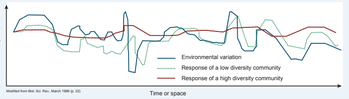
Single species crops (far left), represent low diversity systems that can be vulnerable to disease, pests, and disturbance. In contrast, natural grasslands (left) may appear on the surface to be homogenous, but contain many species which vary in their predominance seasonally. Although they may be easily disturbed, e.g. by burning, they are very resilient and usually recover quickly.

The concept of ecosystem stability

The stability of an ecosystem refers to its apparently unchanging nature over time. Ecosystem stability has various components, including inertia (the ability to resist disturbance) and **resilience** (the ability to recover from external disturbances).

Evidence from both experimental and natural systems indicates that the most diverse ecosystems are also the most stable. This correlation is presumed to be a consequence of the large number of biotic interactions operating to buffer diverse systems against change. However, there is uncertainty over what level of diversity provides insurance against catastrophe. Ecosystems are very complex and stability probably relies more on the differential responses of all its species to variable conditions. Current thinking emphasizes the role of multiple factors, including diversity, in dictating stability.

Community response to environmental change



Modified from Biol. Sci. Rev. March 1998 (p. 22).

In models of ecosystem function, higher species diversity increases the stability of ecosystem functions such as productivity and **nutrient cycling**. In the graph above, note how the diversity system varies more consistently with the environmental variation, whereas the high diversity system is buffered against major fluctuations. In any one ecosystem, some species may be more influential than others in the stability of the system. Such keystone (key) species have a disproportionate effect on ecosystem function due to their pivotal role in some ecosystem functions such as nutrient recycling or production of plant biomass.

Elephants can change the entire vegetation structure of areas into which they migrate. Their pattern of grazing on taller plant species promotes a predominance of lower growing grasses with small leaves.

Termites are among the few larger soil organisms able (through a symbiosis with microbes) to break down plant cellulose. They have a profound effect on the rate of nutrient processing in tropical environments.

The starfish *Pisaster* occurs along the coasts of North America where it feeds on mussels. If it is removed, the mussels dominate, crowding out most algae and leading to a decrease in the number of herbivore species.

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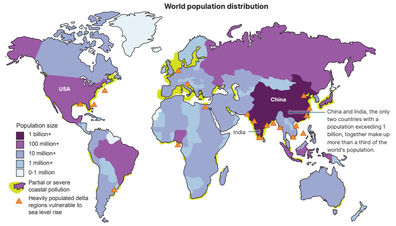
LW

69 World Population Distribution

Key Idea: The human population is not evenly distributed across the globe. More people live in cities and towns than ever before.

In early 2024, the world's population was eight billion people. However, the human population is not evenly distributed across the globe, China and India account for a third of the world's population. Even within countries populations are unevenly dispersed. Population densities can be very high in certain areas, especially in regions with reliable water sources. Over the last few hundred years, **urbanization** (the move to living in cities or towns) has increased. 55% of people now live in urban centers, and this is predicted to increase.

World population distribution



China and India, the only two countries with a population exceeding 1 billion, together make up more than a third of the world's population.

India 1.4 billion
The majority of India's population (66%) live rurally (above) and depend on agricultural activities for income and resources. India also has some very large cities, and they are the site of many important technology-based and manufacturing industries.

USA: 341 million
The night time image of mainland USA (above) shows the population is unevenly distributed: the majority live in the East. Coastal land accounts for 10% of the US footprint, but 40% of the population live in these coastal regions.

Australia: 26.6 million
Australia is the driest inhabited continent in the world. Its 10 deserts (as above) cover 18% of the mainland. The majority of Australia's population lives on or near the coast, near reliable water sources. Only 3% of the population live in desert regions.

1. What factor is an important driver for determining the location of human settlements? _____

2. Calculate how many people in Australia live in a desert region: _____

3. Asia has a large number of heavily populated delta regions vulnerable to sea level rise. Predict how sea level rise would drive the migration patterns of people in affected areas:

   _____

   _____

   _____

   _____

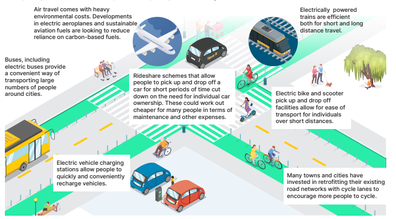
ISBN: 978-1-99-101409-2

LW

108 Transportation

Key Idea: Different means of transport are required for different purposes. Reliance on fossil fuels for transportation can be minimized through alternative transport options.

Efficient movement around and between cities is often limited by the geography, design, and planning of the transport system. To be efficient, public transport systems need a high population density and must be able to transport people to within a short walk of their destination. In many cities, extensive light rail systems are used to achieve this. Roads, especially busy highways, have a significant impact on local ecosystems, contributing to pollution and forming dangerous barriers for animals to cross.



Traditional Transport System	Private petrol/diesel car	Diesel/petrol bus	Non electric train	Plane
Advantages	• Convenient, all-hours transport • Personalized • Can access most locations • Especially useful in areas with low populations	• Flexible access to most locations • Useful for short to medium length journeys • Low proportional operating costs if used by large numbers	• Fast transport over medium to long distances • Low per-person pollution • Can haul large volumes of people and freight	• Fast transport over long distances • Able to cross all geographic barriers
Disadvantages	• Expensive to run and maintain • Produce large amounts of pollution per person • Contributes to road congestion • High risk of accident/injury	• Timetables may be subject to traffic congestion • Can cost more to maintain than they earn • Can be slow to reach destinations because of the many stops	• Run to inflexible timetables • Expensive to run and maintain • Produce heavy vibration and some noise	• Fixed and inflexible schedules • Can be uncomfortable over long distances • Produce large amounts of localized noise • Expensive to run and maintain

1. Explain how effective transport systems can reduce congestion and pollution: _____

   _____

   _____

   _____

2. Explain why all four transport systems described in the table are needed: _____

   _____

   _____

   _____

   _____

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GR

186 What's the Concern for Climate Change?

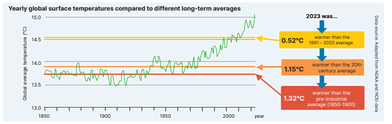
Key Idea: Climate change is happening now, and our responses will determine future impacts.

Over the past two centuries, human activities and industrialization have led to a rise in **greenhouse gas** levels in the atmosphere, affecting the climate. In more recent times, the term 'Anthropocene' has been used to describe the current geological epoch. This term, although not officially recognized as a geologic designation, highlights the influence of human-induced changes on the climate, known as **anthropogenic** forcing. Notably, **global warming** has been a prominent consequence of these activities, with the Earth's average surface temperature increasing by at least 1.19°C in 2024 compared to the mid-19th century. To determine the precise average global temperature, data is collected from (100,000 plus) weather stations worldwide, along with weather balloons, ships, buoys, radars, and satellites that record daily temperature variations. This data is used to calculate an **average global temperature**. The average temperature is then compared with pre-industrial temperature data, obtained before substantial industrial source greenhouse gas **emissions**. The recent rise in the global average means specific regions are encountering notably higher and more harmful temperature extremes. Unprecedented heatwaves in **polar** areas and regions already struggling from human habitation are driving certain Earth systems towards irreversible tipping points.

The world is warming - What's the big deal about 1.5°C anyway?

Many students may have heard about a "**1.5°C** global warming 'line in the sand' not to be overtaken in order to prevent the worst impacts of climate change. Yet, despite the seemingly small 1.5°C target, exceeding this threshold can activate **tipping points** in the climate system, causing irreversible changes due to **positive feedback cycles** that intensify the initial warming effects. The significance of global temperature rise lies in its potential to disrupt ecosystems, weather patterns, and cause **sea level rise**, highlighting the urgent need to address anthropogenic climate forcing to mitigate these impacts.

Data source



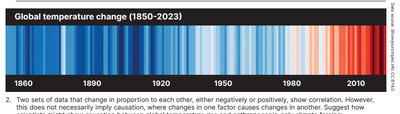
1. The image below shows a visual representative of the last 200 years of global temperature change, using the average from 1961-2010 as a measuring stick. Blue is colder, the darkest over 0.7°C colder, and the red is warmer; again the darker colors showing an extreme of over 0.7°C warmer. In a small group, discuss the implications of the data presented as a means to raise awareness of climate change. Record your thoughts below:

   _____

   _____

   _____

   _____



2. Two sets of data that change in proportion to each other, either negatively or positively, show correlation. However, this does not necessarily imply causation, where changes in one factor causes changes in another. Suggest how scientists might show causation between global temperature rise and anthropogenic-only climate forcing:

   _____

   _____

   _____

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GC

197 Megadroughts

Key Idea: Particularly severe, long-lasting, and widespread doughts are termed megadroughts. Climate change is projected to increase their occurrence.

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The Western US 23-year drought

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- The two largest lakes used as reservoirs on the Colorado River system, Lake Mead (right) and Lake Powell, reached their lowest water level in recorded history, at around 30% capacity. Authorities managing the Colorado River had to place almost total restrictions on water extraction from its remaining small flow during this time.
- Although heavy rainfall in 2023-24 alleviated most of the megadrought, 'patches' of severe (D3) drought are still present in areas such as western Texas.

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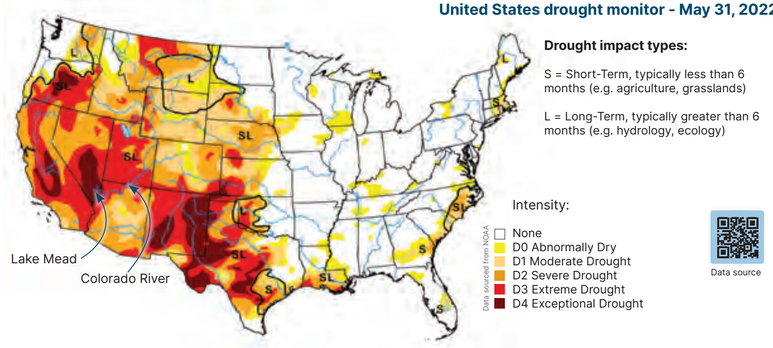
United States drought monitor - May 31, 2022



Drought impact types:

S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

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Intensity:

- None
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Data sourced from NOAA

Data source

1. In late 2023, the El Niño Southern Oscillation (ENSO) caused higher than normal precipitation for the Western US region, relieving the megadrought. However, regions of the US are still experiencing drought.

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   _____

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   _____

   _____

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- As more of the ice shelf disappears, the warm water can access deeper under the ice, shifting the grounding line back. The cliff calving front (break off) above the grounding line becomes higher due to the downward, or retrograde, tilt of the sea floor further back. It is therefore more unstable: taller ice cliffs break off (calve) more easily.
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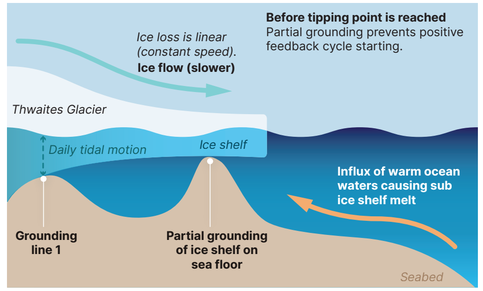
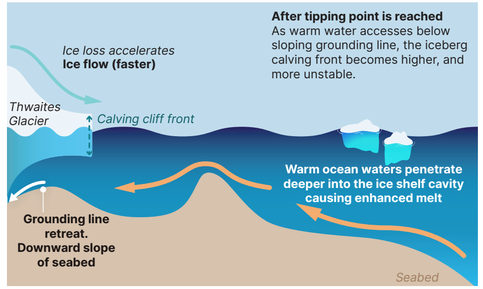




1. The seabed under the Thwaites Glacier is sloping backwards. How does this contribute to a ice loss feedback cycle?

   _____

   _____

   _____

2. NASA Antarctica land mass changes data shows an average of 142 GT per year from the period of 2002-2022, with the most ice lost in the 2018-2022 period.

   (a) What is the total ice mass loss (Gt) for 2002-2022? _____

   (b) Which Antarctic locations have the greatest mass ice loss and why? _____

   _____

   _____

   _____

ISBN: 978-1-99-101409-2

GC

204 Tipping Point: Bo

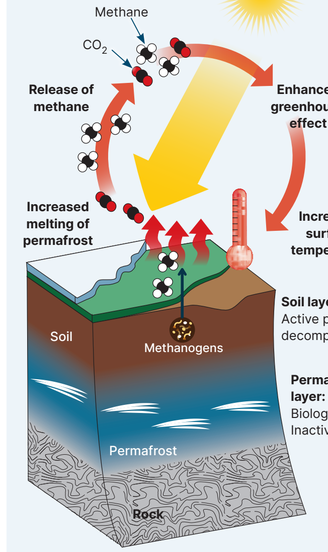
Key Idea: Global warming could make large boreal e
too warm and dry to maintain carbon-storing perm

Cold temperate regions between northern polar re
forested temperate regions are called boreal bio
include Siberia and Northern Europe. The soil is co
in most areas to maintain a permanently frozen gro
permafrost that locks away large quantities of
peat. Increasingly warming temperatures, contr
climate change, are thawing the permafrost and
microbes that decompose the peat. **Greenhou**
including CO_2 and CH_4 (methane), are product

Exploding craters and climate change

- By April 2024, eight large craters up to 20 meters
  and nearly 50 meters deep had been identified in
  Siberian permafrost. Local residents reported hea
  loud explosions and seeing debris thrown across
  distance when craters formed.
- Scientists originally hypothesized that the built-up
  due to decomposition of material in a trapped unc
  prehistoric lake. Microbial processes were 'reawak
  climate change-induced ground warming, leading
  gas bursting through when enough pressure had
- Another hypothesis for crater formation proposes
  hot gases, built-up underground via geological pr
  were able to escape rapidly through the permafro
  has thawed and weakened due to climate change

Feedback cycle and permafrost thaw



The melting of permafrost has the potential to prod
positive feedback cycle, producing even more heati

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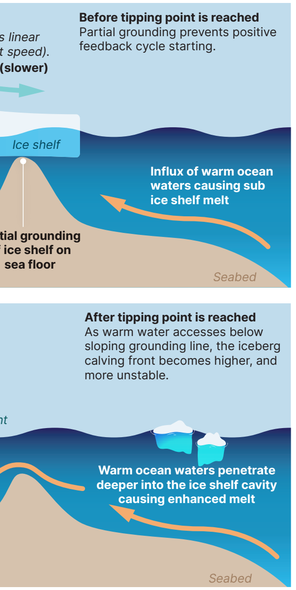
lce Sheet

maintain its current state until around a 7.5°C
hold. Antarctica sits directly over the South
eratures tend to be lower than Greenland,
ce melt. Due to greater contact between ocean
ce sheet margins, ice shelves are formed, also
which thin and melt rapidly. The ice that is
ind will then accelerate forward to replace
ice shelves. The retreat of the ice grounding
rming oceans undercutting ice shelves acts
ng **positive feedback cycle**. After the tipping
heet would continue to melt over 1000 years.



Before tipping point is reached
Partial grounding prevents positive feedback cycle starting.

After tipping point is reached
As warm water accesses below sloping grounding line, the iceberg calving front becomes higher, and more unstable.

is contribute to a ice loss feedback cycle?

year from the period of 2002-2022, with the

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204 Tipping Point: Boreal Permafrost

Key Idea: Global warming could make large boreal ecosystems too warm and dry to maintain carbon-storing permafrost.

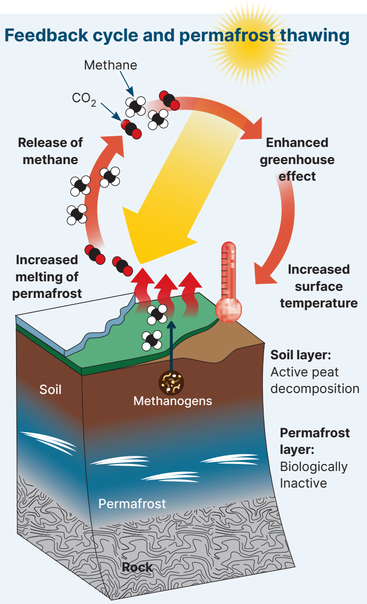
Cold temperate regions between northern polar regions and forested temperate regions are called boreal biomes; they include Siberia and Northern Europe. The soil is cold enough in most areas to maintain a permanently frozen ground called **permafrost** that locks away large quantities of carbon in peat. Increasingly warming temperatures, contributing to **climate change**, are thawing the permafrost and activating microbes that decompose the peat. **Greenhouse gases**, including **CO_2** and CH_4 (methane), are products of peat decomposition and are being emitted at higher levels, leading to even more warming. Thus, a **positive feedback cycle** is being activated. Climate models have projected that specific regions such as Norway, Sweden, and Finland may have passed a **tipping point** already. Unless the world rapidly lowers greenhouse gas emissions, an inevitable collapse of the **boreal permafrost** regions, acting as net **carbon sinks** (taking in more carbon than releasing), is almost certain. However, recent research indicates the collapse will more likely occur at a regional or local level, and aggregation into runaway climate change is unlikely.

Exploding craters and climate change

- By April 2024, eight large craters up to 20 meters wide and nearly 50 meters deep had been identified in the Siberian permafrost. Local residents reported hearing loud explosions and seeing debris thrown across a large distance when craters formed.
- Scientists originally hypothesized that the built-up gas was due to decomposition of material in a trapped underground prehistoric lake. Microbial processes were 'reawakened' by climate change-induced ground warming, leading to the gas bursting through when enough pressure had built up.
- Another hypothesis for crater formation proposes that hot gases, built-up underground via geological processes, were able to escape rapidly through the permafrost which has thawed and weakened due to climate change.


Permafrost crater, Yamal peninsular, Russia

Feedback cycle and permafrost thawing



The melting of permafrost has the potential to produce a positive feedback cycle, producing even more heating.

1. Why does permafrost prevent greenhouse gases from being released?

2. Why might there be more than one hypothesis to explain the formation of the permafrost craters?

3. What is the link between the positive feedback cycle of permafrost melting and passing the tipping point of regional permafrost collapse?

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GC

218 Possibilities of Solar Radiation Modification

Key Idea: Solar radiation modification (SRM) is technology that reduces the amount of incoming solar radiation.

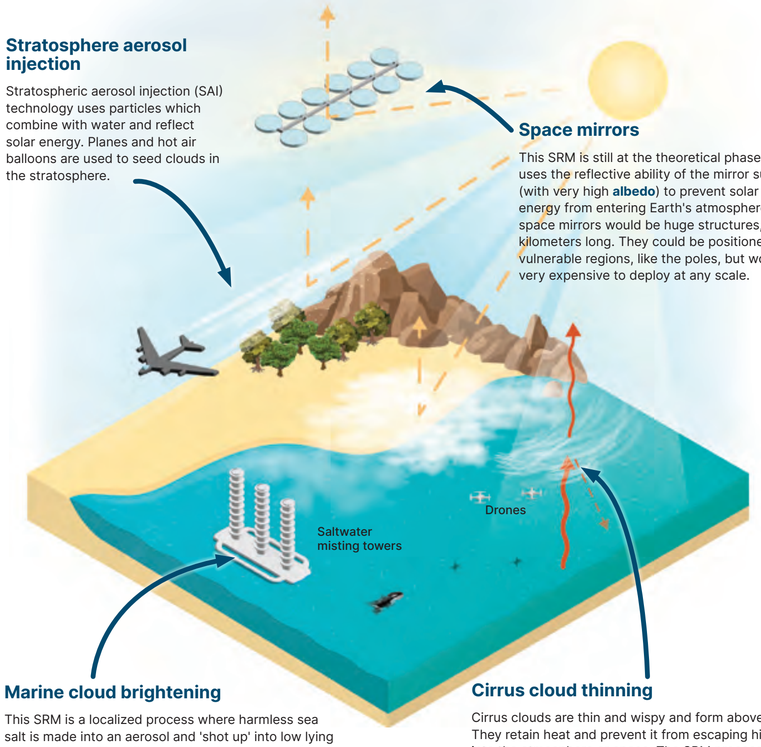
Solar radiation modification (SRM) or solar geoengineering, is a group of technologies that reflect or prevent incoming solar radiation, mostly light, from reaching Earth's surface. Although not a substitute for **climate change mitigation**, the appropriate use of this technology may temporarily reduce global temperature overshoot of the 1.5°C target until **CCS** and other **GHG emission** reductions are deployed at larger scale. Much of this technology is still in the initial development phase or at small scale, and would require strong cooperation between countries to begin use. The SRM that 'seeds' clouds with aerosols to increase reflectivity replicates a naturally occurring phenomenon during volcanic eruptions but the environmental impact of artificial SRM is still uncertain. SRM does not reduce GHG emissions, therefore, effects related to climate change such as **ocean acidification** would not be reduced. Only technologies that remove GHG from the atmosphere are now classified as mitigation strategies by **IPCC**. Scientists propose that careful use of SRM, in tandem with CCS technology and **sequestration**, will allow peak **global warming** to be reduced in the near future. Research estimates each 1.0°C of global cooling from SRM could cost tens of billions (US dollars) each year. However, the technology may be an important last resort, where the need to temporarily reduce temperature outweighs risks and cost.

Stratosphere aerosol injection

Stratospheric aerosol injection (SAI) technology uses particles which combine with water and reflect solar energy. Planes and hot air balloons are used to seed clouds in the stratosphere.

Space mirrors

This SRM is still at the theoretical phase, and uses the reflective ability of the mirror surface (with very high **albedo**) to prevent solar energy from entering Earth's atmosphere. The space mirrors would be huge structures, many kilometers long. They could be positioned over vulnerable regions, like the poles, but would be very expensive to deploy at any scale.



Marine cloud brightening

This SRM is a localized process where harmless sea salt is made into an aerosol and 'shot up' into low lying marine clouds. The US conducted its first trials of this technology in April 2024. The clouds become temporarily brighter, increasing their albedo and enabling more solar energy to be reflected back into space. The equipment needs to be close to a source of salt water, so is likely to be fixed in place, and is limited to the height the sea salt can be shot up. Although considered a safer form of SRM, there are still concerns about unintended impacts to the climate.

Cirrus cloud thinning

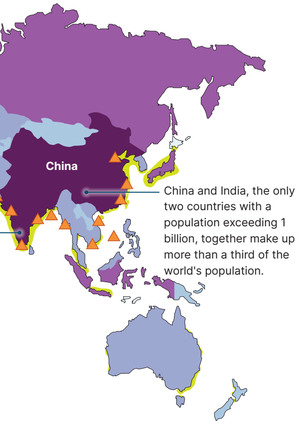
Cirrus clouds are thin and wispy and form above 6km. They retain heat and prevent it from escaping higher into the atmosphere or space. The SRM process would 'seed' the clouds with aerosol particles to form ice crystals. Drones could be used to deliver the particles. The clouds would thin-out as a consequence and allow more heat to escape. This process would also allow more light to enter through them, but on balance they would induce more cooling than heating. Like all SRM, scientists are still unsure how deployment might impact the ozone layer and weather patterns, or if it might cause a harmful cooling overshoot.

GC

ISBN: 978-1-99-101409-2

ulations are unevenly dispersed. Population be very high in certain areas, especially in iable water sources. Over the last few hundred **ation** (the move to living in cities or towns) has of people now live in urban centers, and this increase.

oution



China and India, the only two countries with a population exceeding 1 billion, together make up more than a third of the world's population.

NASA

Unsplashed CC3.0

Australia: 26.6 million
Australia is the driest inhabited continent in the world. Its 10 deserts (red above) cover 18% of the mainland. The majority of Australia's population lives on or near the coast, near reliable water sources. Only 3% of the population live in desert regions.

ettlements? _____

_____

ea level rise. Predict how sea level rise would

_____

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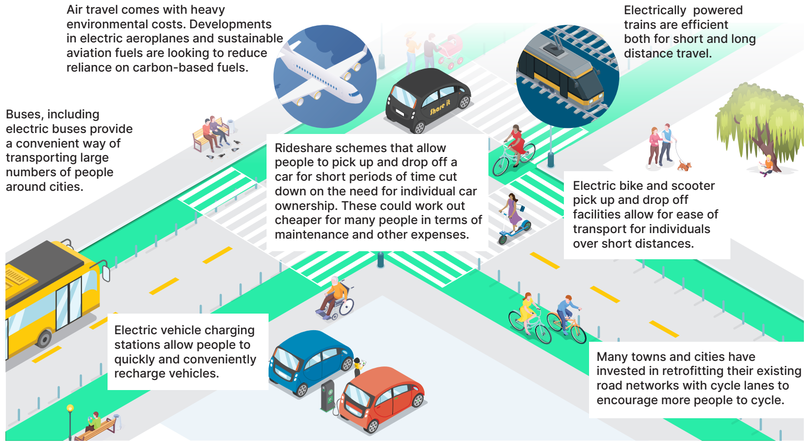
_____

108 Transportation

Key Idea: Different means of transport are required for different purposes. Reliance on fossil fuels for transportation can be minimized through alternative transport options.

Efficient movement around and between cities is often limited by the geography, design, and planning of the transport system. To be efficient, public transport systems need a high population density and must be able to transport people to within a short walk of their destination. In many cities, extensive light rail systems are used to achieve this. Roads, especially busy highways, have a significant impact on local ecosystems, contributing to pollution and forming dangerous barriers for animals to cross.



Traditional Transport System	Private petrol/diesel car	Diesel/petrol bus	Non electric train	Plane
Advantages	• Convenient, all-hours transport • Personalized • Can access most locations • Especially useful in areas with low populations	• Flexible access to most locations • Useful for short to medium length journeys • Low proportional operating costs if used by large numbers	• Fast transport over medium to long distances • Low per-person pollution • Can haul large volumes of people and freight	• Fast transport over long distances • Able to cross all geographic barriers
Disadvantages	• Expensive to run and maintain • Produce large amounts of pollution per person • Contributes to road congestion • High risk of accident/injury	• Timetables may be subject to traffic congestion • Can cost more to maintain than they earn • Can be slow to reach destinations because of the many stops	• Run to inflexible timetables • Expensive to run and maintain • Produce heavy vibration and some noise	• Fixed and inflexible schedules • Can be uncomfortable over long distances • Produce large amounts of localized noise • Expensive to run and maintain

1. Explain how effective transport systems can reduce congestion and pollution: _____

_____

_____

_____

2. Explain why all four transport systems described in the table are needed: _____

_____

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_____

GR

186 What's the Concern for Climate Change?

Key Idea: Climate change is happening now, and our responses will determine future impacts.

Over the past two centuries, human activities and industrialization have led to a rise in **greenhouse gas** levels in the atmosphere, affecting the climate. In more recent times, the term 'Anthropocene' has been used to describe the current geological epoch. This term, although not officially recognized as a geologic designation, highlights the influence of human-induced changes on the climate, known as **anthropogenic** forcing. Notably, **global warming** has been a prominent consequence of these activities, with the Earth's average surface temperature increasing by at least 1.19°C in 2024 compared to the mid-19th century.

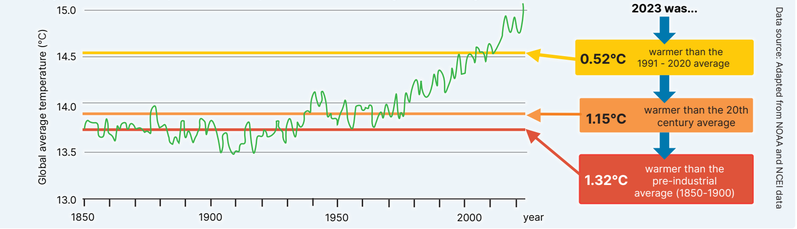
To determine the precise average global temperature, data is collected from (100,000 plus) weather stations worldwide, along with weather balloons, ships, buoys, radars, and satellites that record daily temperature variations. This data is used to calculate an **average global temperature.** The average temperature is then compared with pre-industrial temperature data, obtained before substantial industrial source greenhouse gas **emissions**. The recent rise in the global average means specific regions are encountering notably higher and more harmful temperature extremes. Unprecedented heatwaves in **polar** areas and regions already struggling from human habitation are driving certain Earth systems towards irreversible tipping points.

The world is warming - What's the big deal about 1.5°C anyway?

Many students may have heard about a **'1.5°C'** global warming 'line in the sand' not to be overtaken in order to prevent the worst impacts of climate change. Yet, despite the seemingly small '1.5°C' target, exceeding this threshold can activate **tipping points** in the climate system, causing irreversible changes due to **positive feedback cycles** that intensify the initial warming effects. The significance of global temperature rise lies in its potential to disrupt ecosystems, weather patterns, and cause **sea level rise**, highlighting the urgent need to address anthropogenic climate forcing to mitigate these impacts.

Data source

Yearly global surface temperatures compared to different long-term averages



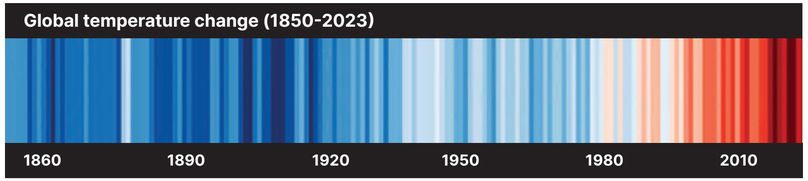
1. The image below shows a visual representative of the last 200 years of global temperature change, using the average from 1961-2010 as a measuring stick. Blue is colder, the darkest over 0.7°C colder, and the red is warmer; again the darker colors showing an extreme of over 0.7°C warmer. In a small group, discuss the implications of the data presented as a means to raise awareness of climate change. Record your thoughts below:

_____

_____

_____

_____



Data source: Showyourstripes.info CC BY4.0

2. Two sets of data that change in proportion to each other, either negatively or positively, show correlation. However, this does not necessarily imply causation, where changes in one factor causes changes in another. Suggest how scientists might show causation between global temperature rise and anthropogenic-only climate forcing:

_____

_____

_____

GC

46 Ecosystem Stability

Key Idea: The greater the species diversity in an ecosystem, the greater the stability of that ecosystem will be.

Ecological theory suggests that all species in an **ecosystem** contribute in some way to ecosystem function. Therefore, species loss past a certain point is likely to have a detrimental effect on the functioning of the ecosystem and on its ability to resist change (its **stability**). Although many species still await discovery, we do know that the rate of species extinction is increasing. This loss of biodiversity has serious implications for the long term stability of many ecosystems.

Rainforest

Deforestation

Rainforests (above left) represent the highest diversity systems on Earth. Whilst they are generally resistant to disturbance, once degraded, (above right) they have little ability to recover. The diversity of ecosystems at low latitudes is generally higher than that at high latitudes, where climates are harsher, niches are broader, and systems may be dependent on a small number of key species.

The concept of ecosystem stability

The stability of an ecosystem refers to its apparently unchanging nature over time. Ecosystem stability has various components, including inertia (the ability to resist disturbance) and **resilience** (the ability to recover from external disturbances).

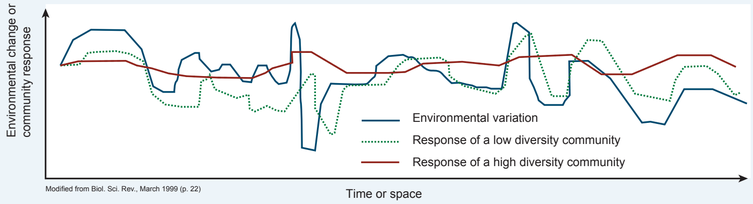
Evidence from both experimental and natural systems indicates that the most diverse ecosystems are also the most stable. This correlation is presumed to be a consequence of the large number of biotic interactions operating to buffer diverse systems against change. However, there is uncertainty over what level of diversity provides insurance against catastrophe. Ecosystems are very complex and stability probably relies more on the differential responses of all its species to variable conditions. Current thinking emphasizes the role of multiple factors, including diversity, in dictating stability.

Monoculture of soy beans

Natural grassland

Single species crops (far left), represent low diversity systems that can be vulnerable to disease, pests, and disturbance. In contrast, natural grasslands (left) may appear on the surface to be homogeneous, but contain many species which vary in their predominance seasonally. Although they may be easily disturbed, e.g. by burning, they are very resilient and usually recover quickly.

Community response to environmental change



Modified from Biol. Sci. Rev., March 1999 (p. 22)

In models of ecosystem function, higher species diversity increases the stability of ecosystem functions such as productivity and **nutrient cycling**. In the graph above, note how the low diversity system varies more consistently with the environmental variation, whereas the high diversity system is buffered against major fluctuations. In any one ecosystem, some species may be more influential than others in the stability of the system. Such keystone (key) species have a disproportionate effect on ecosystem function due to their pivotal role in some ecosystem functions such as nutrient recycling or production of plant biomass.

Elephants can change the entire vegetation structure of areas into which they migrate. Their pattern of grazing on taller plant species promotes a predominance of lower growing grasses with small leaves.

Termites are among the few larger soil organisms able (through a symbiosis with microbes) to break down plant cellulose. They have a profound effect on the rate of nutrient processing in tropical environments.

The starfish *Pisaster* occurs along the coasts of North America where it feeds on mussels. If it is removed, the mussels dominate, crowding out most algae and leading to a decrease in the number of herbivore species.

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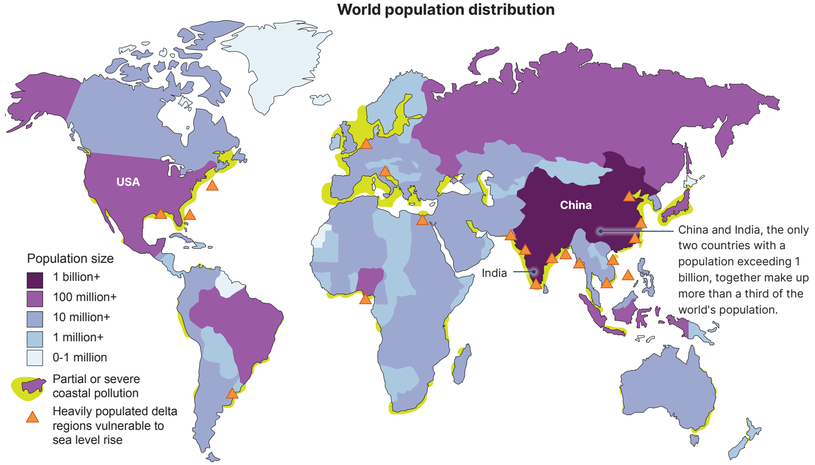
LW

69 World Population Distribution

Key Idea: The human population is not evenly distributed across the globe. More people live in cities and towns than ever before.

In early 2024, the world's population was eight billion people. However, the human population is not evenly distributed across the globe, China and India account for a third of the world's population. Even within countries populations are unevenly dispersed. Population densities can be very high in certain areas, especially in regions with reliable water sources. Over the last few hundred years, **urbanization** (the move to living in cities or towns) has increased. 55% of people now live in urban centers, and this is predicted to increase.

World population distribution



Tapesh Yadav

India 1.4 billion
The majority of India's population (66%) live rurally (above) and depend on agricultural activities for income and resources. India also has some very large cities, and they are the site of many important technology-based and manufacturing industries.

NASA

USA: 341 million
The night time image of mainland USA (above) shows the population is unevenly distributed: the majority live in the East. Coastal land accounts for 10% of the US footprint, but 40% of the population live in these coastal regions.

Ubiquenoid CC3.0

Australia: 26.6 million
Australia is the driest inhabited continent in the world. Its 10 deserts (red above) cover 18% of the mainland. The majority of Australia's population lives on or near the coast, near reliable water sources. Only 3% of the population live in desert regions.

1. What factor is an important driver for determining the location of human settlements? _____
2. Calculate how many people in Australia live in a desert region: _____
3. Asia has a large number of heavily populated delta regions vulnerable to sea level rise. Predict how sea level rise would drive the migration patterns of people in affected areas:

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_____

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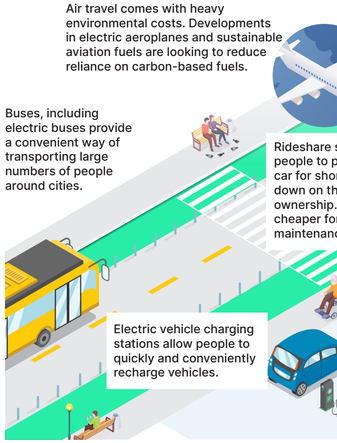
LW

108 Transportation

Key Idea: Different means of transport are req
different purposes. Reliance on fossil fuels for transp
can be minimized through alternative transport opt
Efficient movement around and between cities
limited by the geography, design, and planning
transport system. To be efficient, public transport



Traditional Transport System	Private petrol/diesel car
Advantages	• Convenient, all-hours transport • Personalized • Can access most locations • Especially useful in areas with low populations
Disadvantages	• Expensive to run and maintain • Produce large amounts of pollution per person • Contributes to road congestion • High risk of accident/injury

1. Explain how effective transport systems can re

_____

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_____

2. Explain why all four transport systems describe

_____

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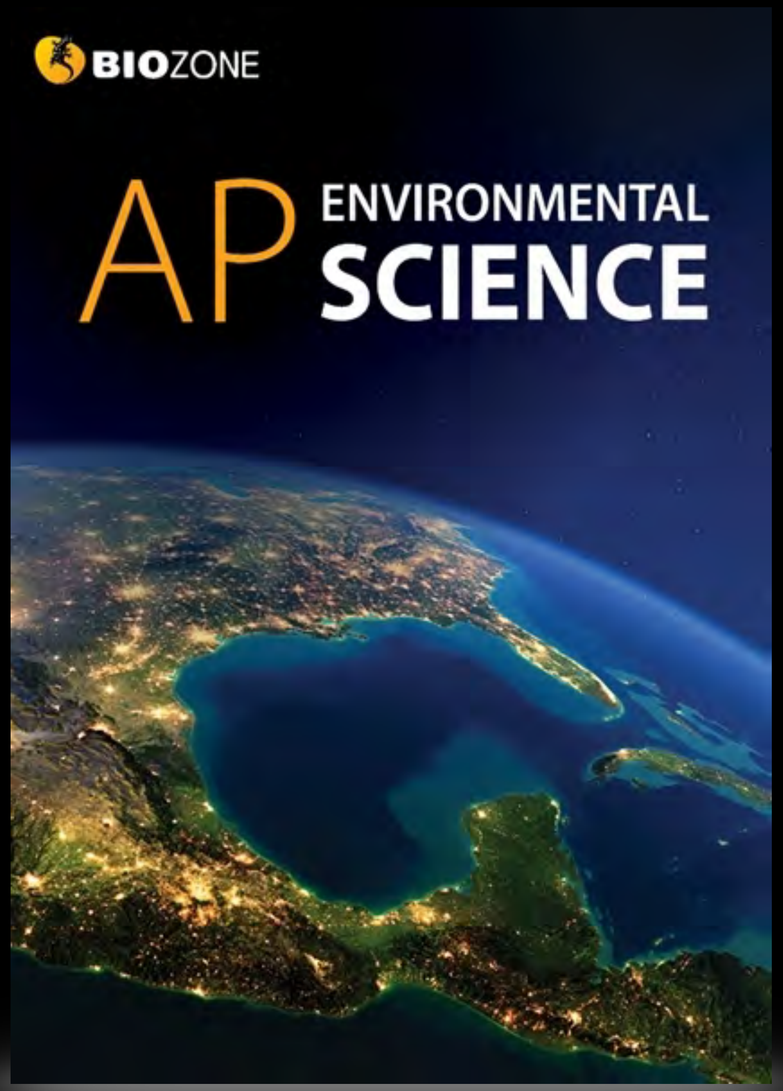
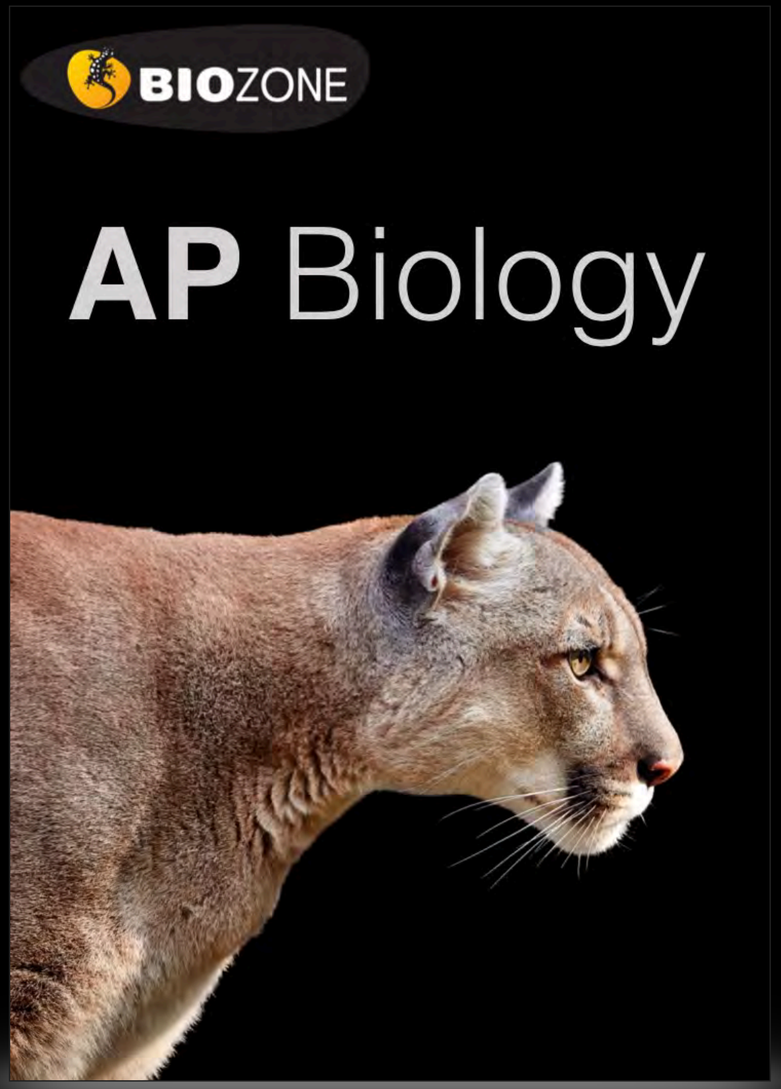
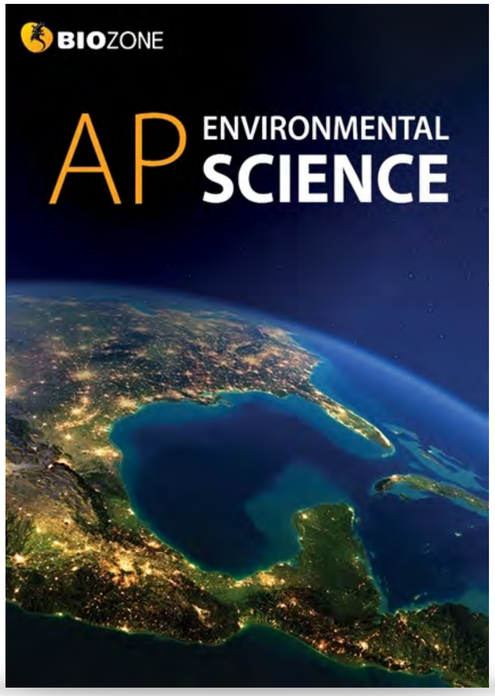
GR

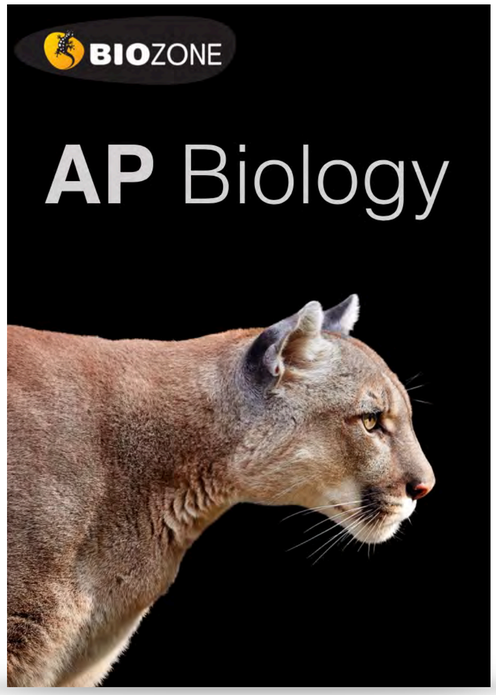
Advanced Placement Titles







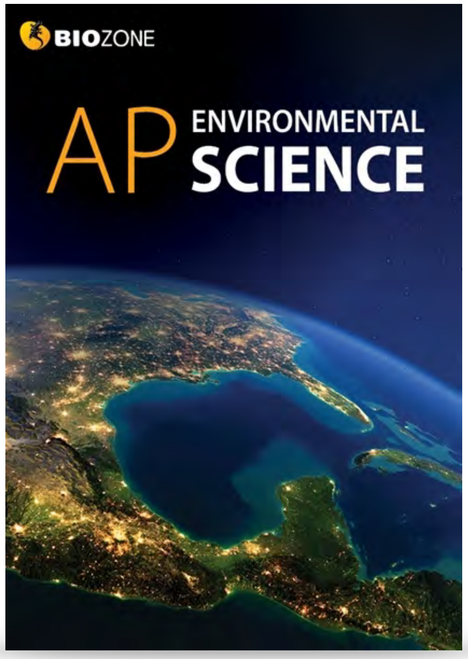
Advanced Placement Titles

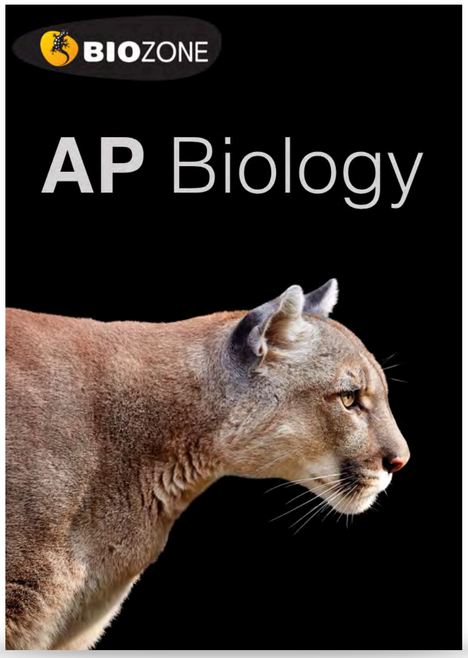


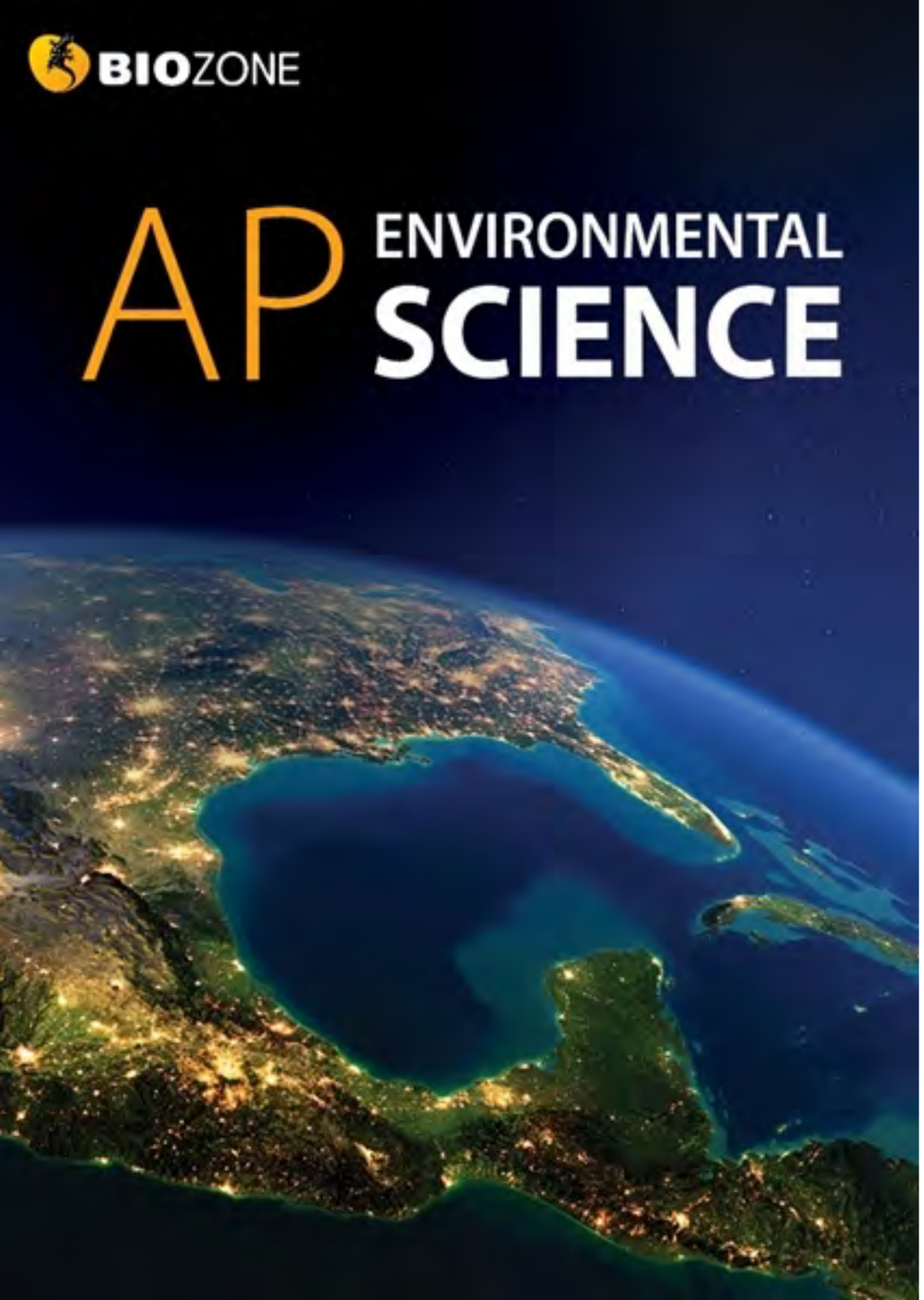
AP Environmental Science: 2019 CED	**AP Biology: 2020 CED**
Structured on the **Units of Study:** content delivery follows each CED	
Science Practices and Skills incorporated throughout	

Features of AP Titles

- ☑ **Science practices** and skills are identified by color coding on page
- ☑ **Practical investigations** and equipment list
- ☑ Rich in **data handling activities** and **case studies**
- ☑ Support for **science practice** and **skills** provided in a dedicated chapter
- ☑ **Glossary** of key terms is provided
- ☑ Group work/**collaboration** opportunities identified
- ☑ **Resource Hub** provides on line content to support activities
- ☑ **Personal progress checks** at the end of each unit prepare students for the AP exam







AP ENVIRONMENTAL SCIENCE

1. The Living World: Ecosystems
2. The Living World: Biodiversity
3. Populations
4. Earth Systems and Resources
5. Land and Water Use
6. Energy Resources and Consumption
7. Atmospheric Pollution
8. Aquatic and Terrestrial Pollution
9. Global Change
10. Science Practices for APES

BIOZONE

AP BIOLOGY

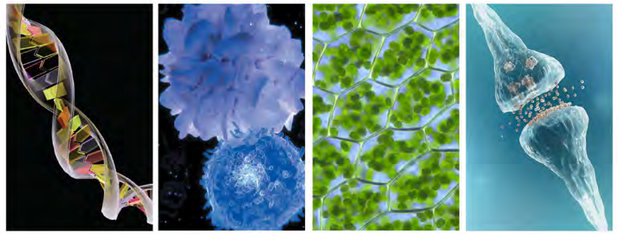
AP BIOLOGY

1. Chemistry of Life
2. Cell Structure and Function
3. Cellular Energetics
4. Cell Communication and Cell Cycle
5. Heredity
6. Gene Expression and Regulation
7. Natural Selection
8. Ecology
9. Science Practices for AP Biology

AP Biology is structured around the four big ideas, they form threads that run throughout the entire course

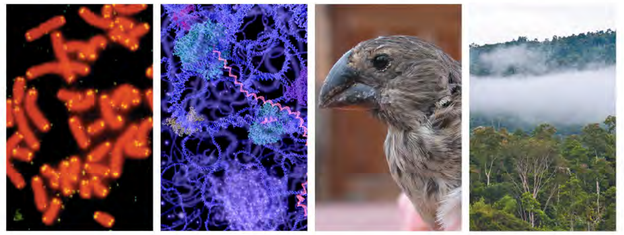
Big Ideas and Enduring Understandings

AP Biology is structured around four BIG IDEAS (below). These big ideas form threads that run throughout the entire course. The big ideas relate to several ENDURING UNDERSTANDINGS, which form the key concepts for learning and from which arise the learning objectives that form the basis of each unit introduction.

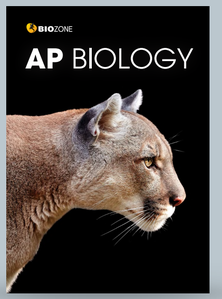


Big Ideas	Unit 1 Chemistry of Life	Unit 2 Cell Structure and Function	Unit 3 Cellular Energetics	Unit 4 Cell Communication and Cell Cycle
EVO **Evolution** The process of evolution drives the diversity and unity of life.		**EVO1** Evolution is characterized by a change in the genetic makeup of a population over time and is supported by multiple lines of evidence.		
ENE **Energetics** Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.	**ENE-1** The organization of living systems requires constant input of energy and the exchange of macromolecules.	**ENE-2** Cells have membranes that allow them to establish and maintain distinct internal environments.	**ENE-1**	**ENE-3** Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues.
IST **Information Storage and Transmission** Living systems store, retrieve, transmit and respond to information essential to life processes.	**IST-1** Heritable information provides for the continuity of life.			**IST-1** **IST-3** Cells communicate by generating, transmitting, receiving, and responding to chemical signals.
SYI **Systems Interactions** Biological systems interact, and these systems and their interactions exhibit complex properties.	**SYI-1** Living systems are organized in a hierarchy of structural levels that interact.	**SYI-1**	**SYI-3** Natural diversity among and between compartments within biological systems affects interactions with the environment.	
PERSONAL PROGRESS CHECKS	20 multiple choice **Free response questions** • Conceptual analysis (partial) • Analyze visual representation or model (partial)	30 multiple choice **Free response questions** • Interpreting and evaluating experimental results (partial) • Analyze model or visual representation (partial)	20 multiple choice **Free response questions** • Interpreting and evaluating experimental results with graphing (partial) • Scientific investigation (partial)	25 multiple choice **Free response questions** • Interpreting and evaluating experimental results (partial) • Analyze data

As part of this learning structure, key science practices are integrated into the activities of this book. The science practices cover important skills students need to describe and analyze scientific ideas and data related to biology. These are described on page xii.



Unit 5 Heredity	Unit 6 Gene Expression and Regulation	Unit 7 Natural Selection	Unit 8 Ecology
EVO-2 Organisms are linked by lines of descent from common ancestry.		**EVO1** **EVO-2** **EVO-3** Life continues to evolve within a changing environment.	**EVO1**
			ENE-1 **ENE-3** **ENE-4** Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment.
IST-1	**IST-1** **IST-2** Differences in gene expression account for some of the phenotypic differences between organisms. **IST-4** The processing of genetic information is imperfect and is a source of genetic variation.		**IST-5** Transmission of information results in changes within and between biological systems.
SYI-3		**SYI-3**	**SYI-1** **SYI-2** Competition and cooperation are important aspects of biological systems. **SYI-3**
25 multiple choice **Free response questions** • Interpreting and evaluating experimental results with graphing • Conceptual analysis	25 multiple choice **Free response questions** • Interpreting and evaluating experimental results • Analyze visual representation or model	40 multiple choice **Free response questions** • Interpreting and evaluating experimental results with graphing • Analyze data	20 multiple choice **Free response questions** • Interpreting and evaluating experimental results with graphing • Scientific investigation



APES is structured around the four big ideas, they form threads that run throughout the entire course

Big Ideas and Enduring Understandings

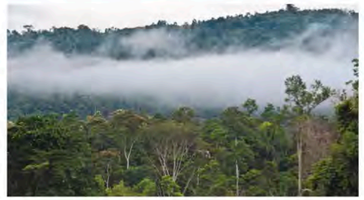
AP Environmental Science is structured around four BIG IDEAS (below). These big ideas form threads that run throughout the entire course. The big ideas relate to several ENDURING UNDERSTANDINGS, which form the key concepts for learning and from which arise the learning objectives that form the basis of each unit introduction. As part of this learning structure, key science practices are integrated into the activities of this book. The science practices cover important skills students need to describe and analyze scientific ideas and data related to environmental science. These are described on page xii.

BIG IDEA 1
Energy transfer (ENG):

Energy conversions underlie all ecological processes. Energy cannot be created or destroyed, only transferred and transformed. At each transfer energy is lost from the system to the environment.

BIG IDEA 2
Interactions between Earth systems (ERT):

The Earth is a complex interconnected system. Systems can change over time and vary in their ability to recover from disturbances.



Big Ideas	Unit 1 The Living World: Ecosystems	Unit 2 The Living World: Biodiversity	Unit 3 Populations	Unit 4 Earth Systems and Resources
Energy transfer ENG	**ENG1** Energy can be converted from one form to another.			**ENG-2** Most of the Earth's atmospheric processes are driven by input of energy from the Sun.
Interactions between Earth systems ERT	**ERT-1** Ecosystems are the result of biotic and abiotic interactions.	**ERT-2** Ecosystems have structure and diversity that change over time.	**ERT-3** Populations change over time in the reaction to a variety of factors.	**ERT-4** Earth's systems interact, resulting in a state of balance over time.
Interactions between different species and their environment EIN			**EIN-1** Human populations change in reaction to a variety of factors, including social and cultural factors.	
Sustainability STB				
PERSONAL PROGRESS CHECKS	24 multiple choice **Free response question** Analyze an environmental problem and propose a solution.	21 multiple choice **Free response question** Design an investigation.	24 multiple choice **Free response question** Analyze an environmental problem and propose a solution doing calculations.	15 multiple choice **Free response question** Design an investigation.

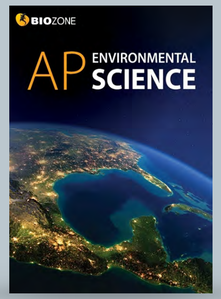
BIG IDEA 3
Interactions between different species and their environment (EIN):

Humans have altered the environment for millennia. The rate and scale of these changes are increasing as technology advances and the human population increases.

BIG IDEA 4
Sustainability (STB):

Human survival depends on developing sustainable solutions for managing resources that take into account social, cultural, and economic factors.

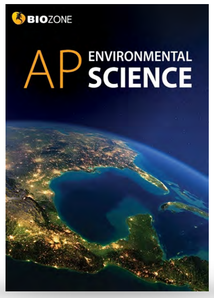
Unit 5 Land and Water Use	Unit 6 Energy Resources and Consumption	Unit 7 Atmospheric Pollution	Unit 8 Aquatic and Terrestrial Pollution	Unit 9 Global Change
	ENG-3 Humans use energy from a variety of sources, resulting in positive and negative consequences.			
EIN-2 When humans use natural resources, they alter natural systems.			**EIN-3** Pollutants can have both direct and indirect impacts on the health of organisms, including humans.	**EIN-4** The health of a species is closely tied to its ecosystem, and minor environmental changes can have a large impact.
STB-1 Humans can mitigate their impact on land and water resources through sustainable use.		**STB-2** Human activities have physical, chemical, and biological consequences for the atmosphere.	**STB-3** Human activities, including the use of resources, have physical, chemical, and biological consequences for ecosystems.	**STB-4** Local and regional human activities can have impacts at the global level.
22 multiple choice **Free response question** Analyze an environmental problem and propose a solution.	28 multiple choice **Free response question** Analyze an environmental problem and propose a solution doing calculations.	28 multiple choice **Free response question** Design an investigation.	26 multiple choice **Free response question** Analyze an environmental problem and propose a solution doing calculations.	23 multiple choice **Free response question** Analyze an environmental problem and propose a solution.

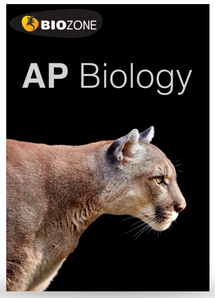


Structure of a chapter

UNIT INTRODUCTION

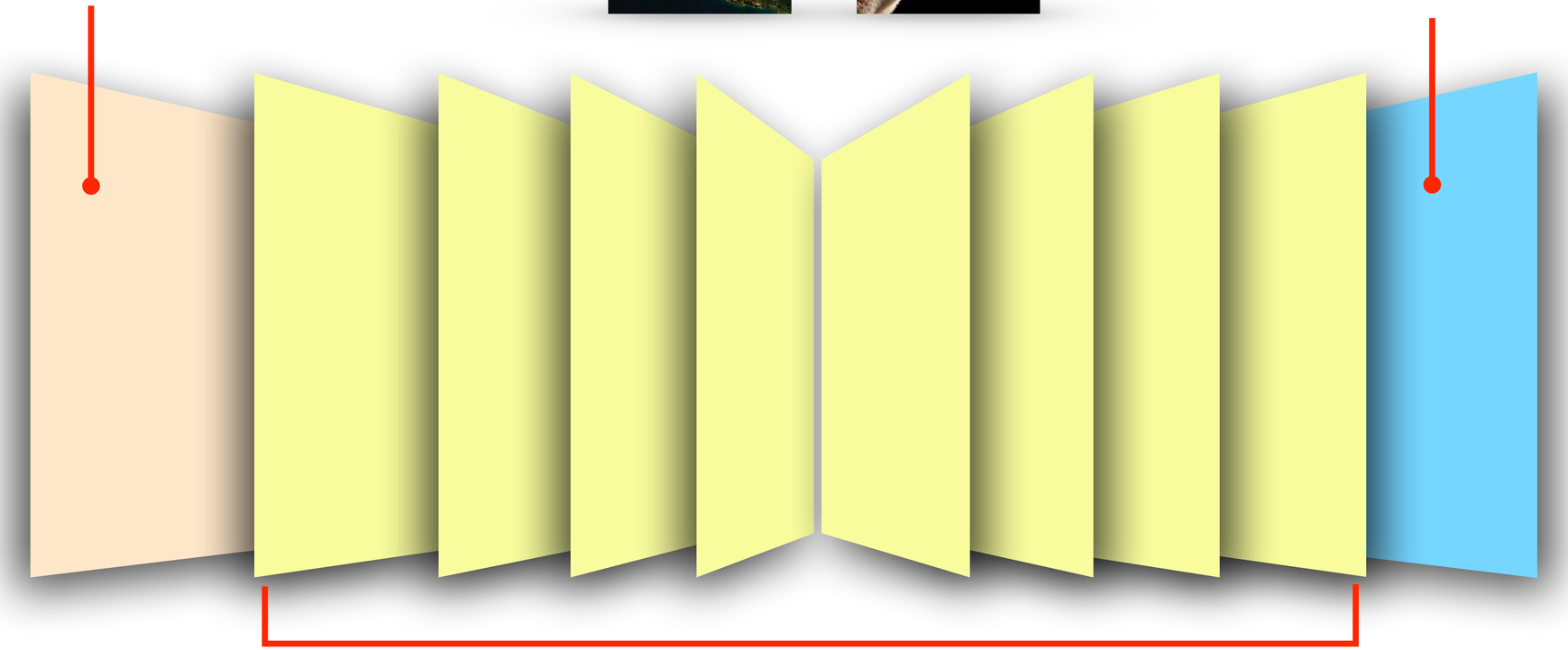
- **Summarize** key content, skills, and learning outcomes.
- Use as a **checklist** for setting work and viewing student progress.





PERSONAL PROGRESS CHECK

- **Assess** student understanding of the chapter content.
- Multiple choice and free response questions

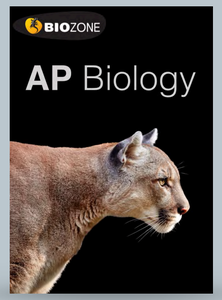


ACTIVITY PAGES

- **Engaging** and informative activities have been designed to cover the required content and skills as stipulated in the AP Biology CED
- **Questions** within activities are designed to evaluate the student's understanding of the content

Unit (Chapter) Introduction

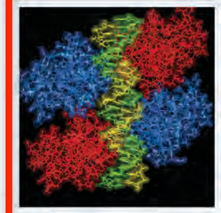
- Each unit (chapter) introduction highlights the content and skills required to develop understanding.
- **Key content**, **skills**, and **learning outcomes** are summarized in bullet points.
- Use the checklist boxes to set work and view student progress.



UNIT 1

Chemistry of Life

Learning Objectives



Developing understanding

CONTENT: This unit sets the foundation for understanding the chemical basis of life and includes a survey of the elements essential to carbon-based systems. You will learn about the central role of water in biological systems and build an understanding of how the organization of living systems depends on an input energy and an exchange of macromolecules. Understanding how macromolecules are constructed from monomers is central to this.

SKILLS: This unit emphasizes skills in describing biological processes, principles, and concepts represented visually. The skill of argumentation is introduced, using a model to predict the causes or effects of a change in a system.

1.1 Structure of water and hydrogen bonding ..... activity 1

- ☐ 1. Explain the structure of a water molecule, identifying how hydrogen bonding between water molecules accounts for water's unique properties. Use visual representations to explain the properties of water in its liquid and solid states.
- ☐ 2. Explain how living systems depend on the properties of water that arise from its polarity and hydrogen bonding. Include reference to cohesion, adhesion, thermal conductivity, high specific heat capacity, heat of vaporization, and heat of fusion, and role as a universal solvent.

1.2 Elements of life ..... activity 2

- ☐ 3. Identify the macromolecules required by living organisms and describe their composition. Describe how organisms must exchange matter with the environment to grow, reproduce, and maintain organization.
- ☐ 4. Describe how carbon moves from the environment to organisms and how it is used to build biological molecules and in storage and cell formation in all organisms.
- ☐ 5. Describe how nitrogen and phosphorus move from the environment to organisms and how they are used in building new molecules in organisms.

1.3 Introduction to biological macromolecules ..... activities 3-5, 10, 13

- ☐ 6. Describe how dehydration synthesis (condensation) and hydrolysis reactions are used to form and cleave covalent bonds between monomers in nucleic acids, proteins, carbohydrates, and lipids.

1.4 Properties of biological macromolecules ..... activities 4-14

- ☐ 7. Describe how biological information is encoded in sequences of nucleotide monomers. Describe the structural components of nucleotides.
- ☐ 8. Describe how the primary structure of a polypeptide determines the overall shape of a protein. Describe the structure of an amino acid and how the properties of the amino acid R groups and their interactions determine final protein structure and function.
- ☐ 9. Describe how the structures of carbohydrate monomers determine the properties and functions of the molecules.
- ☐ 10. Describe the non-polar nature of a typical lipid (e.g. a triacylglycerol) and explain how phospholipids differ in having polar and non-polar regions. Explain how differences in fatty acid saturation determine lipid structure and function.

1.5 Structure and function of biological macromolecules ..... activities 4-12

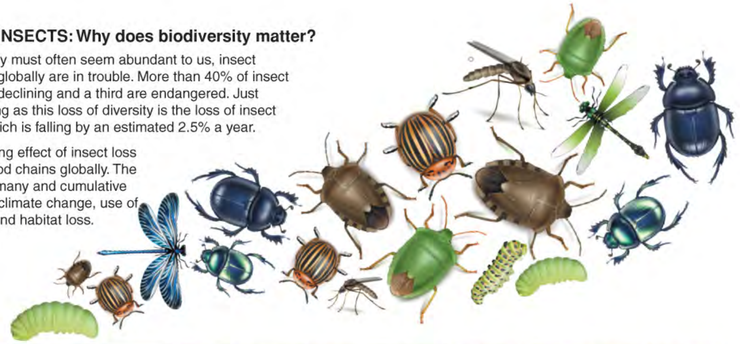
- ☐ 11. Explain how the nucleotides are organized into polymers called nucleic acids, including reference to the phosphodiester bonds that form between adjacent nucleotides. Interpret diagrams and models to explain the directionality of nucleic acids, defined by the 3' and a 5' carbons of the sugar in the nucleotide.
- ☐ 12. Explain the antiparallel, double helix structure of DNA, including how the directionality of the molecule determines the direction of nucleotide addition during DNA and RNA synthesis (5'→3'). Explain the role of hydrogen bonding between nucleobases in formation of the DNA double helix.
- ☐ 13. Explain how proteins have a primary structure comprising linear chains of amino acids connected by covalent peptide bonds formed at the carboxyl end of the growing polypeptide chain. Explain the interactions involved in creating a protein's primary, secondary, tertiary, and quaternary structures.
- ☐ 14. Explain the role of a protein's precise three-dimensional structure to its biological function. Explain how this precise structure can be disrupted and predict the consequences of such disruptions.
- ☐ 15. Explain how carbohydrates are made up of chains of monosaccharide monomers connected by covalent glycosidic bonds. Explain why some polysaccharides are linear and some are branched. To illustrate this, compare and contrast the structure of glucose polymers such as cellulose, starch, and glycogen.

1.6 Nucleic acids ..... activities 3, 4

- ☐ 16. Describe the structural similarities and differences between DNA and RNA, including reference to the sugar present, the nucleobases present, and the number of strands usually present (single/double).

VANISHING INSECTS: Why does biodiversity matter?

- Although they must often seem abundant to us, insect populations globally are in trouble. More than 40% of insect species are declining and a third are endangered. Just as concerning as this loss of diversity is the loss of insect biomass, which is falling by an estimated 2.5% a year.
- The cascading effect of insect loss threatens food chains globally. The causes are many and cumulative and include climate change, use of pesticides, and habitat loss.



A pair of blue tits may collect 100 insects a day to feed one chick

The winter moth caterpillar is an invasive species in the US but provides abundant food for birds.

The larvae of green lacewings feed on aphids and other soft bodied insect pests.

FIVE CRUCIAL INSECT ROLES

Insects have a central role in the ecosystem services humans rely on for survival. The decline in the numbers and diversity of insects has serious consequences for a sustainable future.

1: PROVIDERS

Insects are part of almost all food chains as prey for a wide range of other animals, including birds, bats, amphibians, and fish. Recent declines in many bird populations have been linked to scarcity of insect prey.

PEST CONTROLLERS

Predatory insects play a critical role in controlling the pest insects that threaten crops. They help to reduce pest control costs and increase yields, saving billions of dollars every year.

What may happen without insects:

Species at higher trophic levels may decline in numbers and diversity.

Pests may increase, damaging crops and forests, and pesticide use may increase.

2. (a) Describe the primary cause of the current lack of genetic diversity in modern sea otter po

(b) Describe the likely reason for the low genetic diversity in the California population:

(c) How might this be related to more recent declines in the California population:

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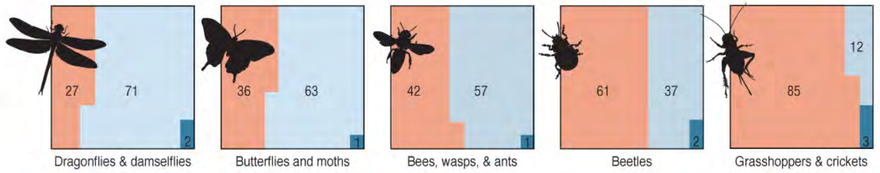
Insect declines: how they're tracking



% of species decreasing
% of species stable
% of species increasing

Species in the five major insect orders (above) have all declined in recent decades. Of the 2200 species tracked by the IUCN almost half are declining. These 2200 species represent just a tiny proportion of total insect biodiversity. Even with today's technological advancement, only 20% of insects species are even identified. We will not even know if they are lost.

Dung beetles process cattle dung in 23 months compared to the 28 it would take without them.

Bumblebees are important pollinators of both crops and wildflowers. A single bee can visit several thousand flowers a day.

One termite colony can excavate 0.2 tonnes of soil per year.

DECOMPOSERS

Insects that feed on wastes and dead material, such as dung, carrion, and dead plants, have an important role in nutrient cycles. Their activities release nutrients that would otherwise remain locked up for a considerable time.

POLLINATORS

Around 75% of crops benefit from insect pollination even if they do not completely depend on it. As the production of pollinator dependent crops increases, so too does our dependence on insect pollinators, which are declining.

SOIL ENGINEERS

Termites and ants are an essential part of arid ecosystems. Their activities aerate hard ground, adding nutrients, improving soil structure, and allowing water to penetrate. They have even been used to rehabilitate regions affected by desertification.

Waste material would be recycled more slowly, hindering nutrient cycling.

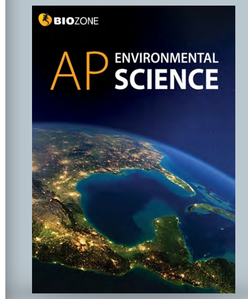
Crops may reproduce poorly and some key food sources may be lost.

Soils in arid regions may become barren, leading to crop failure and desertification.

ple, explain the importance of biodiversity to ecosystem function and to human wellbeing:

ISBN: 978-1-98-856632-0

Content is accessible through the use of engaging diagrams and manageable blocks of text

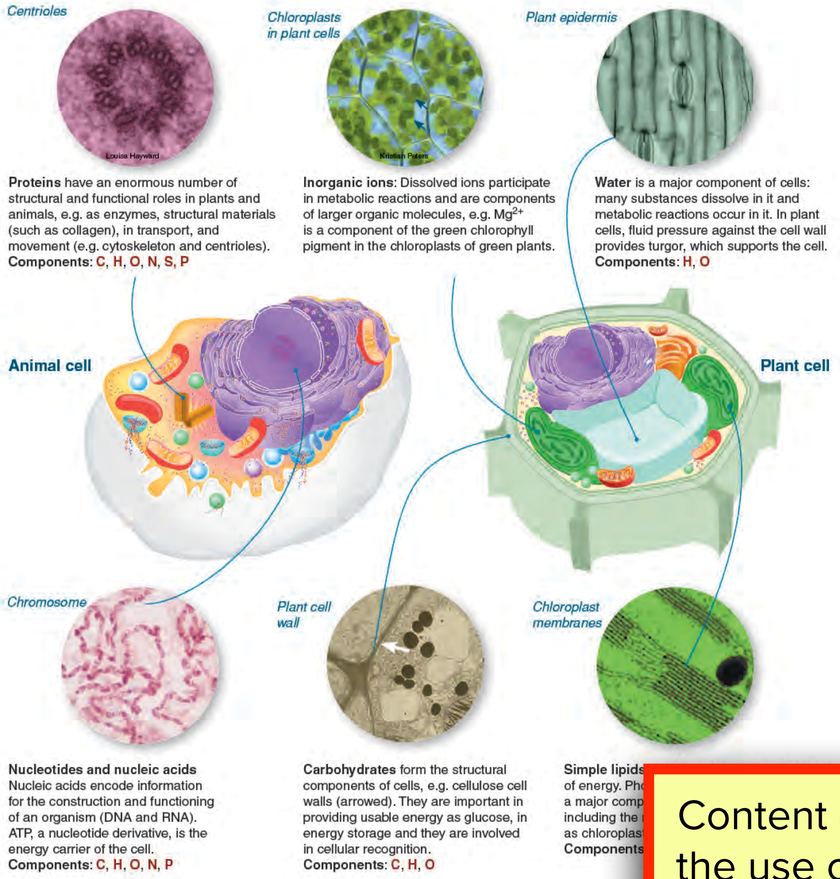


2 The Biochemical Nature of the Cell

Key Question: What atoms and molecules do organisms obtain from their environment and what do they do with them?

Water is the main component of cells and organisms, providing an aqueous environment in which metabolic reactions can occur. Apart from water, most other substances in cells are compounds of carbon, hydrogen, oxygen, and nitrogen. Life on Earth is carbon based. Carbon is able to form up to four valence bonds with other atoms simultaneously so it can combine with many other elements to form a large number of carbon-based (or organic) molecules. The organic molecules that make up living things can be grouped into four broad classes: carbohydrates, lipids, proteins, and nucleic acids. In addition, a small number of inorganic ions are also components of larger molecules.

The components of cells



Proteins have an enormous number of structural and functional roles in plants and animals, e.g. as enzymes, structural materials (such as collagen), in transport, and movement (e.g. cytoskeleton and centrioles).
Components: C, H, O, N, S, P

Inorganic ions: Dissolved ions participate in metabolic reactions and are components of larger organic molecules, e.g. Mg^{2+} is a component of the green chlorophyll pigment in the chloroplasts of green plants.

Water is a major component of cells: many substances dissolve in it and metabolic reactions occur in it. In plant cells, fluid pressure against the cell wall provides turgor, which supports the cell.
Components: H, O

Nucleotides and nucleic acids
Nucleic acids encode information for the construction and functioning of an organism (DNA and RNA). ATP, a nucleotide derivative, is the energy carrier of the cell.
Components: C, H, O, N, P

Carbohydrates form the structural components of cells, e.g. cellulose cell walls (arrowed). They are important in providing usable energy as glucose, in energy storage and they are involved in cellular recognition.
Components: C, H, O

Simple lipids
of energy. Ph
a major comp
including the
as chloroplas
Components

1. (a) List the four main macromolecule components of living organisms: _____

_____

(b) List the elements that all these macromolecules share: _____

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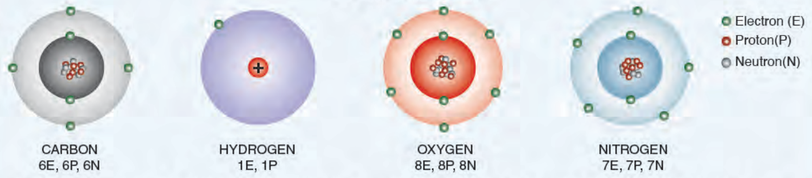
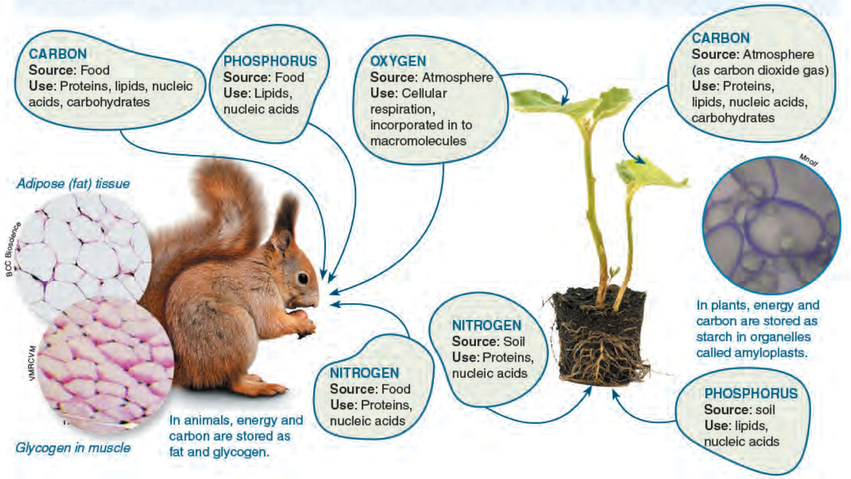
The elements of life



Carbon is very abundant. It has four valence (outer shell) electrons that are available to form up to four covalent (shared electron) bonds with other atoms. Complex biological molecules consist of carbon atoms bonded with other elements, especially oxygen and hydrogen, but also nitrogen, phosphorus, and sulfur. Carbon readily forms stable polymers that can participate in chemical reactions.



2. Summarize the role of each of the following cell components:

(a) Carbohydrates: _____

(b) Lipids: _____

(c) Proteins: _____

(d) Nucleic acids: _____

(e) Inorganic ions: _____

(f) Water: _____

important for building the molecular components of an organism: _____

_____

_____

_____

carbon, phosphorus, and nitrogen for animals: _____

of carbon for plants: _____

(b) State the main source of phosphorus and nitrogen for plants: _____

ISBN: 978-1-98-856656-6

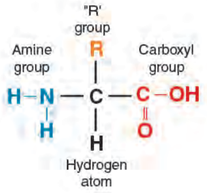
Content is accessible through the use of engaging diagrams and manageable blocks of text

5 Amino Acids

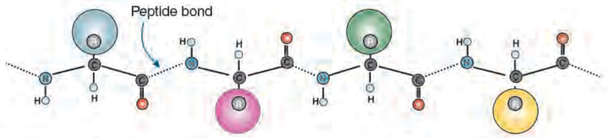
Key Question: How do amino acid monomers come together and interact to form polypeptides?

Amino acids are the basic units from which proteins are made. Twenty amino acids commonly occur in proteins and they can be linked together in a linear sequence by condensation reactions to form polypeptides. Proteins are made up of one or more polypeptide molecules. These can be broken apart by hydrolysis into their constituent amino acids.

The structure and properties of amino acids

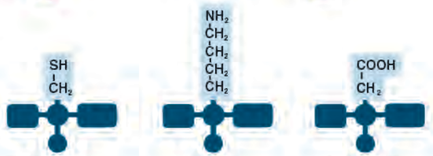


- Amino acids are the building blocks of proteins. They are linked by peptide bonds (below and opposite) for form long chains called polypeptides, which are the basis of proteins. All amino acids have a common structure (left) with an amine group (blue), a carboxyl group (red), a hydrogen atom, and a functional or 'R' group (orange).
- Each type of amino acid has a different functional R group (side chain). Each functional R group has a different chemical property.
- Amino acids are represented by a single upper case letter or a three-letter abbreviation. For example, proline is known by the letter P or the three-letter symbol Pro.



Different amino acids have different R groups

- The R group in the amino acid determines the chemical properties of the amino acid. Different amino acids have different R groups and therefore different chemical properties. Amino acids can be grouped according to these properties. Common groupings are nonpolar (hydrophobic), polar (hydrophilic), positively charged (basic), or negatively charged (acidic).
- The property of the R group determines how the amino acid will interacts with others and how the amino acid chain will fold up into a functional protein. For example, the hydrophobic R groups of soluble proteins will be folded into the protein's interior.



Cysteine
The 'R' group of cysteine forms **disulfide bridges** with other cysteines to create cross linkages in a polypeptide chain.

Lysine
The 'R' group of lysine gives the amino acid an **alkaline** property.

Aspartic acid
The 'R' group of aspartic acid gives the amino acid an **acidic**

1. What makes each of the amino acids in proteins unique and how does this uniqueness contribute to protein st

2. Do some research to assign each of the 20 amino acids found in proteins to one of the four groups below. Use standard 3-letter code to identify each amino acid:

   (a) Nonpolar (hydrophobic): _____

   (b) Polar (hydrophilic): _____

   (c) Positively charged (basic): _____

   (d) Negatively charged (acidic): _____

3. (a) W... Which type(s) would you find in the in...

   (b) W... n a lipid bilayer?

11 SYI-1 2.A SYI-1 1.A

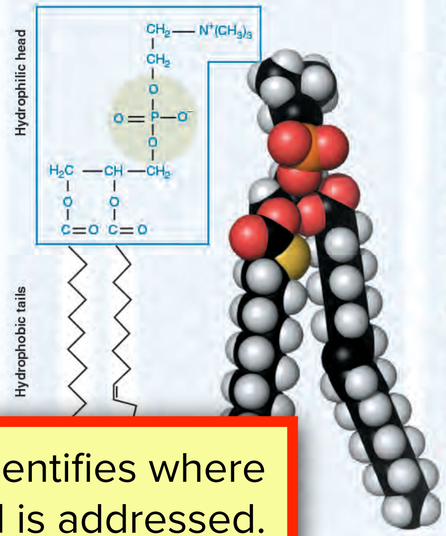
14 Phospholipids

Key Question: How are phospholipids formed, what are their characteristics, and what are their biological roles?

A phospholipid is structurally similar to a triglyceride except that a phosphate group and a nitrogen-containing compound replace one of the fatty acids attached to the glycerol. Phospholipids naturally form bilayers in aqueous solutions and are the main component of cellular membranes. The fatty acid tails can be saturated (straight chains) or unsaturated (kinked chains). The proportion of saturated versus unsaturated fatty acids affects the fluidity of the phospholipid bilayer.

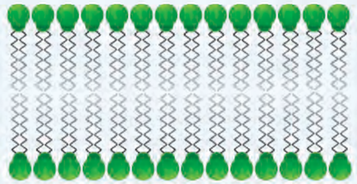
Phospholipids

Phospholipids consist of a glycerol attached to two fatty acid chains and a phosphate (PO_4^{3-}) group. The phosphate end of the molecule is attracted to water (hydrophilic) while the fatty acid end is repelled (hydrophobic). The hydrophobic ends turn inwards to form a **phospholipid bilayer.**

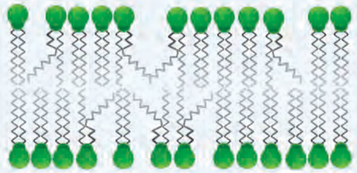


Phospholipids and membranes

The amphipathic (having hydrophobic and hydrophilic ends) nature of phospholipids means that when in water they spontaneously form bilayers. This bilayer structure forms the outer boundary of cells or organelles. Modifications to the different hydrophobic ends of the phospholipids cause the bilayer to change its behavior. The greater the number of double bonds in the hydrophobic tails, the greater the fluidity of the membrane.



Membrane containing only phospholipids with saturated fatty acid tails.



Membrane containing phospholipids with unsaturated fatty acid tails. The fact that the phospholipids do not stack neatly together produces a more fluid membrane.

...to their chemical properties and their functional role in cellular membranes:

(b) Suggest how the cell membrane structure of an Arctic fish might differ from that of tropical fish species: _____

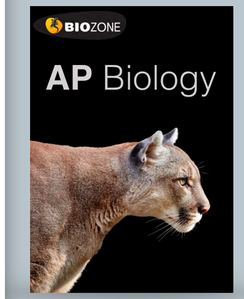
2. Explain why phospholi...

SYI-1 1.A 13 26

Color coding identifies where a particular skill is addressed. The color match the coding in the AP Biology CED

Points to related content elsewhere in the book

The Big Idea and specific skill is identified here



149 The Covid-19 Pandemic

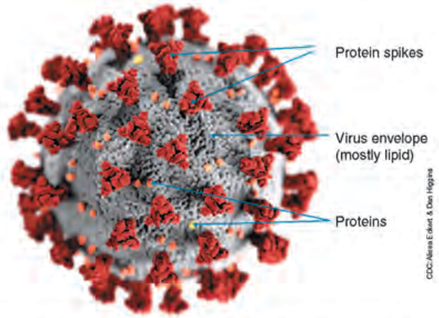
Key Question: What do we know about Covid-19 and how has it affected the environment?

In December 2019, a new strain of coronavirus was detected in Wuhan, China. The new virus was named Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). Infection with the virus causes a disease called Covid-19. The WHO declared a pandemic in March 2020 as the virus spread around the world and a pandemic status was still in place at the time of writing this book. The Covid-19 pandemic has disrupted the world travel and global economies. Millions of people have been infected and hundreds of thousands have died. Enormous stress has been placed on health systems, and the harsh financial impacts will be felt for years because millions of people have lost their jobs.

What is Covid-19?

- Covid-19 is the disease caused when someone is infected with the SARS-CoV-2 virus (right).
- The virus affects the respiratory system.
- 80% of infected people recover without hospital care.
- 20% of infected people develop severe breathing problems and may require high level hospital care. The elderly and people with underlying medical problems are most at risk of becoming very sick.
- The virus is spread through the environment in small droplets from the nose and mouth (e.g. when a person speaks, sneezes, or coughs). People become infected when they breathe these droplets in, or when they touch a surface contaminated with the virus.
- There is currently no vaccine, but attempts to develop one are underway.

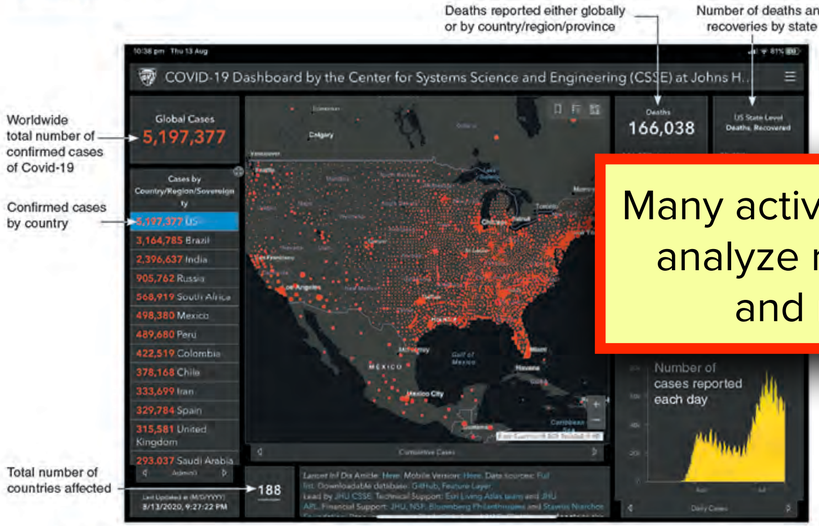
A representation of the SARS-CoV-2 virus



Spread of coronavirus

Reports of viral pneumonia (a lung infection) in Wuhan, China were reported on the 31st December 2019. Early in January 2020, a new coronavirus was identified as the cause of the infections. The new virus, SARS-CoV-2, is thought to have arisen in bats, passing to humans through another, as yet unknown, animal. SARS and MERS probably transferred to humans this way also.

Despite strict restrictions, including travel bans, being placed on the residents of Wuhan and the surrounding region, the virus began to spread through China. On the 13th January 2020 the first case outside of China was recorded in Thailand. Within 10 days the virus had spread to a number of countries, including the US, as infected travelers flew around the world. Over 188 countries and territories have reported infections. The situation is changing daily and the best way to find the most recent information is to visit the WHO Covid-19 Interactive Dashboard or the John Hopkins University of Medicine Covid-19 Dashboard. Find the details for both sites on **BIOZONE's Resource Hub**.



Many activities require students to analyze real second hand data and make conclusions

EIN-3 2.B | EIN-3 2.C | EIN-3 5.A

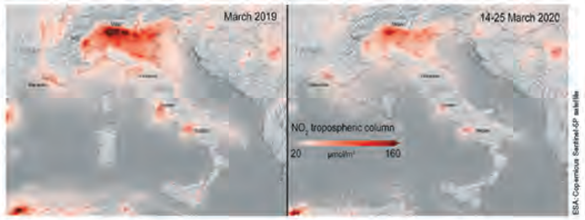
ISBN: 978-1-98-856633-7

150 Environmental Effects of Covid-19

Key Question: How has Covid-19 affected the environment?

Many countries went into some level of lockdown as it became evident strong measures were needed to reduce the spread of the new coronavirus. For many countries this meant banning travel, and closing public facilities, schools, and physical places of business. Industrial activity, energy demand, and the number of vehicles on roads fell dramatically. Scientists have been monitoring the effect of these changes.

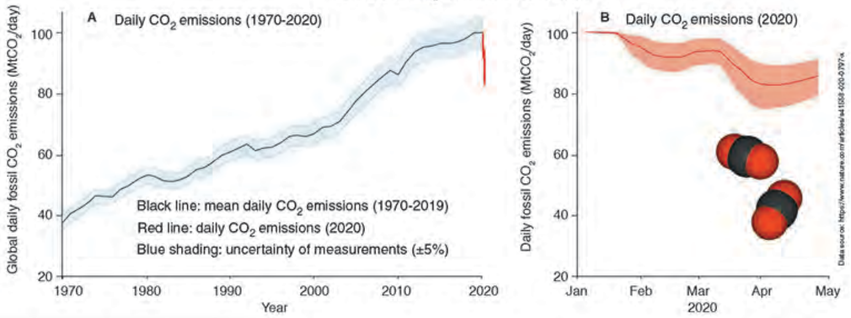
Italy was one of the first European countries to report Covid-19 cases. Italy went into a national lockdown in March 2020 in an attempt to reduce its spread. Within weeks a reduction in air pollution over Italy was observed. The images on the right show nitrogen dioxide concentrations over Italy in March 2019 (left) and during the lockdown in March 2020 (right). The main source of nitrogen dioxide from human activities is the combustion of fossil fuels (coal, gas and oil) especially fuel used in cars.



How has Covid-19 affected daily global CO_2 emissions?

The lockdown reduced the demand for energy and also reduced global carbon dioxide emissions (below). So, what does this mean for the environment? Many countries have signed the Kyoto Protocol, an international treaty designed to lower greenhouse gas emissions and help reduce the effects of global warming. Carbon dioxide is a greenhouse gas, so the reduced CO_2 emissions observed over lockdown are helpful in reducing the effects of global warming. However, for the Kyoto Protocol to succeed, the reduction in emissions must be sustained over a long period. Most researchers predict that maintaining the low emission levels seen between January and May 2020 will be very difficult once the world returns to a pre-pandemic level of activity.

Daily global CO_2 emissions (1970-2020)



...ental benefits observed during the Covid-19 lockdown:

...issions dropped significantly from 100 Mt CO_2 per day to around 85 Mt
...n nitrogen dioxide also dropped significantly as shown by the nitrogen oxide
...sphere in Italy between March 2019 and March 2020 (during lockdown).

2. Suggest why scientists do not think the reduction in emissions will be sustainable after the lockdowns are lifted:

The emissions dropped mostly because people stopped using cars and other forms of vehicular transport (because they were staying home) and some industries shut down or were reduced in output. Once the lockdowns are over, people will again be using vehicular transport and industry will resume full production capacity. It is entirely likely that the emissions will return to previous levels.

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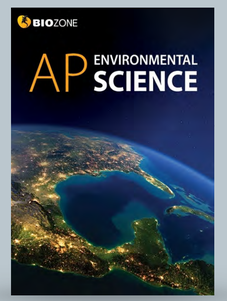
EIN-3 2.C



27 Factors Affecting Membrane Permeability

Key Question: How do temperature and solvents affect the structure of cellular membranes and alter their permeability?

Membrane permeability can be disrupted if membranes are subjected to high temperatures or solvents. At temperatures above the optimum, the membrane proteins become denatured. Alcohols, e.g. ethanol, can also denature proteins. In both instances, the denatured proteins no longer function properly and the membrane loses its selective permeability and becomes leaky. What's more, the combination of alcohol and high temperature can also dissolve lipids.

The aim and hypothesis

To investigate the effect of ethanol concentration on membrane permeability. The students hypothesized that the amount of pigment leaking from the beetroot cubes would increase with increasing ethanol concentration.

Background

Plant cells often contain a large central vacuole surrounded by a membrane called a **tonoplast**. In beetroot plants, the vacuole contains a water-soluble red pigment called betacyanin, which gives beetroot its color. If the tonoplast is damaged, the red pigment leaks out into the surrounding environment. The amount of leaked pigment relates to the amount of damage to the tonoplast.

Beetroot cubes

Method for determining effect of ethanol concentration on membrane permeability

Raw beetroot was cut into uniform cubes using a cork borer with a 4 mm internal diameter. The cubes were trimmed to 20 mm lengths and placed in a beaker of distilled water for 30 minutes. The following ethanol concentrations were prepared using serial dilution: 0, 6.25, 12.5, 25, 50, and 100%.

Eighteen clean test tubes were divided into six groups of three and labeled with one of the six ethanol concentrations. Three cm^3 of the appropriate ethanol solution was placed into each test tube. A beetroot cube (dried by blotting) was added to each test tube. The test tubes were covered with parafilm (plastic paraffin film with a paper backing) and left at room temperature. After one hour the beetroot cubes were removed and the absorbance measured at 477 nm. Results are tabulated, below.

Absorbance of beetroot samples at varying ethanol concentrations

Ethanol concentration (%)	Absorbance at 477 nm			Mean
	Sample 1	Sample 2	Sample 3	
0	0.014	0.038	0.038	
6.25	0.009	0.015	0.023	
12.5	0.010	0.041	0.018	
25	0.067	0.064	0.116	
50	0.945	1.100	0.731	
100	1.269	1.376	0.907	

1. Why is it important to wash the beetroot cubes in distilled water prior to carrying out the experiment? _____

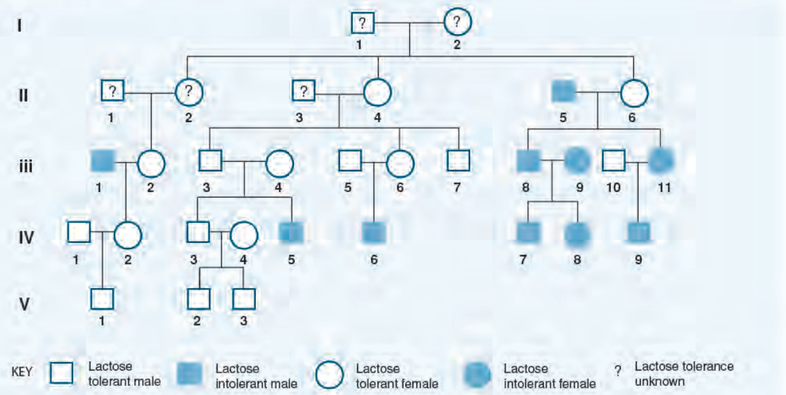
2. Complete the table above by calculating the mean absorbance for each ethanol concent

3. What is absorbance measuring and why is it increasing with increasing ethanol concentr

ENE-2 3.A | ENE-2 3.D | ENE-2 5.A | ENE-2 5.D | 26 | 253

The pedigree of lactose intolerance

Lactose intolerance is the inability to digest the milk sugar lactose. It occurs because some people do not produce lactase, the enzyme needed to break down lactose. The pedigree chart below was one of the original studies to determine the inheritance pattern of lactose intolerance.



2. Use an analysis of the pedigree above to make a claim about the inheritance pattern of lactose intolerance. Support your claim with at least two pieces of evidence:

3. (a) Use the Punnett square below to show the cross between III-10 and III-11 in the pedigree chart above. Use the capital letter L for the dominant allele and the letter l for the recessive allele.

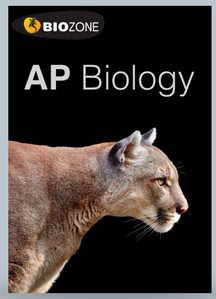
	Male alleles	
Female alleles		

(b) Explain how you can be certain about III-10's genotype:

...terozygous for lactose intolerance (LI)? Show your working or justification:

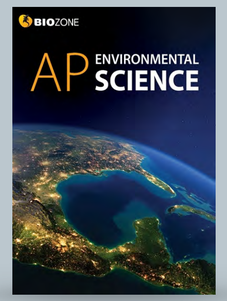
5. Is there any chance that parents III-8 and III-9 could produce a lactose tolerant child? Explain: _____

Many activities require students to analyze real second hand data or case studies to make conclusions



AP Environmental Science
Practical Investigations

- Investigations are varied:
  - Experiments
  - Paper practicals
  - Building models
  - Computer simulations
  - Computational models using spreadsheets
- No special kits are needed
- Equipment list provided in each book



Appendix 3: Equipment list

The equipment list provides the material and equipment needed per student, pair, or group.

1: The Living World: Ecosystems

INVESTIGATION 1.1
Carbon cycling simulation

Per student/pair
Computer
Spreadsheet application e.g. Excel

INVESTIGATION 1.2
Determining primary productivity in grass

Per student/pair
Pre-prepared plots of watered grass (20 x 40 cm)
Fertilizer (e.g. urea)
Light source (e.g. desk lamp)
Scissors
Ruler
Drying oven
Aluminum foil
Electronic balance

3: Populations

INVESTIGATION 3.1
Creating a model of logistic growth

Per student/pair
Computer
Spreadsheet application e.g. ®Excel

4: Earth Systems and Resources

INVESTIGATION 4.1
Identifying soil type part 1

Per student/pair
Samples of sand, silt, and clay.
Measuring cylinders
Stirring rods

INVESTIGATION 4.2
Identifying soil type part 2

Per student/pair
Three different soil samples.
Measuring cylinders
Stirring rods

INVESTIGATION 4.3
Measuring energy

Per student/pair
Torch
Protractor device to measure angles
Clamp stand or similar
Grid paper

5: Land and Water Use

INVESTIGATION 5.1
The Tragedy of the Commons

Per 4 students
Scissors. Packets of wrapped candy.

INVESTIGATION 5.2
Testing water runoff

Per student/pair
Container (500 mL yoghurt container, metal can or similar) with holes in the bottom for water to run through.
500 mL measuring cylinder.
Metal tray or ramp (or similar).
Container that will fit at bottom of ramp to collect water to drain to measuring cylinder.
Sponge or towel that will cover the metal tray of ramp.
Large floor tile that will cover the ramp.
Small tiles with enough total area to cover the ramp.
Enough gravel to cover the ramp.
Thin sponge or sponges that will cover the ramp.

6: Energy Resources and Consumption

INVESTIGATION 6.1
Home electricity survey

No equipment requirements

INVESTIGATION 6.2
Using M&M's® to model half lives

Per group
100 M&Ms®
1 x lidded container
1 x plate

INVESTIGATION 6.3
Solar heating house

Per student/pair
Computer
Energy 2D software
https://energy.concord.org/energy2d/

INVESTIGATION 6.4
Solar power

Per student/pair
Computer
Energy 2D software
https://energy.concord.org/energy2d/

7: Atmospheric Pollution

INVESTIGATION 7.1
Measuring particles in the air

Per student/pair
Thick cardboard sheets
Scissors
Grid paper
Petroleum jelly or similar
Stereomicroscope or magnifying glass
Tape or Blu-tak

8: Aquatic and Terrestrial Pollution

INVESTIGATION 8.1
Cleaning up oil spills

Per group of students
4 liter bucket or container
60 mL vegetable oil
Food coloring
Mixing container (e.g. 100 mL beaker)
Craft or ice block stick
Oil clean up material e.g. cotton or paper towels, straw,
Flexible straws
Detergent

INVESTIGATION 8.2
Recording your trash

Per student
Spill proof bags
Latex or chemical proof gloves

INVESTIGATION 8.3
The role of microbes in sewage treatment

Per student/pair/group
1 x stirring rod
8 x 1 L beakers
Aeration unit with four tubes
Plastic wrap
Water bath
Glucose test paper strips
14 g dried *Saccharomyces* yeast
40 mL warm water
500 mL glucose solution (100 g/L)

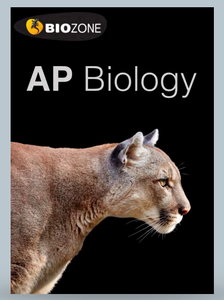
9: Global Change

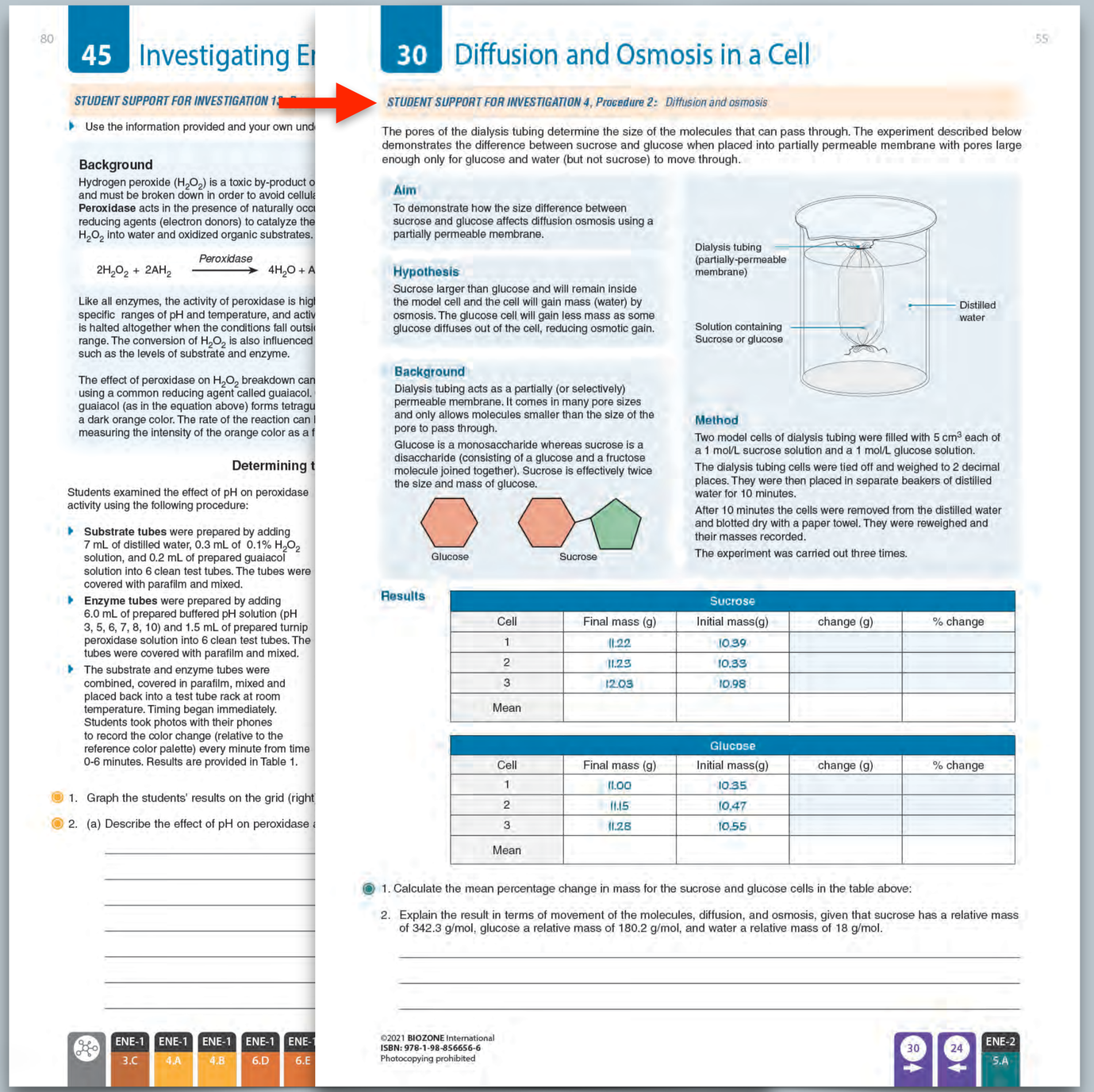
INVESTIGATION 9.1
Albedo and ice cube melting

Per pair/group
2 x Florence or Erlenmeyer flasks
Black paint
Aluminum foil
Ice cubes
2 x thermometers
60W tungsten lamp (optional)
Timer

AP Biology
Supporting investigations

- Practical activities **support** the **13 AP Biology investigations**
- Not designed to replace the practicals
- Prepare students for the AP Practicals
- Integrated in context
- The investigation and procedure are identified at the top of the page.





80

45 Investigating E

STUDENT SUPPORT FOR INVESTIGATION 1

Use the information provided and your own und

Background

Hydrogen peroxide (H_2O_2) is a toxic by-product o and must be broken down in order to avoid cellul **Peroxidase** acts in the presence of naturally occ reducing agents (electron donors) to catalyze the H_2O_2 into water and oxidized organic substrates.

$2H_2O_2 + 2AH_2 \xrightarrow{Peroxidase} 4H_2O + A$

Like all enzymes, the activity of peroxidase is hig specific ranges of pH and temperature, and activ is halted altogether when the conditions fall outsi range. The conversion of H_2O_2 is also influenced such as the levels of substrate and enzyme.

The effect of peroxidase on H_2O_2 breakdown can using a common reducing agent called guaiacol. guaiacol (as in the equation above) forms tetragu a dark orange color. The rate of the reaction can measuring the intensity of the orange color as a f

Determining t

Students examined the effect of pH on peroxidase activity using the following procedure:

- **Substrate tubes** were prepared by adding 7 mL of distilled water, 0.3 mL of 0.1% H_2O_2 solution, and 0.2 mL of prepared guaiacol solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.
- **Enzyme tubes** were prepared by adding 6.0 mL of prepared buffered pH solution (pH 3, 5, 6, 7, 8, 10) and 1.5 mL of prepared turnip peroxidase solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.
- The substrate and enzyme tubes were combined, covered in parafilm, mixed and placed back into a test tube rack at room temperature. Timing began immediately. Students took photos with their phones to record the color change (relative to the reference color palette) every minute from time 0-6 minutes. Results are provided in Table 1.

1. Graph the students' results on the grid (right
2. (a) Describe the effect of pH on peroxidase

ENE-1 3.C | ENE-1 4.A | ENE-1 4.B | ENE-1 6.D | ENE- 6.E

30 Diffusion and Osmosis in a Cell

55

STUDENT SUPPORT FOR INVESTIGATION 4, Procedure 2: Diffusion and osmosis

The pores of the dialysis tubing determine the size of the molecules that can pass through. The experiment described below demonstrates the difference between sucrose and glucose when placed into partially permeable membrane with pores large enough only for glucose and water (but not sucrose) to move through.

Aim

To demonstrate how the size difference between sucrose and glucose affects diffusion osmosis using a partially permeable membrane.

Hypothesis

Sucrose larger than glucose and will remain inside the model cell and the cell will gain mass (water) by osmosis. The glucose cell will gain less mass as some glucose diffuses out of the cell, reducing osmotic gain.

Background

Dialysis tubing acts as a partially (or selectively) permeable membrane. It comes in many pore sizes and only allows molecules smaller than the size of the pore to pass through.

Glucose is a monosaccharide whereas sucrose is a disaccharide (consisting of a glucose and a fructose molecule joined together). Sucrose is effectively twice the size and mass of glucose.

Glucose Sucrose

Method

Two model cells of dialysis tubing were filled with 5 cm^3 each of a 1 mol/L sucrose solution and a 1 mol/L glucose solution.

The dialysis tubing cells were tied off and weighed to 2 decimal places. They were then placed in separate beakers of distilled water for 10 minutes.

After 10 minutes the cells were removed from the distilled water and blotted dry with a paper towel. They were reweighed and their masses recorded.

The experiment was carried out three times.

Results

Sucrose				
Cell	Final mass (g)	Initial mass(g)	change (g)	% change
1	11.22	10.39		
2	11.23	10.33		
3	12.03	10.98		
Mean				

Glucose				
Cell	Final mass (g)	Initial mass(g)	change (g)	% change
1	11.00	10.35		
2	11.15	10.47		
3	11.28	10.55		
Mean				

1. Calculate the mean percentage change in mass for the sucrose and glucose cells in the table above:
2. Explain the result in terms of movement of the molecules, diffusion, and osmosis, given that sucrose has a relative mass of 342.3 g/mol, glucose a relative mass of 180.2 g/mol, and water a relative mass of 18 g/mol.

ISBN: 978-1-98-856656-6

30 | 24 | ENE-2 5.A

SKILLS SUPPORT

Science Practices

Learning Objectives

Developing understanding

CONTENT: Science practices describe the things you should be able to do while you are covering the content of this AP® Biology course. They represent the practices that underlie the study of any science and are categorized into skills. See the table on page xii at the front of this book for a summary of skills and practices and a key to identifying them in the activities.

SKILLS: This supporting unit provides a background reference for the skills you will use throughout this course of study. You will develop competency in these skills as you complete the activities in this book. These skills form the basis of the tasks in the AP® Biology exam.

1 Concept explanation ..... activity 250

Key: Use verbal and/or written skills

- ☐ V. In describing biological concepts or processes you will need to identify relevant features of a concept or process.
- ☐ W. To explain biological concepts or processes you will need to provide explanatory detail relating to the concept or process, rather than just describing its components.
- ☐ X. To explain biological concepts/processes in applied contexts you must relate your explanations to real world situations.

2 Analyze visual representations..... activity 251

Key: Create and use visual representations

- ☐ A. Describing the features of a biological concept, process, or model represented visually might involve describing the features of a diagram or a plot.
- ☐ B. Explaining relationships between characteristics of concepts/processes represented visually might involve comparing or predicting patterns or trends or explaining a visual model.
- ☐ C. Explaining how a visual representation relates to broader principles, concepts, processes, or theories might involve drawing a conclusion based on principles or concepts in the model or representation.
- ☐ D. Representing relationships within biological models might involve interacting with a mathematical formula or chemical equation, or creating a diagram or flowchart.

3 Questions and methods ..... activity 252

Key: Pose, refine, and evaluate scientific questions

- ☐ A. Identifying/posing a testable question means asking, refining, and evaluating questions about natural phenomena and investigating answers, e.g. through experimentation.
- ☐ B. You should be able to state null and alternative hypotheses and predict the results of an experiment.
- ☐ C. Identifying experimental procedures includes identifying variables, and identifying and justifying controls.
- ☐ D. To make observations or collect data from laboratory setups you will need to collect first-hand data from observations.
- ☐ E. Proposing a new investigation may be based on evaluating the evidence from an experiment or the design/methods.

4 Representing and describing data ... activity 253

Key: Plotting and describing different types of data

- ☐ A. Constructing a graph/plot/chart involves correct choice of plot type (e.g. line or bar graph), orientation, labeling, units, scaling, plotting, and trend line (for line graphs).
- ☐ B. Describing data from a table or graph may involve identifying specific data points, describing trends or patterns in the data, or describing the relationships between variables.

5 Statistical tests and data analysis..... activity 254

Key: Use mathematics to solve problems and analyze data

- ☐ A. Performing mathematical calculations includes solving mathematical equations embedded in the curriculum, and calculating means, rates, ratios, and percentages.
- ☐ B. Using confidence intervals and/or error bars involves determining the significance of difference between means.
- ☐ C. Performing chi-square hypothesis-testing for appropriate data involves calculating the statistic, determining the *p*-value for the set of data, and drawing conclusions based on comparing the chi-square value to the *p*-value.
- ☐ D. Using data to evaluate a hypothesis or its prediction involves identifying when to reject or accept the null hypothesis (H_0) in favor of accepting or rejecting the alternative hypothesis (H_A). Given data, you should be able to make and justify predictions.

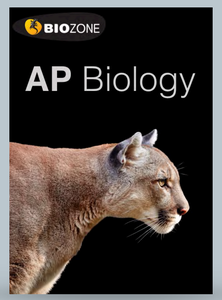
6 Argumentation ..... activity 255

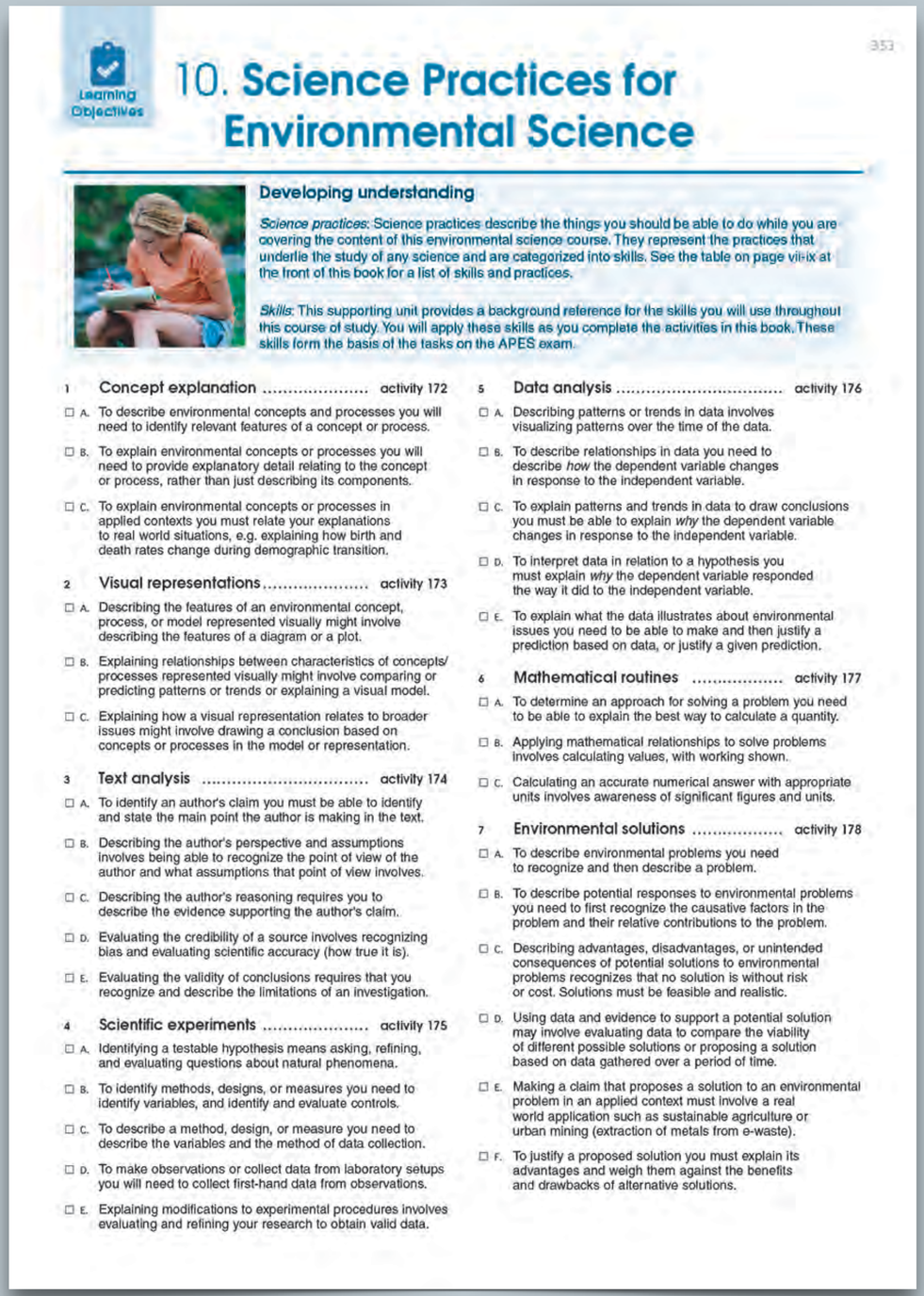
Key: Write & evaluate scientific descriptions & explanations

- ☐ A. Making a scientific claim may involve describing what is being shown in a graph or table, or drawing conclusions for your own or others' experimental results.
- ☐ B. Supporting a claim with evidence from biological principles, concepts, processes or data involves explaining how the claim is supported by the biological evidence provided.
- ☐ C. Providing reasoning to justify a claim by connecting evidence to theories involves explaining how the data relate to a biological theory, or explaining how reasoning supports the claim. For example, an analysis of the peppered moth experiments (original and follow-up).
- ☐ D. Explaining the relationship between experimental results and wider biological concepts, processes, or theories may involve explaining how the results of an investigation explain a biological principle, or connecting observational data to a broader theory. For example, connecting experimental evidence to endosymbiotic theory.
- ☐ E. Predicting the causes or effects of a change in, or disruption to, a biological system could be based on biological concepts or processes, visual representations (e.g. graphs), or data. For example, it might involve predicting the effect of removing a keystone species from an ecosystem, predicting the effect of increased temperature on photosynthetic rate, or interpreting a graph to predict the response of an organism to a change in the external environment.

AP Biology: Support for Science Practices

- **Dedicated chapter** to support students with **math and science skills**





Learning Objectives

353

10. Science Practices for Environmental Science

Developing understanding

Science practices: Science practices describe the things you should be able to do while you are covering the content of this environmental science course. They represent the practices that underlie the study of any science and are categorized into skills. See the table on page vii-ix at the front of this book for a list of skills and practices.

Skills: This supporting unit provides a background reference for the skills you will use throughout this course of study. You will apply these skills as you complete the activities in this book. These skills form the basis of the tasks on the APES exam.

1 Concept explanation ..... activity 172

- ☐ A. To describe environmental concepts and processes you will need to identify relevant features of a concept or process.
- ☐ B. To explain environmental concepts or processes you will need to provide explanatory detail relating to the concept or process, rather than just describing its components.
- ☐ C. To explain environmental concepts or processes in applied contexts you must relate your explanations to real world situations, e.g. explaining how birth and death rates change during demographic transition.

2 Visual representations ..... activity 173

- ☐ A. Describing the features of an environmental concept, process, or model represented visually might involve describing the features of a diagram or a plot.
- ☐ B. Explaining relationships between characteristics of concepts/processes represented visually might involve comparing or predicting patterns or trends or explaining a visual model.
- ☐ C. Explaining how a visual representation relates to broader issues might involve drawing a conclusion based on concepts or processes in the model or representation.

3 Text analysis ..... activity 174

- ☐ A. To identify an author's claim you must be able to identify and state the main point the author is making in the text.
- ☐ B. Describing the author's perspective and assumptions involves being able to recognize the point of view of the author and what assumptions that point of view involves.
- ☐ C. Describing the author's reasoning requires you to describe the evidence supporting the author's claim.
- ☐ D. Evaluating the credibility of a source involves recognizing bias and evaluating scientific accuracy (how true it is).
- ☐ E. Evaluating the validity of conclusions requires that you recognize and describe the limitations of an investigation.

4 Scientific experiments ..... activity 175

- ☐ A. Identifying a testable hypothesis means asking, refining, and evaluating questions about natural phenomena.
- ☐ B. To identify methods, designs, or measures you need to identify variables, and identify and evaluate controls.
- ☐ C. To describe a method, design, or measure you need to describe the variables and the method of data collection.
- ☐ D. To make observations or collect data from laboratory setups you will need to collect first-hand data from observations.
- ☐ E. Explaining modifications to experimental procedures involves evaluating and refining your research to obtain valid data.

5 Data analysis ..... activity 176

- ☐ A. Describing patterns or trends in data involves visualizing patterns over the time of the data.
- ☐ B. To describe relationships in data you need to describe *how* the dependent variable changes in response to the independent variable.
- ☐ C. To explain patterns and trends in data to draw conclusions you must be able to explain *why* the dependent variable changes in response to the independent variable.
- ☐ D. To interpret data in relation to a hypothesis you must explain *why* the dependent variable responded the way it did to the independent variable.
- ☐ E. To explain what the data illustrates about environmental issues you need to be able to make and then justify a prediction based on data, or justify a given prediction.

6 Mathematical routines ..... activity 177

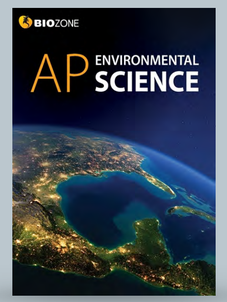
- ☐ A. To determine an approach for solving a problem you need to be able to explain the best way to calculate a quantity.
- ☐ B. Applying mathematical relationships to solve problems involves calculating values, with working shown.
- ☐ C. Calculating an accurate numerical answer with appropriate units involves awareness of significant figures and units.

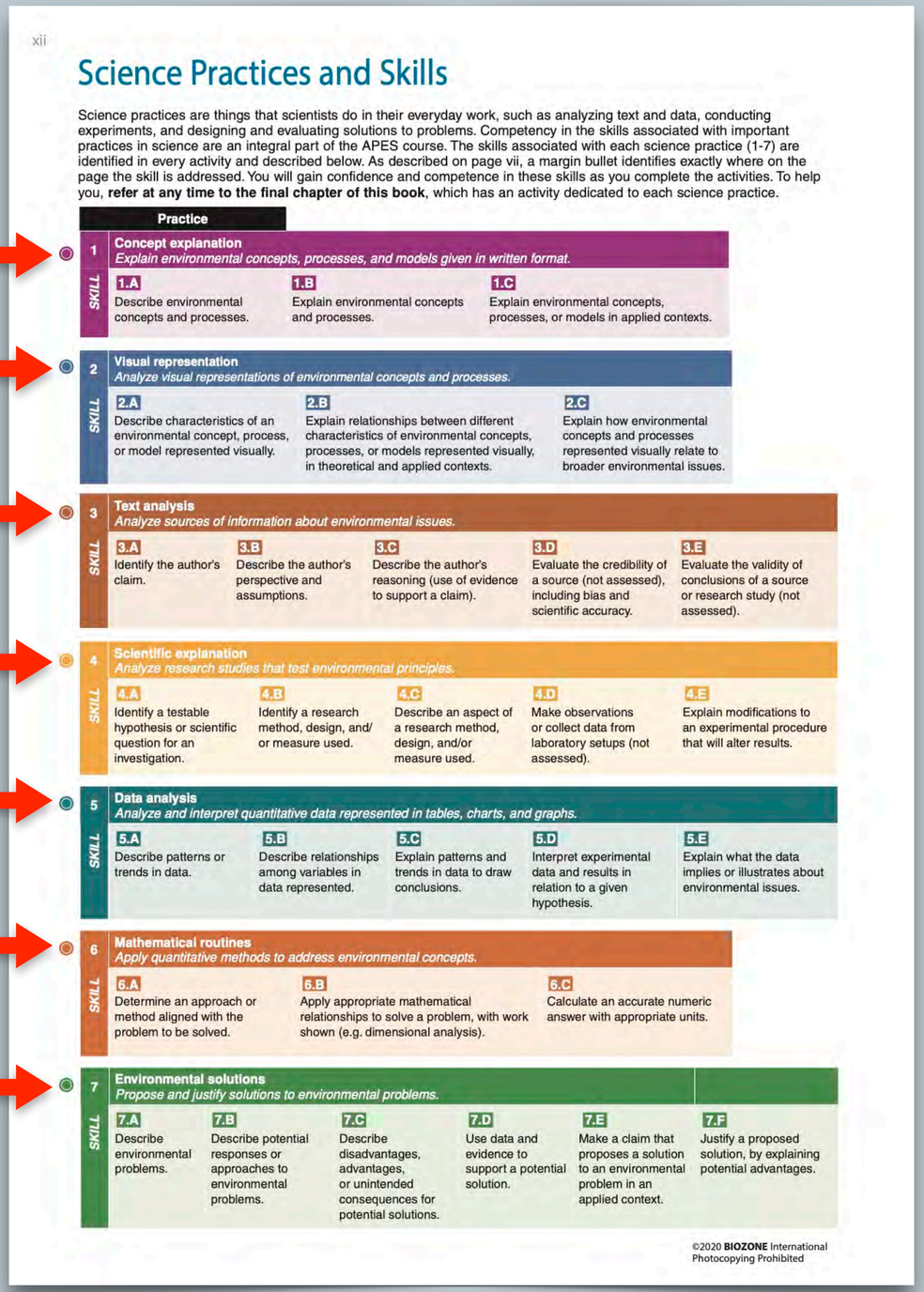
7 Environmental solutions ..... activity 178

- ☐ A. To describe environmental problems you need to recognize and then describe a problem.
- ☐ B. To describe potential responses to environmental problems you need to first recognize the causative factors in the problem and their relative contributions to the problem.
- ☐ C. Describing advantages, disadvantages, or unintended consequences of potential solutions to environmental problems recognizes that no solution is without risk or cost. Solutions must be feasible and realistic.
- ☐ D. Using data and evidence to support a potential solution may involve evaluating data to compare the viability of different possible solutions or proposing a solution based on data gathered over a period of time.
- ☐ E. Making a claim that proposes a solution to an environmental problem in an applied context must involve a real world application such as sustainable agriculture or urban mining (extraction of metals from e-waste).
- ☐ F. To justify a proposed solution you must explain its advantages and weigh them against the benefits and drawbacks of alternative solutions.

APES: Support for Science Practices

- **Dedicated chapter** to support students with **math and science skills**





xii

Science Practices and Skills

Science practices are things that scientists do in their everyday work, such as analyzing text and data, conducting experiments, and designing and evaluating solutions to problems. Competency in the skills associated with important practices in science are an integral part of the APES course. The skills associated with each science practice (1-7) are identified in every activity and described below. As described on page vii, a margin bullet identifies exactly where on the page the skill is addressed. You will gain confidence and competence in these skills as you complete the activities. To help you, **refer at any time to the final chapter of this book**, which has an activity dedicated to each science practice.

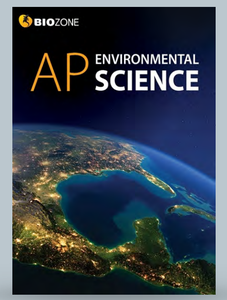
Practice						
1	**Concept explanation** *Explain environmental concepts, processes, and models given in written format.*					
SKILL	1.A Describe environmental concepts and processes.	1.B Explain environmental concepts and processes.	1.C Explain environmental concepts, processes, or models in applied contexts.			
2	**Visual representation** *Analyze visual representations of environmental concepts and processes.*					
SKILL	2.A Describe characteristics of an environmental concept, process, or model represented visually.	2.B Explain relationships between different characteristics of environmental concepts, processes, or models represented visually, in theoretical and applied contexts.	2.C Explain how environmental concepts and processes represented visually relate to broader environmental issues.			
3	**Text analysis** *Analyze sources of information about environmental issues.*					
SKILL	3.A Identify the author's claim.	3.B Describe the author's perspective and assumptions.	3.C Describe the author's reasoning (use of evidence to support a claim).	3.D Evaluate the credibility of a source (not assessed), including bias and scientific accuracy.	3.E Evaluate the validity of conclusions of a source or research study (not assessed).	
4	**Scientific explanation** *Analyze research studies that test environmental principles.*					
SKILL	4.A Identify a testable hypothesis or scientific question for an investigation.	4.B Identify a research method, design, and/or measure used.	4.C Describe an aspect of a research method, design, and/or measure used.	4.D Make observations or collect data from laboratory setups (not assessed).	4.E Explain modifications to an experimental procedure that will alter results.	
5	**Data analysis** *Analyze and interpret quantitative data represented in tables, charts, and graphs.*					
SKILL	5.A Describe patterns or trends in data.	5.B Describe relationships among variables in data represented.	5.C Explain patterns and trends in data to draw conclusions.	5.D Interpret experimental data and results in relation to a given hypothesis.	5.E Explain what the data implies or illustrates about environmental issues.	
6	**Mathematical routines** *Apply quantitative methods to address environmental concepts.*					
SKILL	6.A Determine an approach or method aligned with the problem to be solved.	6.B Apply appropriate mathematical relationships to solve a problem, with work shown (e.g. dimensional analysis).	6.C Calculate an accurate numeric answer with appropriate units.			
7	**Environmental solutions** *Propose and justify solutions to environmental problems.*					
SKILL	7.A Describe environmental problems.	7.B Describe potential responses or approaches to environmental problems.	7.C Describe disadvantages, advantages, or unintended consequences for potential solutions.	7.D Use data and evidence to support a potential solution.	7.E Make a claim that proposes a solution to an environmental problem in an applied context.	7.F Justify a proposed solution, by explaining potential advantages.

APES: Support for Science Practices

- **Color coding** identifies a particular skill … look out for where they appear on a page
- The colors match the coding in the AP Biology CED

Glossary

- Key terms and their definitions are provided.
- Encourage students to use the glossary to:
  - Build their scientific vocabulary
  - Look up terms if they are unsure of their meaning



Appendix 2: Glossary

A

abiotic factor
Non-living component of the environment.

acid rain
Rain containing acids that form in the atmosphere when industrial gas emissions combine with water.

adaptation
A genetically determined characteristic that improves an organism's ability to survive and reproduce under prevailing environmental conditions.

albedo
A measure of how much light that hits a surface is reflected without being absorbed.

anoxic
Having no oxygen

antigenic drift
A mechanism for variation by viruses, where incremental mutations cause small changes in the virus over time.

antigenic shift
Major, rapid change caused when two viral strains (or different viruses) combine to form a new subtype.

anthropogenic
Of, relating to, or resulting from the influence of human beings on nature.

aquaculture
The rearing of aquatic animals or the cultivation of aquatic plants for food.

asthenosphere
The upper layer of the Earth's mantle, which lies below the lithosphere and is fluid-like with viscous and elastic behavior.

atmosphere, Earth's
The envelope of gases surrounding Earth.

B

bioaccumulation
The accumulation over time of a substance (especially a contaminant, such as a heavy metal) in a living organism.

biofuel
A fuel derived from biomass, such as plant or algae material or animal waste.

biomagnification
The process by which pesticides and other substances become more concentrated in each link of the food chain.

biome
Major regional ecological community of plants and animals.

biotic factor
Living component of the environment.

biotic potential
The capacity of a population of organisms to increase in numbers under optimum environmental conditions.

biochemical oxygen demand (BOD)
The amount of dissolved oxygen needed by aerobic biological organisms to break down organic material in a given water sample at certain temperature over a specific time.

C

carrying capacity
Number of individual organisms the resources of a given area can support, usually through the most unfavorable period of the year.

chlorofluorocarbon (CFC)
Any of several simple gaseous compounds that contain carbon, chlorine, fluorine, and sometimes hydrogen; a major cause of stratospheric ozone depletion.

commensalism
Relationship between species that is beneficial to one, but neutral or of no benefit to the other.

community
The living component of an ecosystem.

competition
Any interaction that is mutually detrimental to both participants, occuring between species that share limited resources.

condensation
The transformation of water vapor to a liquid state.

consumer
Any organism that lives on other organisms, dead or alive.

control (experimental)
A 'treatment' in an experiment designed to evaluate the effect of independent variable on the response variable. It usually lacks the variable being tested but is otherwise the same as all other treatments.

convergent plate boundary
A tectonic boundary where two plates are moving toward each other and colliding.

Coriolis effect
Physical consequence of the law of conservation of angular momentum; as a result of the Earth's rotation, a moving object veers to the right in the Northern Hemisphere and to the left in the Southern Hemisphere relative to the Earth's surface.

crust, Earth's
The outermost layer of the Earth, composed of a great variety of igneous, metamorphic, and sedimentary rocks.

D

decomposer
Organism that obtains energy from the breakdown of dead organic matter to simpler substances; most precisely refers to bacteria and fungi.

denitrification
Reduction of nitrates and nitrites to nitrogen by microorganisms.

dependent variable
The variable being tested and measured in an experiment, whose value depends on that of the independent variable.

detritivore
Organism that feeds on dead organic matter; usually applies to detritus-feeding organisms other than bacteria and fungi.

divergent plate boundary
A tectonic boundary where two plates are moving away from each other and new crust is forming from magma that rises to the Earth's surface between the two plates.

E

ecological succession
The process by which the structure of a biological community evolves over time. May be primary or secondary.

endangered species
A species of animal or plant that is facing a very high risk of extinction in the wild.

endemic disease
A disease that is restricted to a given region.

El Niño–Southern Oscillation
A recurring climate pattern involving changes in the temperature of waters in the central and eastern tropical Pacific Ocean.

epidemic
Rapid spread of a bacterial or viral disease in a human population.

erosion
The action of surface processes (water, wind or ice) that removes soil, rock, or dissolved material from one location and then transports it to another location.

estuary
A partially enclosed embayment where freshwater and seawater meet and mix.

eutrophic
Term applied to a body of water with high nutrient content and high productivity.

eutrophication
Nutrient enrichment of a body of water.

evaporation
Loss of water vapor from soil or open water or another exposed surface.

exponential growth
Instantaneous rate of population growth, expressed as a proportional increase per unit of time.

extinction
The dying out or extermination of a species.

extirpation
Local extinction; when a species ceases to exist in a chosen area of study, but still exists elsewhere.

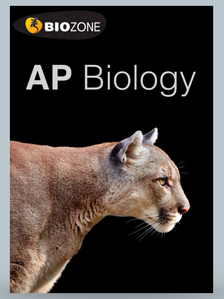
F

fertility
An organism's natural capacity to produce offspring.

fossil fuel
A natural fuel such as coal or gas, formed in the geological past from the remains of living organisms.

Support for investigations

- Activities providing support for specific aspects of each of the **13 investigations** are integrated in context throughout.
- The investigation **number** and **procedure** are identified at the top of the page.



45 Investigating Enzyme Activity

STUDENT SUPPORT FOR INVESTIGATION 13, Procedure 2: *Investigating the effect of p*

- Use the information provided and your own understanding of enzymes to investigat

Background

Hydrogen peroxide (H_2O_2) is a toxic by-product of respiration and must be broken down in order to avoid cellular damage. **Peroxidase** acts in the presence of naturally occurring organic reducing agents (electron donors) to catalyze the breakdown of H_2O_2 into water and oxidized organic substrates.

$$2H_2O_2 + 2AH_2 \xrightarrow{Peroxidase} 4H_2O + A_2$$

Like all enzymes, the activity of peroxidase is highest within specific ranges of pH and temperature, and activity drops off or is halted altogether when the conditions fall outside of the optimal range. The conversion of H_2O_2 is also influenced by other factors such as the levels of substrate and enzyme.

The effect of peroxidase on H_2O_2 breakdown can be studied using a common reducing agent called guaiacol. Oxidation of guaiacol (as in the equation above) forms tetraguaiacol, which is a dark orange color. The rate of the reaction can be followed by measuring the intensity of the orange color as a function of time.

Increasing leve

A time-color pa
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hydrogen perox
recorded at set

Determining the effect of pH on peroxidas

Students examined the effect of pH on peroxidase activity using the following procedure:

- **Substrate tubes** were prepared by adding 7 mL of distilled water, 0.3 mL of 0.1% H_2O_2 solution, and 0.2 mL of prepared guaiacol solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.
- **Enzyme tubes** were prepared by adding 6.0 mL of prepared buffered pH solution (pH 3, 5, 6, 7, 8, 10) and 1.5 mL of prepared turnip peroxidase solution into 6 clean test tubes. The tubes were covered with parafilm and mixed.
- The substrate and enzyme tubes were combined, covered in parafilm, mixed and placed back into a test tube rack at room temperature. Timing began immediately. Students took photos with their phones to record the color change (relative to the reference color palette) every minute from time 0-6 minutes. Results are provided in Table 1.

Table 1. Effect of pH on perox

	Col	
	0 min	1 min
pH 3	0	2
pH 5	0	2
pH 6	0	3
pH 7	0	3
pH 8	0	3
pH 10	0	0

1. Graph the students' results on the grid (right).
2. (a) Describe the effect of pH on peroxidase activity:

ENE-1 3.C | ENE-1 4.A | ENE-1 4.B | ENE-1 6.D | ENE-1 6.E | 43 | 253

30 Diffusion and Osmosis in a Cell

STUDENT SUPPORT FOR INVESTIGATION 4, Procedure 2: *Diffusion and osmosis*

The pores of the dialysis tubing determine the size of the molecules that can pass through. The experiment described below demonstrates the difference between sucrose and glucose when placed into partially permeable membrane with pores large enough only for glucose and water (but not sucrose) to move through.

Aim

To demonstrate how the size difference between sucrose and glucose affects diffusion osmosis using a partially permeable membrane.

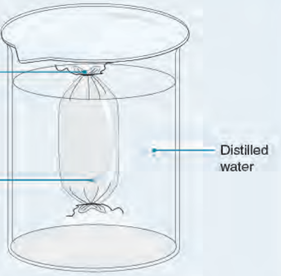
Hypothesis

Sucrose larger than glucose and will remain inside the model cell and the cell will gain mass (water) by osmosis. The glucose cell will gain less mass as some glucose diffuses out of the cell, reducing osmotic gain.

Background

Dialysis tubing acts as a partially (or selectively) permeable membrane. It comes in many pore sizes and only allows molecules smaller than the size of the pore to pass through.

Glucose is a monosaccharide whereas sucrose is a disaccharide (consisting of a glucose and a fructose molecule joined together). Sucrose is effectively twice the size and mass of glucose.



Method

Two model cells of dialysis tubing were filled with 5 cm^3 each of a 1 mol/L sucrose solution and a 1 mol/L glucose solution.

The dialysis tubing cells were tied off and weighed to 2 decimal places. They were then placed in separate beakers of distilled water for 10 minutes.

After 10 minutes the cells were removed from the distilled water and blotted dry with a paper towel. They were reweighed and their masses recorded.

The experiment was carried out three times.

Results

Sucrose				
Cell	Final mass (g)	Initial mass(g)	change (g)	% change
1	11.22	10.39		
2	11.23	10.33		
3	12.03	10.98		
Mean				

Glucose				
Cell	Final mass (g)	Initial mass(g)	change (g)	% change
1	11.00	10.35		
2	11.15	10.47		
3	11.28	10.55		
Mean				

1. Calculate the mean percentage change in mass for the sucrose and glucose cells in the table above:
2. Explain the result in terms of movement of the molecules, diffusion, and osmosis, given that sucrose has a relative mass of 342.3 g/mol, glucose a relative mass of 180.2 g/mol, and water a relative mass of 18 g/mol.

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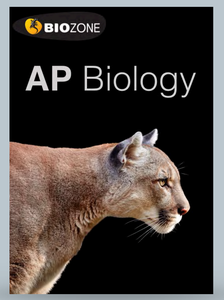
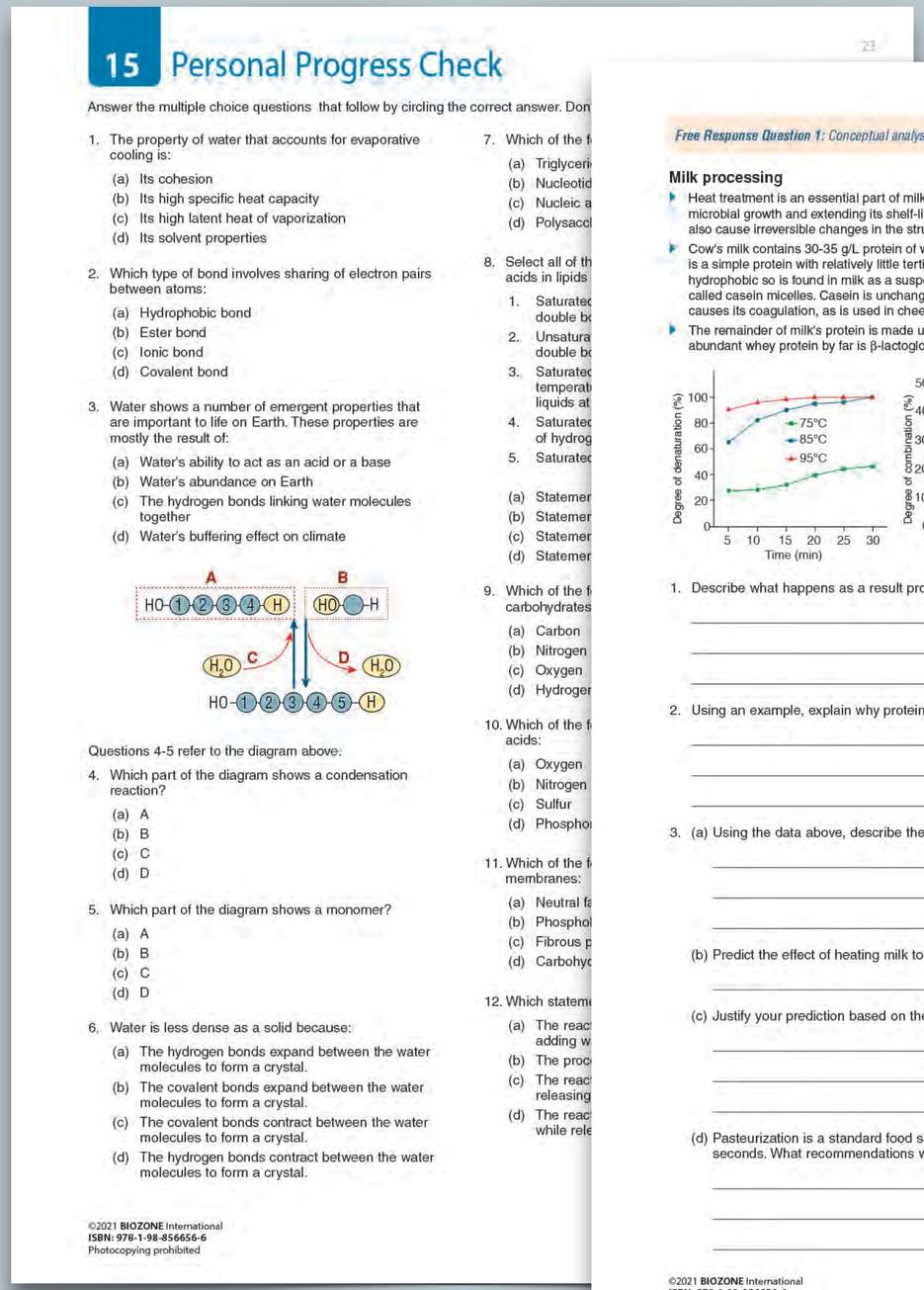
30 | 24 | ENE-2 5.A

ASSESSMENTS

Assessment

- **Personal Progress Checks** conclude each unit.
- These assessments follow the format stipulated in the CED.
  - **Multiple choice** questions
  - **Free response** questions
- Use as **formative assessment** or for **exam practice**.





15 Personal Progress Check

Answer the multiple choice questions that follow by circling the correct answer. Don

1. The property of water that accounts for evaporative cooling is:
   (a) Its cohesion
   (b) Its high specific heat capacity
   (c) Its high latent heat of vaporization
   (d) Its solvent properties

2. Which type of bond involves sharing of electron pairs between atoms:
   (a) Hydrophobic bond
   (b) Ester bond
   (c) Ionic bond
   (d) Covalent bond

3. Water shows a number of emergent properties that are important to life on Earth. These properties are mostly the result of:
   (a) Water's ability to act as an acid or a base
   (b) Water's abundance on Earth
   (c) The hydrogen bonds linking water molecules together
   (d) Water's buffering effect on climate

Questions 4-5 refer to the diagram above.

4. Which part of the diagram shows a condensation reaction?
   (a) A
   (b) B
   (c) C
   (d) D

5. Which part of the diagram shows a monomer?
   (a) A
   (b) B
   (c) C
   (d) D

6. Water is less dense as a solid because:
   (a) The hydrogen bonds expand between the water molecules to form a crystal.
   (b) The covalent bonds expand between the water molecules to form a crystal.
   (c) The covalent bonds contract between the water molecules to form a crystal.
   (d) The hydrogen bonds contract between the water molecules to form a crystal.

7. Which of the f
   (a) Triglyceri
   (b) Nucleotid
   (c) Nucleic a
   (d) Polysacc

8. Select all of th
   acids in lipids
   1. Saturated
   2. Unsatura
   3. Saturated
   4. Saturated
   5. Saturated
   (a) Statemer
   (b) Statemer
   (c) Statemer
   (d) Statemer

9. Which of the f
   carbohydrates
   (a) Carbon
   (b) Nitrogen
   (c) Oxygen
   (d) Hydroger

10. Which of the f
    acids:
    (a) Oxygen
    (b) Nitrogen
    (c) Sulfur
    (d) Phospho

11. Which of the f
    membranes:
    (a) Neutral fa
    (b) Phospho
    (c) Fibrous p
    (d) Carbohyd

12. Which stateme
    (a) The reac
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    (d) The reac
    while rele

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Free Response Question 1: *Conceptual analysis*

Milk processing

- Heat treatment is an essential part of milk processing by inhibiting microbial growth and extending its shelf-life. However, heating raw milk can also cause irreversible changes in the structure of the milk proteins.
- Cow's milk contains 30-35 g/L protein of which 80-85% is casein. Casein is a simple protein with relatively little tertiary structure. It is relatively hydrophobic so is found in milk as a suspension of spherical particles called casein micelles. Casein is unchanged by heat treatment but low pH causes its coagulation, as is used in cheese making.
- The remainder of milk's protein is made up of whey proteins. The most abundant whey protein by far is β-lactoglobulin (β-lg).

β-lactoglobulin

β-lg is a relatively small protein and makes up most of the volume of whey proteins in milk. It is acid stable but when exposed to heat it forms large aggregates by associating with the casein micelles. These aggregations compromise milk quality and digestibility in people with reduced digestive ability.

Researchers wanted to study the effect of different heat treatments on the extent of whey protein denaturation and combination with casein micelles. Raw milk was subjected to heat treatments at different temperatures (75-95°C) and for varying lengths of time (0-30 minutes). The proportion of whey proteins denatured or combining with casein micelles was determined.

1. Describe what happens as a result protein denaturation and identify likely causes: _____

2. Using an example, explain why protein denaturation causes a change in the properties or biological function of a protein:

3. (a) Using the data above, describe the effect of increasing temperature and heating time on the whey proteins in milk:

   (b) Predict the effect of heating milk to 100°C for 45 minutes: _____

   (c) Justify your prediction based on the data presented:

   (d) Pasteurization is a standard food safety process and involves heating milk for 63°C for 30 minutes or 72°C for 15 seconds. What recommendations would you make to food processors when receiving raw milk for processing?

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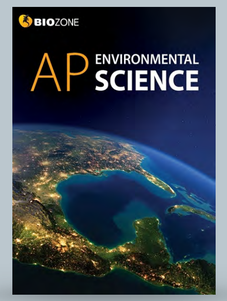
College Board-style assessments

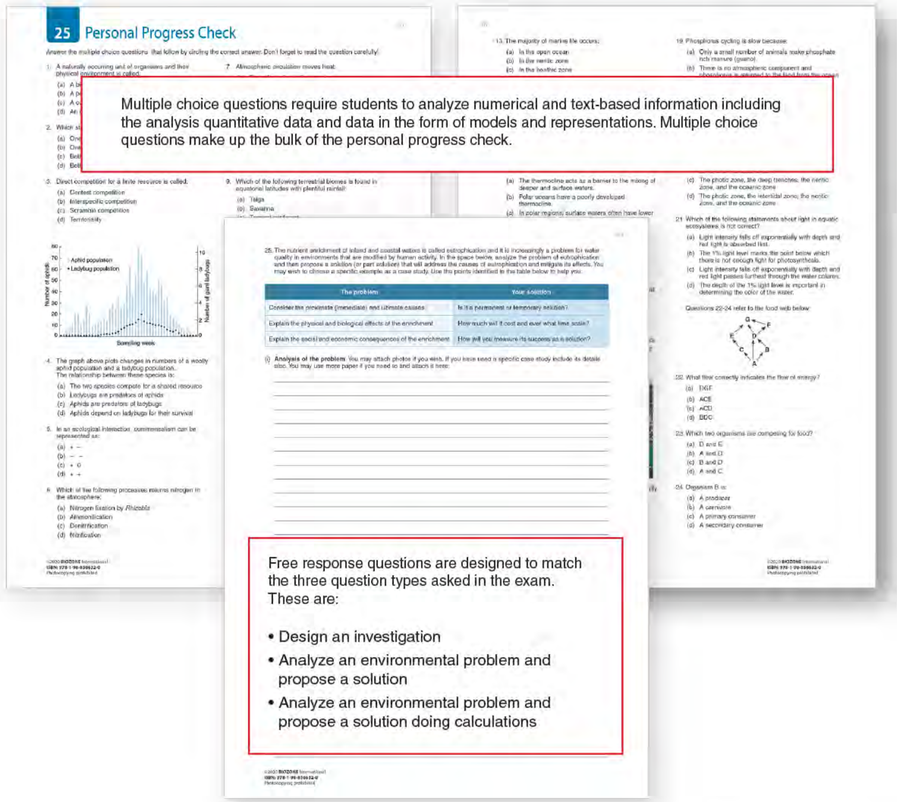
- **Personal Progress Checks** conclude each unit
- Assessment follows the stipulated CED format:
  - **Multiple choice** questions
  - **Free response** questions
- Use as **formative assessment** or for **exam practice**

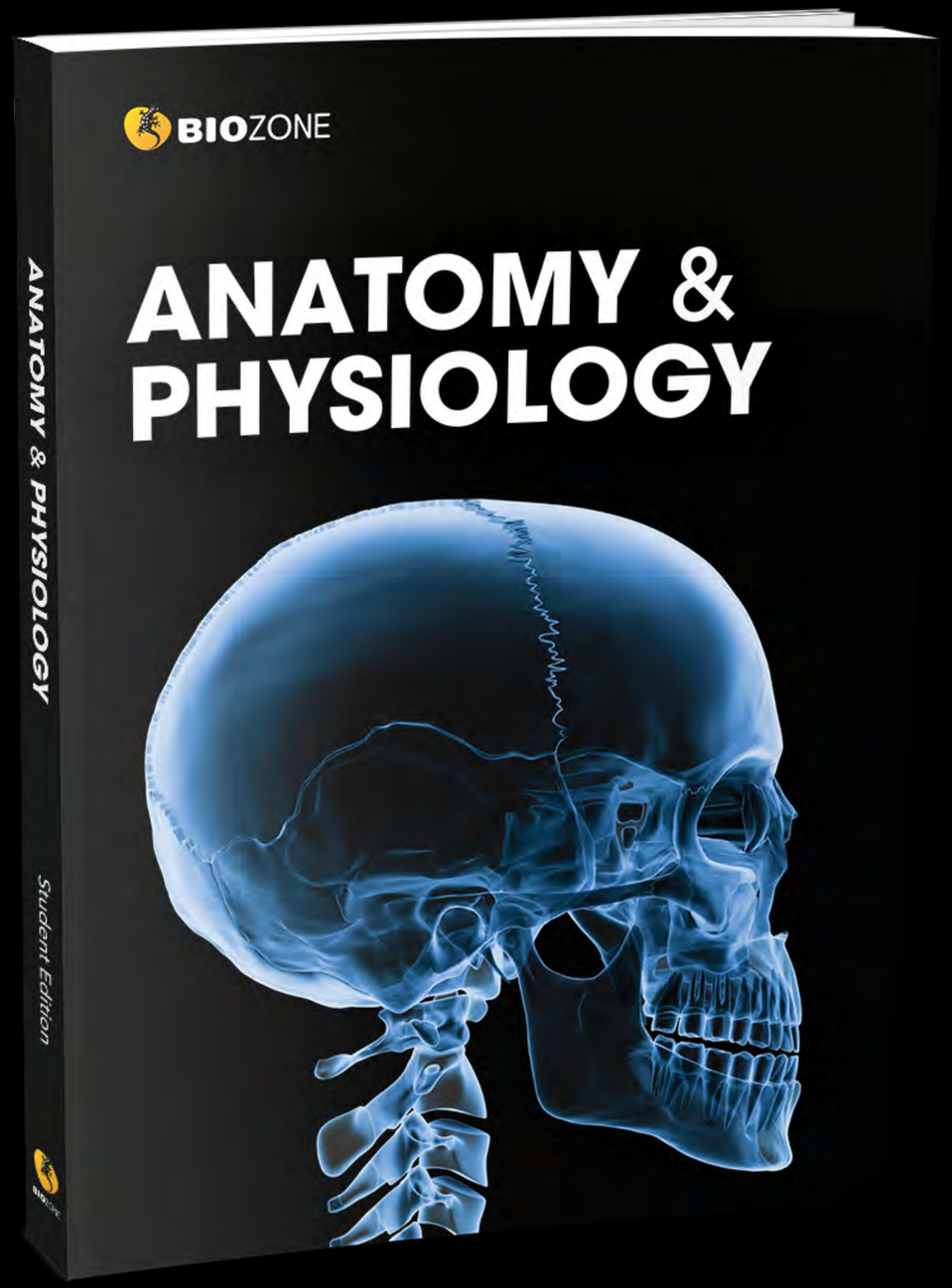


Evaluating Student Performance

Personal Progress Checks conclude each of the units (1-9). Each one comprises 20-35 multiple choice questions followed by a free response question, simulating the types of questions students encounter in the AP Environmental Science exam. Teachers may assign these as formal assessments to gauge student understanding (e.g. taken in class under test conditions) or they can be given as formative assessments providing opportunities for exam practice before students sit the online tests provided in the AP classroom. We have followed the format stipulated in the AP Environmental Science CED when designing these assessments.

PERSONAL PROGRESS CHECK								
UNIT 1 The Living World: Ecosystems	UNIT 2 The Living World: Biodiversity	UNIT 3 Populations	UNIT 4 Earth Systems & Resources	UNIT 5 Land & Water Use	UNIT 6 Energy Resources & Consumption	UNIT 7 Atmospheric Pollution	UNIT 8 Aquatic & Terrestrial Pollution	UNIT 9 Global Change
24 multiple choice Analyze an environmental problem and propose a solution	21 multiple choice Design an investigation	24 multiple choice Analyze an environmental problem and propose a solution doing calculations	15 multiple choice Design an investigation	22 multiple choice Analyze an environmental problem and propose a solution	28 multiple choice Analyze an environmental problem and propose a solution doing calculations	28 multiple choice Design an investigation	26 multiple choice Analyze an environmental problem and propose a solution doing calculations	23 multiple choice Analyze an environmental problem and propose a solution

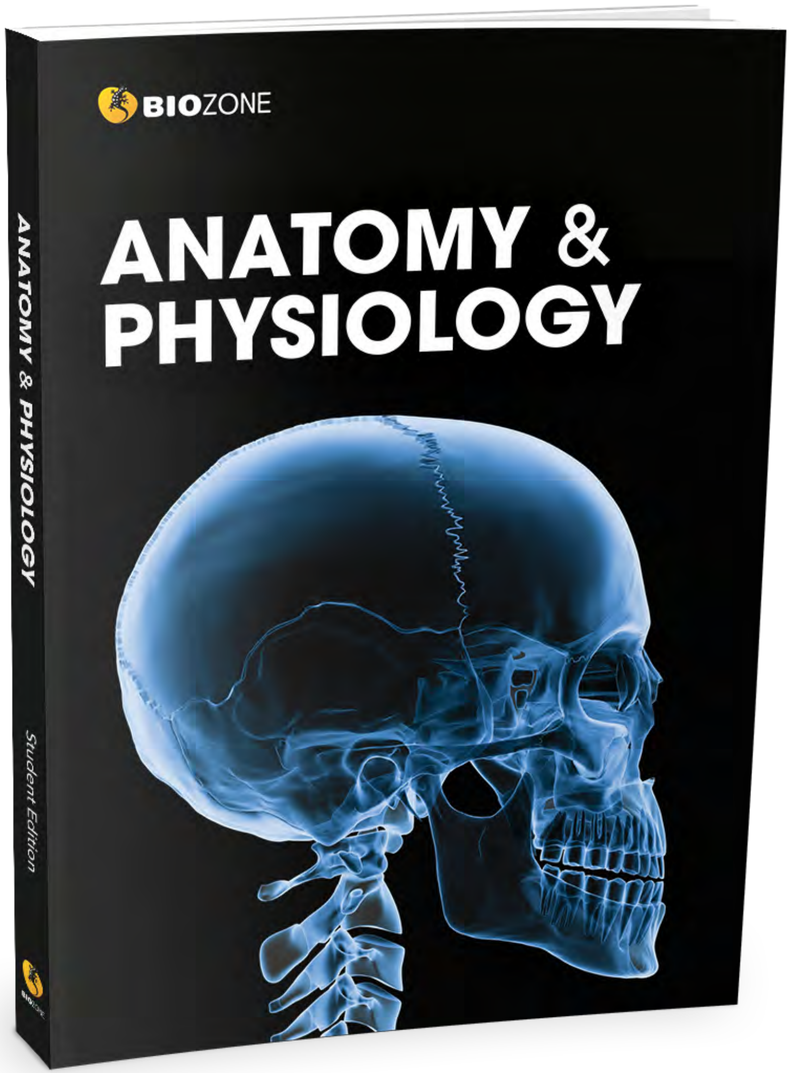




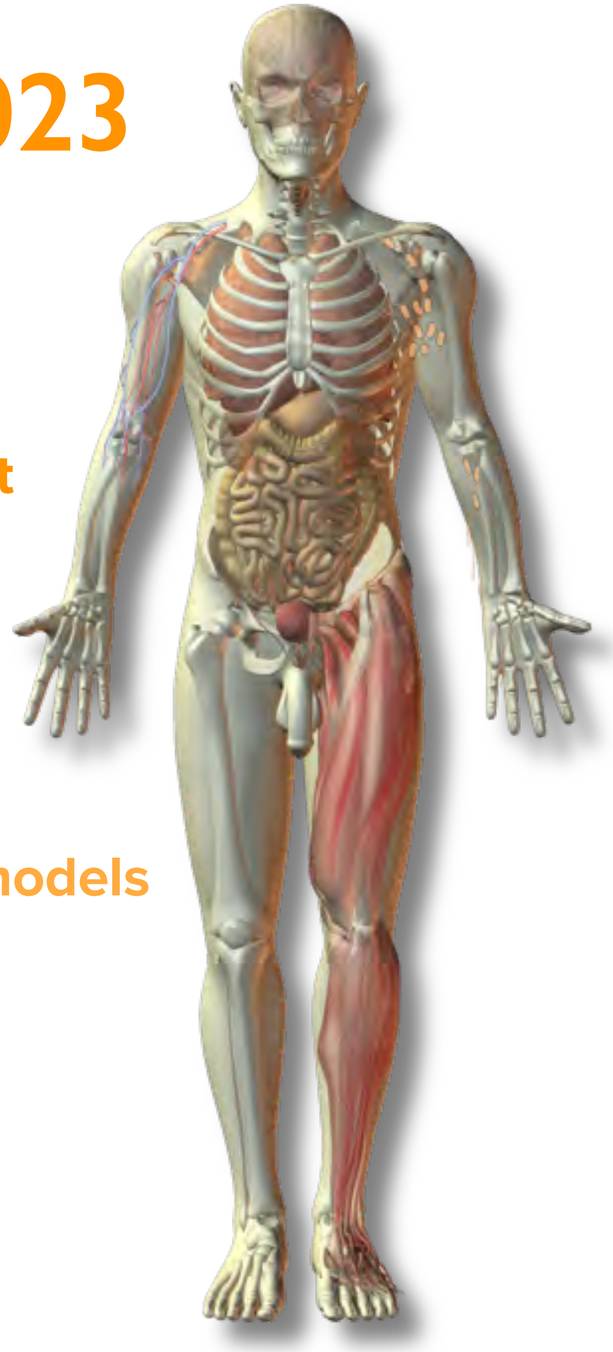
Anatomy & Physiology

- Designed to support courses:
  - general **human biology**
  - **anatomy and physiology**
- Ideal for **electives** at grades 10 -12
- Useful **supplemental** for any **CTE** or undergraduate **health sciences** (vocational training)

NEW EDITION 2023



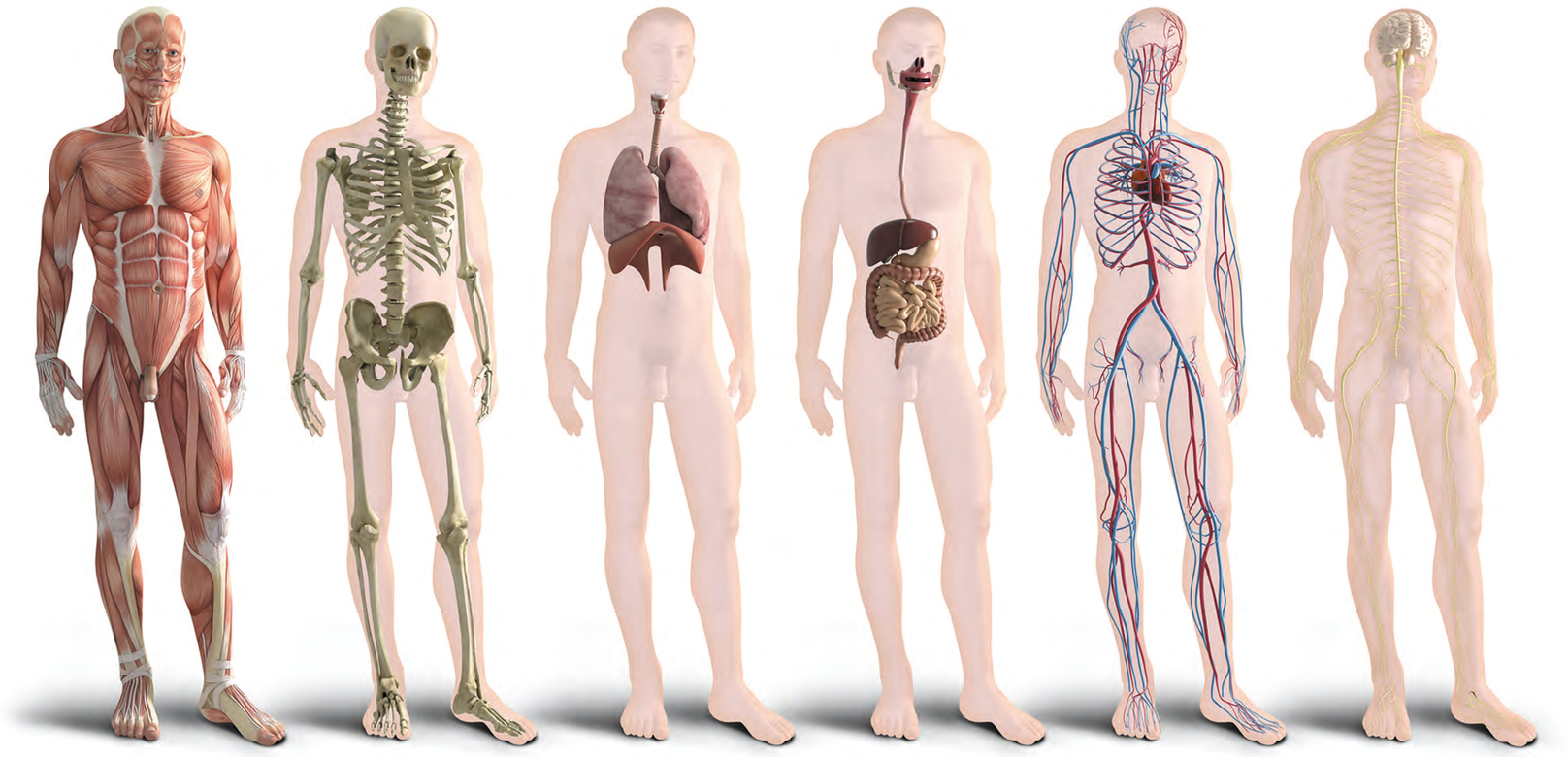
- **Full color**
- **New, expanded & updated content**
- Investigations **Equipment list**
- **Classroom Guide**
- **Glossary**
- **QR codes** for direct access to **3D models**
- **Teacher's Edition** (print and online)



Chapters and content

The content is divided into 12 chapters:

- 1 chapter covering **Cells and Tissues**
- 11 chapters - each covering a **single body system**



CHAPTERS

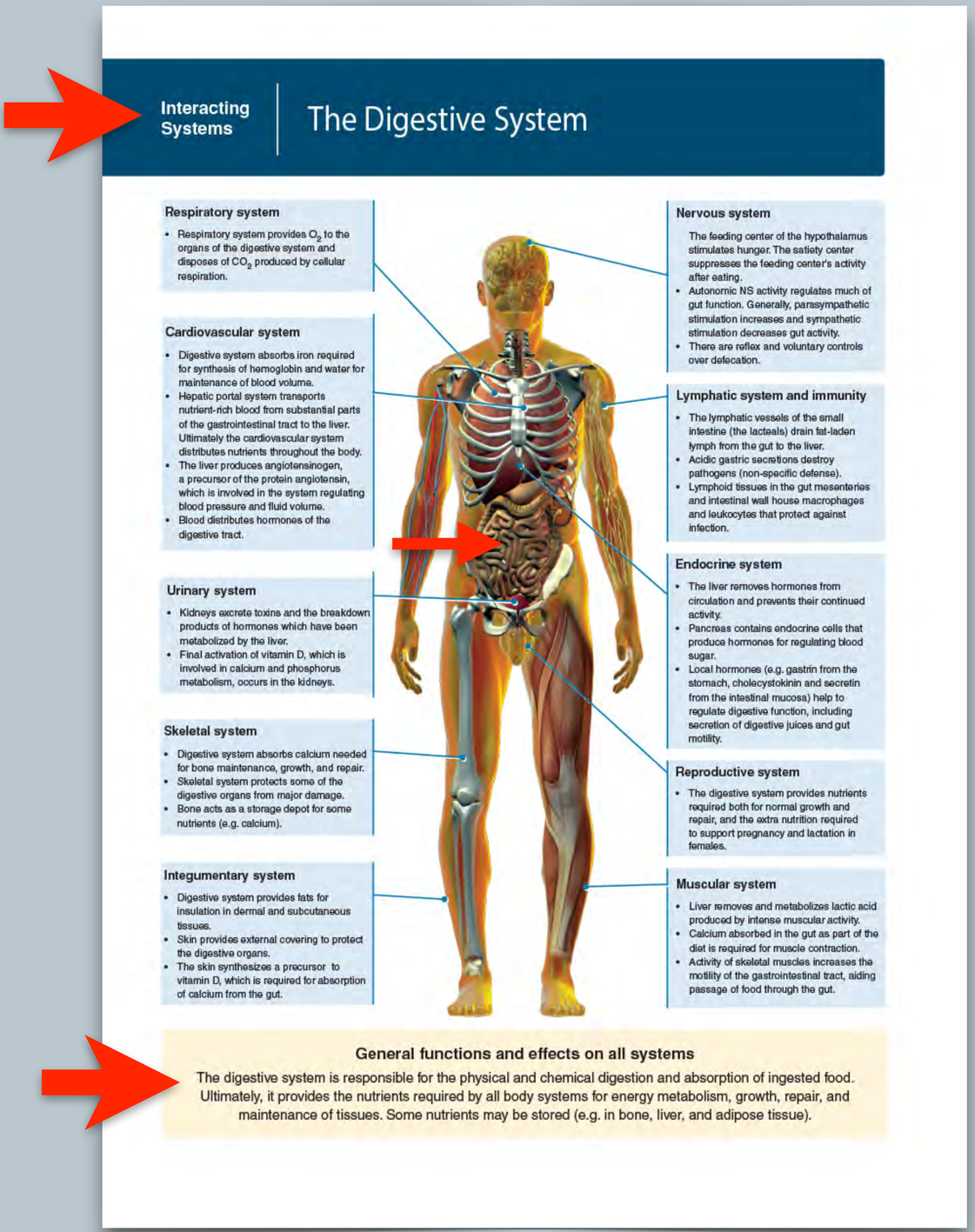
- Cell and Tissues
- The Integument & Homeostasis
- The Skeletal System
- The Muscular System
- Nervous System
- The Endocrine System
- Cardiovascular System
- Lymphatic System & Immunity
- Respiratory System
- The Digestive System
- The Urinary System
- Reproduction & Development

Context and delivery

Each body system is explored in depth.

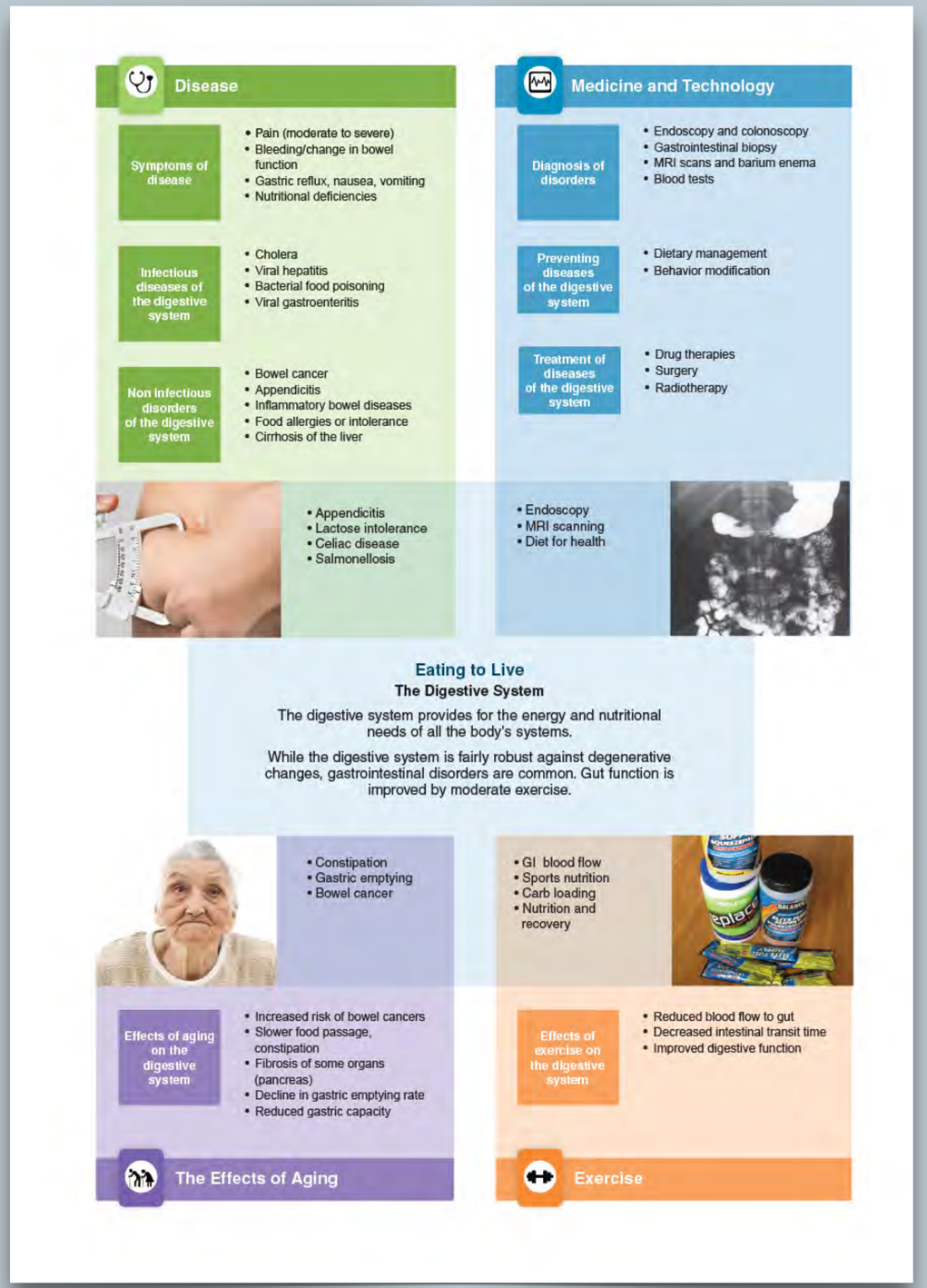
Students gain an understanding of:

- The **key components** of each system
- **General functions** and **roles** of the system
- **Interactions with other body systems** (interrelatedness between systems)



4 Learning in contexts

- **Homeostasis provides a unifying theme**
- **Four contextual themes** provide a way for students to explore each body system in a systematic way. The four themes are:
  - **Disease**
  - **Medicine and technology**
  - **Aging**
  - **Exercise**
- Provides a well-rounded exploration of the human body.



Eating to Live

The Digestive System

The digestive system provides for the energy and nutritional needs of all the body's systems.

While the digestive system is fairly robust against degenerative changes, gastrointestinal disorders are common. Gut function is improved by moderate exercise.

- Constipation
- Gastric emptying
- Bowel cancer

Effects of aging on the digestive system

- Increased risk of bowel cancers
- Slower food passage, constipation
- Fibrosis of some organs (pancreas)
- Decline in gastric emptying rate
- Reduced gastric capacity

The Effects of Aging

- GI blood flow
- Sports nutrition
- Carb loading
- Nutrition and recovery

Effects of exercise on the digestive system

- Reduced blood flow to gut
- Decreased intestinal transit time
- Improved digestive function

Exercise

Disease

Symptoms of disease

- Pain (moderate to severe)
- Bleeding/change in bowel function
- Gastric reflux, nausea, vomiting
- Nutritional deficiencies

Infectious diseases of the digestive system

- Cholera
- Viral hepatitis
- Bacterial food poisoning
- Viral gastroenteritis

Non infectious disorders of the digestive system

- Bowel cancer
- Appendicitis
- Inflammatory bowel diseases
- Food allergies or intolerance
- Cirrhosis of the liver

- Appendicitis
- Lactose intolerance
- Celiac disease
- Salmonellosis

Medicine and Technology

Diagnosis of disorders

- Endoscopy and colonoscopy
- Gastrointestinal biopsy
- MRI scans and barium enema
- Blood tests

Preventing diseases of the digestive system

- Dietary management
- Behavior modification

Treatment of diseases of the digestive system

- Drug therapies
- Surgery
- Radiotherapy

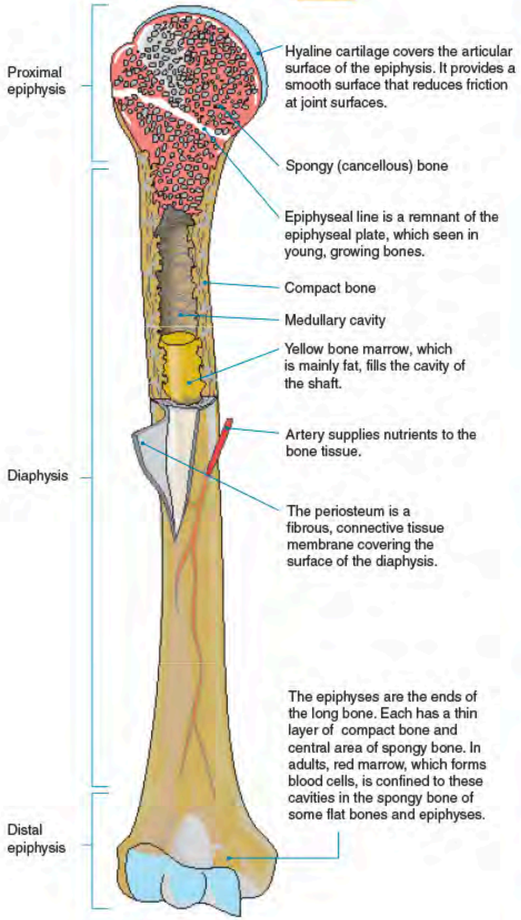
- Endoscopy
- MRI scanning
- Diet for health

34 Bone

Key Idea: The skeleton is formed from two stiffened connective tissues: bone and cartilage.

Although bone is hard, it is dynamic and is continually remodeled and repaired according to needs and in response to blood calcium levels and the pull of gravity and muscles. Hormones from the thyroid, parathyroids, and gonads, as well as growth hormone, are involved in this activity. Most bones of the skeleton are formed from hyaline cartilage by a process of ossification (bone formation) and they grow by bone remodeling. Bone remodeling is also important in bone repair. Bones have a simple gross structure, as illustrated by a long bone such as the humerus (below). The hard (dense) bone surrounds spongy (cancellous) bone filled with red bone marrow.

Mature long bone



An X-ray shows the epiphyseal plates (growth plates) of a child's hand, seen as separate from the longer bones.

A fibrocartilage callus or tissue mass (indicated) begins the repair process on a fractured humerus. Cigarette smoking slows bone healing markedly.

Red bone marrow is stored in the cavities of spongy bone. Here it is being extracted for transplant. Bone marrow is a source of stem cells.

A section of a femur head shows the compact bone surrounding inner spongy bone and marrow. Blood cells are formed in the red marrow.

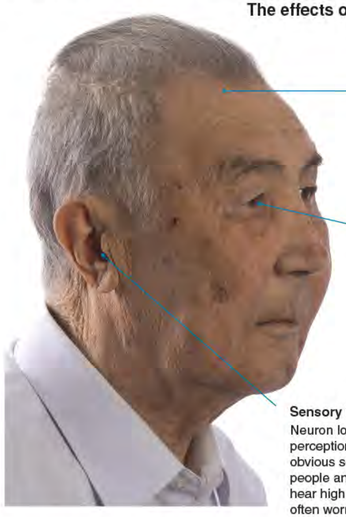
ISBN: 2 978-1-99-101408-5

77 Aging and the Nervous System

Key Idea: The aging process affects all body systems, including the nervous system.

Neuron loss begins around age 30, and accumulates over time, which is why the changes are often more obvious in the elderly. Common changes include impaired (diminished) hearing and vision, short term memory loss, slower reaction times, and loss of fine motor skills. Performing mental and physical exercise slows down the loss of **neurons** in the areas of the brain associated with memory, and helps the remaining neurons to function properly. Lack of mental and physical stimulation, a poor diet, and the consumption of two or more alcoholic drinks a day can increase the rate of neuron loss in the brain.

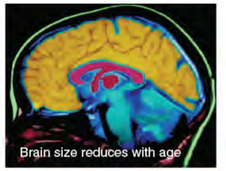
The effects of aging on the nervous system



Loss of neurons
Brain size reduces with age as neurons are lost, but this does not lead to dementia. Dementia disorders, such as Alzheimer's and vascular dementia, severely reduce the number of neurons in the brain and retard its functioning.

Changes in vision
Visual acuity diminishes with age. The lens becomes less flexible and cannot focus light on to the retina correctly. The lens also becomes more opaque, reducing the amount of light falling on the retina. Cataracts (clouding of the lens) obstruct the passage of light and are common in the elderly.

Sensory impairment
Neuron loss leads to a decrease in sensory perception. Hearing loss is often the most obvious sensory impairment in elderly people and usually begins with inability to hear high pitched sounds. Hearing aids are often worn to correct the problem.



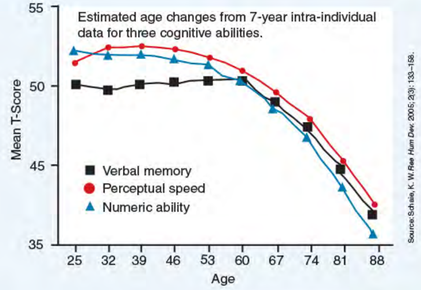
Brain size reduces with age

An elderly man with cataracts

The elderly often require hearing aids

How age affects cognitive ability

- The Seattle longitudinal study began in 1956 with the purpose of determining how cognitive (mental) ability and intelligence change with age. Every seven years, additional subjects were added to the study, and all participants undertook a series of cognitive tests and psychological questioning. Approximately 6,000 people have been tested.
- The graph (right) summarizes some of the results to date. Some cognitive abilities (perceptual speed and numeric ability), begin to decrease from early maturity, while others, such as verbal memory, do not begin to deteriorate until much later in life (60 years old). The study also showed that training (use of specific mental techniques) could slow the decline in cognitive ability.



1. (a) Why do many cognitive abilities diminish with age? _____

_____

_____

(b) What steps can be taken to reduce the rate of cognitive decline? _____

_____

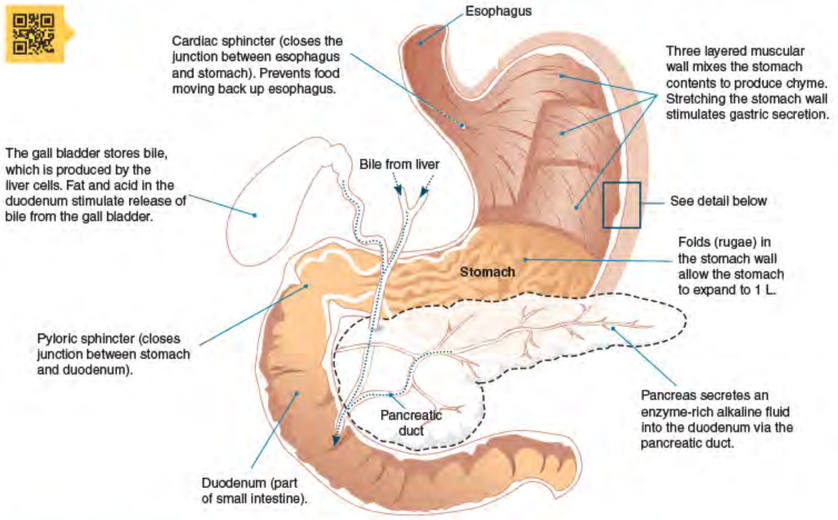
_____

ISBN: 978-1-99-101408-5

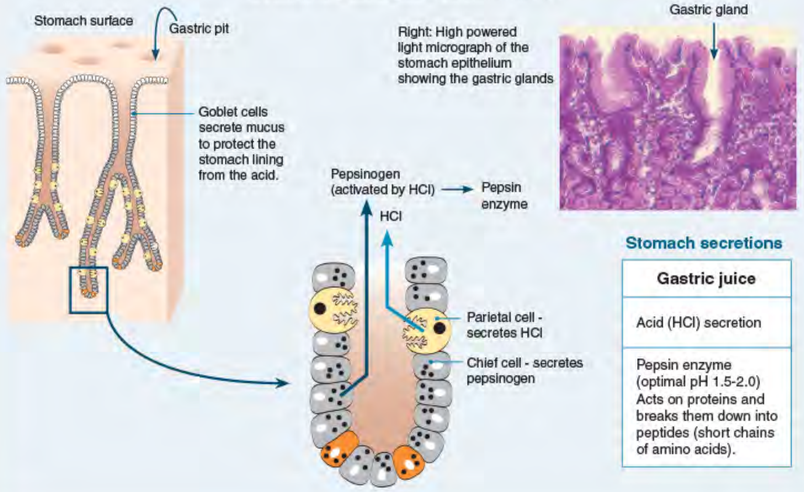
169 The Stomach and Small Intestine

Key Idea: The stomach produces acid and a protein-digesting enzyme, which breaks food down into a slurry, called chyme.

The **stomach** is a hollow, muscular organ between the oesophagus and small intestine. In the stomach, food is mixed in an acidic environment to produce a semi-fluid mixture called chyme. The low pH of the stomach destroys microbes, denatures proteins, and activates a protein-digesting enzyme precursor. There is very little absorption in the stomach, although small molecules (glucose, alcohol) are absorbed across the stomach wall into the surrounding blood vessels.



Detail of a gastric gland (stomach wall)



Right: High powered light micrograph of the stomach epithelium showing the gastric glands

Stomach secretions

Gastric juice
Acid (HCl) secretion
Pepsin enzyme (optimal pH 1.5-2.0) Acts on proteins and breaks them down into peptides (short chains of amino acids).

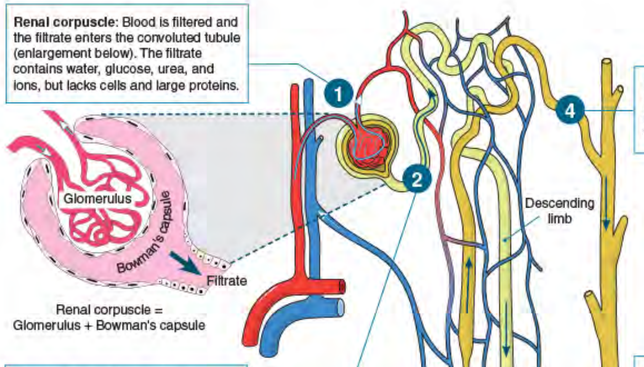
ISBN: 978-1-99-101408-5

186 The Physiology of the Kidney

Key Idea: The functional unit of the kidney is the nephron. It is a selective filter element, comprising a renal corpuscle and its associated tubules and ducts.

Ultrafiltration, i.e. forcing fluid and dissolved substances through a membrane by pressure, occurs in the first part of the nephron, across the membranes of the capillaries and the glomerular capsule. The formation of the glomerular filtrate depends on the pressure of the blood entering the nephron (below). If it increases, filtration rate increases; when it falls, glomerular filtration rate also falls. This process is precisely regulated so that glomerular filtration rate per day stays constant. The initial filtrate, now called urine is modified through secretion and tubular reabsorption according to the body's needs at the time.

Renal corpuscle: Blood is filtered and the filtrate enters the convoluted tubule (enlargement below). The filtrate contains water, glucose, urea, and ions, but lacks cells and large proteins.



Distal convoluted tubule: Further modification of the filtrate by active reabsorption and secretion of ions.

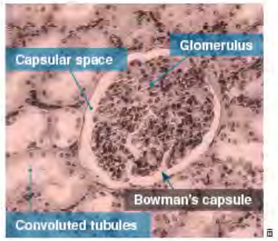
Proximal convoluted tubule: Reabsorption of ~ 90% of filtrate, including glucose and valuable ions.

Loop of Henle: Transport of salt and passive movement of water create salt gradient through the kidney. The water is transported away by blood vessels around the nephron.

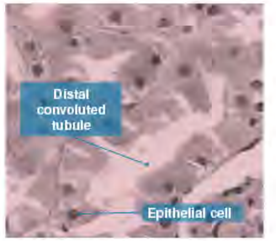
Collecting duct: Water leaves the filtrate (urine) by osmosis, making it more concentrated. The salt gradient established by the loop of Henle allows water to be removed along the entire length of the collecting duct.

Dr G. Dacpar, University of California San Francisco

The epithelium of Bowman's capsule is made up of specialized cells called podocytes. The finger-like cellular processes of the podocytes wrap around the capillaries of the glomerulus, and the plasma filtrate passes through the filtration slits between them.



Bowman's capsule is a double walled cup, lying in the cortex of the kidney. It encloses a dense capillary network called the glomerulus. The capsule and its enclosed glomerulus form a renal corpuscle. In this section, the convoluted tubules can be seen surrounding the renal corpuscle.



There are around 16 different types of epithelial cells in the kidney, lining the surface of tubules, each with different functions. The kidney tissue also contains endothelial cells lining blood vessels, interstitial cells in the space between functional cells, and immune cells.

1. Explain how water is reabsorbed in the kidneys? _____

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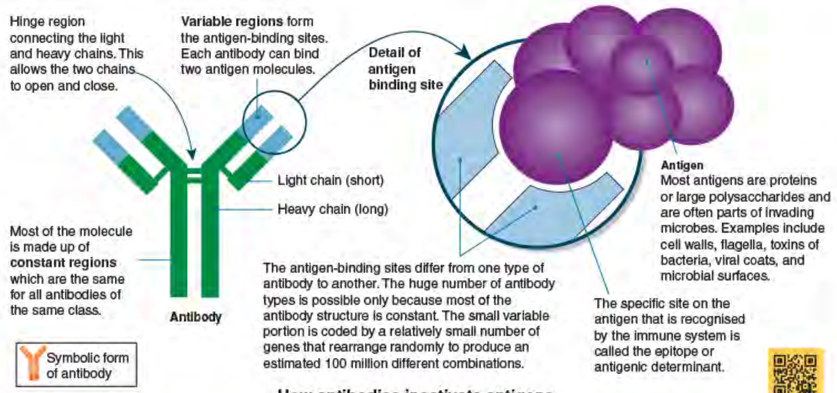
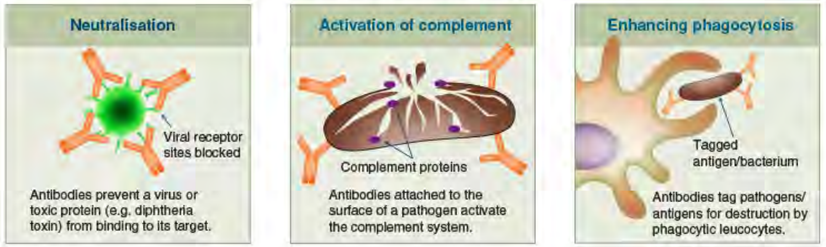
134 Antibodies

Key Idea: Antibodies are large, Y-shaped proteins, made by B cells, which destroy specific antigens.

Antibodies and **antigens** play key roles in the response of the immune system. Recall that antigens are foreign molecules which promote a specific immune response. Antigens include pathogenic microbes and their toxins, as well as substances such as pollen grains, blood cell surface molecules, and the surface proteins on transplanted tissues. Antibodies (also called immunoglobulins) are proteins made in response to antigens. They are secreted from plasma B cells into the plasma where they can recognize, bind to, and help destroy antigens. There are five classes of antibodies, each plays a different role in the immune response. Each type of antibody is specific to only one particular antigen.



How antibodies inactivate antigens



1. Describe the structure of an antibody, identifying the specific features of its structure that contribute to its function:

2. Explain how the following actions by antibodies enhance the immune system's ability to stop infections:

   (a) Acting as agglutinins:

   (b) Acting as antitoxins:

   (c) Tagging foreign cells with chemical markers:

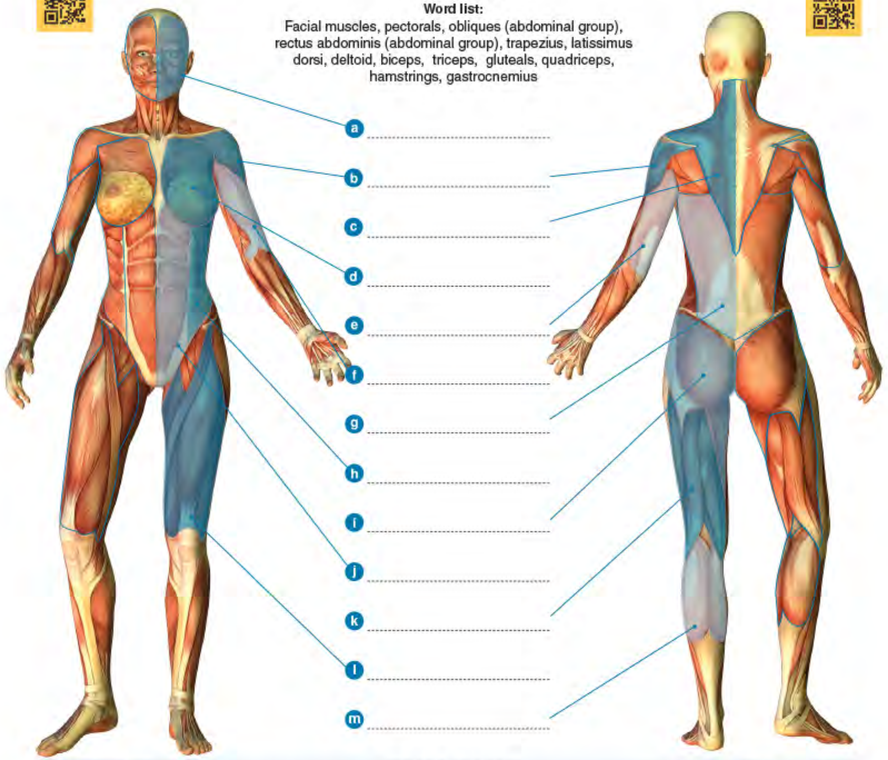
41 Muscles of the Human Body

Key Idea: The muscles of the human body can be placed into specific groups.

The muscles of the human body occur as groups which work together to achieve an outcome. For example, the raising of the forearm is achieved by the contraction of the biceps brachii and the brachialis. This muscle group is sometimes referred to simply as the biceps. Similarly, abdominals is used to refer to the muscle layers covering the body's anterior midsection. Muscle groups are divided between the head, trunk, upper and lower arms, thorax and midsection, and upper and lower legs, each with anterior and posterior muscles. Some common muscle groupings are illustrated below.

Muscle groups

Word list:
Facial muscles, pectorals, obliques (abdominal group), rectus abdominis (abdominal group), trapezius, latissimus dorsi, deltoid, biceps, triceps, gluteals, quadriceps, hamstrings, gastrocnemius



Head muscles

Head muscles are divided into the facial muscles, which make expressions, and the chewing muscles. Facial muscles are inserted into soft tissues (e.g. skin) and enable a range of facial expressions.

Smiling involves about 12 muscles. Major muscles involved include:
- Zygomaticus major (A) raises the corners of the mouth and produces the cheek dimples
- Zygomaticus minor (B) raises the upper edges of the lips
- Levator anguli oris (C) raises the upper lip to show the canine teeth.

Frowning involves about 11 muscles. Muscles involved include:
- Procerus (D) pulls the skin between the eyebrows down towards the nose producing the "fighters fold"
- Depressor anguli oris (E) pulls the corners of the mouth down to form the lips into an inverted U.

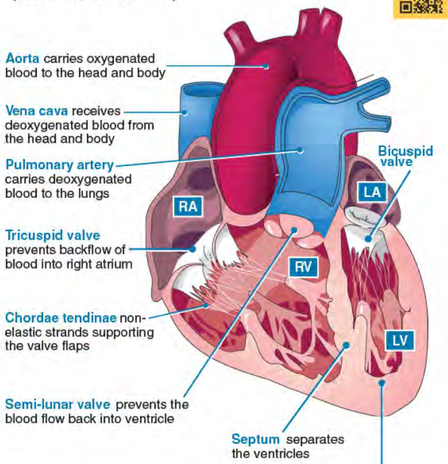
106 Structure of the Mammalian Heart

Key Idea: Humans have a four chambered heart, divided into left and right halves, acting as a double pump.

The heart is the centre of the human cardiovascular system. It is a hollow, muscular organ made up of four chambers (two atria and two ventricles) that alternately fill and empty with blood, acting as a double pump. The left side (systemic circuit) pumps blood to the body tissues and the right side (pulmonary circuit) pumps blood to the lungs. The heart lies between the lungs, to the left of the midline, and is surrounded by a double layered pericardium of connective tissue, which prevents over distension of the heart and anchors it within the central compartment of the thoracic cavity.

Human heart structure

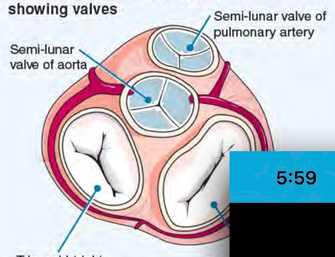
(sectioned, anterior view)



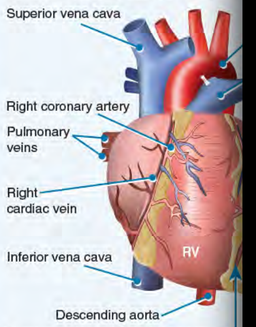
The heart is not a symmetrical organ. Although the quantity of blood pumped by each side is the same, the walls of the left ventricle are thicker and more muscular than those of the right ventricle. The difference affects the shape of the ventricular cavities, so the right ventricle is twisted over to the left.

RA	Right atrium: receives deoxygenated blood via the anterior and posterior vena cava
RV	Right ventricle: pumps deoxygenated blood to the lungs via the pulmonary artery
LA	Left atrium: receives blood returning to the heart from the lungs via the pulmonary veins
LV	Left ventricle: pumps oxygenated blood to the head and body via the aorta

Top view of a heart in section, showing valves

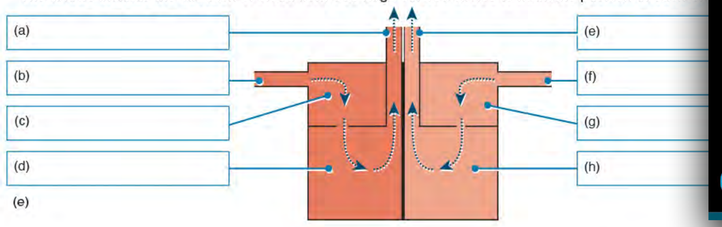


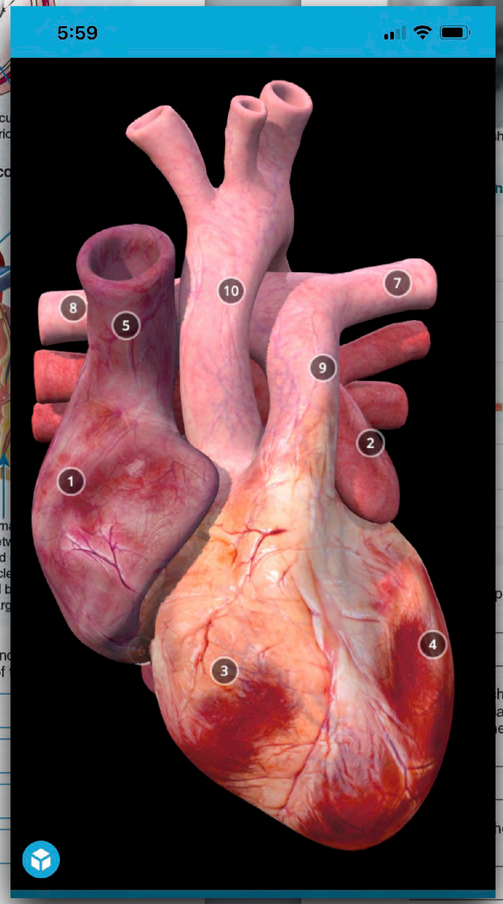
Anterior view of heart to show co



Coronary arteries: The high oxygen dema muscle are met by a dense capillary netv arteries arise from the aorta and spread of the heart supplying the cardiac muscle blood. Deoxygenated blood is collected b and returned to the right atrium via a larg

1. In the schematic diagram of the heart below, label the four chambers, and the main vessels entering and The arrows indicate the direction of blood flow. Use large colored circles to mark the position of each of





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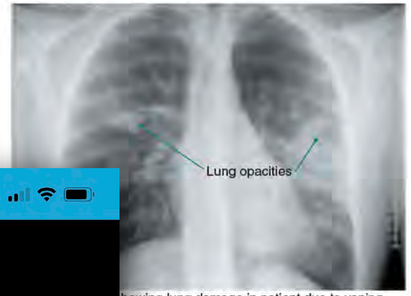
160 Vaping and the Lungs

Key Idea: Vaping is a method of inhaling a vapor containing nicotine and other compounds, including some that may have an unknown negative impact on the respiratory system.

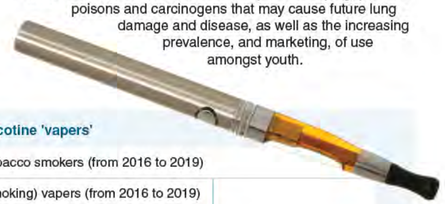
Nicotine 'vaping', through an electronic device, is a new phenomenon and research links its uptake to a decrease in tobacco smoking. Although 'vaping' is often promoted as a safe alternative to tobacco smoking, developing evidence is showing a multitude of possible negative health impacts, including cardiovascular and lung disease. Long-term health impacts are still unknown.

Vaping and lung damage

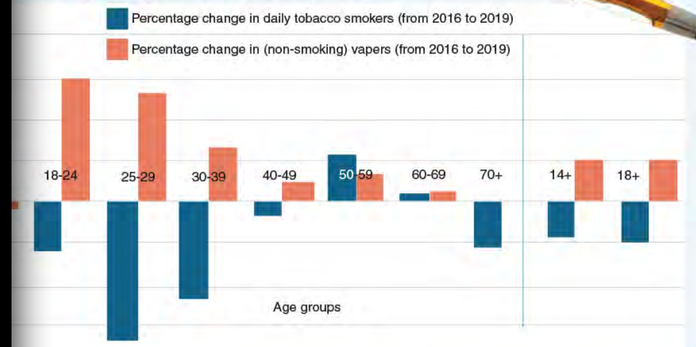


howing lung damage in patient due to vaping,

Lung damage in some patients has been linked to vaping, and was defined by the CDC (Centres for Disease Control and prevention) in 2019 as e-cigarette or vaping product use-associated lung injury (EVALI). Symptoms including coughing, chest pain, and shortness of breath. Studies concluded that additives to the vaping liquid, such as Vitamin E acetate, were likely to a major contributor to the lung damage seen in over 2800 people, and over 68 deaths in the US, by early 2020. Although this additive was mainly linked to THC-containing vape liquids, other additives in nicotine-based vape liquids are thought to contribute to EVALI, and lung damage in general. Physicians and health specialists are concerned about the small amount of research around health impacts of vaping, possible poisons and carcinogens that may cause future lung damage and disease, as well as the increasing prevalence, and marketing, of use amongst youth.



n percentage of daily tobacco smokers vs nicotine 'vapers'



Source: https://www.aihw.org.au/

oh above, describe the patterns you see in the data for tobacco smoking vs 'vaping': _____

h from the CDC shows around 9% of middle school and high school students in the US have vaped in ays, 3 times higher than the rate of adults. Why is promoting vaping as a healthy alternative to tobacco e 18-24 youth age scientifically and statistically incorrect?

he impacts to lung health due to vaping: _____

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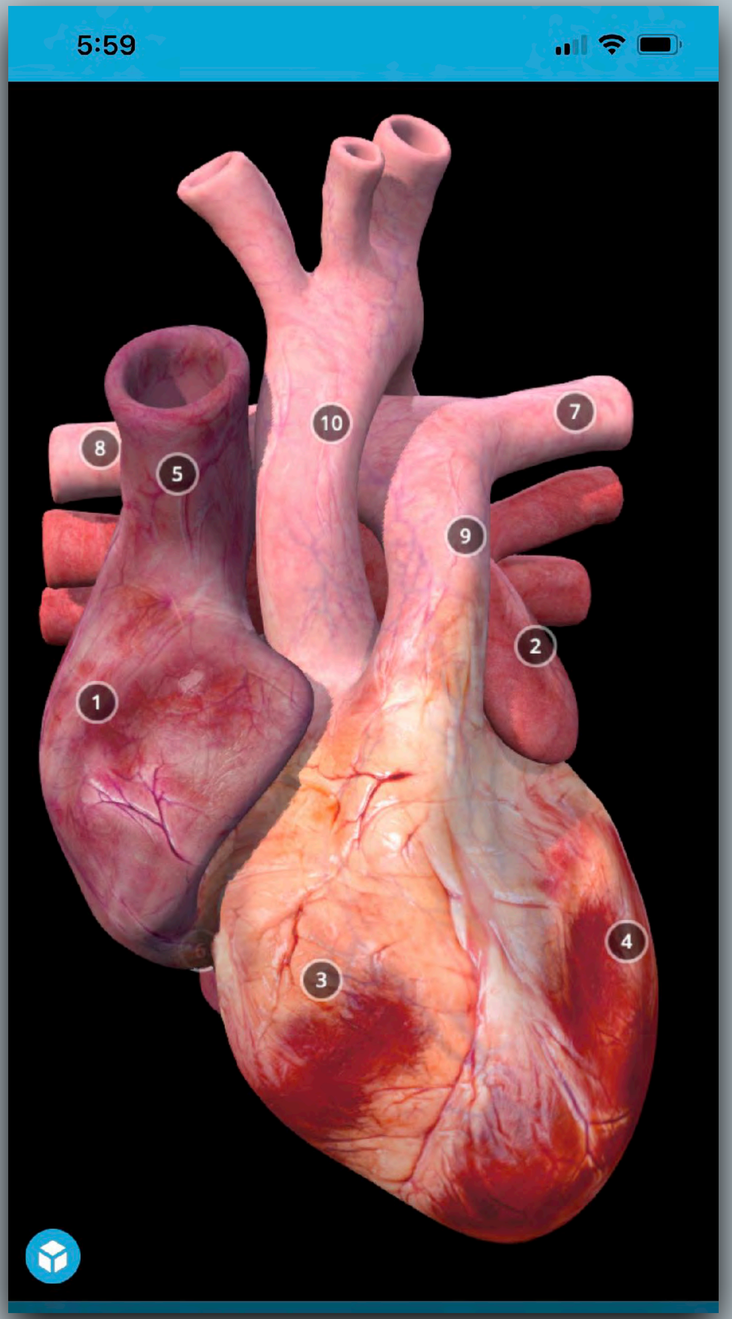
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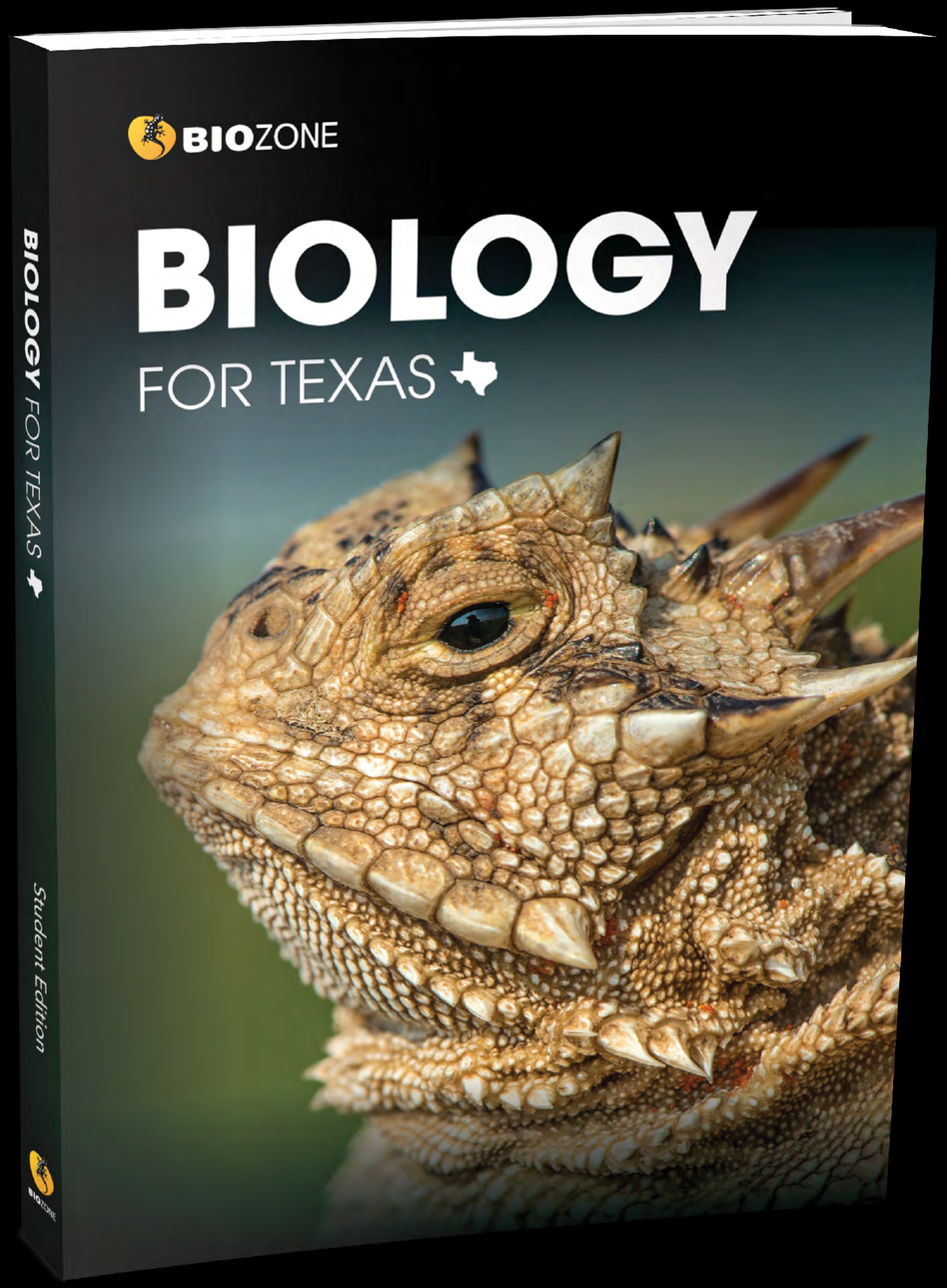

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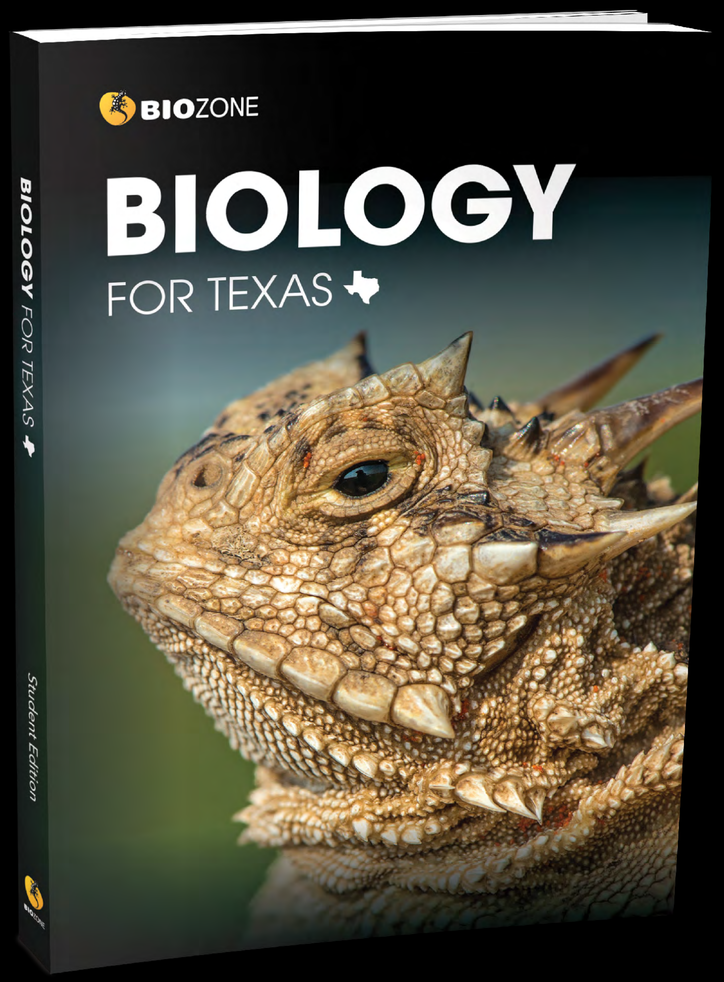


- Written and structured on the HS Biology TEKS
- **100% TEKS** clearly identified
- **100% ELPS** clearly identified (4 levels)
- In built assessments
- Practical Investigations and equipment list
- Science Skills chapter
- Glossary (English and Spanish)
- QR codes for direct 3D model access

CHAPTER 8

Evolution and Natural Selection

TEKS
Scientific and Engineering Practices

B.1: Investigation and Inquiry
1.B 1.C 1.E 1.F 1.G

B.2: Data and Patterns
2.A 2.B 2.C 2.D

B.3: Communicating in Science
3.A 3.B

B.4: Science as a Human Endeavor
4.A 4.B

TEKS
Science Concepts

B10.A analyze and evaluate how natural selection produces change in populations and not in individuals

B10.B analyze and evaluate how the elements of natural selection, including inherited variation, the potential of a population to produce more offspring than can survive, and a finite supply of environmental resources, result in differential reproductive success

B10.C analyze and evaluate how natural selection may lead to speciation

B10.D analyze evolutionary mechanisms other than natural selection, including genetic drift, gene flow, mutation, and genetic recombination, and their effect on the gene pool of a population

RESOURCE HUB
bit.ly/3yaOp7Z

Learning Outcomes
I know I have achieved this when I can:

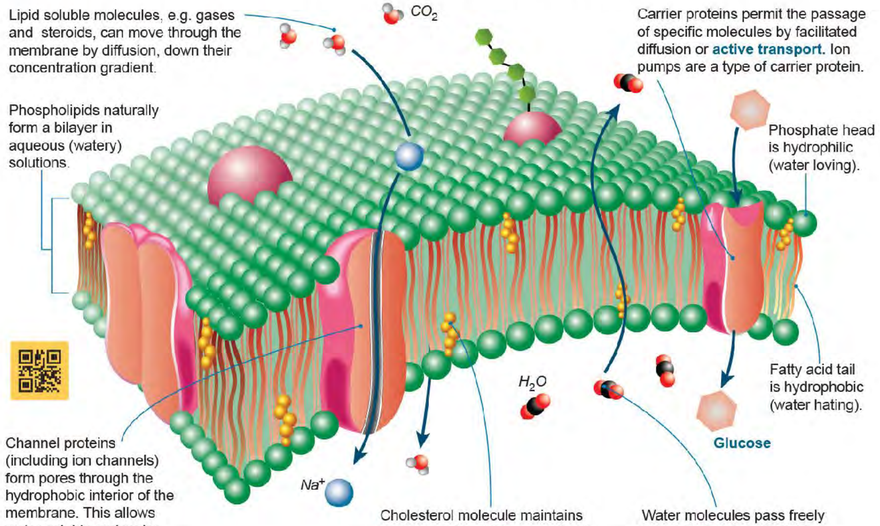
ELPS English Language Proficiency Standards

20 Cell Membrane Structure

Key Question: What are the key components of plasma membranes and how do they enable cellular homeostasis?

B.5C (i) N

- The **plasma membrane** encloses the contents of a **cell**. It is a key structure in regulating cellular homeostasis: the process of maintaining a steady state of conditions inside the cell. The membrane does this by enabling and controlling movement of substances in and out of the cell.
- Recall **lipid** structure from activity 8. The fluid-mosaic model of membrane structure (below) describes a **phospholipid** bilayer with **proteins** of different types moving freely within it.
- The double layer of lipids is quite fluid. It is a dynamic structure and is actively involved in cellular activities.



1. List the important components of the plasma membrane: _____

2. Identify which kind of molecule on the diagram:

B.5C (i) A

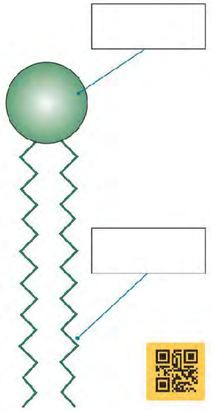
(a) Can move through the plasma membrane by diffusion: _____

(b) Forms a channel through the membrane: _____

3. List the types of proteins pictured in the diagram: _____

4. (a) On the diagram (right) label the hydrophobic and hydrophilic ends of the phospholipid.

(b) Which end is attracted to water? _____



48 Cell Cycle Disruptions and Cancer

Key Question: What happens when cell cycle checkpoints fail?

B.6C (i) N

Formation of cancerous cells

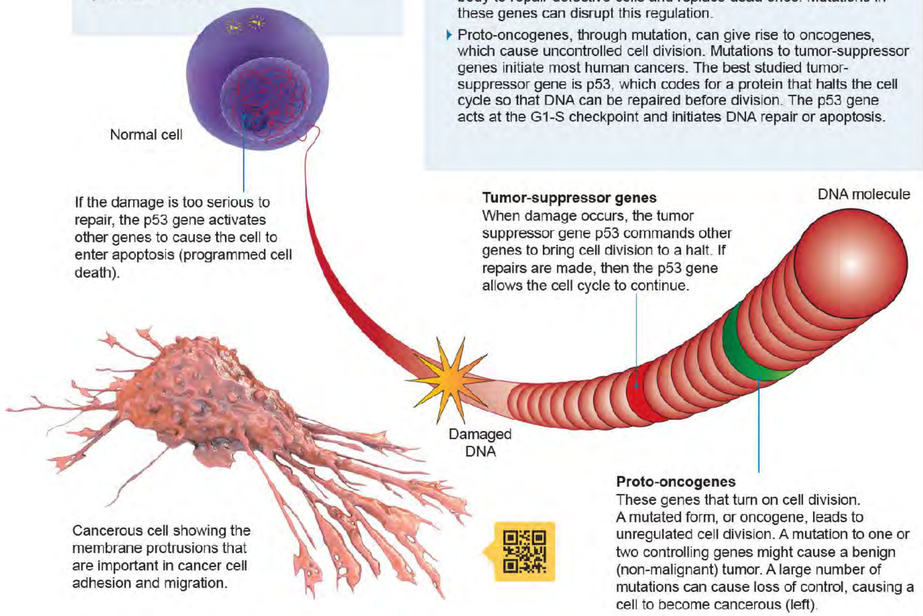
- The formation of cancer cells results from changes in the genes controlling normal cell growth and division. The resulting cells become immortal and no longer carry out their functional role.
- Two types of gene are normally involved in controlling the **cell cycle**:
  - Proto-oncogenes
  - Tumor-suppressor genes

Cancer: cells out of control

Cancerous transformation results from changes in the genes controlling normal cell growth and division. The resulting cells are no longer destroyed at the normal end of their life span and malfunction.

Proto-oncogenes and tumor-suppressor genes

- Proto-oncogenes start **cell division** and are essential for normal cell development.
- Tumor-suppressor genes switch off cell division.
- In their normal form, these types of gene work together, enabling the body to repair defective cells and replace dead ones. Mutations in these genes can disrupt this regulation.
- Proto-oncogenes, through mutation, can give rise to oncogenes, which cause uncontrolled cell division. Mutations to tumor-suppressor genes initiate most human cancers. The best studied tumor-suppressor gene is p53, which codes for a protein that halts the cell cycle so that DNA can be repaired before division. The p53 gene acts at the G1-S checkpoint and initiates DNA repair or apoptosis.



1. How do cancerous cells differ from normal cells? _____

2. Describe the involvement of regulatory genes in control of the cell cycle: _____

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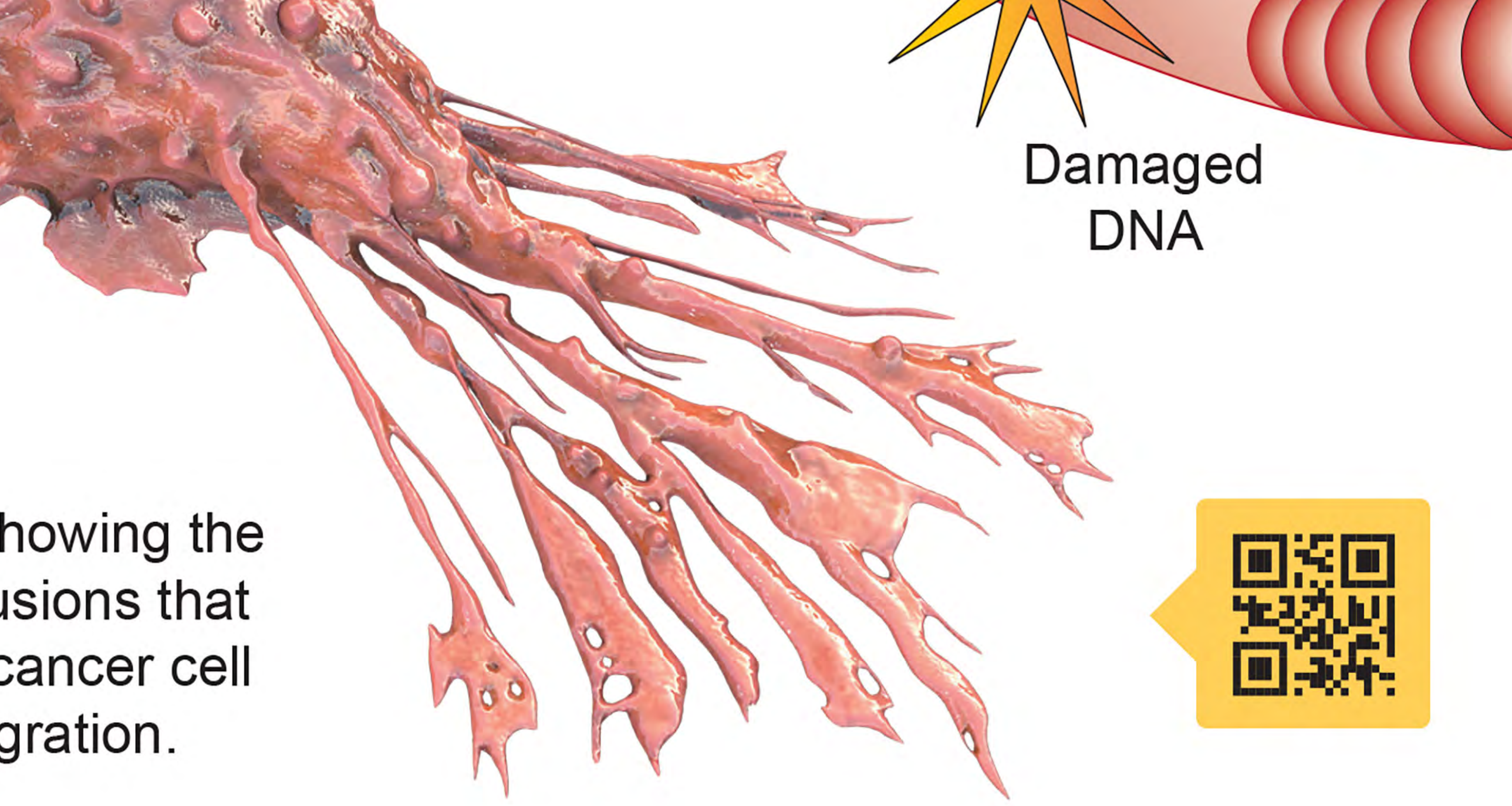

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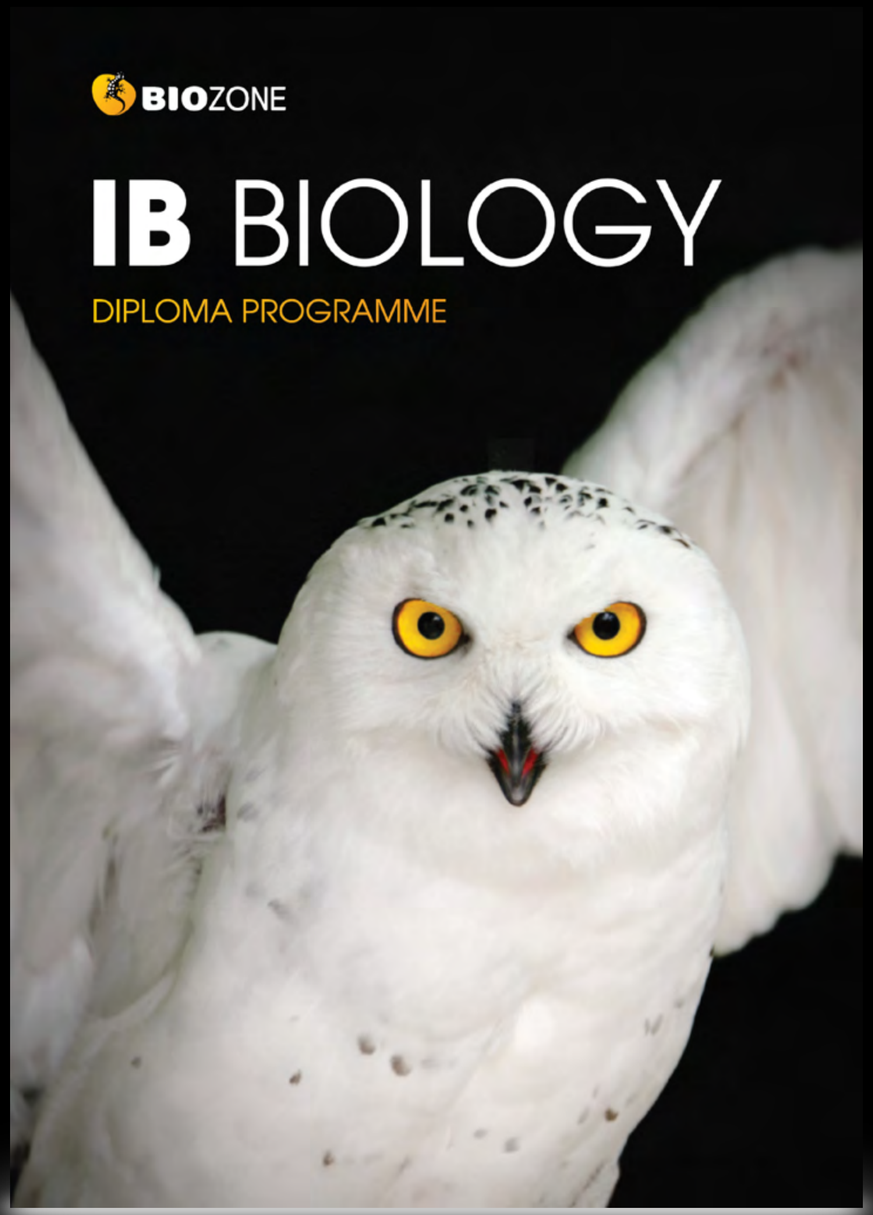

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Chapter 1: Unity and Diversity

Molecules

A1.1 Water

Activity Number

Guiding Questions:
- What physical and chemical properties of water make it essential for life?
- What are the challenges and opportunities of water as a habitat?

Learning Outcomes:

☐	1	Explain the significance of water as a medium for cellular processes, and a requirement for the origin of cells.	1
☐	2	Model a water molecule, showing the hydrogen bonding with correct notation.	1
☐	3	Link the property of water cohesion to its importance to biological processes, including transport in the xylem and movement of organisms on water due to surface tension.	1
☐	4	Link the property of water adhesion to materials, due to polarity, to its significance for organisms, including soil and plant cell wall capillary action.	1
☐	5	Explain how solvent properties of water allow it to function as a medium for plant and animal metabolism and transport in plants and animals, for both hydrophilic and hydrophobic molecules.	1
☐	6	Compare and contrast the physical properties of water and air, and how they impact the animals in aquatic habitats.	1
☐	7	AHL: Evaluate the extraplanetary asteroid hypothesis for the origin and retention of water on Earth.	2
☐	8	AHL: Explain the relationship between water on 'Goldilocks zone' planets and the possibility of finding extraterrestrial life.	2

A1.2 Nucleic acids

Activity Number

Guiding Questions:
- How does the structure of nucleic acids allow hereditary information to be stored?
- How does the structure of DNA facilitate accurate replication?

Learning Outcomes:

☐	1	Identify DNA as the genetic material found in all living organisms.	3
☐	2	Use and draw models of a nucleotide, identifying the components.	3, 8
☐	3	Link the properties of the sugar-phosphate bonding to its role as the 'backbone' of DNA and RNA.	3, 5
☐	4	Recall nitrogenous base names in DNA and RNA.	3
☐	5	Understand that RNA polymers are formed by condensation of nucleotide monomers. Draw and recognise nucleotides and RNA polymers.	3
☐	6	Recognise DNA as a double helix. Use diagrams to show the two DNA strands as anti-parallel.	3, 8
☐	7	Draw diagrams to compare and contrast the components of DNA and RNA.	3, 5
☐	8	Explain how complementary base pairing enables DNA to function as genetic material. Base pairs are held together by hydrogen bonds.	3
☐	9	Link the structure of DNA to its ability to economically store huge quantities of information using almost limitless different sequence combinations.	3
☐	10	Explain that all living organisms using the same genetic code in DNA is evidence of common ancestry.	3
☐	11	AHL: Relate the DNA and RNA 5' to 3' linkage directionality to the processes of replication, transcription and translation.	4
☐	12	AHL: Explain the purpose of purine-to-pyrimidine bonding in enabling DNA helix stability.	4
☐	13	AHL: Understand that histone proteins make up the core of a nucleosome. AOS: Use digital molecular visualization to investigate the structure of a nucleosome.	6
☐	14	AHL: Understand how the Hershey Chase experiment supported the conclusion that DNA was the genetic material. NOS: Appreciate how technological developments provided tools for Hershey and Chase to carry out their investigation into DNA.	7
☐	15	AHL: NOS: Investigate Chargaff's pyrimidine and purine data, and how their ratios addressed the 'problem of induction' and falsified the tetranucleotide hypothesis.	7

er in Living Systems

lecular structure accounts for its ntral role in life's processes.
in component of living things, and out 70% of any organism. Water is istry as it takes part in, and is a

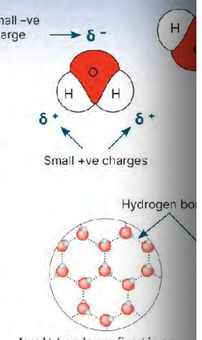
common product of, many reactio thermal, and solvent properties polarity and its ability to form h polar molecules. Water's physica are essential for sustaining life.

ogen bonds

, meaning it has a positively and a negatively each oxygen has a slight negative charge as a slight positive charge (δ+). Water nbers of weak hydrogen bonds with other t). Individually, hydrogen bonds are weak, strong enough to account for the unique ding its cohesion, high boiling point, high quired to cause a change of state from solid heat of vaporization (below, right).

state, it has enough energy that hydrogen aking and reforming. When water loses hydrogen bonds are strong enough to lace, forming a lattice which causes ice to auses ice to be less dense than liquid water.

ween water and other polar molecules biological systems. Inorganic ions may e charge, e.g. positive sodium ion (Na^+) (Cl^-). The charged water molecules ions and surround them. This formation between water and the ions keeps ions molecules such as amino acids and ve readily in water.



Adhesive properties

Water is attracted to other molecules because of its polar nature. Water will form thin films and 'climb' up surfaces when the molecular forces between them (adhesive forces) are greater than the cohesive forces.

Example: Adhesion enables capillary action, i.e. the ability of a liquid to flow against gravity in a narrow space. This property is also shown by the meniscus of a liquid in a tube.

Solvent properties

Water's polarity allows it to dissociate ions in salts and bond to other polar substances, e.g. alcohols and acids, dissolving them. In contrast, non-polar substances such as fats and oils are not water soluble.

Example: Blood plasma in humans and other animals is largely water and transports many water-soluble substances, including ions, glucose, and amino acids, around the body.

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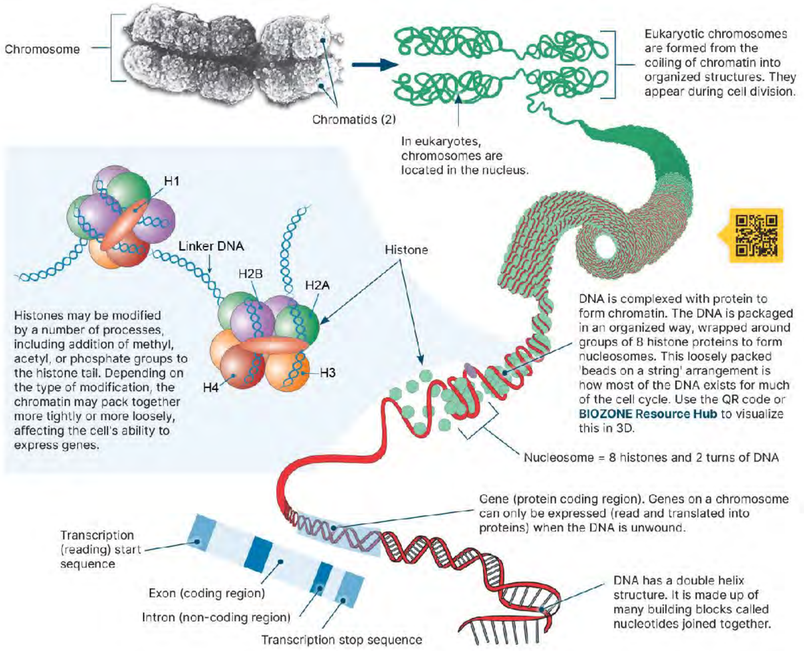
nd ater broken n of ssential e soil.

6 The DNA Molecule

Key Idea: DNA is packaged around proteins called histones. The DNA in eukaryotes is packaged as discrete linear chromosomes that vary in number from species to species.

The extent of DNA packaging changes during the life cycle of the cell, but classic chromosome structures (below) appear during metaphase of mitosis.



1. Explain why eukaryotic DNA needs to be packaged to fit inside a cell nucleus?

2. How do histone proteins help in the coiling up of DNA?

3. Suggest why a cell coils up its chromosomes into tight structures when it is going to divide:

4. Explain how the packaging of DNA in an organized way enables closer regulation of gene expression:

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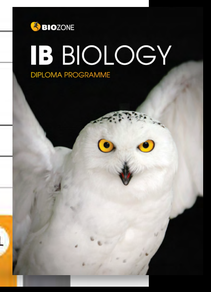
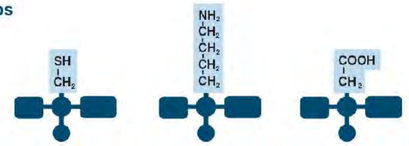


73 R-Groups

Key Idea: The variable R group gives amino acids their properties and ultimately determines the final protein shape. All amino acids have a common structure, but the R group is different in each type of amino acid. The property of the R group determines how it will interact with other amino acids and ultimately determines how the amino acid chain folds up into a functional protein. For example, the hydrophobic R groups of soluble proteins are folded into the protein's interior, while hydrophilic groups are arranged on the outside.

Different amino acids have different R groups

- The R group in the amino acid determines the chemical properties of the amino acid. Different amino acids have different R groups and therefore different chemical properties. Amino acids can be grouped according to these properties. Common groupings are nonpolar (hydrophobic), polar (hydrophilic), positively charged (basic), or negatively charged (acidic).
- The property of the R group determines how the amino acid will interact with others and how the amino acid chain will fold up into a functional protein. For example, the hydrophobic R groups of soluble proteins will be folded into the protein's interior.

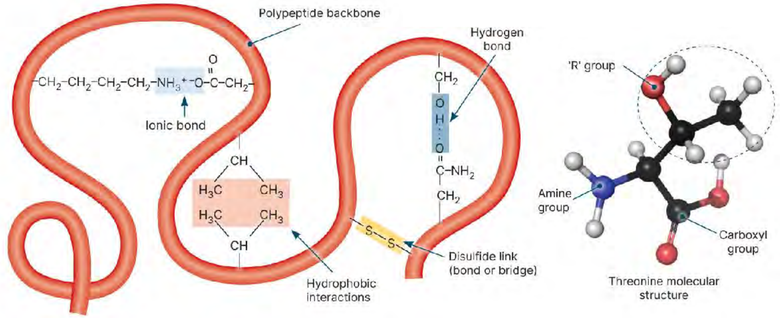


Cysteine
The 'R' group of cysteine forms disulfide bridges with other cysteines to create cross linkages in a polypeptide chain.

Lysine
The 'R' group of lysine gives the amino acid an alkaline property.

Aspartic acid
The 'R' group of aspartic acid gives the amino acid an acidic property.

Links between amino acids



1. (a) Name the different interactions that can shape the polypeptide: _____

   _____

   (b) Which of the interactions would be the strongest: _____

2. Do some research to assign each of the 20 amino acids found in proteins to one of the four groups below. Use a standard 3-letter code to identify each amino acid:

   (a) Nonpolar (hydrophobic): _____

   (b) Polar (hydrophilic): _____

   (c) Positively charged (basic): _____

   (d) Negatively charged (acidic): _____

3. Which type(s) of amino acids would you find on the surface of a soluble protein? Which type(s) would you find in the interior? Explain:

   _____

   _____

   _____

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4 Carbohydrate Chemistry

a: Monosaccharides are the building blocks for larger ydrates. They can exist as isomers.
(monosaccharides and disaccharides) play a central cells, providing energy and joining together to form ydrate macromolecules, such as starch and glycogen.

Monosaccharide polymers form the n most plants (as cellulose). Monosacch as a primary energy source for c Carbohydrates have the general formul and y are variable numbers (often but n

nosaccharides

onosaccharides are single-sugar molecules and clude glucose (grape sugar and blood sugar) and uctose (honey and fruit juices). They are used as a rimary energy source for fuelling cell metabolism.

hey can be joined together to form disaccharides (two onomers) and polysaccharides (many monomers).

onosaccharides can be classified by the number f carbon atoms they contain. Some important onosaccharides are the hexoses (6 carbons) and the entoses (5 carbons). The most common arrangements ound in sugars are hexose (6 sided) or pentose (5 ded) rings (below).

he commonly occurring monosaccharides contain etween three and seven carbon atoms in their carbon hains and, of these, the 6C hexose sugars occur most equently. All monosaccharides are reducing sugars hey can participate in reduction reactions).

mples of monosaccharide structures

Triose

lyceraldehyde

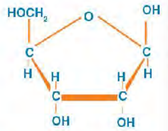
Pentose

e.g. ribose deoxyribose

Hexose

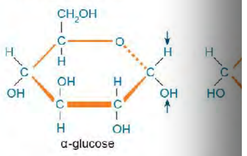
e.g. glucose, fructose, galactose

Ribose: a pentose monosaccharid



Ribose is a monosacch a ring struc a compone ribonucleic

Glucose isomers



α-glucose

Isomers are compounds with the same ch types and numbers of atoms) but different atoms. The different arrangement of the a isomer has different properties.

Molecules such as glucose can have many e.g. α and β glucose, above, including stra

is a versatile molecule. It provides o power cellular reactions, can rgy storage molecules such gen, or it can be used to build l molecules.

Plants make their glucose via the process of photosynthesis. Animals and other heterotrophic organisms obtain their glucose by consuming plants or other organisms.

Fructose, often calle simple monosacchar from sugar cane (ab and glucose can be the bloodstream.

cribe the two major functions of monosaccharides: _____

cribe the structural differences between the ring forms of glucose and ribose: _____

g glucose as an example, define the term isomer and state its importance: _____

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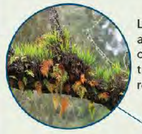
138 Adaptations to Tropical Environments

Key Idea: Tropical rainforests have the greatest biodiversity on Earth, with organisms showing a vast array of adaptations. Tropical environments have a large amount of light, warmth, and moisture: ideal for plant growth. This combination of factors has produced tropical rainforests with the highest biodiversity of any terrestrial environment. A single hectare may have over 42,000 different species of plants and animals. With such large numbers of organisms all competing for space and nutrients, it is unsurprising that the inhabitants of a tropical rainforest have evolved a vast array of adaptations, including camouflage, mimicry, and specialized diets.

Plant adaptations

Plants in tropical rainforest have adaptations to deal with excessive rain, low soil nutrients, low light levels, and other competing plants.



Lianas and epiphytes are adapted to live high on branches or climb up tree trunks in order to reach the light.

Bark helps reduce water loss. This isn't problem in tropical rainforests so many tropical trees have much thinner, smoother bark than temperate trees. This also helps in stopping vines getting a grip.

Many tropical plant have drip tips on their leaves and microscopic hairs that prevent water pooling. This quickly removes water from the leaves and stops organisms such as fungi growing on them.

Tropical soils are nutrient poor, so most trees have shallow roots. Large trees like the kapok have massive buttresses to spread their weight and provide support.

Animal adaptations

In tropical rainforests, animals have adaptations to take advantage of the variety of habitats. These include mimicry, camouflage and poisons.

Many animals have specialized in foraging for foods. Toucans have specialized in eating fruit that is available throughout the year.

Many insects mimic other types of animal either for defence or for predation, such as the ant mimicking spider (left).

Many animals (and plants) have developed poisons for defence, e.g. poison arrow frog above, or for predation.

Many animals in tropical rainforests show an extraordinary degree of adaptation for camouflage. The dead leaf butterfly (left) looks exactly as its name suggests.

1. In a group of four, research plant and animal adaptations in tropical rainforests. Each person should identify one adaptation in a named plant and one in a named animal. Report back to your group with your findings and record all four plant and four animal adaptations below:

   _____

   _____

   _____

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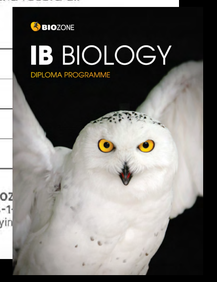

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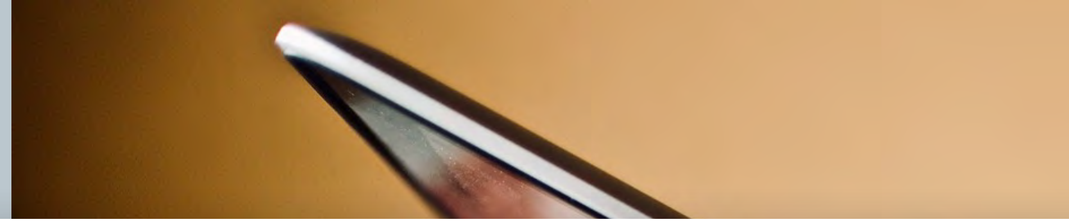

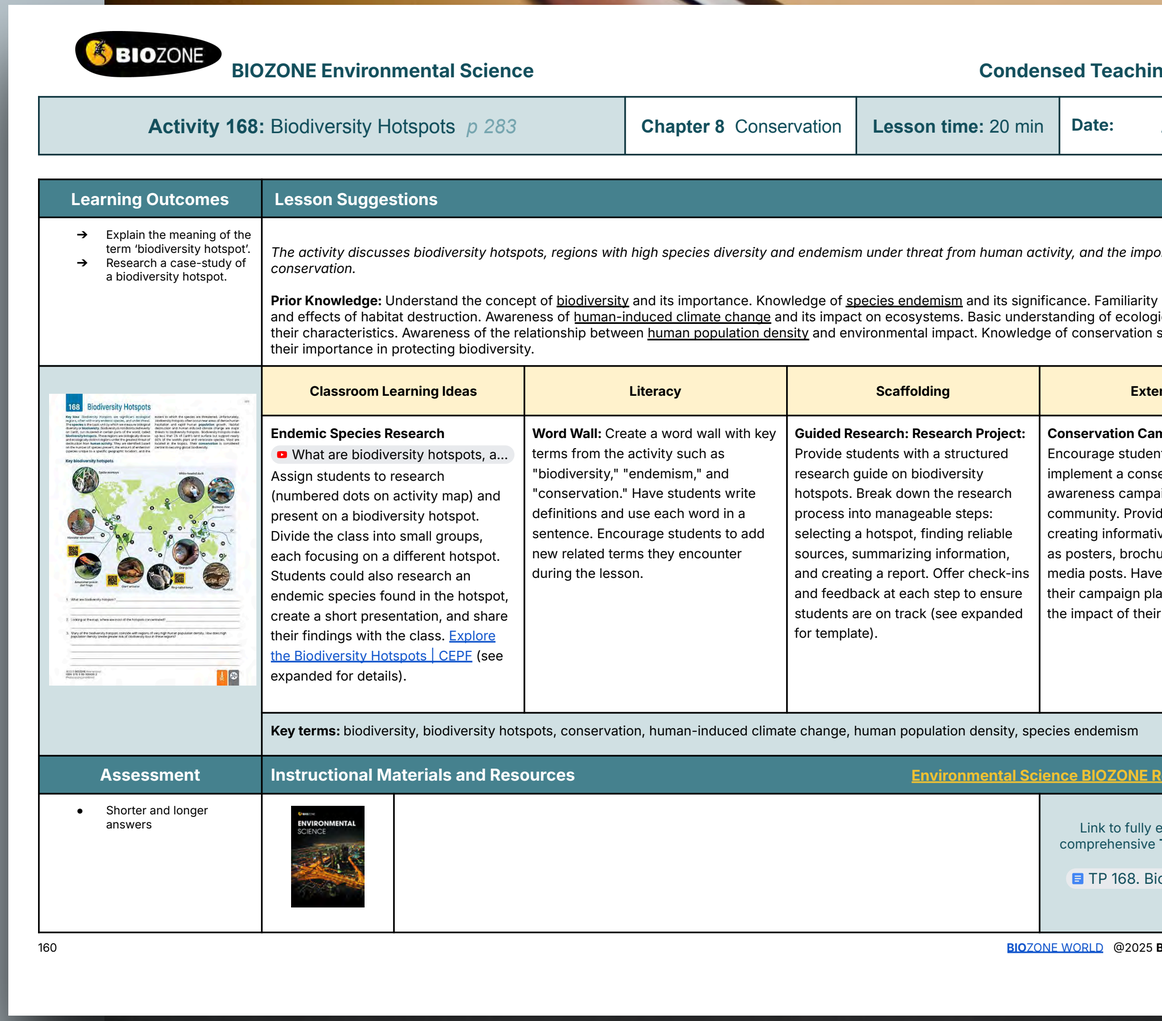

BIOZONE Environmental Science — Condensed Teachin

Activity 168: Biodiversity Hotspots *p 283*	Chapter 8 Conservation	Lesson time: 20 min	Date:

Learning Outcomes

- Explain the meaning of the term 'biodiversity hotspot'.
- Research a case-study of a biodiversity hotspot.

Lesson Suggestions

The activity discusses biodiversity hotspots, regions with high species diversity and endemism under threat from human activity, and the impo conservation.

Prior Knowledge: Understand the concept of biodiversity and its importance. Knowledge of species endemism and its significance. Familiarity and effects of habitat destruction. Awareness of human-induced climate change and its impact on ecosystems. Basic understanding of ecologi their characteristics. Awareness of the relationship between human population density and environmental impact. Knowledge of conservation s their importance in protecting biodiversity.

168 Biodiversity Hotspots

Classroom Learning Ideas	Literacy	Scaffolding	Exte
Endemic Species Research What are biodiversity hotspots, a... Assign students to research (numbered dots on activity map) and present on a biodiversity hotspot. Divide the class into small groups, each focusing on a different hotspot. Students could also research an endemic species found in the hotspot, create a short presentation, and share their findings with the class. Explore the Biodiversity Hotspots | CEPF (see expanded for details).	**Word Wall:** Create a word wall with key terms from the activity such as "biodiversity," "endemism," and "conservation." Have students write definitions and use each word in a sentence. Encourage students to add new related terms they encounter during the lesson.	**Guided Research: Research Project:** Provide students with a structured research guide on biodiversity hotspots. Break down the research process into manageable steps: selecting a hotspot, finding reliable sources, summarizing information, and creating a report. Offer check-ins and feedback at each step to ensure students are on track (see expanded for template).	**Conservation Can** Encourage studen implement a conse awareness campa community. Provid creating informati as posters, brochu media posts. Have their campaign pla the impact of their

Key terms: biodiversity, biodiversity hotspots, conservation, human-induced climate change, human population density, species endemism

Assessment

- Shorter and longer answers

Instructional Materials and Resources — Environmental Science BIOZONE R

Link to fully e comprehensive

TP 168. Bio

Classroom Guide

- Explains the **pedagogy** and **features** of the worktext.
- Identifies **curricula specific components**.
- Provides *teaching strategies* using BIOZONE, including:
    - **Collaborative learning** in the classroom
    - **Differentiated instruction**
    - **Assessments**

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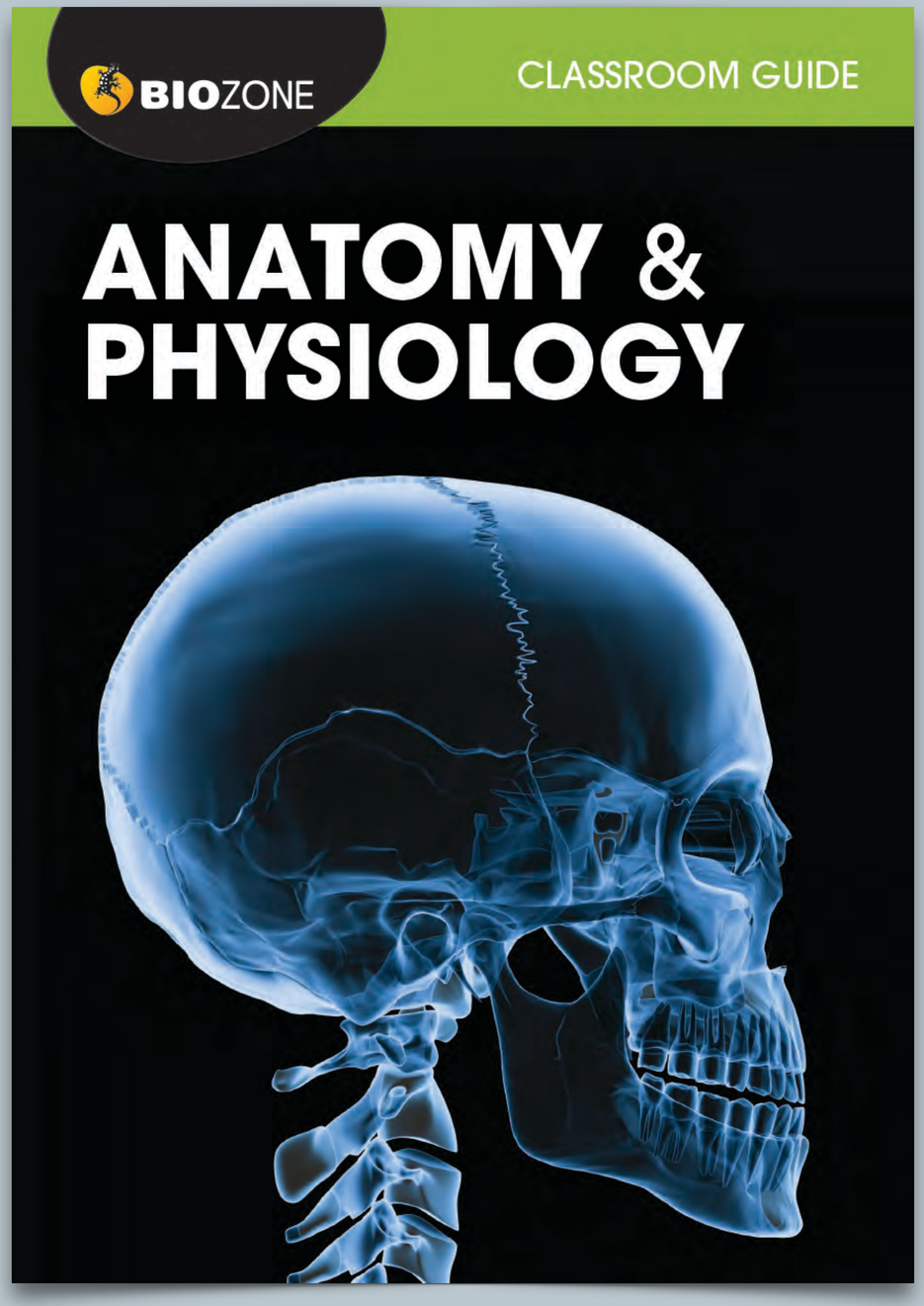

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- Available formats:
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- Additional content:
  - Classroom Guide
  - Model answers in place
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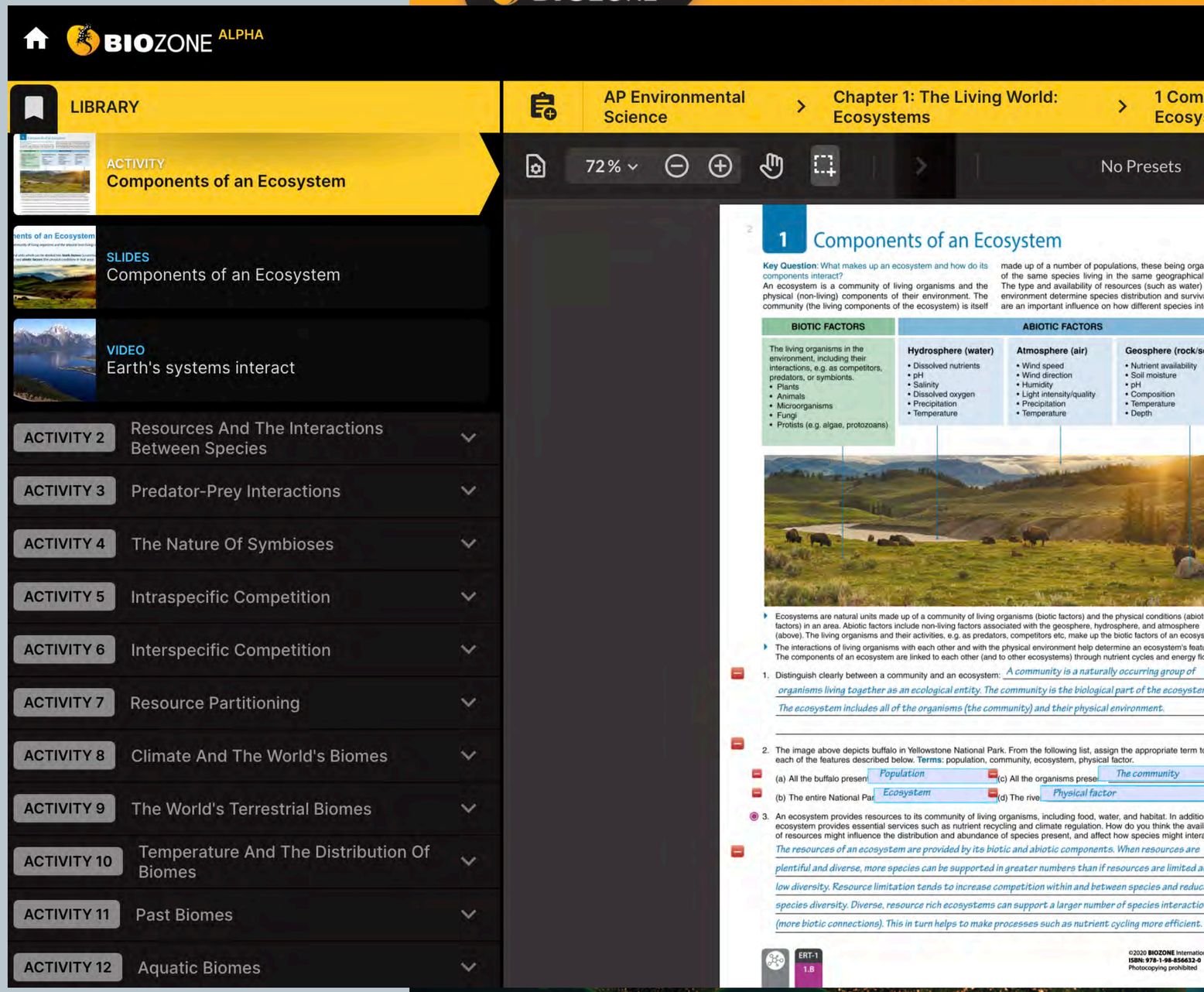


9 Carbohydrate Chemistry

Key Question: Monosaccharides are the building blocks for larger carbohydrates. They can exist as isomers.

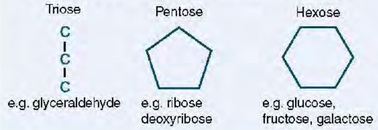
Sugars (monosaccharides and disaccharides) play a central role in cells, providing energy and joining together to form carbohydrate macromolecules, such as starch and glycogen.

Monosaccharide polymers form the major component of most plants (as cellulose). Monosaccharides are important as a primary energy source for cellular metabolism. Carbohydrates have the general formula $C_x(H_2O)_y$, where x and y are variable numbers (often but not always the same).

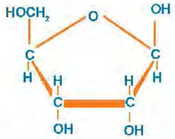
Monosaccharides

- Monosaccharides are single-sugar molecules and include glucose (grape sugar and blood sugar) and fructose (honey and fruit juices). They are used as a primary energy source for fuelling cell metabolism.
- They can be joined together to form disaccharides (two monomers) and polysaccharides (many monomers).
- Monosaccharides can be classified by the number of carbon atoms they contain. Some important monosaccharides are the hexoses (6 carbons) and the pentoses (5 carbons). The most common arrangements found in sugars are hexose (6 sided) or pentose (5 sided) rings (below).
- The commonly occurring monosaccharides contain between three and seven carbon atoms in their carbon chains and, of these, the 6C hexose sugars occur most frequently. All monosaccharides are reducing sugars (they can participate in reduction reactions).

Examples of monosaccharide structures

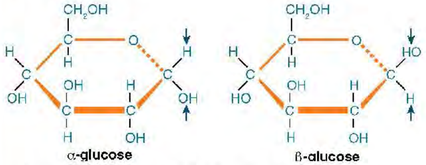


Ribose: a pentose monosaccharide



Ribose is a pentose (5 carbon) monosaccharide which can form a ring structure (left). Ribose is a component of the nucleic acid ribonucleic acid (RNA).

Glucose isomers



Isomers are compounds with the same chemical formula (same types and numbers of atoms) but different arrangements of atoms. The different arrangement of the atoms means that each isomer has different properties.

Molecules such as glucose can have many different isomers (e.g. α and β glucose, above) including straight and ring forms.

Glucose is a versatile molecule. It provides energy to power cellular reactions, can form energy storage molecules such as glycogen, or it can be used to build structural molecules.

Plants make their glucose via the process of photosynthesis. Animals and other heterotrophic organisms obtain their glucose by consuming plants or other organisms.

Fr… m… ca… be…

1. Describe the two major functions of monosaccharides:

   (a) *Primary energy source for cellular metabolism*

   (b) *Structural units for disaccharides and polysaccharides (energy sources and structural carbohydrates).*

2. Describe the structural differences between the ring forms of glucose and ribose:

   Glucose is a hexose sugar (6 carbon atoms). Ribose is a pentose sugar (5 carbon atoms).

3. Using glucose as an example, define the term isomer and state its importance:

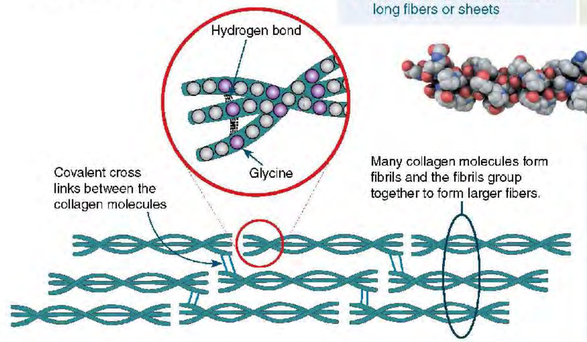
   Isomers have the same molecular formula but their atoms are linked in different sequences. α-glucose and β-glucose are isomers because although they have the same molecular formula, they are structurally different and have different properties.

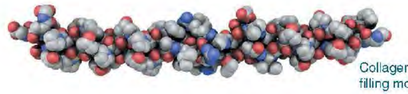
ISBN: 978-1-98-856656-6

Fibrous proteins

Fibrous proteins are elongated and fibrous in nature or have a sheet like structure. These fibers and sheets are strong and water insoluble. Some, such as keratin, are even insoluble in organic solvents. They have important structural roles.

Properties of fibrous proteins	Functions of fibrous proteins
Water insoluble	Structural role in cells and organisms *e.g. collagen in connective tissues, skin, and blood vessel walls.*
Very tough physically; may be supple or stretchy	Contractile *e.g. myosin and actin polymers in muscles*
Parallel polypeptide chains in long fibers or sheets	



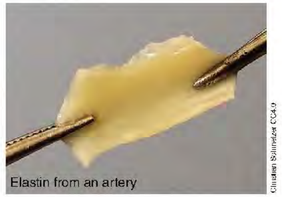


Collagen space filling model

A collagen molecule consists of three polypeptides wound together to form a helical 'rope'. Every third amino acid in each polypeptide is a glycine (Gly) where hydrogen bonding holds the three polypeptides together. Collagen molecules self assemble into **fibrils** held together by **covalent cross linkages**. Bundles of fibrils form fibers. Collagen is the main component of connective tissue, e.g. tendons and skin.

Mammalian hair and claws are α-keratin

The scales, beak, and feathers of birds are β keratin



Elastin from an artery

Claudine Blamont CC4.0

Keratins are found in hair, nails, claws, horn, hooves, wool, feathers, and the outer layers of skin. They fall into two classes: α keratins found in all vertebrates and the harder β keratins, found in reptiles and birds. The polypeptide chains are arranged in parallel sheets held together by hydrogen bonding. A distinguishing feature of keratins is the high sulfur content, with large numbers of disulfide bridges between cysteine residues. These form permanent, thermally stable covalent cross linkages and provide additional strength and rigidity.

Elastin is a connective tissue protein with elastic properties that enable tissues to resume their shape after stretching. Elastin has many hydrophobic amino acids, which form mobile hydrophobic regions flanked by covalent cross links between lysine residues.

…in the functioning of organisms? Use examples to help illustrate your answer:
…en and elastin, are the major component of many connective tissues,
…s (and also in skin), providing support and rigidity to the more fluid
…s are fibrous proteins that make up hair, nails, wool, feathers, horns, and
…ming durable structural and functional components of organisms.

4. Using an example, explain how the shape and properties of a fibrous protein relate to its functional role:

   The tertiary structure of fibrous proteins produces long fibers or sheets, with many cross-linkages. This makes them very tough physically and ideal as structural molecules. For example collagen consists of polypeptides wound together to form rope like structures, which then self assemble into fibrils held together by covalent cross linkages.

5. What common feature contributes to the strength and stability of collagen, keratin, and elastin?

   All three fibrous proteins form stable covalent cross linkages between amino acid residues in adjacent polypeptide chains, making stable and strong fibrous structures.

ISBN: 978-1-98-856656-6

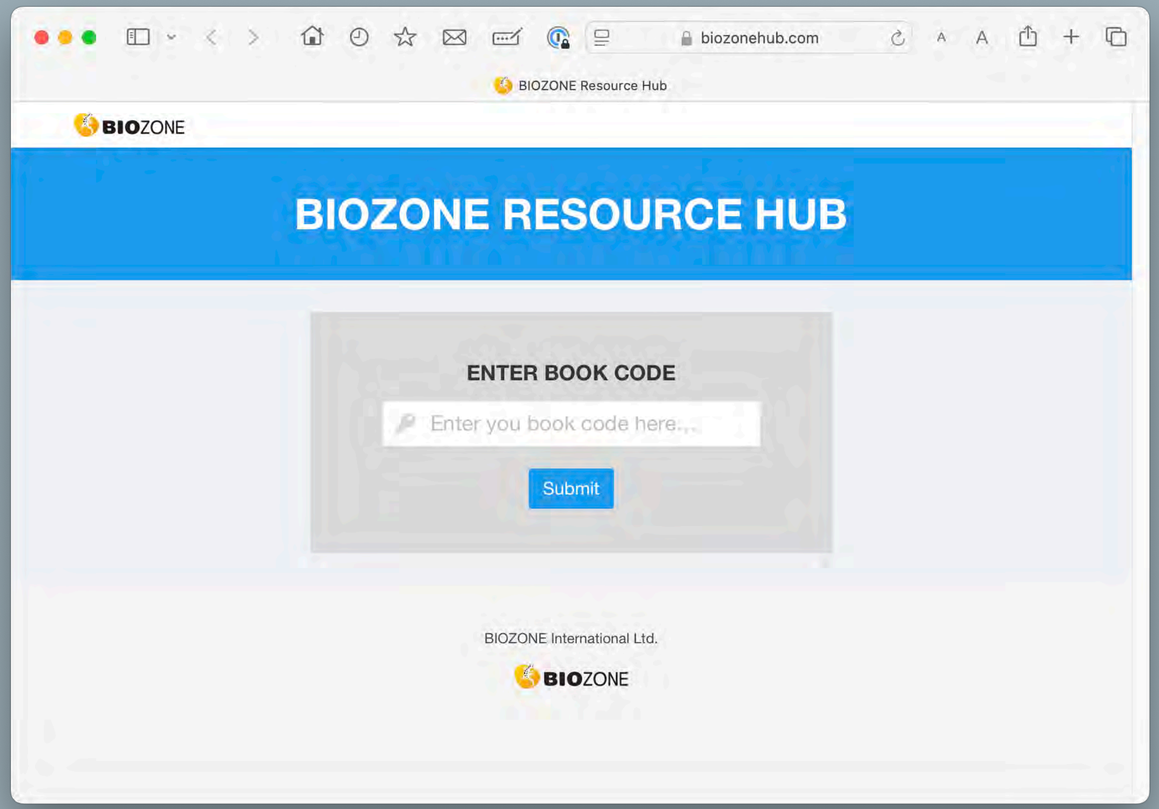
Answers are in place on the Teacher's Editions (printed and digital versions).

Resource Hub

Curated Digital Resources

www.biozonehub.com

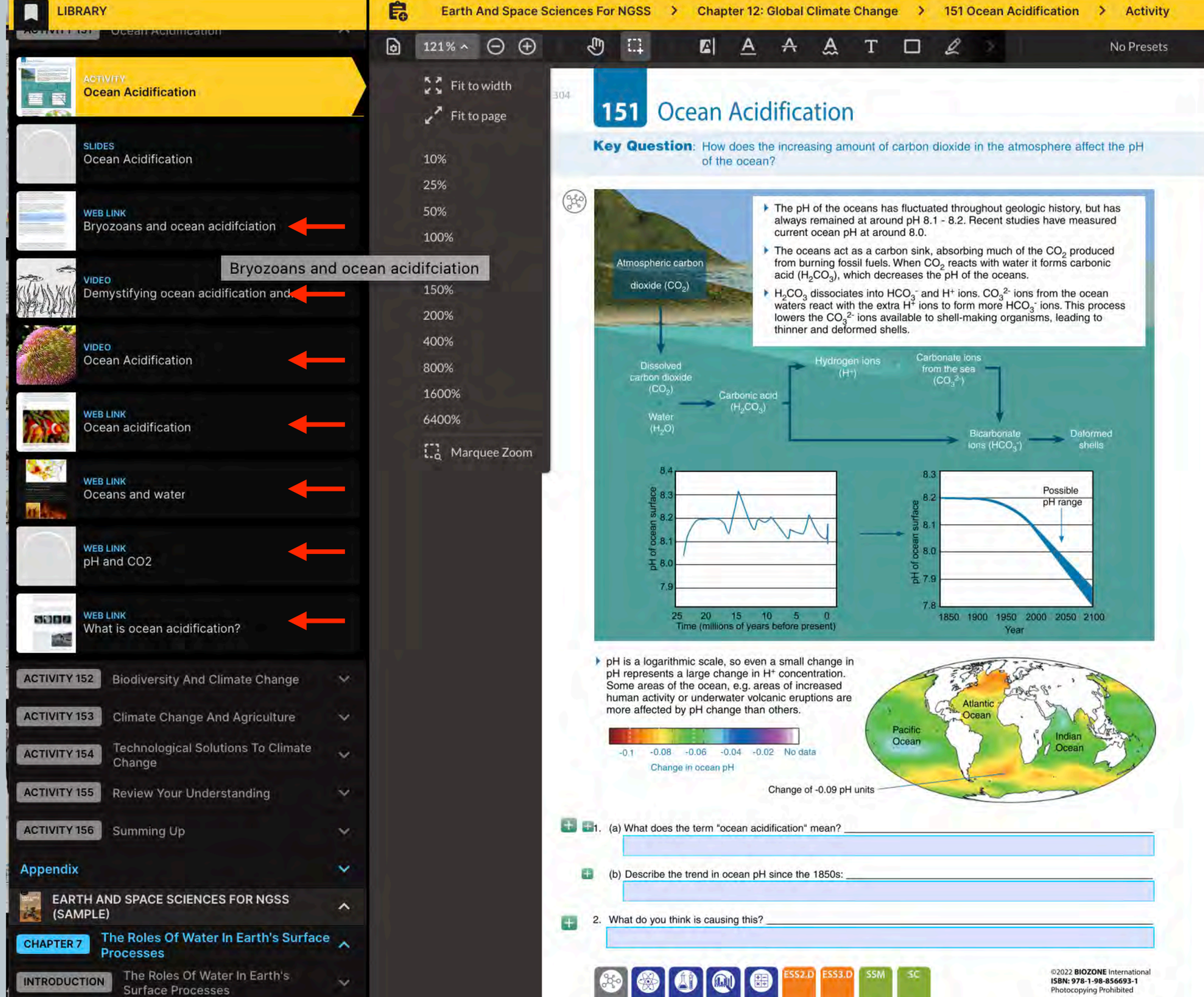
- **FREE access for teachers and students**
- Curated materials and resources which support the content of the work text with resources to engage your students
- Resources to further your **Gifted & Talented** students learning:
    - Web site links
    - Curated Videos
    - Curated Simulations
    - Spreadsheets
    - 3D Models



Locating the Resource Hub

- **Print users**:
  Details are found in the introduction chapter.

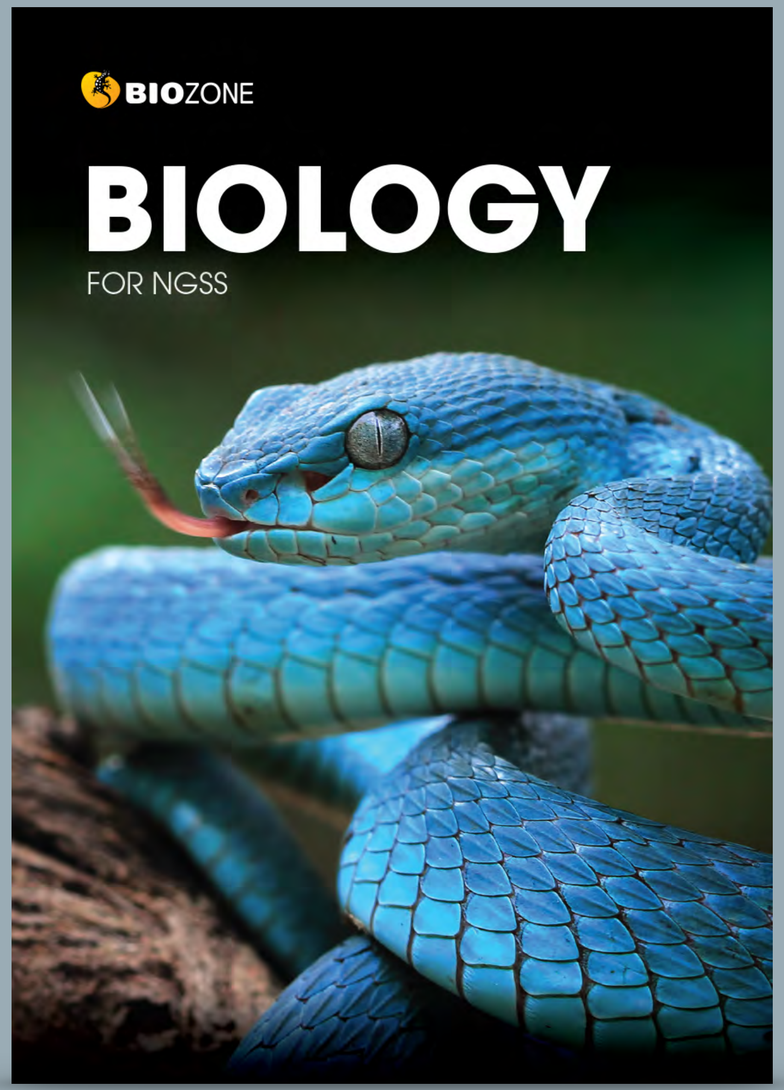
- **BIOZONE WORLD**:
  Resources are embedded and show up automatically with an activity.



Example: Biology for NGSS

In addition to a digital replica of the print book, BIOZONE World provides the following resources:

Presentation slides:	590
3D Models:	149
Intreractives:	79
PDF Downloads:	11
Curated OER Videos:	383
Web Links:	169

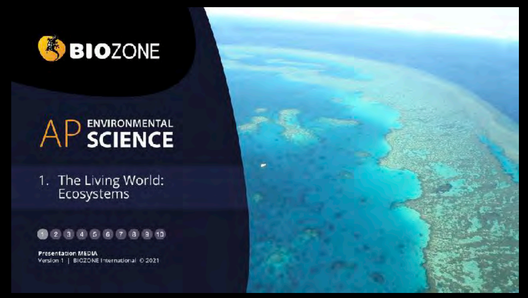


Presentation Slides

Fully Editable

- Deliver the BIOZONE content in a different and **engaging way**
- **Edit slides** to suit your teaching styles and methods
- Present to your students using a **projector** or **interactive whiteboard**
- Share slides with your students via secure network for their own note-taking and revision

Total Slides: **1156**



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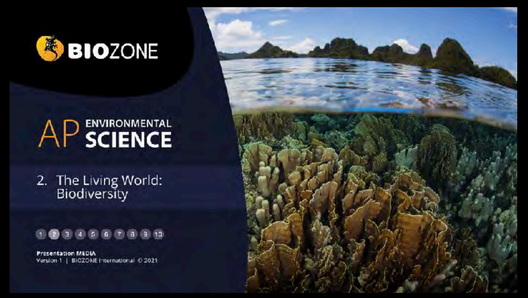

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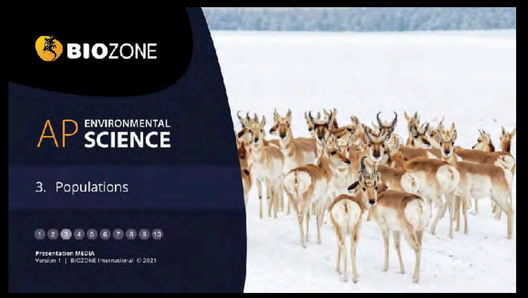

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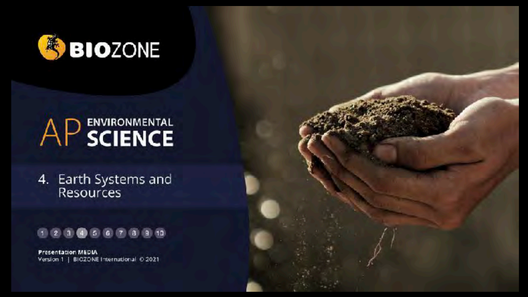

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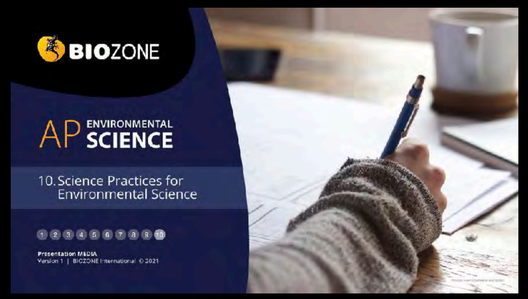
Slides: 163

Slides: 159



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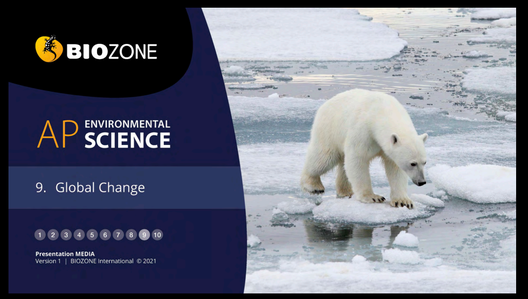
Slides: 173



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BIOZONE

AP ENVIRONMENTAL SCIENCE

9. Global Change

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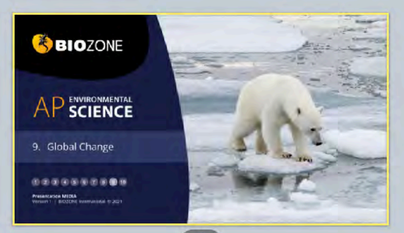

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5

Stratospheric Ozone Depletion

Earth's atmosphere is divided into layers. The **stratosphere** begins at an altitude of ~10 km.

Within the stratosphere, mostly at around an altitude of 20 km, incoming UV radiation from the Sun is involved in the splitting and reforming of ozone (O_3).

This process absorbs 99% of the UV radiation from the Sun.

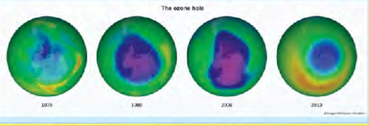
- UV radiation is very dangerous. Exposure can cause damage ranging from sunburn to cancer and cataracts.

6

Stratospheric Ozone Depletion

In 1984, scientists discovered the ozone layer above Antarctica was thinning, due to chemicals called **chlorofluorocarbons** commonly used in refrigeration.

Decades after these were banned, the ozone layer is beginning to show signs of repairing itself.



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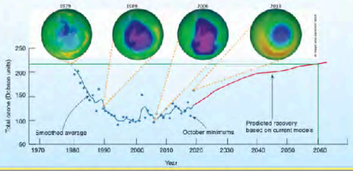
The Ozone Hole



8

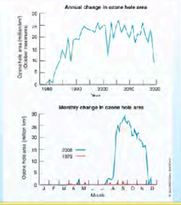
The Ozone Hole

Under certain conditions the ozone layer is thinned in certain places.

This thinning is most well known for its annual occurrence over Antarctica, however it also thins more rarely over the Arctic.

- In 2020, the Arctic experienced its largest ozone hole at nearly three times the size of Greenland, which lasted for over a month.

Mapping of the ozone layer first began in 1979 and the hole over Antarctica was discovered shortly afterwards.



9

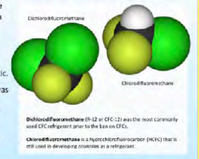
What Causes the Ozone Hole?

The primary cause for ozone depletion was the increased use of **chlorofluorocarbons (CFCs)** in the 1960s and 1970s.

- These were used as **refrigerants** and **propellants**, and were considered a considerable advancement on earlier refrigerants such as ammonia, which are toxic.

It was only after their widespread use that it was found that CFCs became unstable at high altitudes where they could be exposed to UV radiation from the Sun.

There they react with ozone, breaking it down into oxygen.

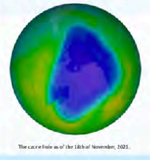


Dichlorodifluoromethane (F-12 or CFC-12) was the most commonly used CFC refrigerant prior to the ban on CFCs.

Chlorodifluoromethane is a hydrochlorofluorocarbon (HCFC) that is still used in developing countries as a refrigerant.

10

What Causes the Ozone Hole?



The ozone hole as of the 18th of November, 2021.

In 1987, the **Montreal protocol** banned the production of ozone-depleting CFCs.

However, there continues to be a considerable black market for CFCs, and CFCs are just one group of ozone depleting chemicals:

- Others include halons, methyl bromide, methyl chloroform and carbon tetrachloride.

Free chlorine in the stratosphere peaked around 1995 and is projected to decline for more than a century. Ozone loss is projected to diminish gradually but will take another 100-200 years for full recovery.

11

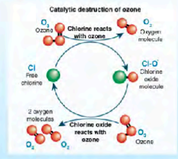
Mechanism of Ozone Depletion

CFCs are swept by winds to high altitudes. There, UV light causes them to lose chlorine atoms. These react in two ways:

$$Cl + O_3 \rightarrow ClO. \quad ClO + NO_2 \rightarrow ClONO_2$$
$$Cl + CH_4 \rightarrow HCl$$

$ClONO_2$ and HCl **do not** react with ozone, and instead form **reservoirs** in the stratosphere.

These reservoirs are concentrated and isolated by the **polar vortex** formed over the Antarctic by winter winds.



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Mechanism of Ozone Depletion

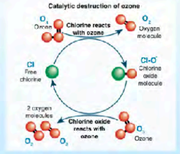
The stratosphere can become cold enough to form **polar stratospheric clouds**.

Crystals of ice form within these clouds.

HCl and $ClONO_2$ react together on these ice crystals, forming HNO_3 (nitric acid) and a Cl_2 molecule (chlorine gas). This process removes NO_2 from the atmosphere.

In the Antarctic spring, the ice crystals melt, releasing the Cl_2.

This is split by sunlight into two free chlorine atoms which enter the catalytic cycle.



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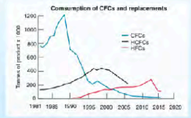
Replacing CFCs

The chemicals that have been developed to replace CFCs have their own sets of problems, primarily that most of them are very potent greenhouse gases.

- **HCFCs** were developed, which have a lesser effect on the ozone layer but are greenhouse gases.
- **HFCs** have no effect on the ozone layer but are potent greenhouse gases.
- A new replacement, **HFOs**, appear to have no effect on the ozone layer and are only weak greenhouse gases.



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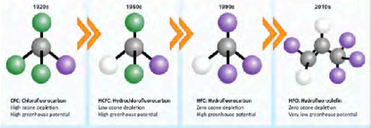
Replacing CFCs

Since the banning of CFC use, other chemicals have been developed to replace them.



CFC Chlorofluorocarbon
High ozone depletion
High greenhouse potential

HCFC Hydrochlorofluorocarbon
Low ozone depletion
High greenhouse potential

HFC Hydrofluorocarbon
Zero ozone depletion
High greenhouse potential

HFO Hydrofluoro-olefin
Zero ozone depletion
Very low greenhouse potential

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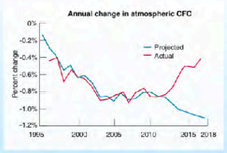
Replacing CFCs



Until the early 2010s, reduction in CFC use was proceeding as expected.

However, a decrease in the rate of reduction has been observed, which has been traced to the manufacture of **CFC-11 (trichlorofluoromethane)** in China for use in polyurethane insulation manufacture.

International agreements meant the manufacture of CFC-11 should have ended in 2010.

16

The Greenhouse Effect

The Earth's atmosphere comprises a mix of gases including nitrogen, oxygen, and water vapor, as well as small quantities of carbon dioxide, methane, and a number of other trace gases.

The term '**greenhouse effect**' describes the natural process by which heat is retained within the atmosphere by these greenhouse gases.

- The greenhouse effect results in the Earth having a mean surface temperature of about 15°C, 33°C warmer than it would have without an atmosphere.

17

The Greenhouse Effect

Greenhouse gases act as a **thermal blanket** around the Earth, letting in sunlight, but trapping the heat that would normally radiate back into space.

18

Global Warming

Fluctuations in the Earth's surface temperature as a result of climate shifts are normal.

However since the mid 20th century, the Earth's surface temperature has been increasing.

This phenomenon is called **global warming**.

Most researchers attribute global warming to the increase in atmospheric levels of CO_2 and other greenhouse gases emitted into the atmosphere as a result of human activity (i.e. it is **anthropogenic**).

19

Water and the Greenhouse Effect

Water vapor plays an important part in keeping the planet's temperature stable.

Water vapor is influenced by the Earth's temperature.

- An increase in temperature causes more water to evaporate.
- This can enhance the warming effect of other greenhouse gases.

Water constantly cycles from the atmosphere and back, so its effect is short lived, unlike other greenhouse gases.

20

Sources of Greenhouse Gases

Major sources of **carbon dioxide** include: exhaust from cars; combustion of coal, wood, oil; **burning** rainforests.

Major sources of **methane** include: plant debris, growing vegetation; belching and flatus of cattle.

Major sources of **chlorofluorocarbons** include: leaking coolant from refrigerators; leaking coolant from air conditioners.

The major source of **nitrous oxide** is car exhaust.

Tropospheric ozone, found in the lower atmosphere, is triggered by car exhaust (smog).

21

Controlling Greenhouse Gases

The **Kyoto protocol**, an international treaty adopted in 1997, aims to reduce global warming by controlling greenhouse gases.

- Greenhouse gas emission limits are set on countries depending on their industrial ability, historic greenhouse gas output, and the average 1990 greenhouse gas level.

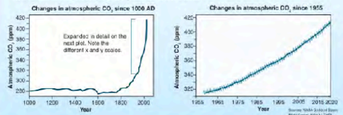
The protocol has had limited success, and reductions in greenhouse gas emissions since 1997 have been limited. Global reductions are largely due to the collapse of the Soviet Union and its industrial sector in 1991.

22

Changes in Atmospheric CO_2

Around the world are a network of observatories that are constantly measuring the concentration of CO_2 in the atmosphere.

- Below are the measurements from Mauna Loa, Hawaii. These match readings from around the world. Concentration rises and falls on an annual basis.



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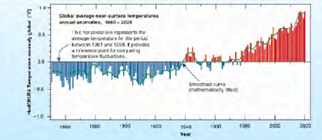
Global Near-Surface Temperature

Adding greenhouse gases to the atmosphere causes the Earth's surface temperature to rise. There has been an increase in near-surface temperatures around the globe over the last half a century.



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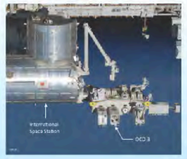
Mapping Greenhouse Gases



The **Orbiting Carbon Observatory-3** (OCO-3) was launched on 4 May 2019 and installed in the International Space Station (ISS).

It is an additional carbon observatory that will supplement OCO-2, an independent satellite.

OCO-3 will map CO_2 for just 3 years. However, unlike OCO-2, it is able to see the same part of the globe at different times of the day due to the timing of the ISS orbit.

The two sets of measurements should provide high precision data for changes in atmospheric CO_2.

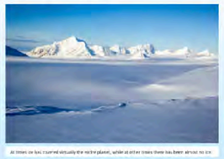
25

Earth's Long Term Climate

The Earth's climate has varied considerably when viewed over the long term. There have been frequent **ice ages** consisting of **glacials** and **interglacials**.

These changes in climate are related to many different variables, including changes in the orbit and tilt of the Earth, and the evolution of life.

Carbon dioxide and other greenhouse gases also play a part in these changes.



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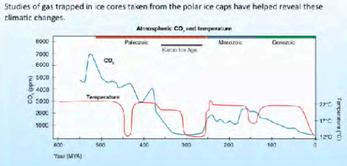
Earth's Long Term Climate

Studies of gas trapped in ice cores taken from the polar ice caps have helped reveal these climatic changes.



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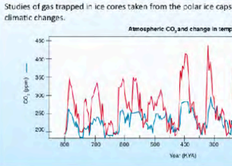

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What is Climate Change?

The **greenhouse effect** refers to the warming effect of the Earth's atmosphere, and **global warming** to the steady measured increase in the Earth's surface temperature.

Climate change refers to the long term climatic effects of those.

It is important to separate climate from weather.

- **Climate** is widespread and long term, over many years or decades.
- **Weather** is local and short term.

29

Potential Effects of Climate Change

The potential effects of climate change are wide ranging.

Sea levels are expected to rise by 30-50 cm by the year 2100. This is the result of the thermal expansion of ocean water and melting of glaciers and ice shelves.

Many of North America's largest cities are near the coast. The predicted rises in sea levels could result in **inundation** of these cities and entry of salt water into agricultural lands.

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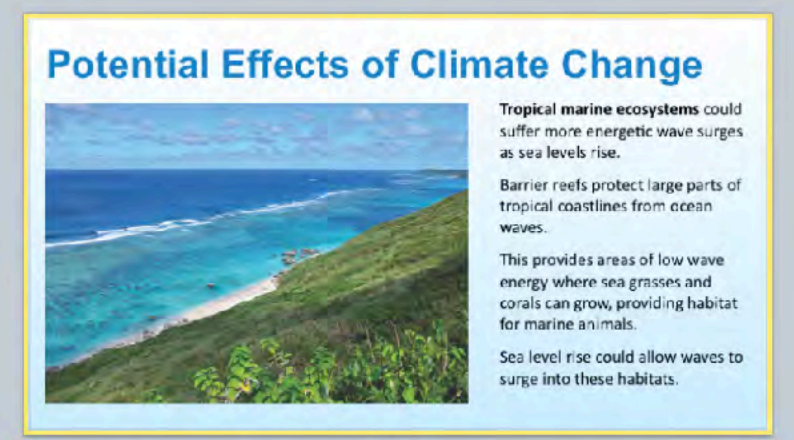

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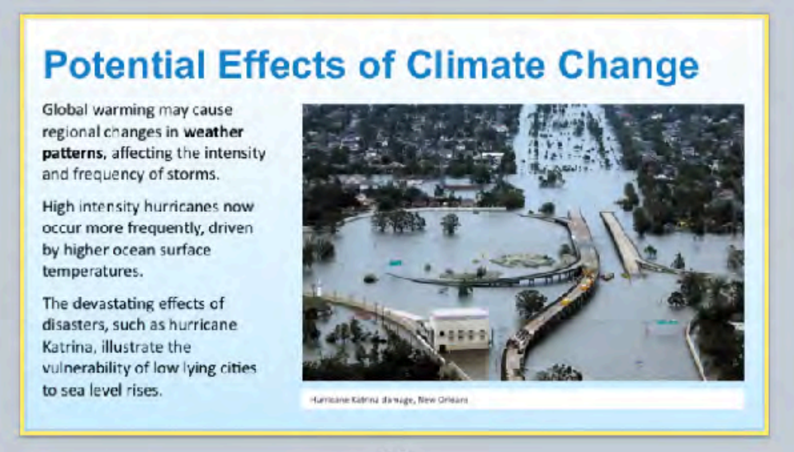

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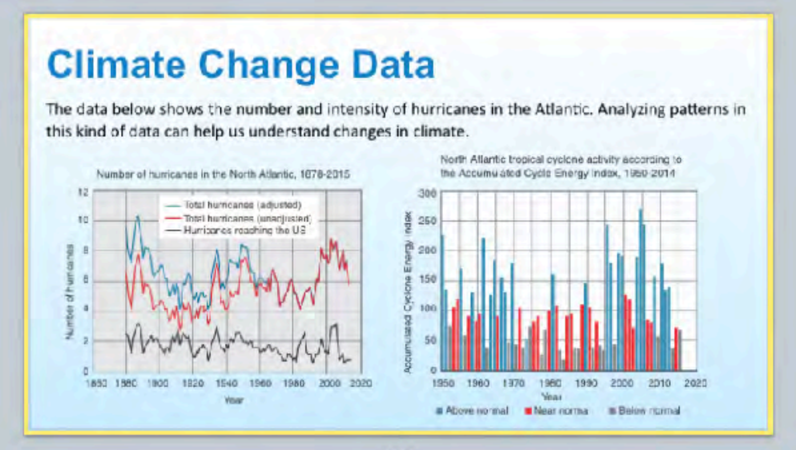

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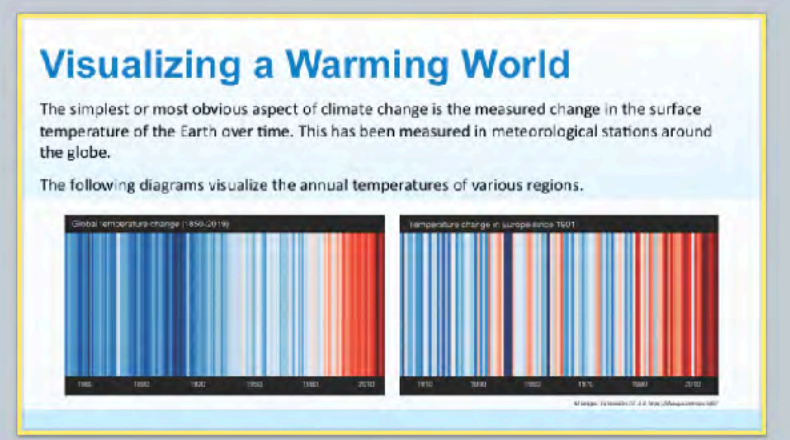

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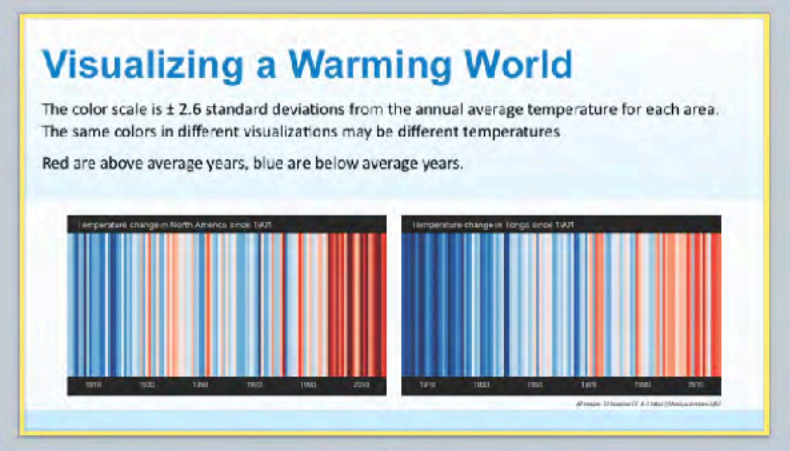

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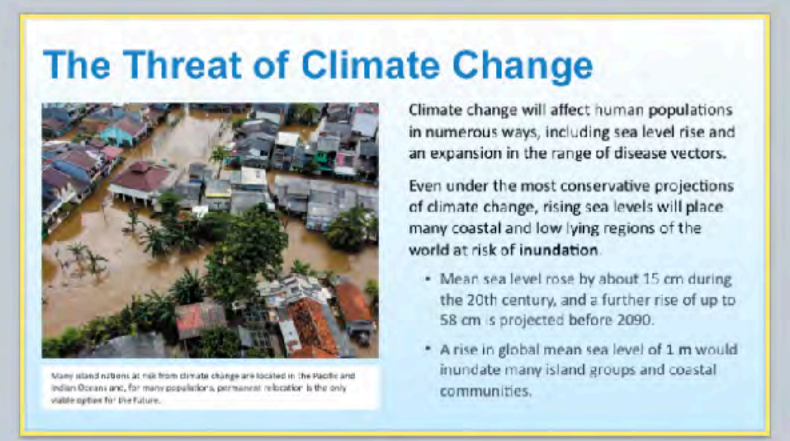

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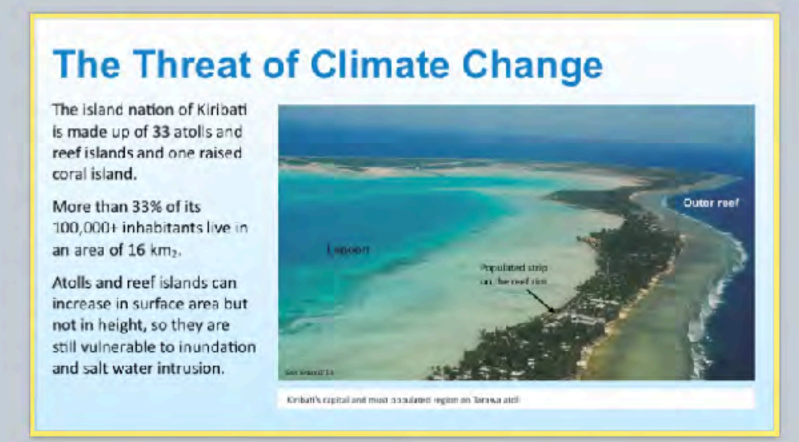

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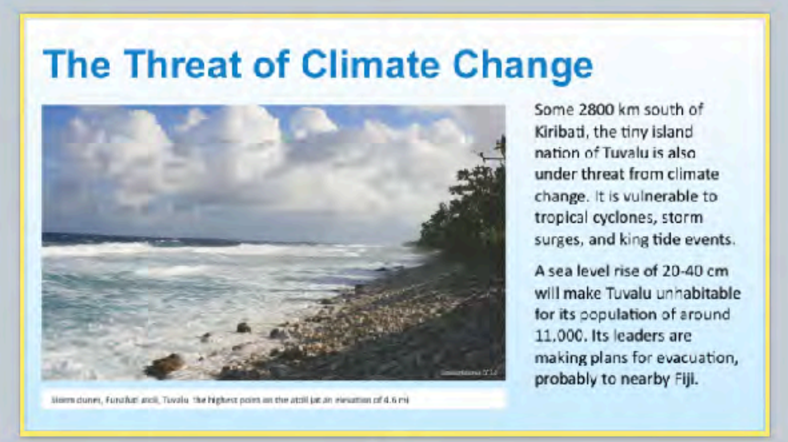

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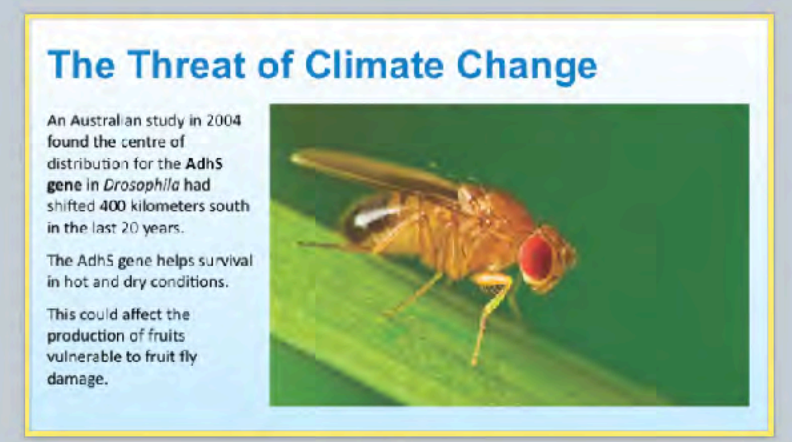

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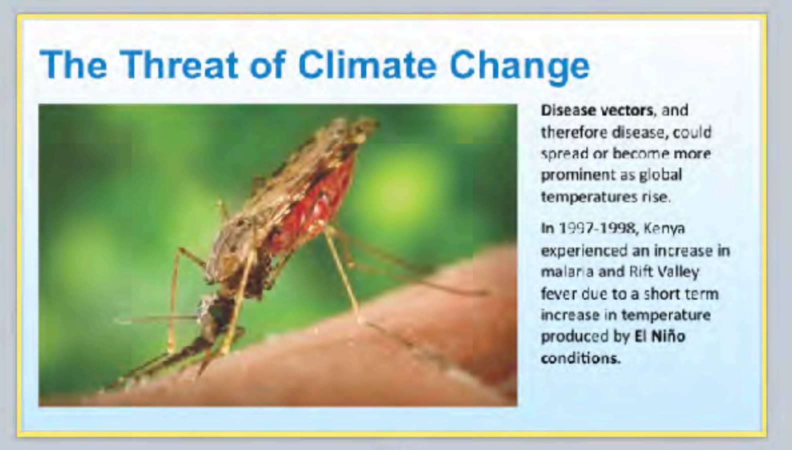

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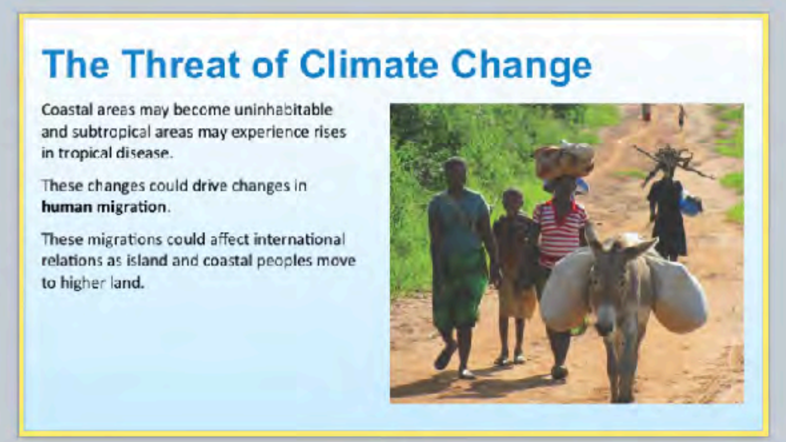

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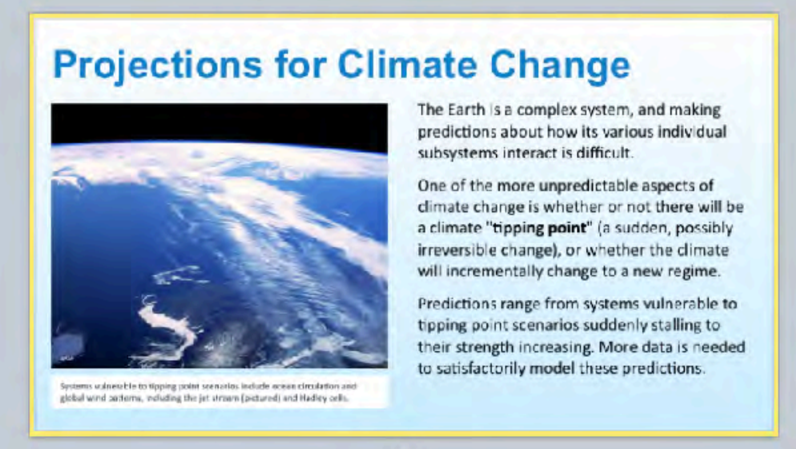

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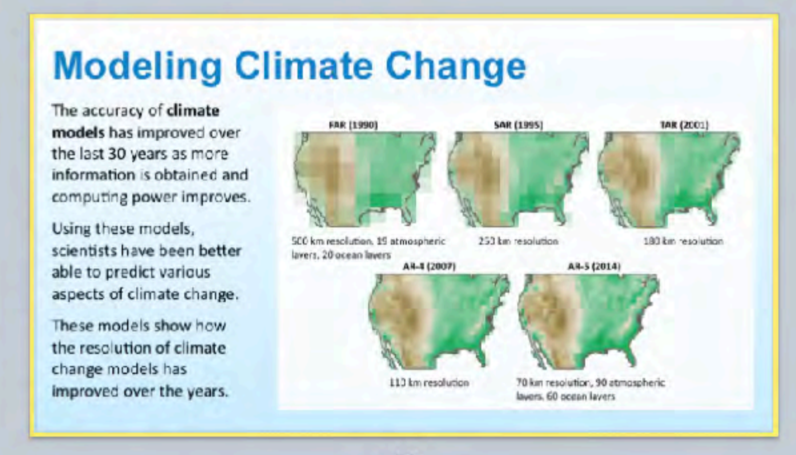

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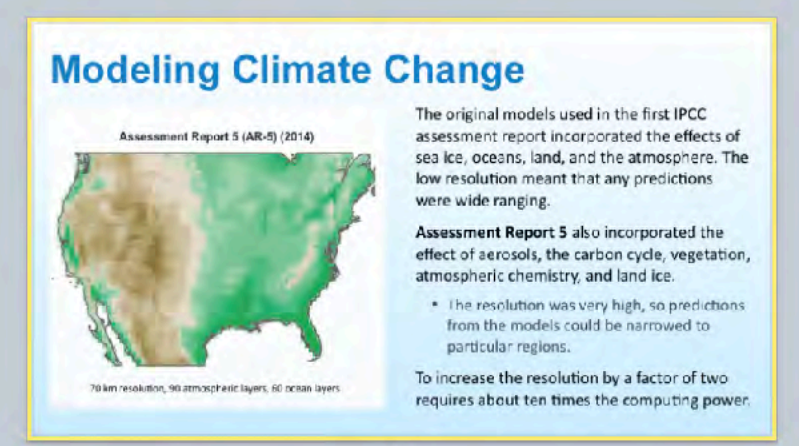

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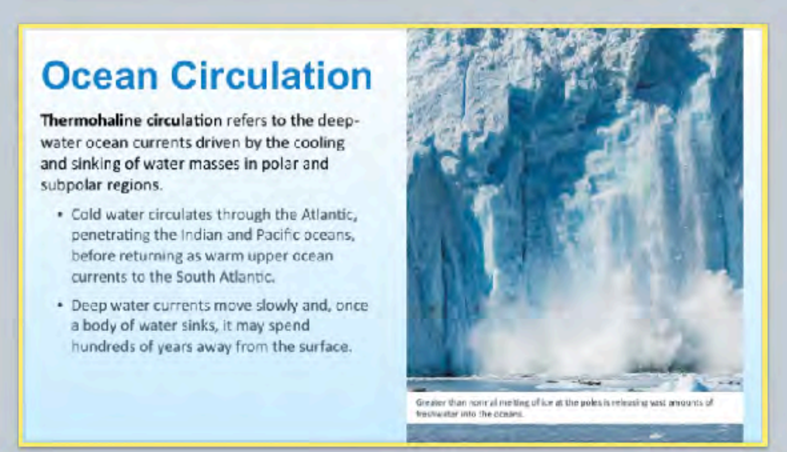

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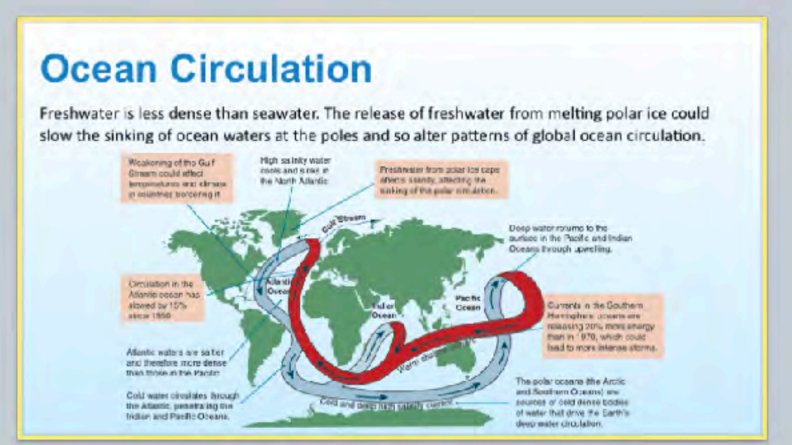

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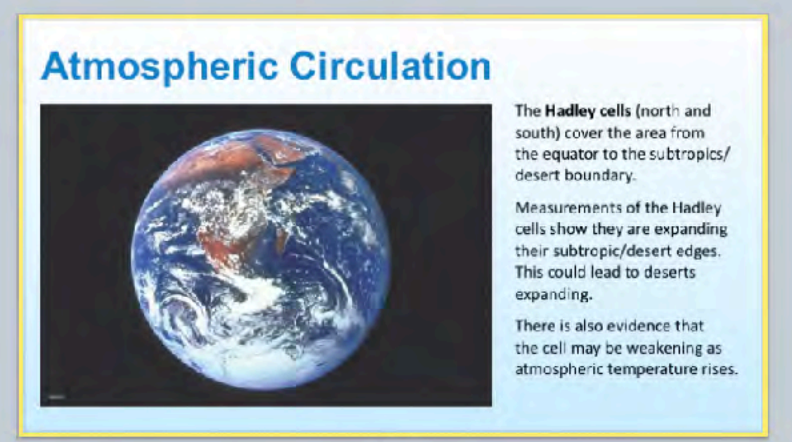

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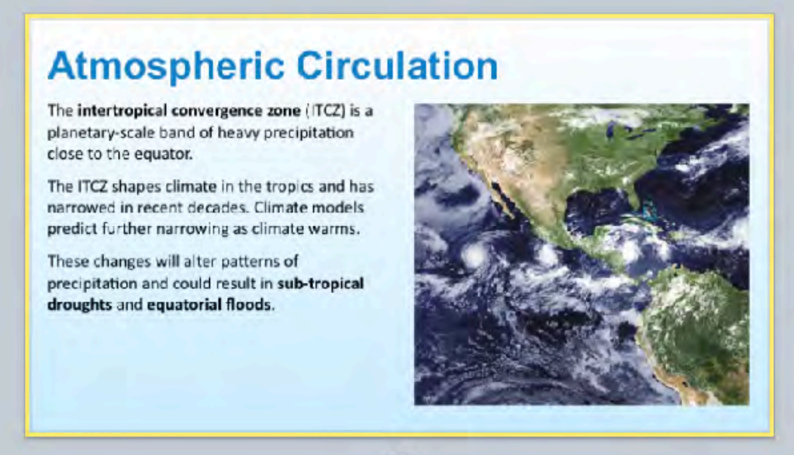

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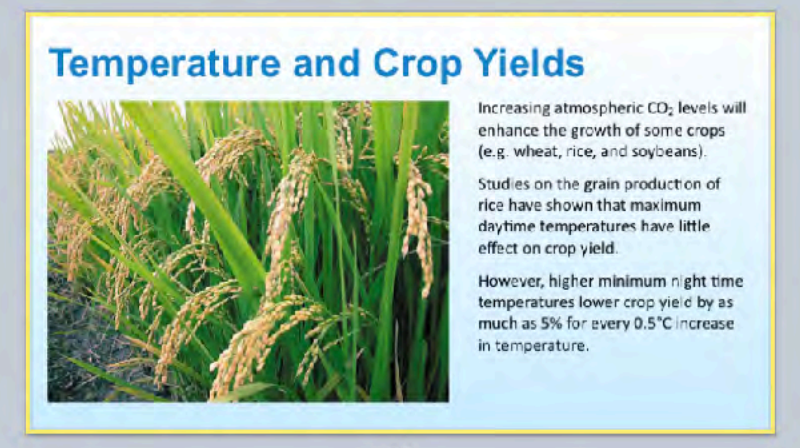

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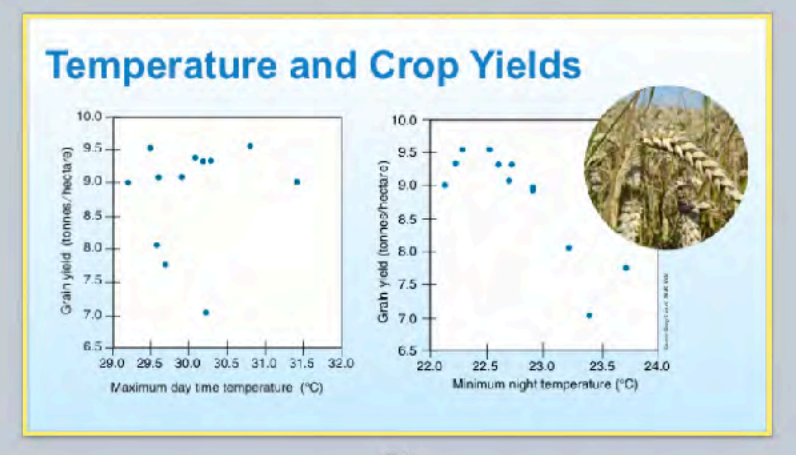

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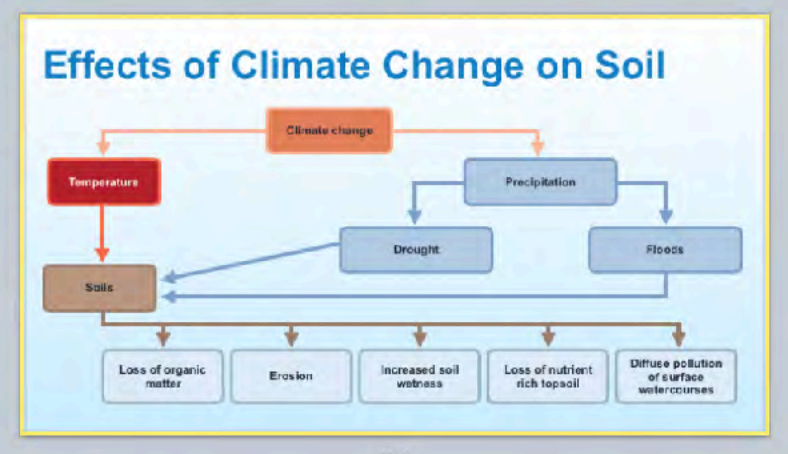

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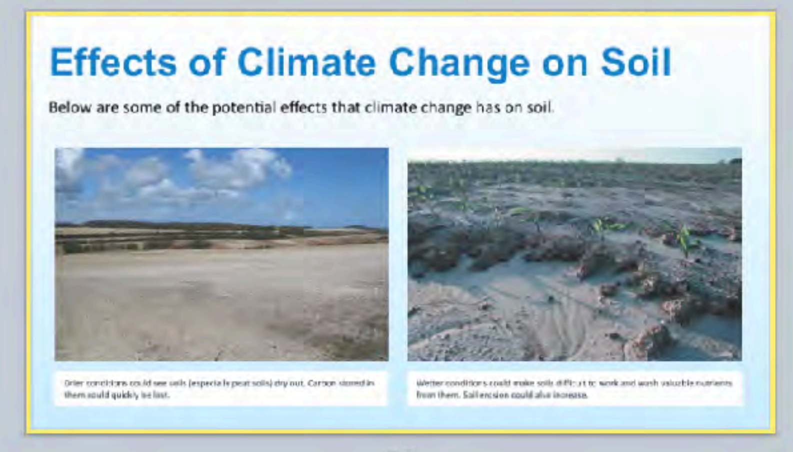

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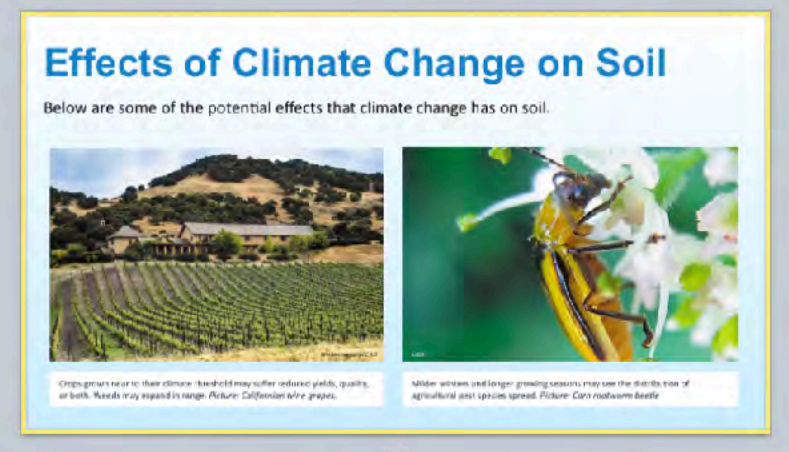

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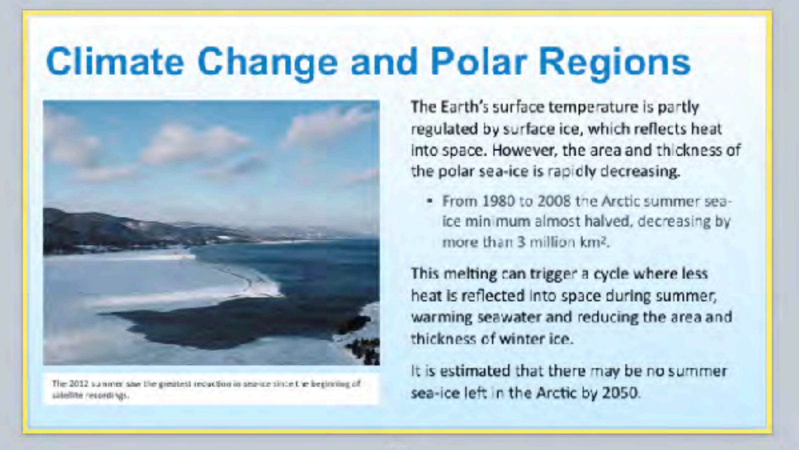

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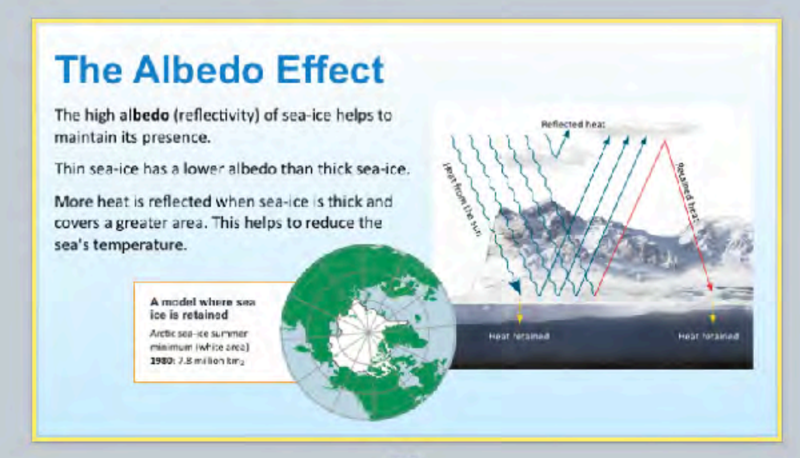

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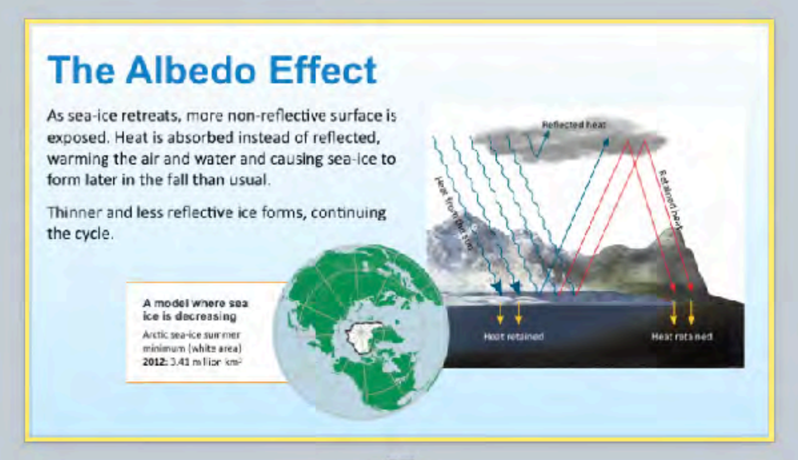

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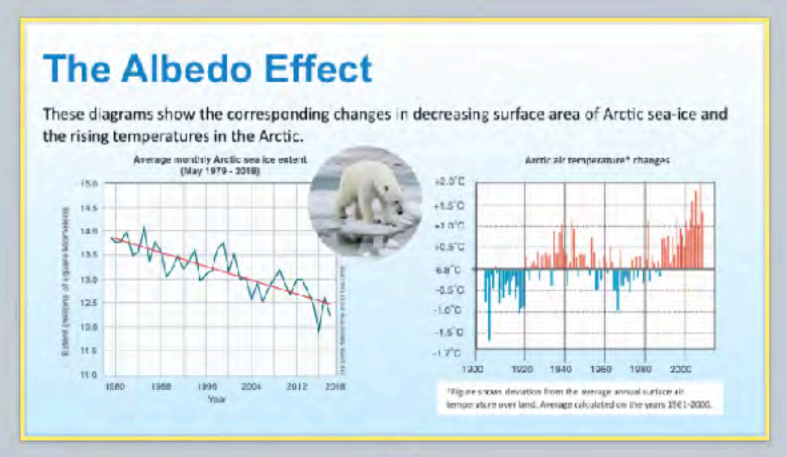

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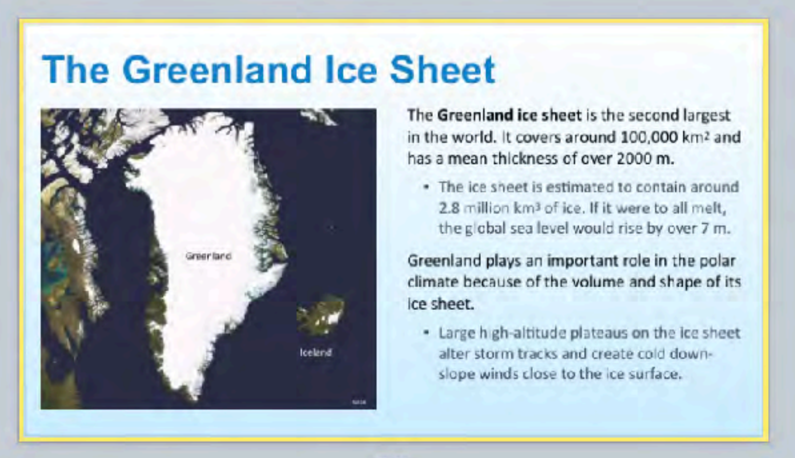

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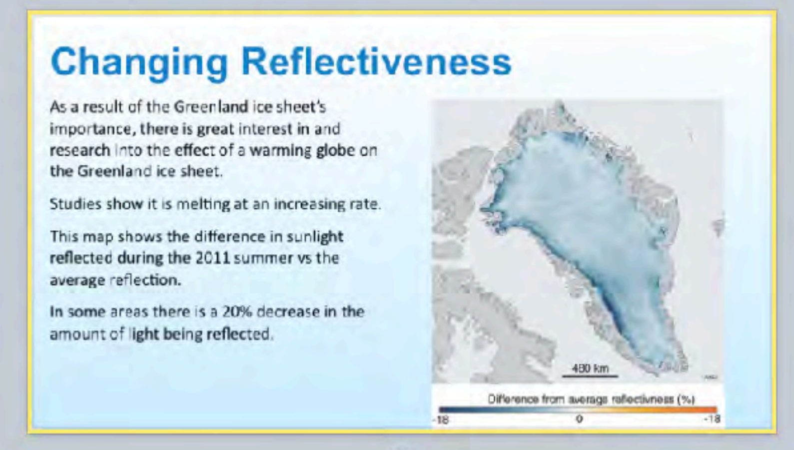
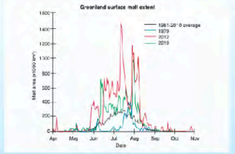


60

The Greenland Ice Sheet



Melting of the Greenland ice sheet occurs during the Arctic summer.

Since 1979 the area of ice melting and the length of time melting occurs has increased.

2012 saw the greatest amount of melting on the ice sheet.

61

The Polar Habitat: Melting Permafrost

Permafrost is ground that remains continuously frozen for two years or more at a time. It underlies nearly 25% of the Northern Hemisphere.

Climate change is beginning to have an effect on permafrost, with areas beginning to melt as Arctic temperatures rise.

This causes a number of problems, including the collapse of overlying ground, the formation of **thaw lakes**, and the release of methane and CO_2.

62

The Polar Habitat: Melting Permafrost

Melting permafrost causes the increase, extension, or exacerbation of the **thermokarst**.

During the Arctic summer, areas of ice across the tundra melt, forming **thaw lakes**.

With increasing Arctic temperatures, these landscapes have expanded, causing parts of the Arctic, including areas of boreal forest, to **permanently collapse**.

Thaw has also caused hillsides to collapse as the underlying permafrost loses structure and gives way.

63

The Polar Habitat: Melting Permafrost

When permafrost melts, **methane** and **carbon dioxide** can be released.

This is due to the decomposition of thawing organic matter, and also because methane trapped in thawing material is released.

These releases can result in **positive feedback** and lead to increased warming.

- Positive feedback loops on Earth tend to drive large scale changes to environments and the climate. The current increase in CO_2 in the atmosphere is driving many positive feedback loops.

64

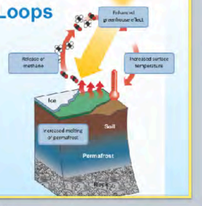
Driving Feedback Loops

This diagram shows the effect of methane release from permafrost.

Methane is a potent greenhouse gas.

The melting of permafrost has the **potential** to produce a **positive feedback loop**, producing even more heating.

Several positive feedback loops acting at the same time can cause large, potentially destabilizing changes to the climate.

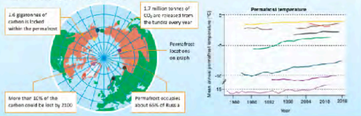


65

The Melting of Arctic Permafrost

Although positive feedback loops are balanced to some extent by counterbalancing **negative feedbacks**, there may be a "tipping point" at which a runaway climate change event will occur.

Various studies in the Arctic region show the temperature of the permafrost is indeed increasing, in some areas by 2-3°C since 1980.



66

Polar Bears

Polar bears mainly hunt seals. Reduced sea ice levels have changed seal distribution patterns, and many polar bears are forced to swim long distances to hunt.

In addition, the thinner sea ice cannot hold the weight of an adult bear, forcing them to return to the mainland **without** essential fat stores.

The loss of condition is affecting reproductive rates, and so juvenile survival rates are lower.

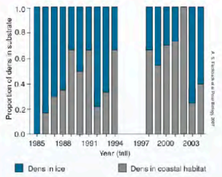
In the period between 1992 to 2004, only 33% of bears observed were on sea ice during summer (down from 87% in 1979-1991).

67

Polar Bears

Pregnant female polar bears must also swim for longer distances to reach their dens, and so lose more condition in the process.

A 2007 study (right) shows a decrease in the number of bears denning in pack ice over a 20 year period.



68

Antarctica

The effect of climate change on Antarctica is often overlooked. However, recent research into changes in the **Antarctic ice sheet** has produced very worrying results.

- The Antarctic ice sheet covers 98% of the continent at about 14 million km². It contains 26.5 million km³ of ice, enough to raise sea levels by 58 m if it were to all melt.

Recent studies of the ice sheet show rapid melting in some areas.

Large ice shelves, such as the the Larsen ice shelf, have already disintegrated.

69

The Melting of Thwaites Glacier

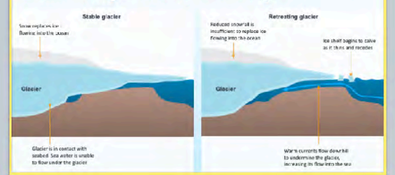
The **Thwaites Glacier**, which drains part of the West Antarctic ice sheet, is about 192,000 km².

The ice in Western Antarctica is anchored on land that is far below sea level, and the topography of the land and seabed under the glacier is contributing to its melting.

- The downward angle of the seabed beneath Thwaites Glacier allows warm water to flow beneath as ice retreats.
- As the glacier melts it moves faster towards the sea, draining ice off the glacier into the sea at an ever increasing rate.

70

Examining Glacier Stability



71

Ocean Warming

The rise in the global atmospheric temperature **ultimately affects the oceans**. The average ocean temperature is rising, although more slowly than atmospheric temperatures.

The rise in temperature is of concern for two primary reasons.

- Rising temperatures will affect marine communities adapted to live at certain temperatures.
- Above 4°C, water volume increases as temperature rises. This could have serious effects on sea levels and coastal communities, adding to sea level rise.

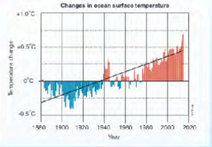
72

Changes in Ocean Temperature

Average ocean temperatures have risen sharply since 1970.

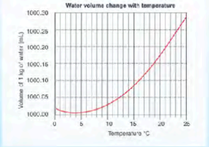
Water absorbs a large amount of energy for every degree Celsius it rises (4.2 joules per milliliter or gram).

Even a small rise in sea temperature equates to the absorption of an enormous amount of energy when considering the entire ocean.



73

Ocean Temperature and Sea Level



Water at 0°C is less dense than water at 4°C. That is why icebergs float.

Above 4°C, water begins to expand.

A rise of 2°C above 4°C produces a small expansion per kg of water.

With trillions of tonnes of water in the ocean, the increase in volume would be enormous.

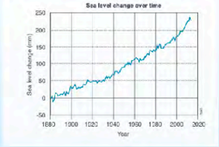
74

Ocean Temperature and Sea Level

Tidal measurements show that the average sea level has steadily risen since at least the 1880s.

Part of this is a gain in water volume from melting ice caps and glaciers

However, a large part is the thermal expansion of the water in the oceans themselves.



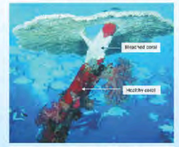
75

Habitat Effects of Ocean Warming

An increase in sea temperatures could mean the death of coral reefs.

Coral reefs depend on the symbiotic relationship between a coral polyp and photosynthetic protistans called **zooxanthellae**.

- Zooxanthellae live within the polyp tissues and provides it with most of its energy.
- A 1-2°C temperature increase is enough to disrupt the photosynthetic enzymes.
- The zooxanthellae either die, or are expelled from the coral due to stress.



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Oxygen Saturation

Warm water holds less oxygen than cold water.

As the oceans warm, **oxygen saturation** decreases. Ocean oxygen saturation has declined by about 2% since the middle of the 20th century and is expected to fall by about 3-4% by 2100.

- This could cause shifts in species distribution, expanding algal blooms, and reductions in fisheries resources.
- Much of the ocean's oxygen is concentrated in the upper 1000 m, where biodiversity is highest. A reduction in oxygen will affect marine biodiversity.

77

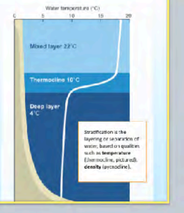
Oxygen Saturation

Warm water increases the oxygen demand of organisms.

As a result organisms in warmer oceans are increasingly likely to suffer from **hypoxia**.

Eutrophication due to runoff from the land will add to this problem.

Warming the upper layer of the ocean increases **stratification** and reduces mixing of the upper and lower layers. This will result in deep ocean waters becoming even more **oxygen depleted**.



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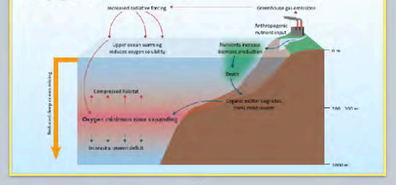
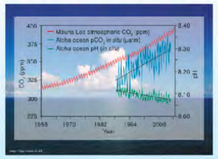
Oxygen Saturation



79

Ocean Acidification



The oceans act as a **carbon sink**, absorbing CO_2 from the atmosphere.

When CO_2 reacts with water it forms **carbonic acid**, which produces hydrogen ions, which decreases the pH of the oceans.

- This could have major effects on marine life, especially shell-making organisms.

Ocean acidification is a relative term, referring to the oceans becoming less basic as the pH decreases.

80

Carbon Dioxide and pH

The effect of CO_2 on water can be seen by bubbling it through water containing a pH indicator.

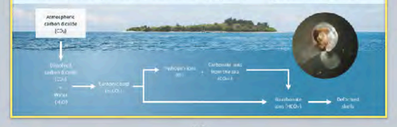
- Bromothymol blue is an indicator that is blue in basic (alkaline) solutions, blue/green in neutral water and yellow/green in acidic solutions.
- Adding CO_2 to water containing bromothymol blue causes the solution to turn yellow/green as the CO_2 dissolves into the water.

81

The Chemistry of Ocean Acidification

CO_2 dissolved into ocean waters reacts with water to form **carbonic acid** and lowers the pH of the water. The carbonic acid dissociates into HCO_3^- and H^+ ions.

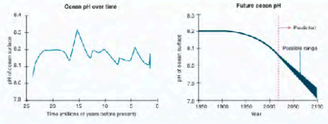
- Carbonate ions (CO_3^{2-}) from the water react with the extra H^+ ions to form more HCO^{3-} ions.
- This lowers the CO_3^{2-} ions available to shell-making organisms, leading to thinner, deformed shells.



82

Ocean pH

The pH of the oceans has fluctuated throughout geologic history but has always remained at around pH 8.2.

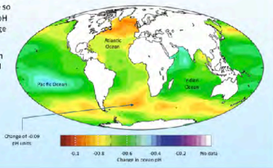


83

Change in Ocean pH

pH is a logarithmic scale so even a small change in pH represents a large change in H^+ concentration.

Some areas of the ocean are more affected by pH change than others.



84

The Effects of Ocean Acidification

Shell-building marine organisms build their shells from **calcium carbonate** ($CaCO_3$), which occurs as two minerals: calcite and **aragonite.**

Aragonite is stronger than calcite but more soluble. In solution, it forms an equilibrium with its ions Ca^{2+} and CO_3^{2-}.

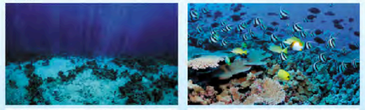
Ocean acidification results in the reduction of carbonate (CO_3^{2-}) ions in the water, because more carbonate ions react with H^+ ions to form bicarbonate.

Decreasing the pH (by increasing H^+) reduces available CO_3^{2-}.

85

The Effects of Ocean Acidification

There is direct evidence that high levels of dissolved CO_2 negatively affect marine life. This has been obtained by comparing sites where CO_2 seeps naturally from volcanic vents to sites where it does not.



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The Effects of Ocean Acidification

The increase in CO_2 favors the **dissolution** of aragonite from shells and affects the ability of shell-making organisms to obtain the CO_3^{2-} ions needed for shell building.

The shells of molluscs and corals that rely on aragonite are weakened and deformed.

The organism must expend more energy on shell building than normal.

Therefore, less energy in available to carry out other biological functions such as growth and reproduction. Fertilization is also affected.

87

The Effects of Ocean Acidification

Echinoderms such as brittle stars have a skeleton of calcium carbonate.

Experiments have shown that larval brittle stars die in less than a week in seawater with higher than normal CO_2.

Adults (pictured) show a loss of muscle mass.

88

The Effects of Ocean Acidification

Ocean acidification has been linked to coral whitening, or "**bleaching**" and the reduction in the growth of corals.

Warmer waters also cause corals to expel the zooxanthellae in their tissues, causing bleaching.

- Corals can survive bleaching events, but it indicates stress and results in reduced survival.

89

Ocean Acidification and Molluscs

Pteropods are mollusks specialized for life in the open ocean.

- They are called sea butterflies because of the wing-like structures that help them swim in the oceans.

Shelled pteropod species have calcium carbonate shells that are around 5-10 mm in diameter.

Because pteropods have calcium carbonate shells and live in parts of the ocean saturated with aragonite, they are likely to be indicators of the wider effects of ocean acidification.

90

Ocean Acidification and Molluscs

The effect of ocean acidification on *Limacina helicina* shell deposition was studied under CO_2 levels equal to 350 ppm (pH 8.09) and 760 ppm (pH 7.78).

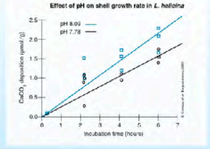
Specimens were grown with $^{45}CaCl_2$.

^{45}Ca is radioactive with a half life of 163 days.

Conditions	pH	pCO_2 (ppm)	Ω	Temperature
Normal pH (as per 1990 average)	8.09	350	1.50	5
Low pH (predicted 2100)	7.78	765	1.00	5
Fjord where collected	8.12	320	1.81	2.2

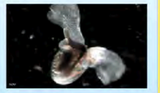
91

Ocean Acidification and Molluscs



The rate of $CaCO_3$ shell deposition was estimated from the radioactivity in each shell after incubation with ^{45}Ca.

This graph shows the effect on $CaCO_3$ shell deposition:



92

Ocean Acidification and Fish

A lower ocean pH and increased CO_2 can affect the behavior and survival of fish and other marine organisms.

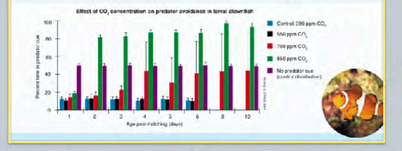
A study of the behavior of clownfish (*Amphiprion percula*) was carried out.

- Larval clownfish were raised in seawater at ambient CO_2 (390 ppm), 550 ppm, 700 ppm and 850 ppm CO_2.
- At each CO_2 concentration, the larval fish were given a choice of water streams. One contained the chemical cue of a natural predator and the other did not.

93

Ocean Acidification and Fish

The results of this experiment are shown in the graph below. For each set of trials, there was also an untreated control, where both water streams lacked the predator cue (purple bars).

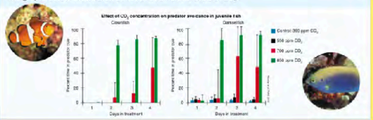


94

Ocean Acidification and Fish

The clown fish were tested for predator avoidance again at the **settlement stage** (transformation to a juvenile). These were compared to wild caught damselfish (*Pomacentrus wardi*) that were also treated with the same levels of CO_2.

The graphs below shows their behavior at different levels of CO_2.



95

Invasive Species

Introduced species are species that have evolved in one region and have been transported by humans, either intentionally or inadvertently, to another.

Invasive species are introduced species that have a detrimental effect on the ecosystems into which they have been imported.

- Many of these have been **deliberately introduced**, whereas others have been **accidentally imported**.
- Some have been deliberately introduced to control another pest species and have themselves become a problem.

96

Kudzu

Kudzu (*Pueraria lobata*) is a climbing vine native to south-east Asia that was introduced to the US in the 1800s as an ornamental plant. It was later widely distributed as cattle fodder and as a cover plant.

It spreads aggressively and is a serious invasive pest in the southern US. Kudzu grows so fast that it climbs and grows over other plants, blocking out sunlight and killing them.

It was finally listed as a weed in 1970.

Today, kudzu is estimated to cover **3 million** ha of land in the southeastern US.

97

Red Imported Fire Ant

Red fire ants (*Solenopsis invicta*) were accidentally introduced into the US from South America in the 1920s.

Red fire ants displace populations of native insects and ground-nesting wildlife. They also damage crops and are very aggressive.

The USDA estimates damage and control costs for red fire ants at more than $6 billion a year.

Red fire ants lack natural control agents in North America and thrive in disturbed habitats such as agricultural lands.

98

Red Imported Fire Ant

Red fire ants are now resident in **14 US states.**

They have been spreading progressively northwards into the US (dark blue on map) from South America (red on map).

They have also been accidentally introduced to many other countries, where they are causing similar problems as those in North America.

99

What Makes an Invasive Species?

Many native species live in balance with their ecosystem. Their populations are limited by native predators, parasites, or pathogens, and by food or space.

Slow-breeding species and animals with specific habitats or diets are unlikely to become invasive.

Invasive species therefore tend to be ***r*-selected species** and **generalists**.

In a new environment they have few predators or pathogens, and their populations can increase rapidly.

100

The New Zealand Mud Snail

The **New Zealand mud snail** (*Potamopyrgus antipodarum*) is another example of an invasive species. It is a small freshwater snail (12 mm long).

The NZ mud snail has been accidentally introduced to at least a dozen countries including in Europe and North America.

The snail tolerates a wide range of environments. It breeds both sexually and asexually and can produce up to 230 young per year.

Outside of New Zealand it has no predators, parasites, or pathogens. It spreads rapidly through water and via the guts of birds and fish.

101

The New Zealand Mud Snail

Outside of New Zealand, the NZ mud snail is considered one of the **worst invasive freshwater species**.

It was first detected in the US in 1987. It has since spread throughout the United States. It possibly arrived in ship ballast, or via live game fish or contaminated wading gear.

Densities have reached up to 500,000 per m² in some rivers.

The NZ mud snail outcompetes native species, affecting species further up the food chain as their natural food source is reduced.

102

Endangered Species

Species under threat of severe population loss or extinction are classified as either **endangered** or **threatened**.

An **endangered species** is one with so few individuals that it is at high risk of local extinction.

Extinctions are a natural phenomenon, but the rapid increase in the rates of species extinction in recent decades is of major concern.

It is estimated that every day up to 200 species become extinct as a result of human activity.

103

Causes of Species Declines

Habitat destruction

Natural habitat can be lost through clearance for agriculture, logging, urban development and land reclamation, or vegetation destruction by introduced pest plants and animals.

Habitats may become too small or isolated to support viable populations.

104

Causes of Species Declines

Pollution

Toxic substances released by humans into the environment cause harm directly or accumulate in food chains.

Estuaries, wetlands, river systems and coastal ecosystems near urban areas are particularly vulnerable to the effects of pollutants.

105

Causes of Species Declines

Introduced exotic species

Introduced predators (e.g. rats, mustelids, pigs, and cats) prey on endangered birds and invertebrates.

Introduced grazing and browsing animals damage sensitive plants.

Invasive pest plants, such as kudzu and purple loosestrife, may outcompete native species.

106

Causes of Species Declines

Hunting and collecting

Decline can be caused by hunting or collecting specimens where rare or scale are poorly controlled.

Some species are hunted because they interfere with human use of an area.

Illegal trade threatens the population viability of some species.

107

Causes of Species Declines

Poaching

Black rhinoceros were once plentiful throughout much of Africa but now only remnant populations remain. In 2019, there were 5500 in the wild.

Despite armed patrols by park rangers and risk of prosecution, poachers still target rhinos for their horn, which is sold for traditional Asian remedies.

108

Technological Protection of Reserves

Increasingly, technology such as **infrared tracking** is being used to monitor the perimeters of reserves, and to provide early warning of poaching activity.

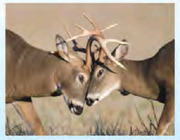
- In trials, this technology has been highly successful in reducing rhino losses.

Infrared tracking technology is used in tandem with other techniques, such as **injecting dyes** into rhino horns.

- This technique allows poached horns to be tracked and discourages purchase of the horns by consumers.

109

Competition and Endangered Species



Competition can play a large role in the extinction of a species.

- **Interspecific competition** is important when native species are out-competed by invasive species and lose habitat or food resources.
- **Intraspecific competition** can play a role when declining populations compete for mates, limiting genetic diversity and leading to inbreeding.

When the gene pool is large, competition within populations is beneficial to the species as a whole, leading to increased **population fitness over time.**

110

Competition and Endangered Species

However in small populations with restricted ranges, intraspecific competition can **reduce genetic diversity** by causing only some to breed, and so removing some genes from an already limited gene pool.

This is especially so when males compete for females.

In these cases, too many of the next generation can be related and **inbreeding depression** is a likely (and adverse) outcome.

111

Intraspecific Competition in Kakapo

Kakapo are one of the world's most endangered parrots, with only around 200 individuals left.

Because this population was built up from just 50 kakapo they have little genetic diversity, and maintaining genetic diversity is important.

However kakapo mate using a **lek** breeding system, where males display to females and females mate with their most preferred male.

This means that just a few individuals sire the majority of offspring, reducing genetic diversity and increasing the likelihood of inbreeding.

112

Interspecific Competition in Squirrels

Interspecific competition can drive organisms to extinction if one species cannot compete with another that uses the same resources.

Eurasian red squirrels (*S. vulgaris*) are native to the UK, while **gray squirrels** (*S. carolinensis*) were introduced to the UK from the US.

Reds have declined drastically in recent years and an important contributor is competition with gray squirrels for food.

Gray squirrels are larger and able to monopolize food resources in areas where the two are found together.

113

Adaptation, Migration or Extinction

Most species have **phenotypic plasticity**.

- This means they are able to change their behavior, physiology, or morphology as their environment changes. If this plasticity is extensive enough individuals can keep up with environmental changes, giving them time to adapt genetically.

However phenotypic plasticity is not adaptation. It involves changes to the **phenotype** without a change in **genotype**.

If the environmental changes are not within the range of of each generation's plasticity, the species will be at high risk of extinction.

114

North American Red Squirrels

North American red squirrels (*Tamiasciurus hudsonicus*) in Canada have adapted to a 2°C increase in spring temperature by breeding earlier in the year.

Records were kept of female squirrel cohorts to determine the day of the year they gave birth. Over a period of ten years, squirrel breeding time shifted to be earlier in the year.

This shows that breeding time is not heavily influenced by genetics.

Its plasticity means that the squirrel has a good ability to survive climate changes and breed.

115

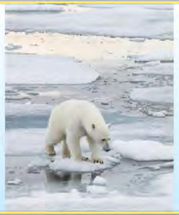
Polar Bears

For organisms with limited phenotypic plasticity, **relocation** may be their only chance for survival in the face of climate shifts.

Species with an already limited range may be faced with extinction as food supplies dwindle.

Polar bears are specialized hunters. Sea ice losses have reduced their hunting range.

Polar bears have a limited capacity to change hunting behavior. Some are able to scavenge the remains of whales but this is not a substitute for hunting, because it is too scarce and unpredictable.



116

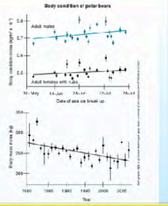
Polar Bears

Data shows that polar bears are not able to change their physiology or behavior to keep pace with their changing environment.

The **BMI** of measured bears is dropping every year, indicating decreased feeding.

Early ice break up means a shorter hunting period and so reduced feeding and reduced body condition.

The success of polar bear reproduction is linked to feeding and body condition. As their hunting grounds reduce, they become at greater risk of extinction.



117

Migration as a Survival Strategy

In some cases, the range of a species will either expand or shift in response to a warming climate.

There are already numerous examples of species moving into new areas that were previously unsuitable.

- These species are less likely to feel the impacts of climate change.
- Their risk of extinction is significantly reduced (at least in the short to medium term) providing their food resources are still available.

118

Migration as a Survival Strategy

Atlantic mackerel have moved up to 250 km north since 1968.

Their move appears to be linked to a warming of the waters along the continental shelf of North America.

Whether this is directly linked to climate change or to a cyclic event is not fully understood.

119

Migration as a Survival Strategy

A warming Arctic has had widespread effects on the tundra.

Shrubbery that once grew close to the ground and very slowly now grows taller and more rapidly.

This has attracted animals such as moose, thus expanding their range north. Snowshoe hares have also moved north.

120

Migration as a Survival Strategy

Studies of non-migratory butterflies in the UK have shown 63% have ranges that have shifted northwards between 35 and 240 km since record keeping began.

In Europe, the purple emperor butterfly (*Apatura iris*), pictured right, moved about 200 km northwards over just 5 years.

121

Conservation Legislation

Rhinoceroses are hunted for their horn, and elephants for their tusks.

Trade in various species has been part of human culture for millennia.

However when a species is endangered, its continued trade can affect its survival.

Often the rarer a species is, the more valuable it becomes and so it is hunted even more.

Countries have enacted legislation to control this trade, and pass laws that help the conservation of species that are not traded.

122

The CITES Treaty

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a voluntarily adopted framework around which signature parties can base their own national laws.

CITES controls trade in species, whether or not they are traded as live specimens.

- Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival.
- It includes everything from dried specimens to fur coats and powders.

A pallet of snowy leopard furs, seized by the U.S. Fish and Wildlife Service, ready to be crushed (2013).

123

CITES and Wildlife Trade

Illegal trade in pangolins

CITES lists species under appendixes.

- **Appendix I** is reserved for species that are in imminent danger of extinction. These species can't be traded commercially.
- **Appendix II** species are those that could face extinction if traded freely. They require permits for export trade.

Many of CITES achievements are based on legislation, such as voting to move certain species into Appendix I.

However this only works if all countries enforce the changes.

124

Problems with CITES

Often when adding species to appendixes, there is not enough data to accurately know a species' sustainability. The data is often inconsistent.

Like most international treaties, CITES power comes from those countries that enforce it. However enforcement varies from country to country, and many fail to return data.

It is estimated the international volume of trade in wildlife registered under CITES is less than a tenth of unregistered trade in wildlife.

Illegal animal parts for sale at a Chinese market. China has many problems with wildlife conservation due to the sale of tiger parts for traditional medicine.

125

The Endangered Species Act

The purpose of the 1973 **Endangered Species Act (ESA)** is to protect and recover endangered or threatened wildlife in the United States and the ecosystems they depend upon.

- Under the ESA, species can be listed as **threatened** or **endangered**.
- There are around 1500 species listed as endangered or threatened in the US.

Species may be listed based on their biological status and threats to their environment. Ultimately the goal of the ESA is to recover the population of a protected species.

The American crocodile was listed as endangered in 1975 (only 200 were left). By 1983 the population reached 3000. In 2007 it was down-listed to 'threatened.'

126

The Endangered Species Act

In 1978, critical habitat was designated to help **whooping crane** recovery.

In 1941 the crane was on the brink of extinction, and numbered just 21 wild and two captive whooping cranes.

Intensive habitat management and captive breeding have helped to save it from extinction.

127

The Endangered Species Act

Gray wolves were listed as endangered as early as 1967.

After recovering from near extinction they were delisted in 2008 and are now again subject to heavy hunting.

The global wild wolf population in 2003 was estimated at 300,000. While it is no longer considered threatened globally, some individual populations are still at risk due to hunting.

128

The Need for Legislation Enforcement

Producing legislation is of no use unless it is enforced and has public buy in. Without this, enacted laws of any kind inevitably fail.

The **illegal wildlife trade** is a prime example.

Another example is the side effects of illegal harvesting, such as **by-catch** or **illegal logging.**

By-catch from shrimp trawling, showing different species of animals and fish. Non-target species are discarded.

129

The Need for Legislation Enforcement

Year	Vaquita population
1997	567
2008	245
2015	59
2016	30
2018	19

The **vaquita** (*Phocoena sinus*) is a species of porpoise endemic to the Gulf of California.

It is on the brink of extinction with fewer than 20 (possibly fewer than 10) known individuals.

Its numbers have declined rapidly since it was first described in the 1980s, despite various conservation laws passed by the Mexican government.

This is due primarily to bycatch from the illegal totoaba fishery. Totoaba fishing uses gillnets in which the vaquita can become entangled in and so drown.

130

The Need for Legislation Enforcement

Silhouettes often mark from nylon, and can last for many years if not recovered. These abandoned "ghost" nets are of great environmental concern.

The fish **totoaba** (*Totoaba macdonaldi*) is intensively fished in the Gulf of California, even though it is very rare and listed under CITES Appendix I.

- It is caught for its swim bladder, which is highly prized in Chinese cuisine.

Totoaba fishing has been banned, and gillnets are banned from at least half the vaquita's range. Sonar is being used to locate **ghost nets** left by illegal totoaba fishermen.

Despite this, the vaquita population has continued to decline.

131

Habitat Fragmentation

The many factors causing the global decline in biodiversity can be summarized as **HIPPCO** (**Hab**itat destruction, **I**nvasive species, (human) **P**opulation growth, **P**ollution, **C**limate change, and **O**ver exploitation).

Habitat destruction is a major part of HIPPCO.

Vast areas of land and sea are exploited for their resources and land is needed to grow food, often with no concern as to the damage on the environment.

This can result in large areas of habitat becoming **fragmented**.

132

Habitat Fragmentation

Habitat can also happen naturally (e.g. when lava flows divide areas of land).

Habitat fragmentation is the process by which large habitats become divided up into smaller ones, usually with areas of completely changed (often uncrossable) land between them.

- This most often occurs as a result of human activities.

Habitat fragmentation can be a driver of evolution in smaller organisms, such as insects.

Usually, however, it causes a loss of biodiversity, especially in larger animals.

133

Fragmentation and Biodiversity

Habitat fragmentation **reduces population sizes** and can reduce **gene flow** because individuals are unable to move easily between habitat fragments.

This can lead to **inbreeding** because access to mates is limited.

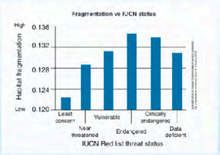
Fragmentation also affects plants.

- Invasive plant species are more able to invade fragments due to more open edges, which often provide disturbed land where they can easily become established.

Forest fragmentation, Brazil

134

Fragmentation and Biodiversity



The degree of fragmentation of a species' habitat is a significant predictor of the likelihood of a species going extinct.

The **IUCN (International Union for Conservation of Nature)** lists species from least concern to critically endangered.

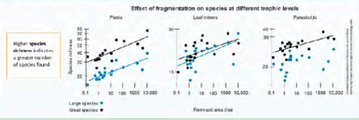
Matching the species in these categories against the degree of their habitat's fragmentation shows a clear pattern.

135

Fragmentation and the Ecosystem

Research into habitat fragmentation has become very important, and studies have shown that fragmentation affects all trophic levels, from producers to all levels of consumers.

- The study below was carried out in central Argentina, where 94% of forest and has been cleared. Three trophic levels are shown, with parasitoids being level 2 consumers (feeding on leaf miners).



136

Habitat Fragmentation in Madagascar

Madagascar has three main forest types: dry, humid, and spiny.

It is known as a biodiversity **"hotspot"**. Over 90% of its wildlife is endemic.

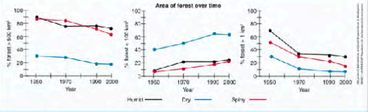
Madagascar's forests and wildlife are increasingly threatened by encroaching human activity.

Many of its forests are being slowly destroyed by activities such as slash and burn farming.

137

Habitat Fragmentation in Madagascar

This destruction through human activity has led to an increasing amount of **forest fragmentation**, with large areas of forest in Madagascar becoming increasingly scarce.



138

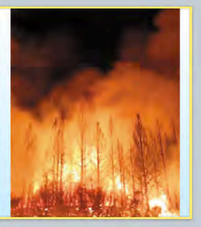
Wildfires

From 2010 to 2020, there has been an unprecedented increase in the number, area, and intensity of forest and bush fires around the world.

Forest fires have always been part of nature, with fire seasons occurring every year.

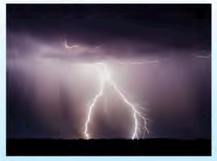
However the last decade has seen fires begin earlier in the season and become larger and more frequent.

- Some of these fires are deliberately lit, either through **arson** or farm fires that get out of control, or as part of **controlled burns** and debris clearing.



139

Wildfires



Some wildfires arise naturally from **lightning strikes.**

However, since the world is warming, the results of these lightning strikes are far more severe, especially after **droughts**, which themselves are becoming more frequent.

- Recent years have seen fires in the Alaskan and Siberian tundra.
- These threaten to affect permafrost and fundamentally change the Arctic landscape.

140

Australian Bush Fires

The Australian bush fire season in 2019-2020 (also known as the **Black Summer**) was a period of unusually intense bush fires throughout Australia.

The fire season began earlier than normal in 2019 and peaked around January 2020.

Most fires in Australia are caused by lightning, and so are not linked to deforestation by farmers or logging.

Smoke from Australian bush fires as seen from the ISS

141

Australian Bush Fires

Grasses blackened by fire, New South Wales

The Black Summer fires came after a prolonged drought and higher than normal temperatures. Bush and forest that would normally withstand large fires were particularly dry.

Australian bush fires often occur near populated regions. Fire fronts can move extremely quickly, fanned by high winds, trapping residents and fire fighters.

Because of this, the fire fighting effort is extremely intensive.

142

Australian Bush Fires

An estimated 186,000 square kilometers of bush and scrub land was destroyed.

143

Australian Bush Fires

It is estimated that **more than a billion** mammals, birds, and reptiles were killed in the 2019-2020 season.

- Deaths from starvation and thirst added to the large number of animal deaths from the fires.

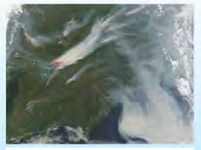
In December 2019, NASA estimated the fires had emitted over 330 million tonnes of CO_2.

The damage from the fires not only releases the CO_2, but affects the forest's ability to absorb it.

Kangaroo Island fire (Feb): Kangaroo Island, an important habitat for a number of native and endangered species, was severely affected. More than a third of the island burned.

144

Arctic Tundra



Tundra fires, Siberia

As the Arctic region warms, **permafrost** melts and the tundra is dried out, making it extremely susceptible to fire.

The freezing temperatures mean there is little decay of plant material on the tundra, and organic material builds up over the centuries. This has helped to store vast quantities of carbon.

This carbon is now under threat of decaying and burning, releasing CO_2 and trapped methane could be released. This would accelerate warming.

145

Arctic Tundra

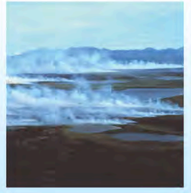
In 2019, more than 3 million hectares of tundra was affected by fire.

The fires can be typical large surface fires, but can also form slow **smoldering fires**.

These smoldering fires can persist through cold and wet conditions.

- Because they burn longer, these fires can actually transfer heat deeper into the soil and permafrost, melting and burning it.

Tundra fires in 2019 released at least 100 million tonnes of CO_2.



146

California Wildfires

California's hot, dry environment is also prone to **wildfires**. These have been becoming more intense since the start of the century.

A number of factors influence the frequency and severity of fires.

- These include moisture level, the amount of undergrowth, tree density, and the types of trees present.

Climate variability (especially moisture levels) is the main driver of forest fires.

147

California Wildfires

The eruption of wildfire plume near Calpine.

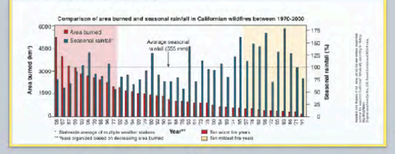
When fires become more frequent and more intense, the forest may be less able to regenerate. There are several reasons for this.

- Trees do not have time to regenerate or grow between fires, they reestablish more slowly, or fail to reestablish at all.
- Fast growing shrubs and grasses establish more quickly than tree seedlings, which then cannot compete for resources. Fewer tree species will establish, and the make-up of the area will change.
- Seed stock is reduced, so fewer seedlings grow after a fire.

148

California Wildfires

Fourteen of the largest 20 wildfires in California have occurred since 2007. There are 78 more annual fire days now than 50 years ago.



149

Amazon Forest Fires

2019 saw a spike in the number of fires in the Amazon.

These became a concern because the Amazon is the largest **terrestrial carbon sink**.

- It absorbs about a quarter of all the carbon taken up by forests each year.

The spike in fires threatened to release huge amounts of CO_2 back into the atmosphere and damage future uptake ability.

150

Arctic Tundra

Tundra fires, Siberia

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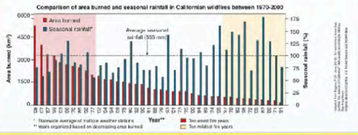

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Amazon Forest Fires

Fires in the Amazon, 2020, can be clearly seen by the cameras on the International Space Station. Around 43,000 square kilometers of forest was burned in 2020.

Up to 60 million hectares of the Brazilian Amazon are considered public areas.

- This means they have no defined legal purpose. They are not declared as conservation areas or indigenous territories, for example.

With no legal purpose, people simply clear the land by logging. Once logs are removed, the debris is burned and the land occupied, normally as cattle ranches.

The fires in Brazil are normally directly linked to **deforestation or logging.**

151

Amazon Forest Fires

The **MODIS** (**Moderate Resolution Imaging Spectroradiometer**) instrument onboard NASA's Terra satellite can detect hot spots caused by fires.

The red patches on the image show fires from August 15 to August 22, 2019.

Smoke plumes from the wildfires were visible from space.

152

Climate Change and Habitat Loss

Rising atmospheric **temperatures** will cause numerous changes in habitats around the world.

153

Climate Change and Habitat Loss

Rising atmospheric **temperatures** will cause numerous changes in habitats around the world.

154

Domestication and Biodiversity

Various breeds of domestic cattle and sheep now dominate grazing land, and vast areas of natural ecosystems have been converted to cattle pasture or domestic crops.

Domestication of plants and animals involves genetic selection. Only certain species of animal or plant are suitable for domestication, and only the most domesticable of those are allowed or able to breed.

This limits the genetic diversity of the domesticated population.

Domesticated species are spread about the globe through human activity. Their numbers increase, which can displace other species.

This reduces the biodiversity of the local ecosystem.

155

Reduction of Genetic Diversity

The process of domestication takes the most suitable individuals of each successive generation and breeds them together to produce more desirable offspring.

Over time this produces docile animals or crop plants that produce large fruit.

It also has the effect of reducing **genetic** variation in the domestic population.

A recent study of the New Zealand rock lily (*Arthropodium cirratum*) has shown how quickly a loss of genetic variation can occur.

New Zealand was only populated about 800 years ago, so domestication-free lines are much easier to study.

Soon after they arrived, the first Māori began cultivating the endemic rock lily.

Around the country there are at least 29 genetic lineages of the rock lily. However, just two lineages were domesticated.

In fact, cultivated lines found in the South Island were shown to have been transported from the southern part of the North Island, hundreds of kilometers away.

156

Increases in Genetic Diversity

Managed honey bee populations in Asia va have been slower to have higher genetic diversity than European bees.

There are also instances in which diversity appears to **increase** due to domestication.

Until very recently it was thought that the genetic diversity of domesticated honey bees was very low, and could be a contributing factor to the recent loss of many colonies.

However new research shows that honey bee diversity may actually increase due to domestication.

- This appears to be because of the transportation and interbreeding of honey bee lineages around the world.

157

Reduction of Ecosystem Biodiversity

One of the biggest effects of domestication on biodiversity has been on the wider ecosystem.

Domestication of plants and animals requires land (for farming and cultivation).

This has been obtained by clearing forests or grasslands and replacing them with **monocultures** of genetically very similar plants or animals.

- Vast parts of the North American prairies are now used to grow just a few types of crops or grasses. Less than 1% of the original prairie tall grass cover is left.

The once dominant buffalo and pronghorn that roamed central North America have been replaced by vast numbers of domesticated cattle or sheep.

158

Reducing Biodiversity Loss

USFWS worker with two critically endangered red wolf pups, bred in captivity.

Today, species are being lost at a rapidly accelerating rate. Various strategies are available to protect at-risk species and help the recovery of those that are threatened.

Ecological protection and **restoration** are important tools in maintaining biodiversity.

- Restoration is often a long term process and usually involves collaborative work between scientific institutions and local communities.

Captive breeding programs and intensive management in the wild have in many cases saved endangered populations from the brink of extinction.

159

Reducing Habitat Fragmentation

Fragments of habitat left over after land disturbance are often too small to support large animals on their own.

However it is possible to join smaller fragments together using **green corridors.** These are strips of land connecting areas of habitat.

Organisms, especially larger animals, can use these corridors to travel between reserves, allowing wider foraging and maintaining gene flow in populations.

Green corridors can include windbreaks, hedgerows, riparian zones along water ways, or simply narrow bands of vegetation connecting habitats (pictured, connecting two areas of forest).

160

Pinhook Swamp Corridor, Florida, USA

The Okefenokee National Wildlife Refuge (-left) and a red-cockaded woodpecker.

The **Okefenokee National Wildlife Refuge** straddles the border of Florida and Georgia.

It spans 162,000 ha and is the largest wildlife refuge in the eastern United States.

The Okefenokee swampland preserve is **home** to a **number** of endangered species, such as the red-cockaded woodpecker and gopher tortoises.

161

Pinhook Swamp Corridor, Florida, USA

Sixteen kilometers to the south of the Okefenokee swampland preserve is the **Osceola National Forest.**

It is an area of wetlands, swamps, and pine forests that spans 65,000 ha.

The Osceola swamp forest is not large enough to support many larger species on its own (such as the red-cockaded woodpecker and the black bear).

Osceola National Forest

162

Pinhook Swamp Corridor, Florida, USA

Between these two refuges is the **Pinhook Swamp**, which covers 24,000 ha.

The swamp is privately owned, but has been bought by conservation groups and the government patch-by-patch.

Now, about a third of the Pinhook Swamp is publicly owned.

Together these three sections of swamp forest cover a continuous areas of over 250,000 ha.

163

Pinhook Swamp Corridor, Florida, USA

The continuous habitat allows populations from the Okefenokee wildlife refuge to move further south and so establish territories and maintain gene flow.

Green corridors allow larger species in particular to move between different areas of habitat in search of food, space, or mates.

Alligator

164

Habitat Restoration

Habitat restoration is an important part of conservation efforts.

A habitat must be suitable for plants and especially animals in order for populations to flourish, and waste introduced by humans must be removed.

Restoring habitat may involve **replanting** the original flora. This is important in stabilizing cleared land and making the habitat more suitable for native animals already living there or for reintroductions.

165

Habitat Restoration

Restoring habitat may involve **controlling, removing,** or **excluding introduced pests and predators.**

This is an important but difficult part of habitat restoration.

Automatic traps (pictured) can remove many pests between servicing.

166

Habitat Restoration

Mainland islands are important ecological sites that are **surrounded** with **predator proof fences.**

They are used to rebuild native populations of animals and plants.

167

Habitat Size

Species	MVP (m^2 or km²)	IAR (km²)
Bighorn sheep	224	0.29
Gray wolf	411	7.8
Chimpanzee	20	0.56
Tiger	973	27.7
Brown bear	172	3.2

Restoring a habitat is only useful if it is large enough to sustain the organisms in it.

Different animals have different area requirements that need to be carefully considered before reintroducing a species.

- The **minimum** area requirement (**MAR**) [in km²] can be calculated from the **individual** area requirement (**IAR**) and the **minimum viable population** (**MVP**):

$$MAR = MVP \times IAR$$

where MVP refers to the smallest population required to minimize the species

168

Glossary

BMI	*Body mass index; a person's weight in kilograms divided by the square of height in meters.*
dissolution	*The process of dissolving or breaking apart; this process by which a dissolved component forms a solution in a solvent.*
eutrophication	*Excessive nutrients in a body of water, usually caused by nutrient runoff, causing a dense growth of plants that eventually decompose and depletes the oxygen supply.*
glacial	*A geological interval within an ice age that is marked by colder temperatures and glacier advances; also glaciation or glacial period.*
hypoxia	*The depletion of oxygen in a body of water, often caused by eutrophication.*
inbreeding depression	*Reduced fitness in an organism or species as a result of inbreeding.*
interglacial	*A geological interval of warmer average temperature that separates glacial periods.*
inundation	*The rising of a body of water and its overflowing onto normally dry land.*

169

Glossary

monoculture	*The cultivation or growth of a single crop species or organism in a field at a time.*
permafrost	*Ground that continuously remains frozen for two or more years, located on land or under the ocean.*
positive feedback loop	*A process in which the end products of an action cause more of that action to occur. This amplifies the original action, causing a beneficial loop.*
species richness	*The number of species within a defined region.*
stratification (water)	*The separation of water in layers based on a specific quantity.*
thermokarst	*A landscape pattern formed by the melting of permafrost, characterized by an irregular hummocky surface.*

170

Conditions of Use

171

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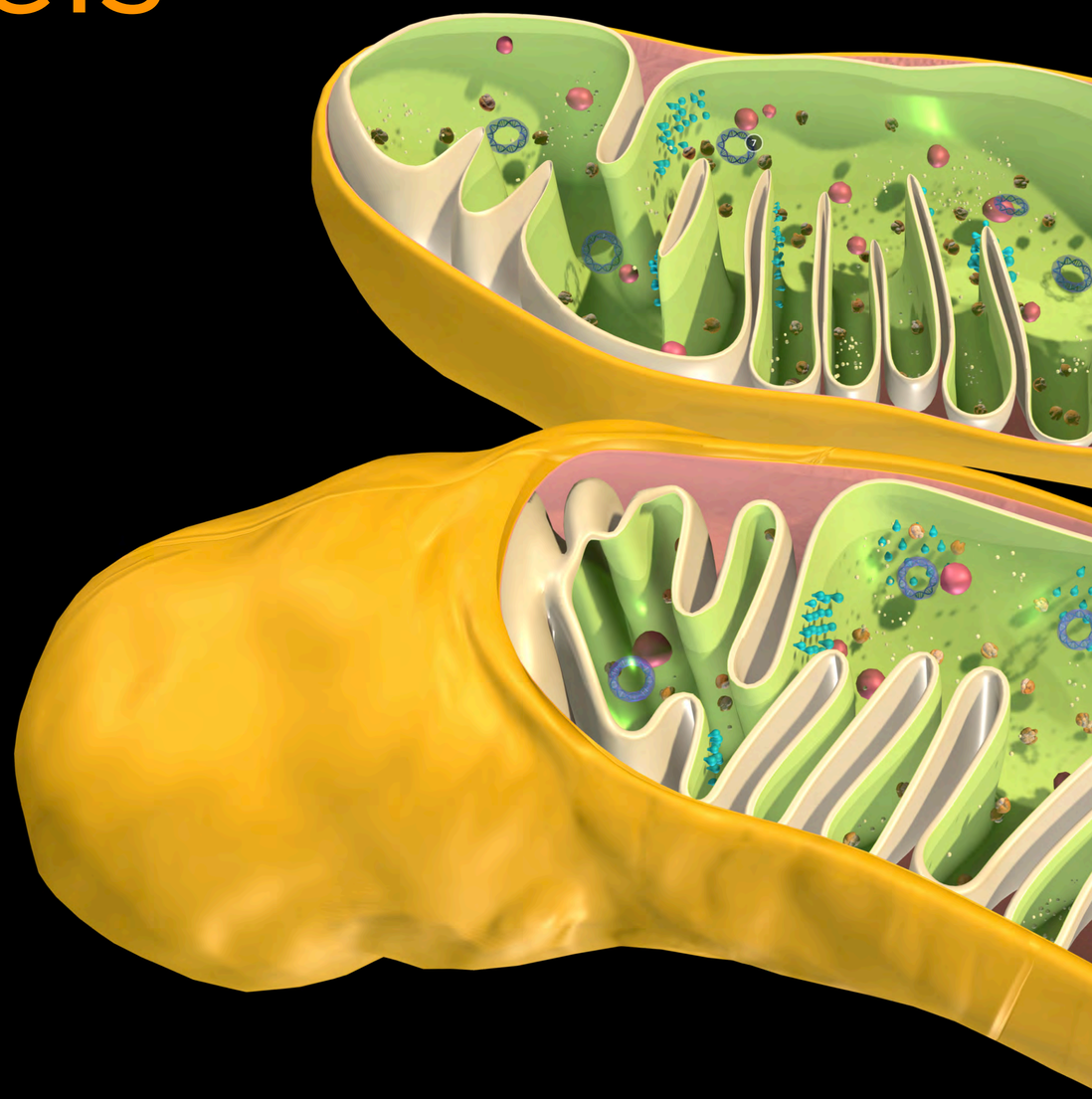
172

Purpose of 3D Models

- Structural details at the:
  - **molecular** level
  - **cellular** level
  - **organism** level
  - **ecosystem** level
- Illustrate behavior & processes
- Show context
- Allow comparisons



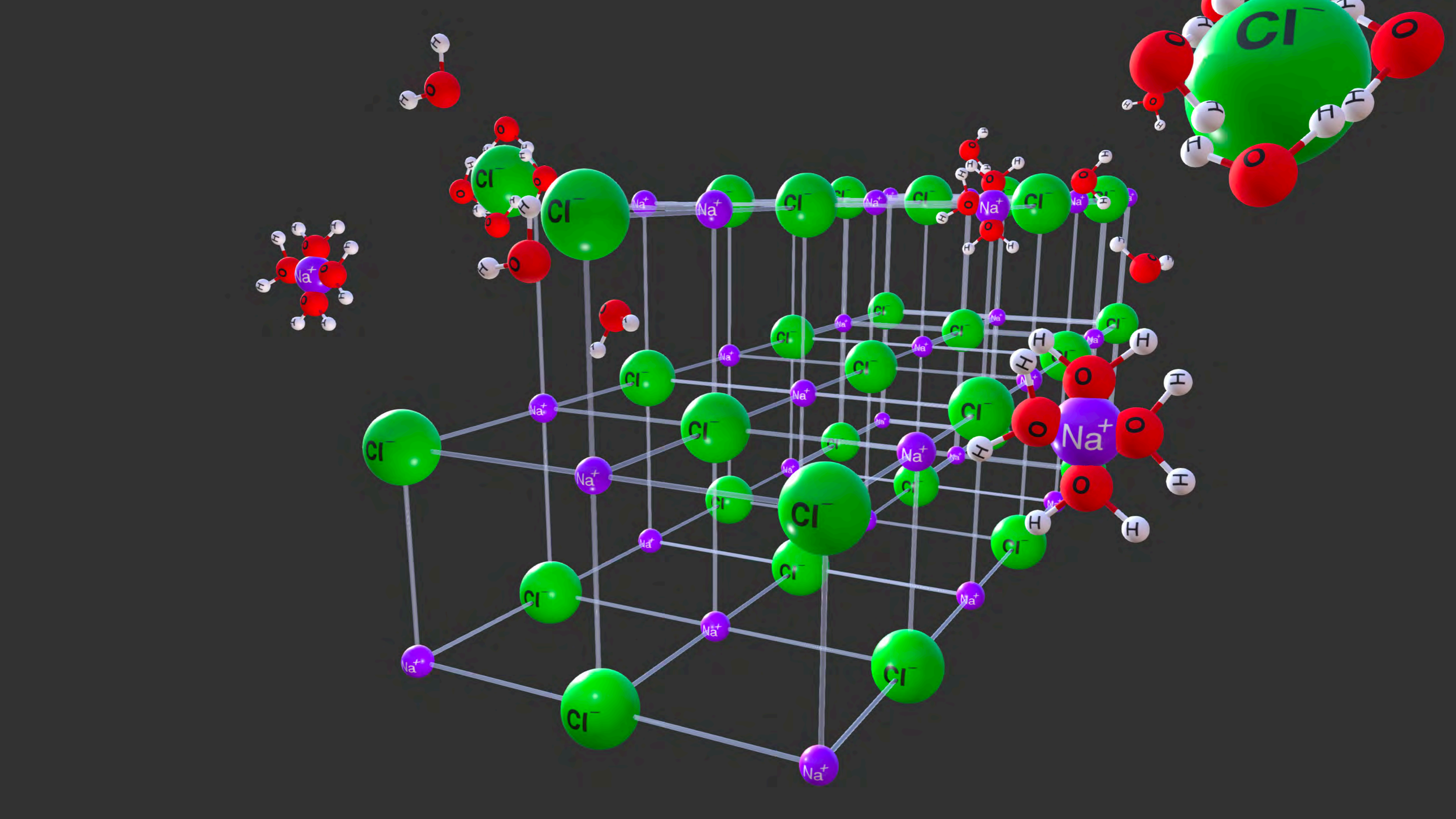
Purpose of 3D Models

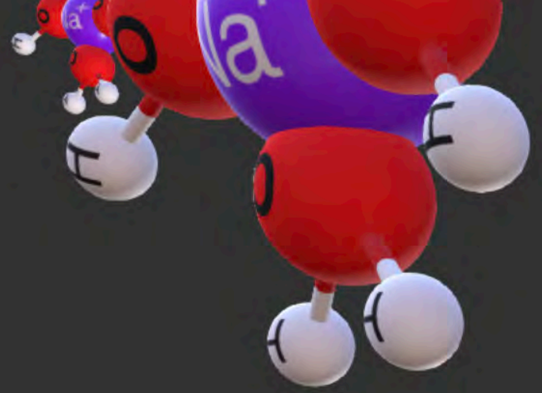
- **Engage** your students … have fun!

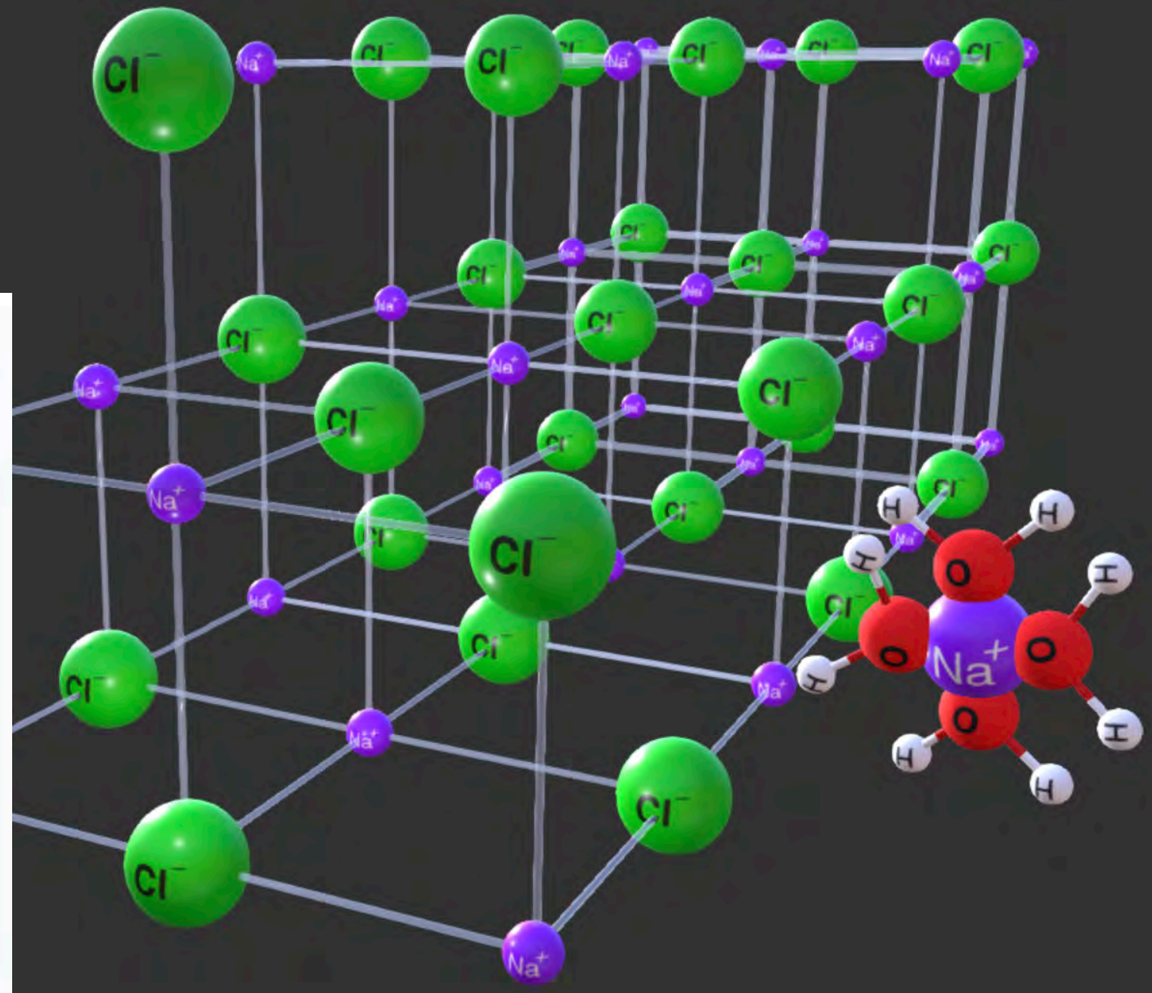
- Provide **useful visual information** that cannot easily be discerned from diagram in a print book or video.

- Put your students in control of their learning moment - allow **full manipulation** of the models:

  - **rotate – zoom in – click on labels**


Cl⁻
Na⁺
O
H




Cl⁻
Na⁺
O
H

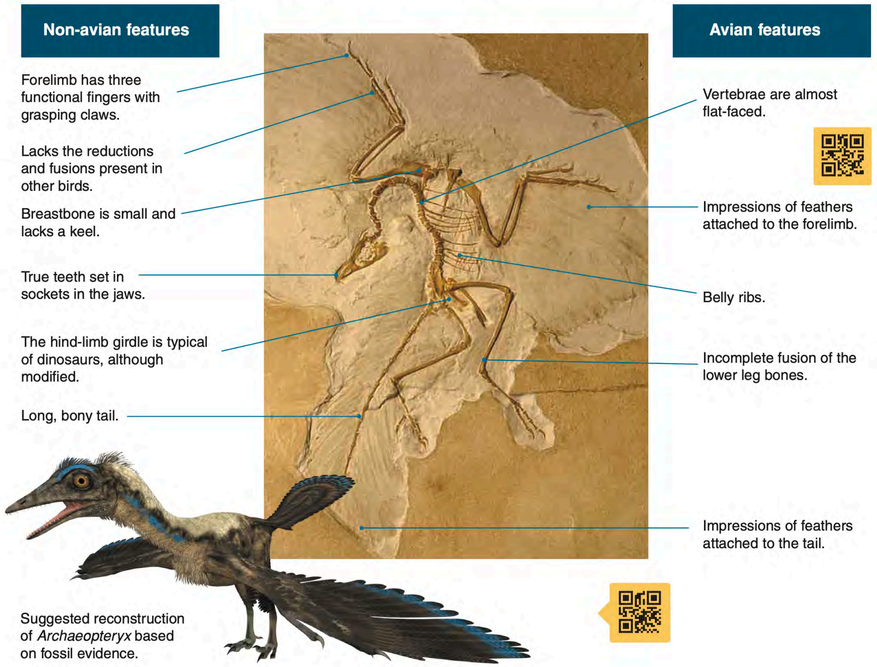
225 Transitional Fossils

Key Question: How do transitional fossils provide important links in the fossil record?

Transitional fossils are **fossils** which have a mixture of features, showing intermediate states, that are found in two different, but related, groups. Transitional fossils provide important links in the fossil record and provide evidence to support how one group may have given rise to the other by evolutionary processes.

Important examples of transitional fossils include horses, whales, and *Archaeopteryx* (below), a transitional form between birds and non-avian dinosaurs.

Archaeopteryx was crow-sized (50 cm length) and lived about 150 million years ago. It had a number of birdlike (avian) features, including feathers. However, it also had many non-avian features, which it shared with theropod dinosaurs of the time. Although not a direct ancestor of birds, the *Archaeopteryx* and birds shared a common ancestor.



Suggested reconstruction of *Archaeopteryx* based on fossil evidence.

1. (a) What is a transitional fossil? _____

(b) Why are transitional fossils important in understanding evolution? _____

LS4.A P

ISBN: 978-1-98-856692-4

Non-avian features

Forelimb has three functional fingers with grasping claws.

Lacks the reductions and fusions present in other birds.

Breastbone is small and lacks a keel.

True teeth set in sockets in the jaws.

The hind-limb girdle is typical of dinosaurs, although modified.

Long, bony tail.

Avian features

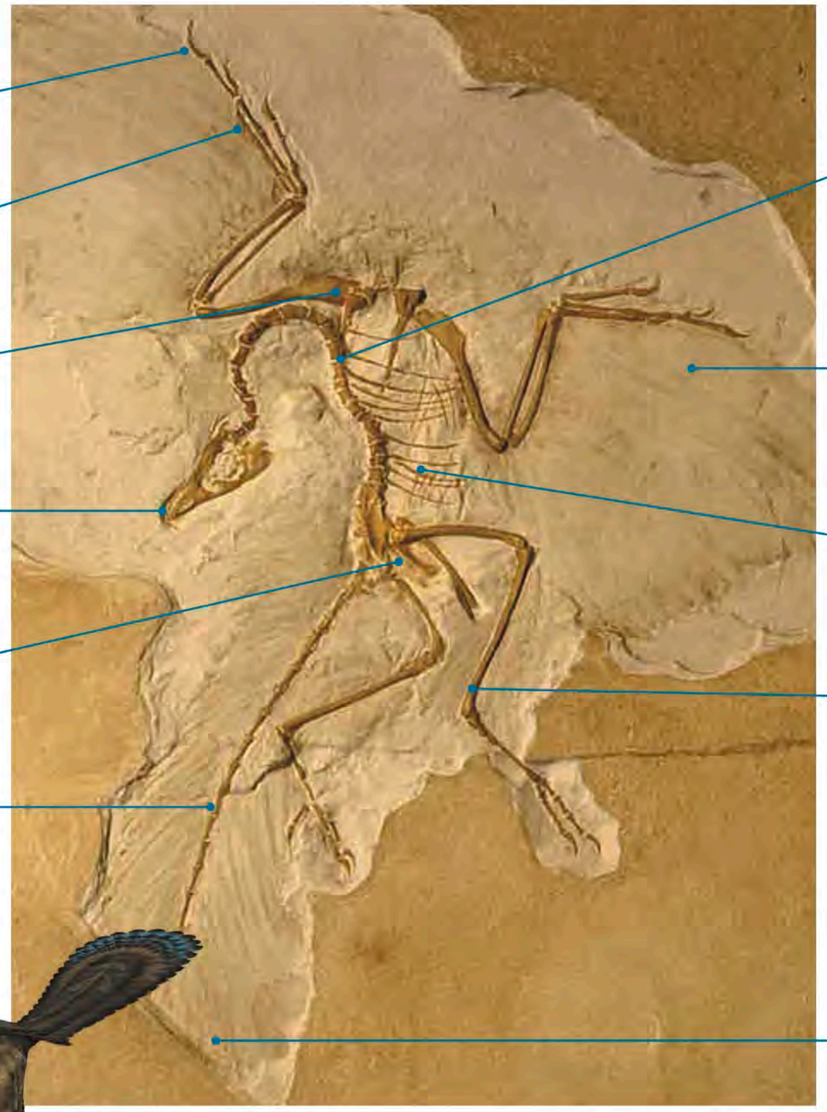
Vertebrae are almost flat-faced.

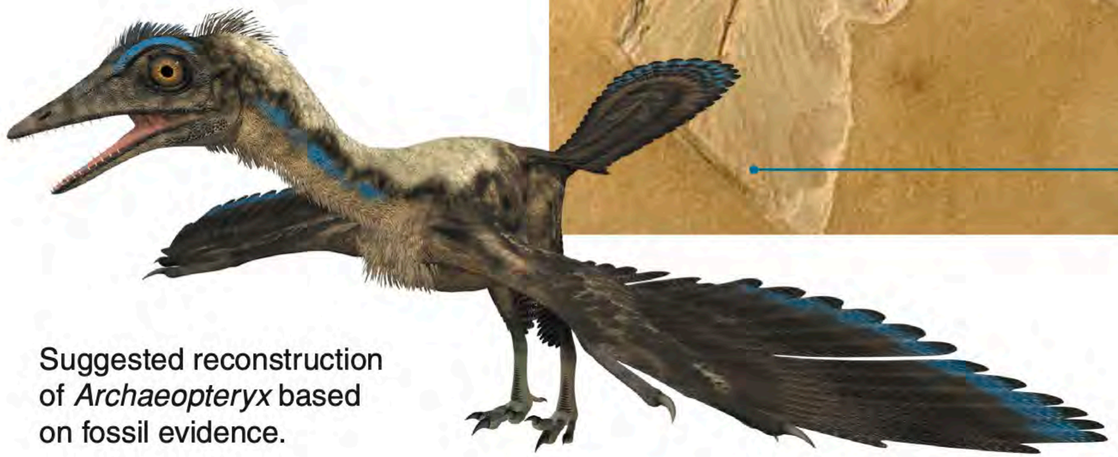
Impressions of feathers attached to the forelimb.

Belly ribs.

Incomplete fusion of the lower leg bones.

Impressions of feathers attached to the tail.





Suggested reconstruction of *Archaeopteryx* based on fossil evidence.

sockets in the jaws.

The hind-limb girdle is typical of dinosaurs, although modified.

Long, bony tail.

Suggested reconstruction of *Archaeopteryx* based on fossil evidence.


1
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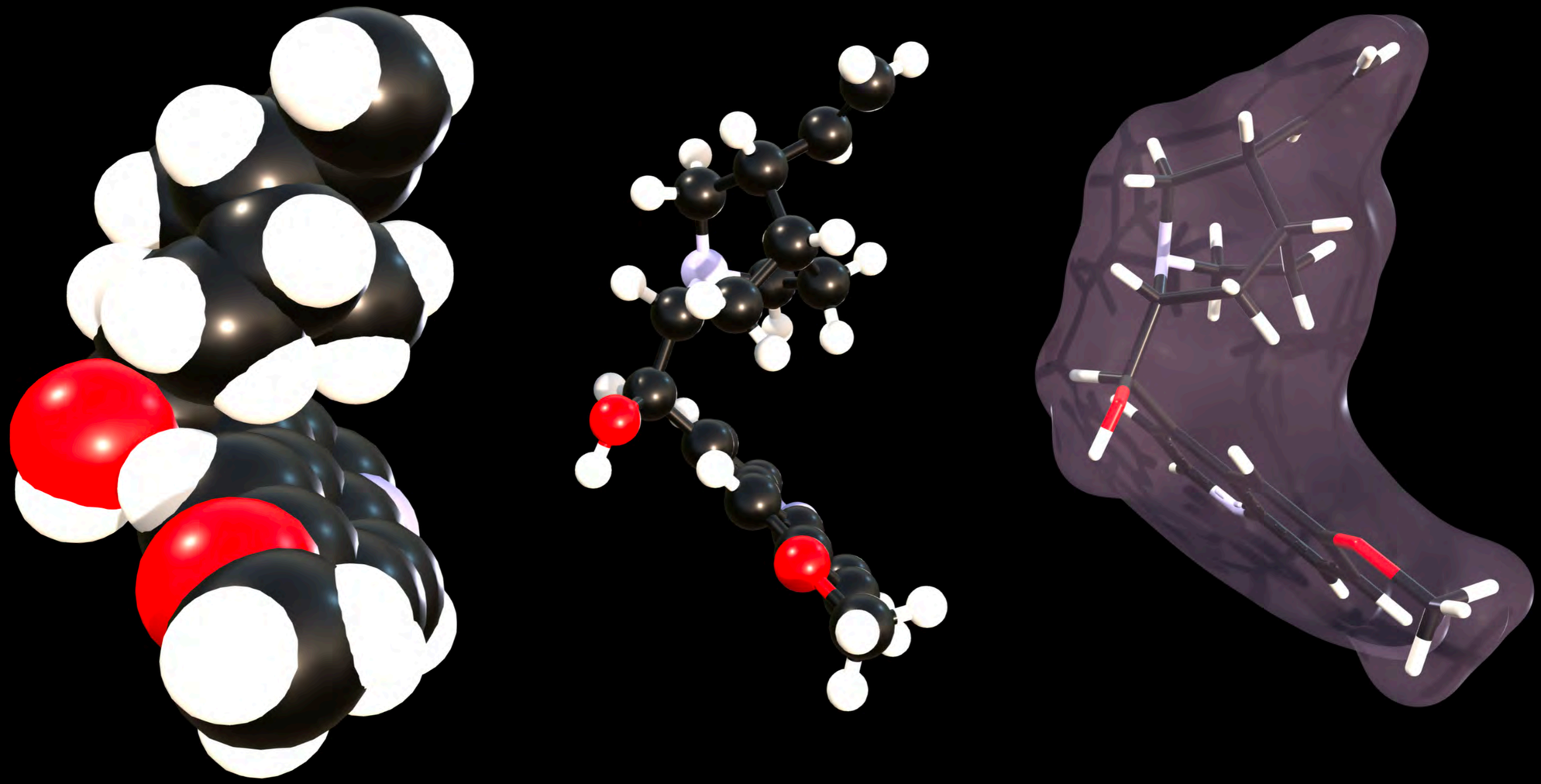
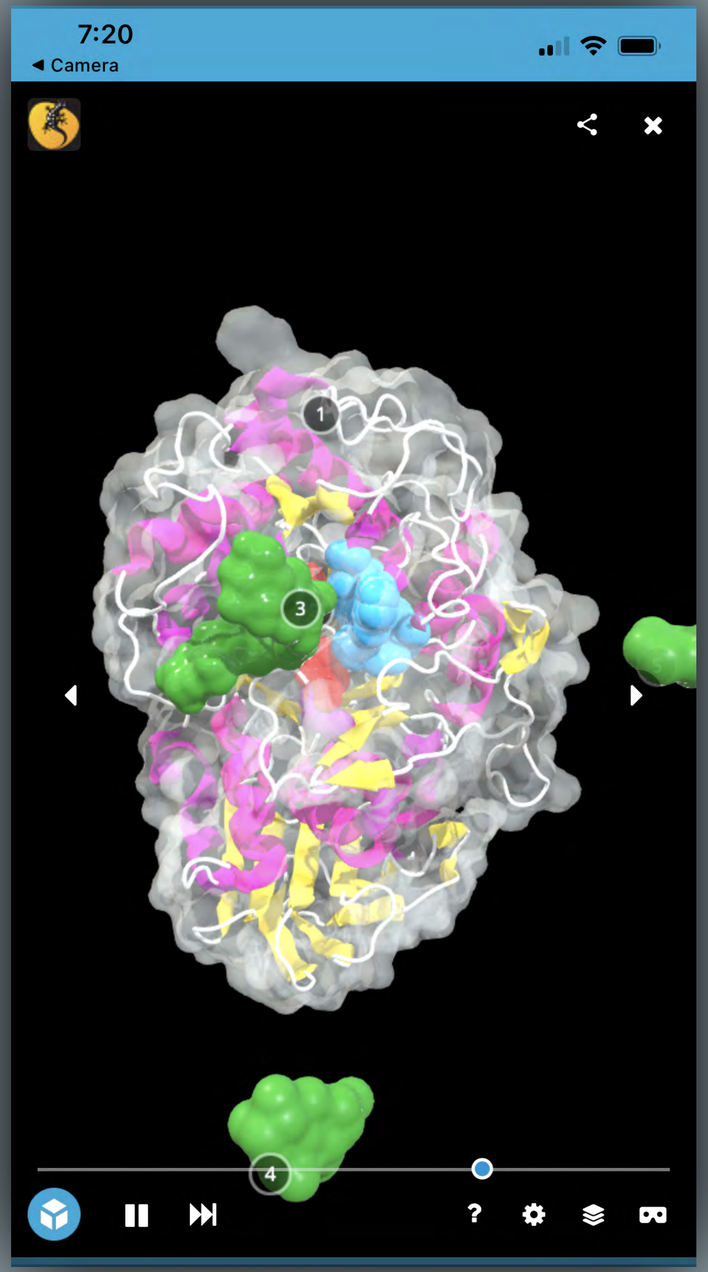
6



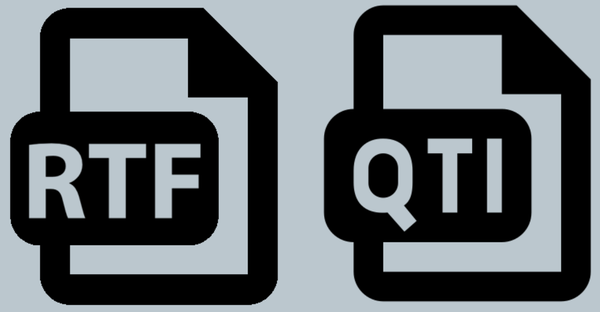
Processes



Test Banks

Testing DCI content in each chapter

- NGSS titles only.
- Tests DCI knowledge.
- Two test bank collections:
  - Regular test
  - Recovery test
- Formatted in RTF and QTI to ingest directly into your own test software or LMS for a familiar and seamless teacher workflow.

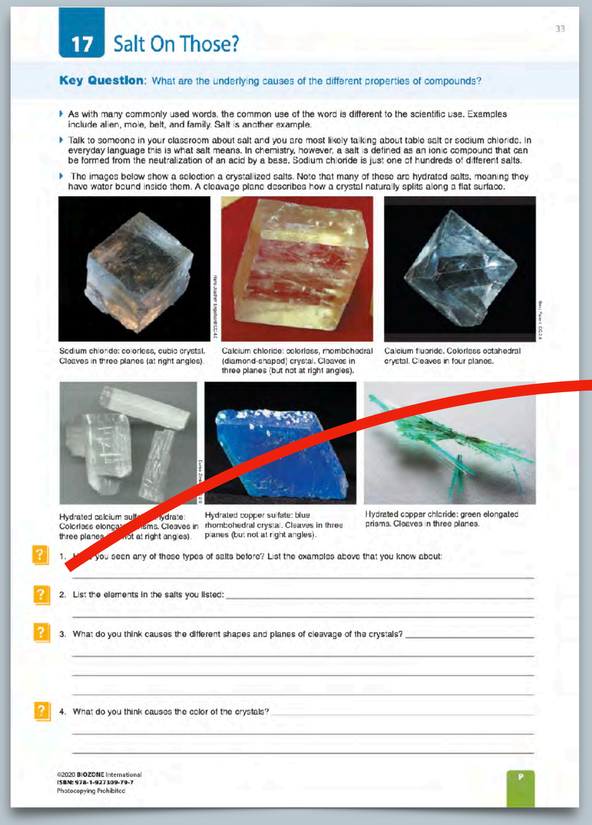


NOTE: **Test Banks** are only available to schools/districts committing to **multi-year adoptions**

Question library

- Embedded questions in the printed worktext are also provided digitally as a **question library**.
- BIOZONE's question library allows you to:
  - Deliver the same questions from the print version to students via an **online service** such as Google Classroom
  - **Modify our questions** to meet the diverse needs of your students:
    1. **Customize questions** to suit students' **reading ability** and possible **ELS** support
    2. Provide **differentiated** question material to students of all abilities

Two Formats:


17 Salt On Those?

Key Question: What are the underlying causes of the different properties of compounds?

- As with many commonly used words, the common use of the word is different to the scientific use. Examples include alien, mole, belt, and family. Salt is another example.
- Talk to someone in your classroom about salt and you are most likely talking about table salt or sodium chloride. In everyday language this is what salt means. In chemistry, however, a salt is defined as an ionic compound that can be formed from the neutralization of an acid by a base. Sodium chloride is just one of hundreds of different salts.
- The images below show a selection of crystallized salts. Note that many of these are hydrated salts, meaning they have water bound inside them. A cleavage plane describes how a crystal naturally splits along a flat surface.

Sodium chloride: colorless, cubic crystal. Cleaves in three planes (at right angles).

Calcium chloride: colorless, rhombohedral (diamond-shaped) crystal. Cleaves in three planes (but not at right angles).

Calcium fluoride. Colorless octahedral crystal. Cleaves in four planes.

Hydrated copper sulfate: blue rhombohedral crystal. Cleaves in three planes (but not at right angles).

Hydrated copper chloride: green elongated prisms. Cleaves in three planes.

1. Have you seen any of those types of salts before? List the examples above that you know about:
2. List the elements in the salts you listed:
3. What do you think causes the different shapes and planes of cleavage of the crystals?
4. What do you think causes the color of the crystals?

NOTE: **Question Library** is only available to schools/districts committing to **multi-year adoptions**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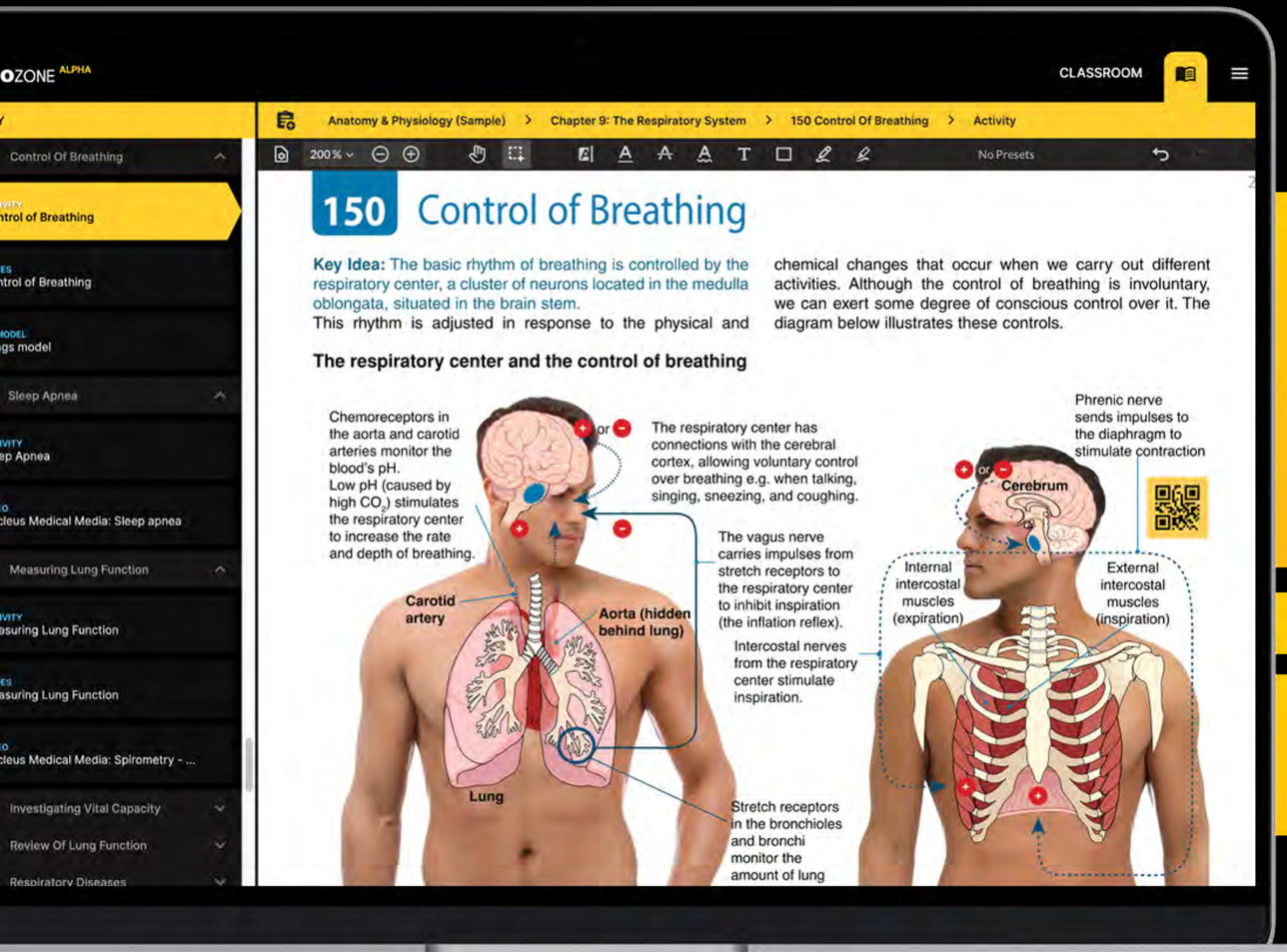

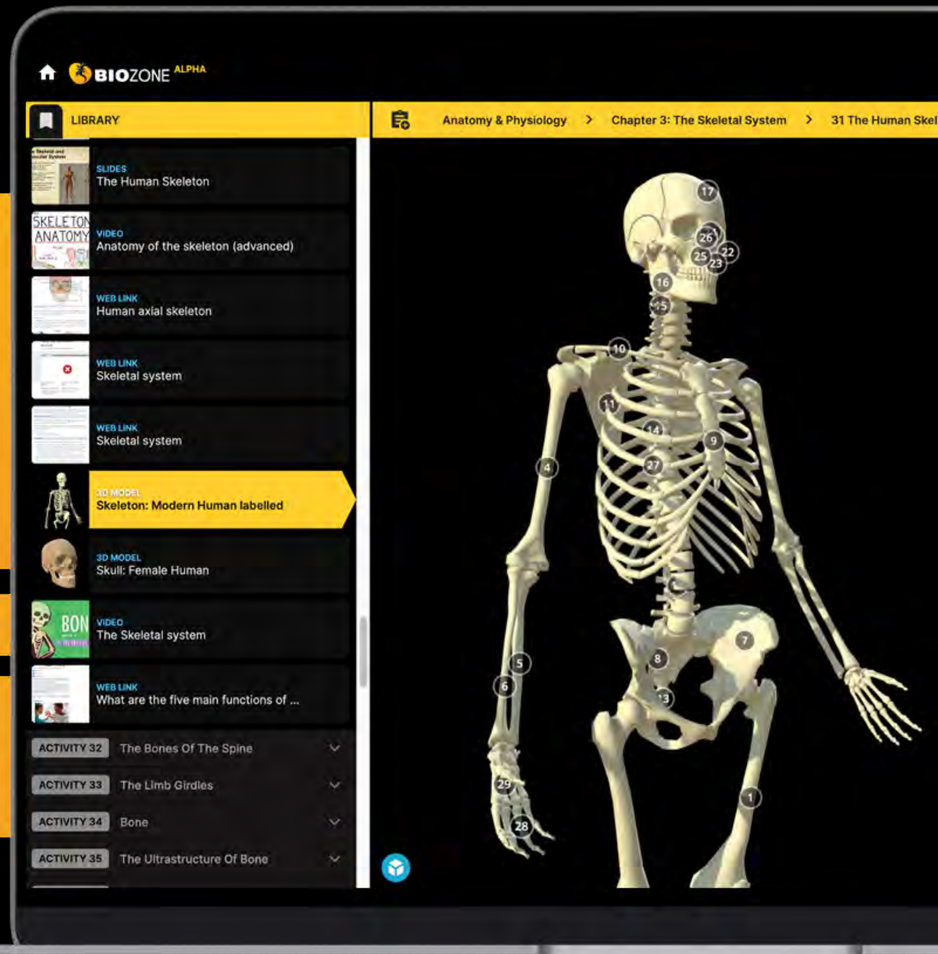

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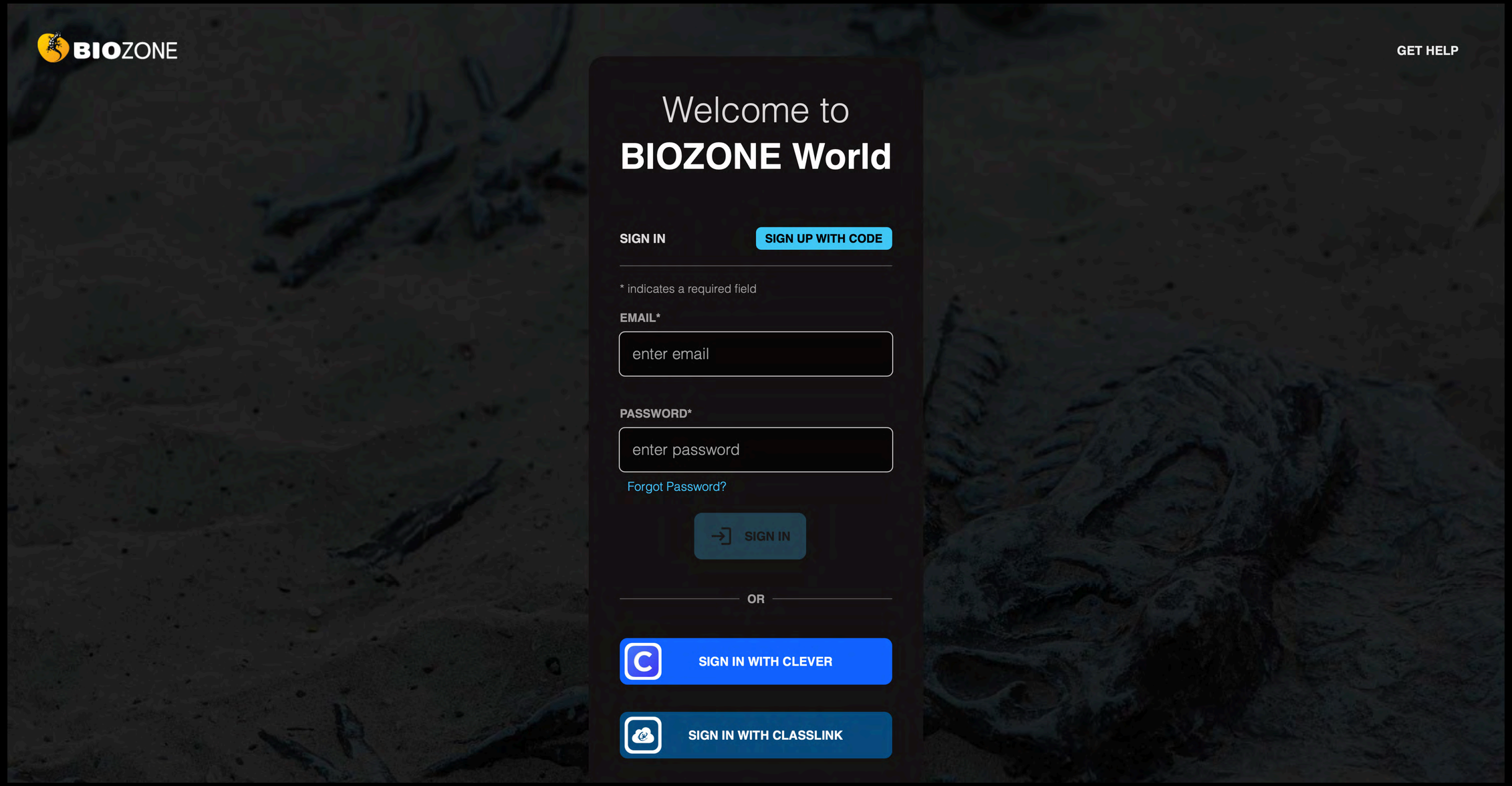

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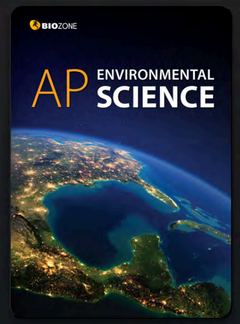
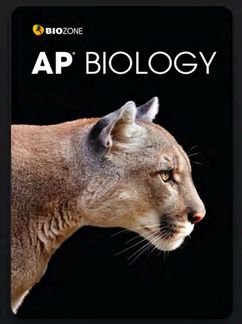
DASHBOARD ASSIGNMENTS STUDENTS

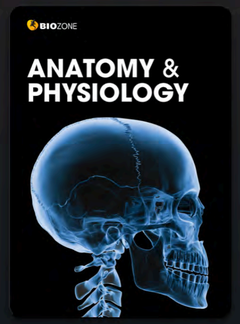
CLASS SETTINGS

ADVANCED PLACEMENT





ANATOMY & PHYSIOLOGY



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ENVIRONMENTAL SCIENCE

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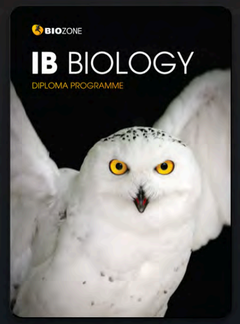

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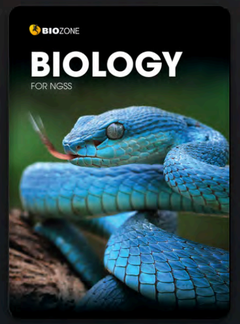
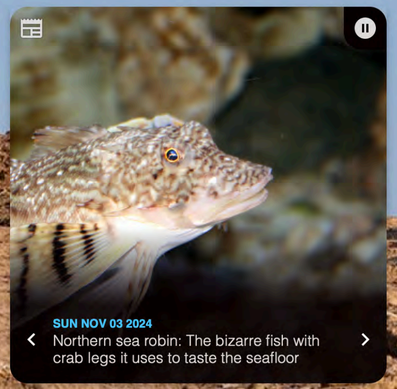


LAST ACTIVITY

ACTIVITY
Population Growth

REMINDERS



SUN NOV 03 2024
Northern sea robin: The bizarre fish with crab legs it uses to taste the seafloor

SAT NOV 30 2019
Natural Histories : Aye-Aye

225 Transitional Fossils

Key Question: How do transitional fossils provide important links in the fossil record?

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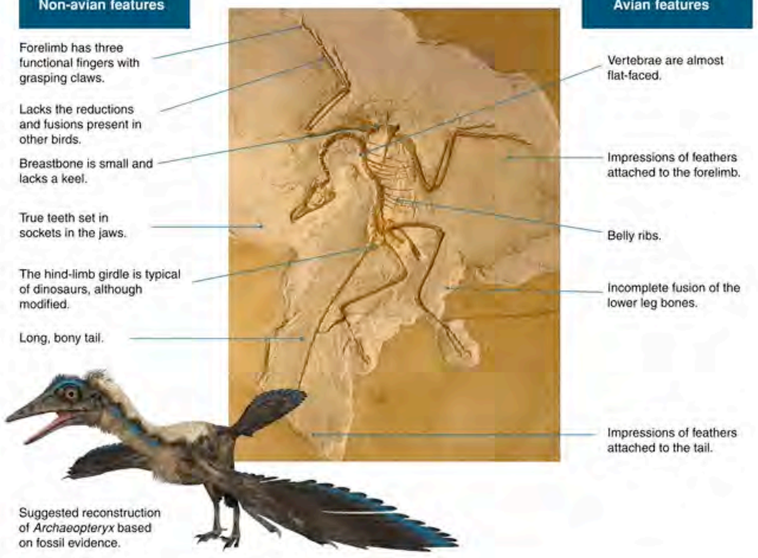
Important examples of transitional fossils include horses, whales, and *Archaeopteryx* (below), a transitional form between birds and non-avian dinosaurs.

Archaeopteryx was crow-sized (50 cm length) and lived about 150 million years ago. It had a number of birdlike (avian) features, including feathers. However, it also had many non-avian features, which it shared with theropod dinosaurs of the time. Although not a direct ancestor of birds, the *Archaeopteryx* and birds shared a common ancestor.



Suggested reconstruction of *Archaeopteryx* based on fossil evidence.

1. (a) What is a transitional fossil? _____

(b) Why are transitional fossils important in understanding evolution? _____

LS4.A P

ISBN: 978-1-98-856692-4

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- A **minimum of 20 licences** per title must be purchased.
- Licences are **annual subscriptions** - multiyear license options are available.

Two licence types in **BIOZONE World** are:

STUDENT Access

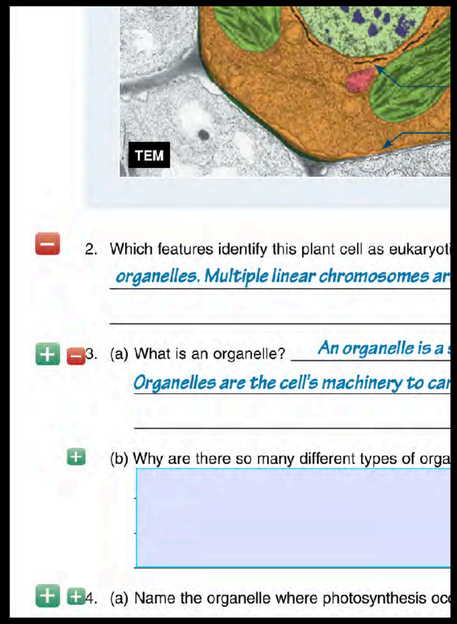
Digital interactive replica of the book:

- **Digital replica**: students can view the book, add **annotations** and **markup**.
- Students can enter **answers online** and **submit** them to their teacher.
- Digital resources available: **3D models**, **presentation slides**, curated OER **videos**, **weblinks**.

TEACHER Access

All the functions the student has plus:

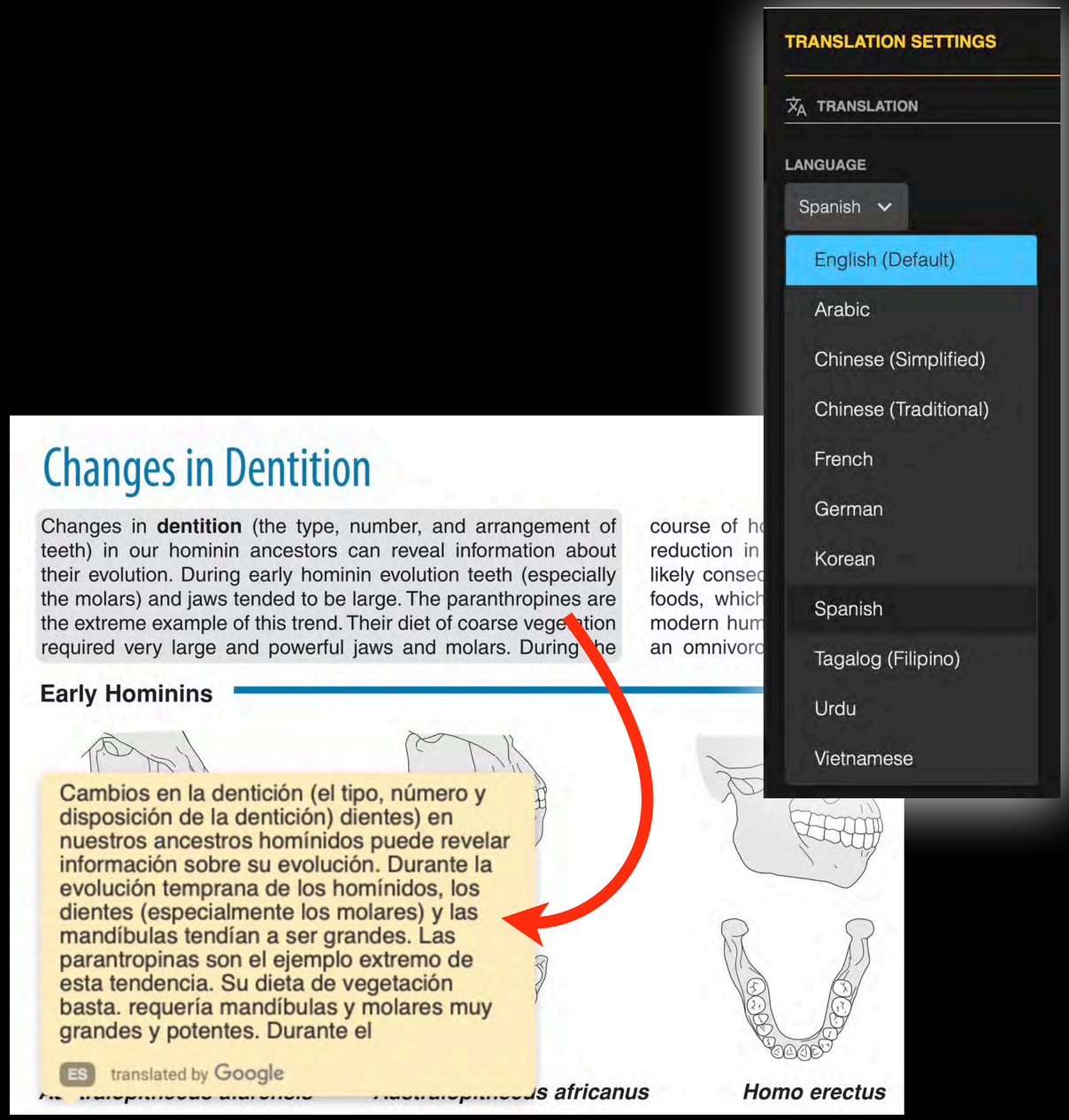
- Teacher has access to **model answers** via display buttons.
- Teacher can **assign activities** as time-sensitive coursework to be submitted by students.
- Teacher can **view**, **comment** and **grade** student responses to questions.



Translation **Feature**

- **Translation for 150 languages:** Realtime translation - highlight the English text to display text translation in the selected language (25 languages active).

- Once activated, pointing the mouse at a text block in the book page will show the translated version on a nearby pop-up panel.



Features In Development

- **Accessibility** well advanced for students with disabilities.
- Text **reading level simplification** in real time (experimental)
- Teacher will be able to add links to their **own resources** (files and links)
- Integration with **LMS platforms**:
  e.g. *Google Classroom*, *Canvas*, *Schoology*, etc.
- **Personal Licences**: single-user, untethered to an institution

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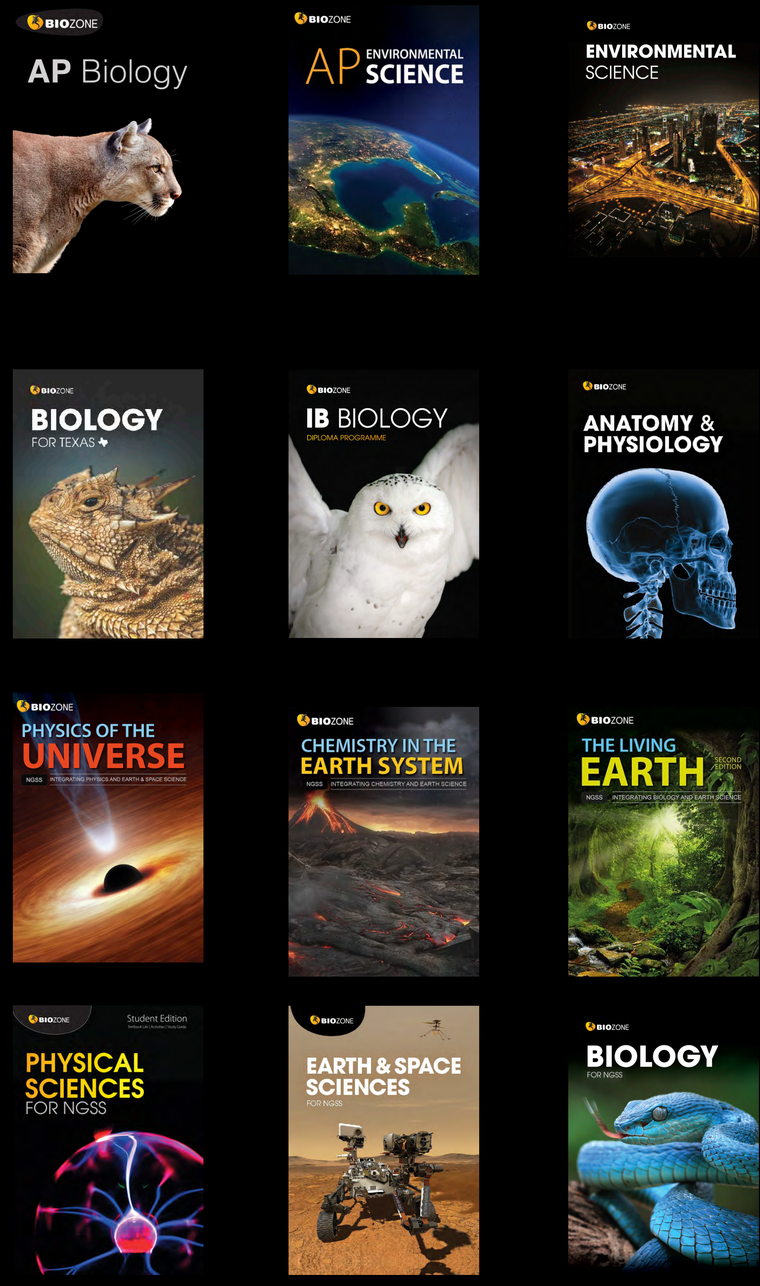

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If you like what you see ....
you can also request a **90-Day classroom trial** of a complete program of your choice.

You will also have access to:

- **BIOZONE WORLD User Guide**
- **BIOZONE Virtual Lab** (experimental)

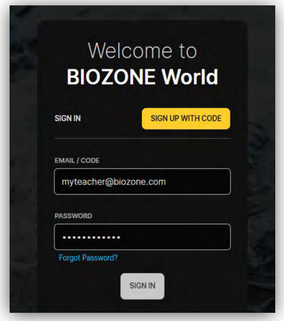
Quick Start Guide

Go to the web site: world.BIOZONE.com

Registering and Logging On:

Either:

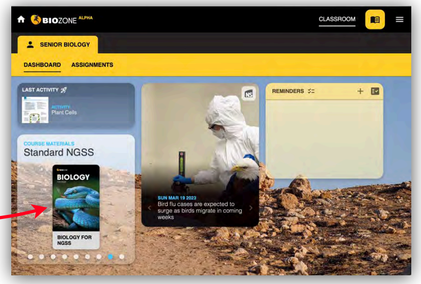
1. **SIGN IN**: Enter your registered **email address** and **password** (this may already have been set up by your school IT Admin)



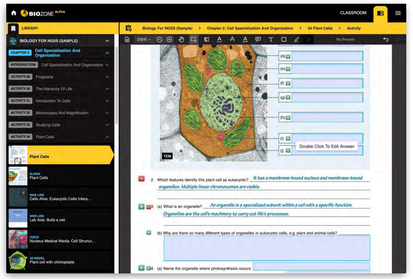
Or:

2. **SIGN UP WITH CODE**: Enter a code supplied to you to enrol in the platform (if you have been provided one by your IT Admin).

3. **HOME SCREEN**: Click on the book title cover you see here. Your licence may give you access to more than one book, so click on the blue dots under the book cover images.



4. **EXPLORE THE BOOK**:
Click on the chapter titles (blue), and then the individual activity titles (grey). This will display the pages of the book.
Your licence may provide limited access to some features. You should be able to view pages, and access the linked resources attached to each activity:
   - **Presentation Slides**
   - **3D Models**
   - **Videos**
   - **Weblinks**



NOTE: Some weblinks and videos require to be opened in a new TAB in your browser.

Home Screen:

Once logged in you will be presented with the Home Screen (depicted below).
The home screen allows you to see the **Dashboard.**

DASHBOARD Displays:

- **Book titles** that are registered to your account
- **Last Activity** that you were work on or accessed
- **RSS science news feeds** from major science journals and magazines
- **Reminders** for things like due dates for assignments.

Features not active in the LITE version (PLUS only):

- **Assignments** (allows teacher to set assignments and monitor progress of students)
- **Students** (allows teacher to manage class lists)

Home: Navigate back to the home screen by clicking on the BIOZONE logo or home icon

Your Classes: Your classes will show here - name them as you wish (you may have more than one class)

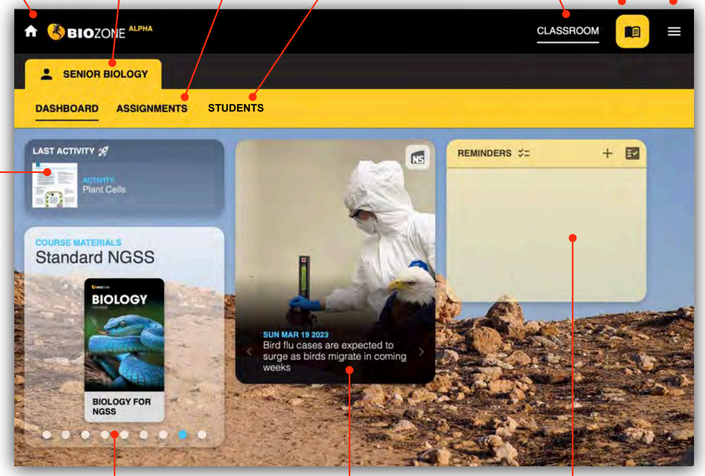
Assignments (PLUS only): Allows teacher to set activities as assignments to whole classes or individual students.

Students (PLUS only): Manage class lists and grading.

Book viewer: Opens the last book you viewed. Also provides list of titles available under your licence

Go To Dashboard: Returns to this Home Page

Subscription: Show your licence and ability to Log Out



Go To Last Activity: This provides quick access to the work in progress

Titles Available: Access the books that are licensed to your school account. Any blue dots indicate additional titles are available.

RSS Science News Feeds: BIOZONE has live news feeds to several science journals and magazines that are refreshed daily, including:

- ***Scientific American***
- ***New Scientist***
- ***Science News***

Reminders: Provides a list of current reminders such as assignment due dates.

Accessing a Book

When a student logs on to the eBOOK platform, the dashboard shows the eBook title attached to their account. Click on the eBook title to open the book and start exploring.

PLUS License Only Features:

- **Interactive Replicas** of the printed books allow students to answer questions online …

  … this forms a "Record of Work" and may be graded by the teacher (if desired).

- **Presentation Slides**: Many of the activities have a selection of presentation slides that can be used by the teacher to provide context and background notes for the students - great for introducing a lesson - or reviewing at the end.

TEACHER VIEW shown below:

Library Toggle:
Click this button to show or hide book pages and resources.

Chapter Title:
All chapters are displayed in blue.

Activity Title:
Activities are numbered and displayed in grey

QR Codes: Some of our newer books feature QR codes. A student can use their mobile phone or tablet to scan this code and link to a 3D model.

eBook Title:
More than one book may be displayed.

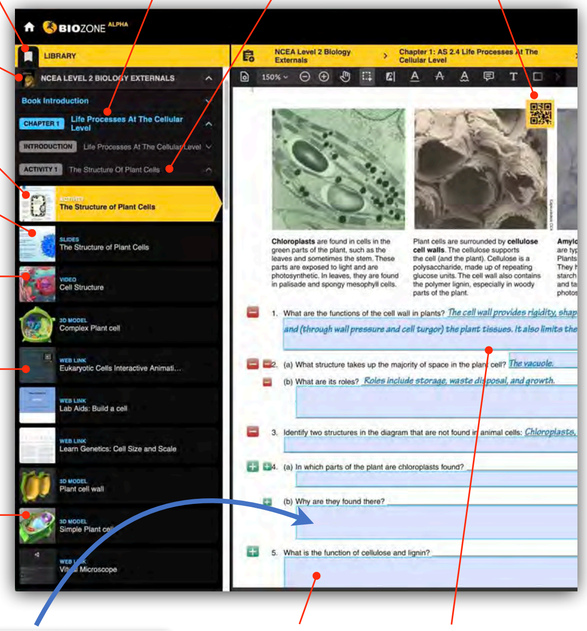
Activity Pages:
May be a single page or several pages.

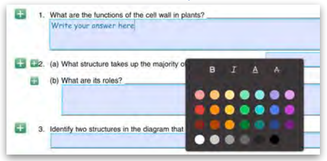
Presentation Slides:
Available for PLUS licenses only.

Curated Videos:
Mostly hosted on YouTube, these play within the platform.

Curated Web-links:
These will display in a new TAB in your browser as some have special display requirements.

3D Models:
BIOZONE's collection of 3D models are often annotated and a provide a great lesson enrichment opportunity.





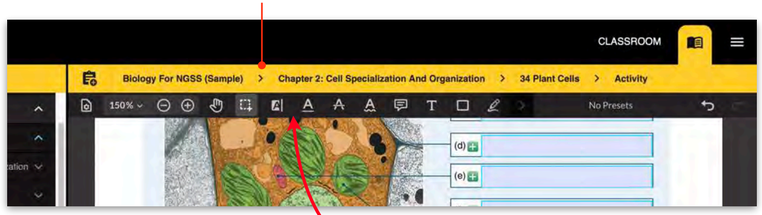
Student Responses:
Available in PLUS licenses only - students double-click on one of the blue fields to type in their responses to questions.

Reveal Answers:
Teacher Only access - Use the (+) and (-) buttons to display or hide the suggested answers. HINT: use this feature with an interactive whiteboard to review a lesson.

Additional Features

Don't get lost - there is a clear roadmap of where you are currently in any title in BIOZONE World:

Breadcrumbs:
This shows you the path of where you are in any book



Tool Bar: There are various tools available to highlight, markup and comment on the page. See the explanation below.

Student Annotations and Markup

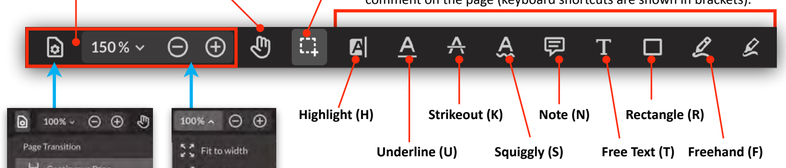
Students can add their own additional notes, draw on the page and highlight text passages.

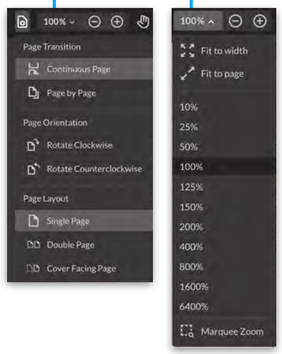
Page Display Options:
There are various options to improve the way the pages of the eBook are displayed. When viewing videos and 3D models, you may wish to switch to FULL SCREEN mode.

Select (Esc): Use this to select text on the page

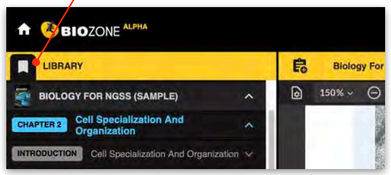
Pan (P): Use this to grab the page and move it around

Markup Tools: Use markup tools to highlight, markup and comment on the page (keyboard shortcuts are shown in brackets).





HINT: **Library Icon**
Click this library/bookmark icon - if you wish to **temporarily hide** the library index



BIOZONE

Virtual Science Lab


Periodic Table of Elements
Centrifuge


Homework Assignment
BIOZONE's The Living Earth: Activity 37
to be completed by Tuesday
alizarin

BIOZONE

Virtual Science Lab:

Orientation

Teacher Notes:

Overview: Designed to introduce high school students to a well set up science laboratory and provide a fun orientation. The lab features a lot of equipment that would appear in chemistry lab, with other materials added for biology and earth sciences. There are also extra items of scientific apparatus that would normally only be found in a research lab or college lab (centrifuge, bioreactor, PCR thermal cycler machine).

Objectives: The game requires that the students become familiar with **health** and **safety hazards** and equipment. This requires them to do an "audit" to **identify risks** and become familiar with **safety equipment**, by discovering items in both categories. They will also learn the names of some of the more common (and exotic) lab equipment.

Student Instructions:

Welcome to the BIOZONE Science Lab orientation! This is an early look at an exciting project we are working on. Right now your interaction is limited to moving around and looking at things. In the future, we will allow you to have useful interactions with the equipment.

In this simulation, you can move around and look at the equipment and features of a modern school science lab. The lab features a lot of equipment that would appear in chemistry lab, with other materials added for biology and earth sciences. There are also extra items of scientific apparatus that would only be found in a research lab or college lab (bioreactor, PCR machine).

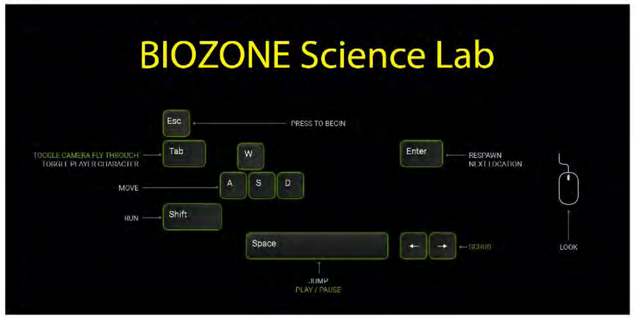
- Read the **Lab Rules** on the notice board in the Lab (next two the teacher's front bench)
- Can you spot **8 lab safety rules** being broken (HINT: look on bench tops as well as the floor)?
- Can you find up to 12 items of **safety equipment** that reduce or respond to hazards in the lab (HINT: look on bench tops, walls, ceiling, as well as the floor)?

NOTE: Please be patient while the simulation loads - it may take a few minutes (depending on the speed of your internet connection.

To experience the best graphics, speed and interaction, try downloading one of the App versions of the simulation for **Windows** or **Mac OS**:

BIOZONE SciLab VR 2023 - MacOSX 482MB

BIOZONE SciLab VR 2022 - Windows 332MB



Use the **arrow keys** or (**WASD**) to move and use the **mouse** to look around (look in different directions).

1. The player must carry out a **Health & Safety audit**:

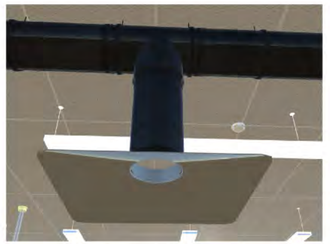
   (a) Read the **Lab Rules** on the notice board in the Lab (next two the teacher's front bench).

   (b) Identify and record (inventory) up the 8 health and safety **hazards** in the lab:

   1. Broken glass
   2. Spilled chemical on bench
   3. Water on the floor
   4. Scalpel blade near the edge of the bench
   5. Drink in the lab
   6. Food in the lab
   7. Bunsen burner too near the edge of the bench
   8. Petri dishes exposed with bacterial colonies

(c) Identify and record (inventory) on the 12 **mitigations** that ensure safety:

1. Fire extinguisher
2. Fire alarm
3. Fire blanket
4. First aid kit on the wall
5. Emergency EXIT sign
6. Safety glasses
7. Biohazard Waste bin
8. Fume cupboard for dangerous experiments that give of noxious gases
9. Safety tongs for handling hot test tubes
10. Smoke detector (ceiling)
11. Fire sprinkler system
12. Extractor fan duct over benches



BIOZONE
Virtual Science Lab

You will be able to access the experimental version in 3 ways:

- **Online** (browser) version
- **Windows** OS App version
- **Mac** OS App version

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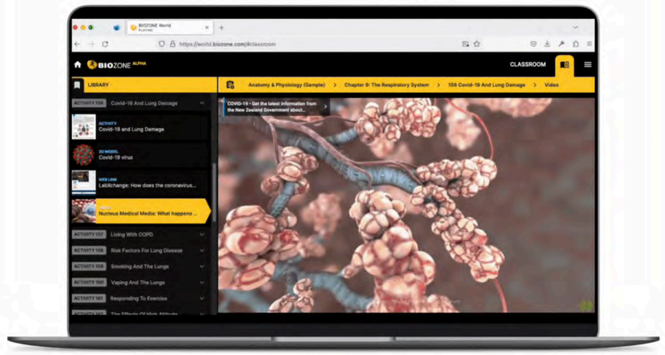

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BIOZONE stands out by uniquely blending the best elements of a highly-visual **textbook** with the practicality of an interactive workbook. This innovative hybrid, known as an **worktext**, eliminates the need for a separate **textbook**, offering an all-in-one educational resource.

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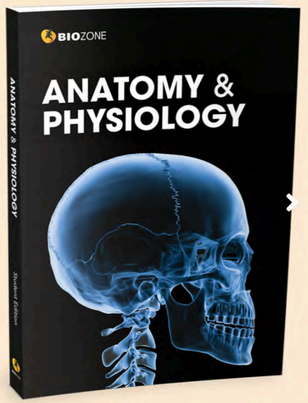

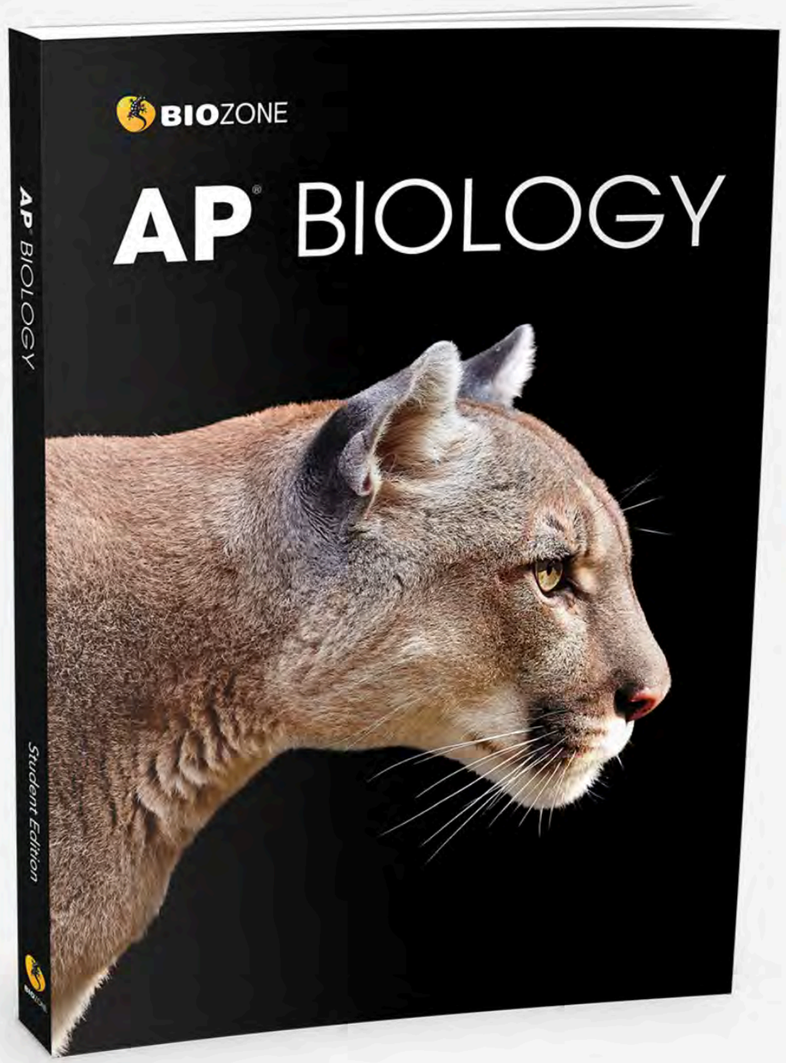

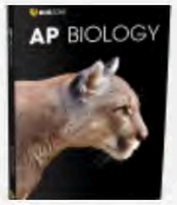

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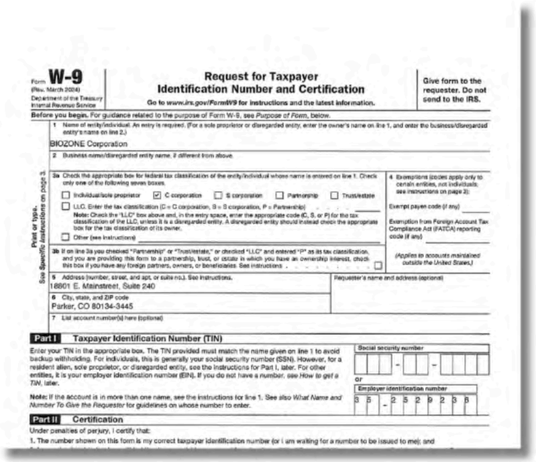

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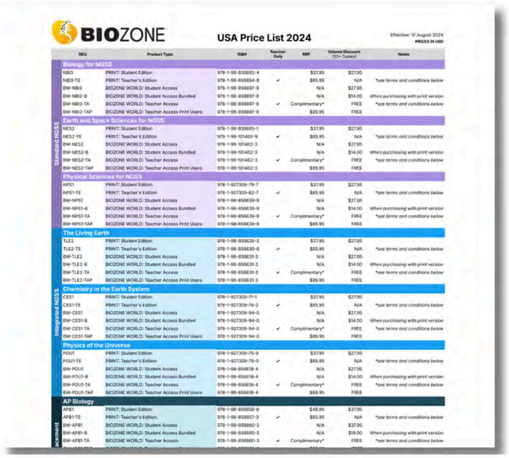

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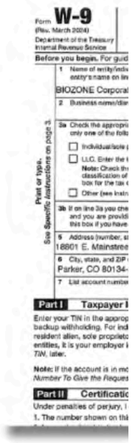

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	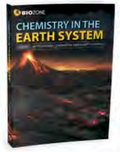	**Chemistry in the Earth System**						
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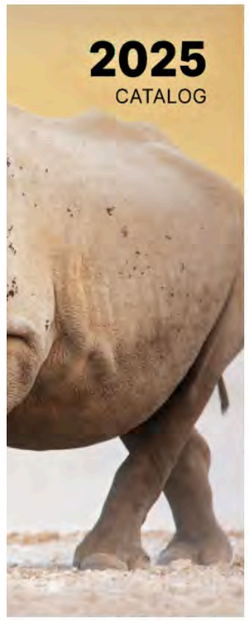

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