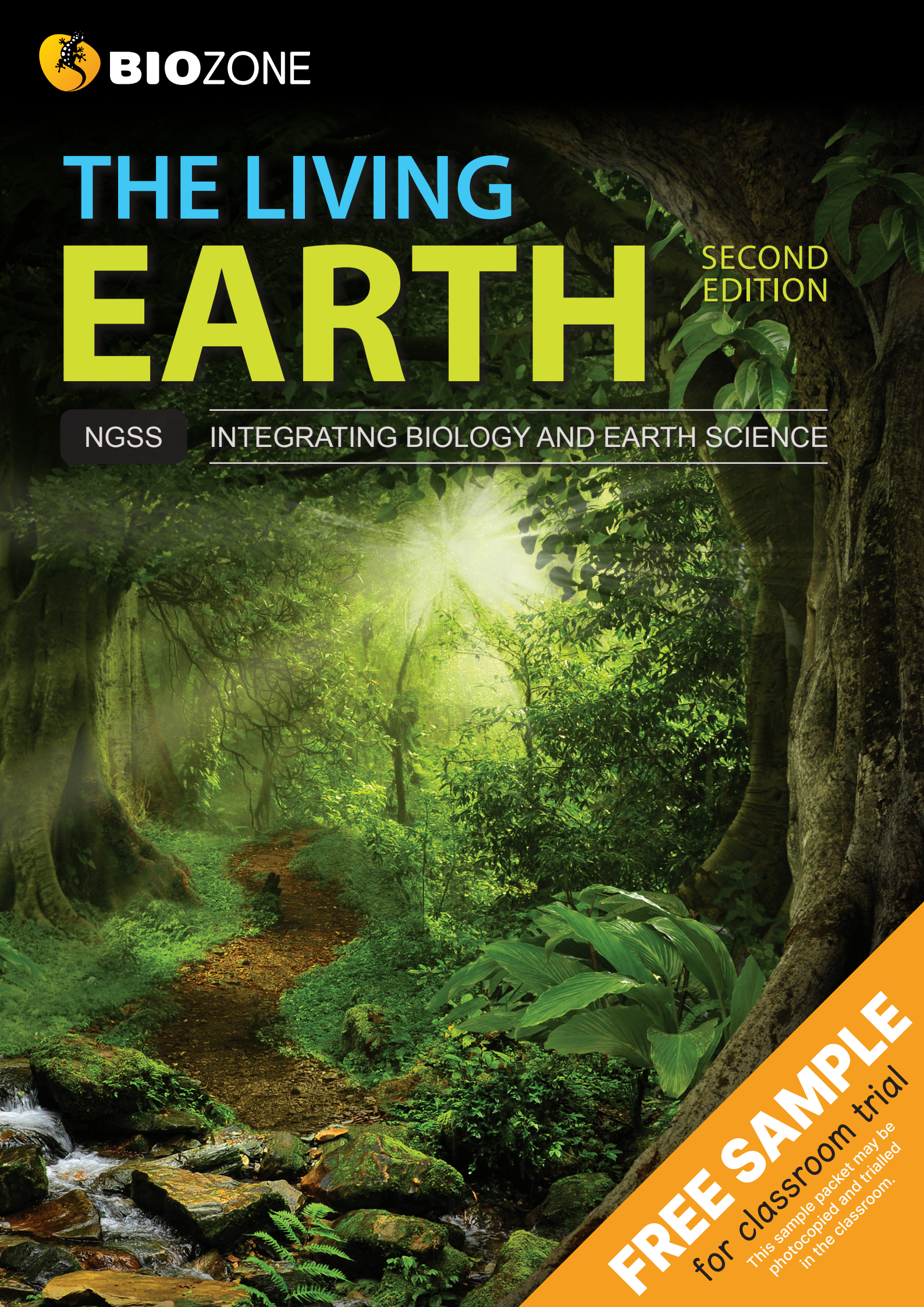
BIOZONE

THE LIVING EARTH

SECOND EDITION

NGSS

INTEGRATING BIOLOGY AND EARTH SCIENCE

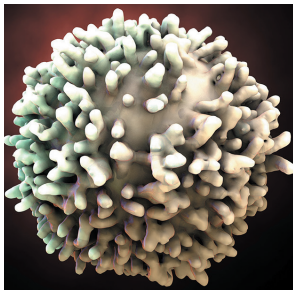


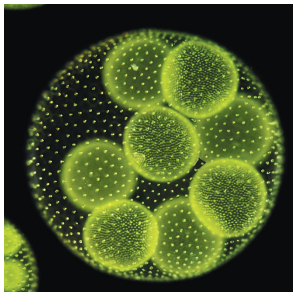
FREE SAMPLE for classroom trial

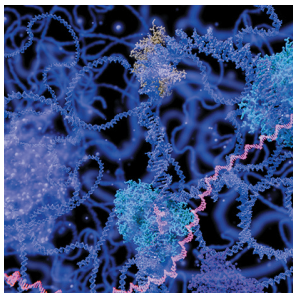
This sample packet may be photocopied and trialled in the classroom.

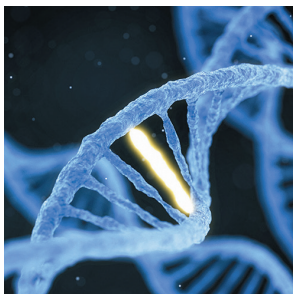
Instructional Segment 5

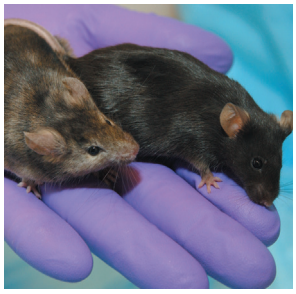
Structure, Function, and Growth











NIH

Activity number

Anchoring Phenomenon

Breast Cancer: Breast cancers are cell masses distinct from the tissue around them. 62 75

How do systems work in a multicellular organism (emergent properties) and what happens if there is a change in the system?

☐ 1 What do you understand by the term alive? What are your criteria for deciding if something is living or not? Is non-living the same as dead? Categorize objects as living or non-living according to your criteria *[SEP-6] LS1.A] [CCC-6]*. 63

☐ 2 Recognize cells as the fundamental unit of life. Categorize cells as either prokaryote or eukaryote based on the presence or absence of characteristic features. Recall when multicellular organisms arose on Earth (IS2) and what advantages multicellularity provided to those organisms. Using evidence from a model organism *[SEP-2]*, explain how cells within a multicelluar organism are specialized to perform specific roles that contribute to the functioning of the organism as a whole *[SEP-6] LS1.A] [CCC-6]*. 63

☐ 3 Develop and use a model *[SEP-2]* to show how a complex multicellular organism is produced and maintained through cell division and differentiation from stem cells. Use the model to explain *[SEP-6]* how the expression of different genes during development leads to cells with different structure and function *[LS2.B] [CCC-6] [HS-LS1-4]*. Using skin as an example, construct an explanation for how differentiation of stem cells in the skin replenish the dead cells lost from the skin's surface. Use a model *[SEP-2]* to explain *[SEP-6]* how stem cells can be used to engineer new tissues such as skin *[ETS1.B] [CCC-6]*. 64 76

☐ 4 Develop and use a model *[SEP-2]* to investigate *[SEP-3]* or show how the hierarchical organization of interacting systems (cells, tissues, organs, and organ systems) provides specific functions within multicellular organisms *LS1.A] [CCC-6] [HS-LS1-2]*. 64 65 76

How does the structure of DNA affect how cells look and behave?

☐ 5 Recall that proteins are responsible for the traits we see in organisms and that these traits are encoded by genes carried on chromosomes. Develop and use a model *[SEP-2]* to investigate *[SEP-3]* the importance of a protein's three dimensional structure to its functional role in the cell *[LS1.A] [CCC-6]*. What happens if the protein's precise structure is damaged? 66

☐ 6 Describe the structure of proteins and explain how the variety of amino acid building blocks and their many possible arrangements enables a great protein diversity. Can you think why scientists in the early 20th century thought that proteins must carry the code? 66

☐ 7 Use a model to show how proteins are made by first transcribing (rewriting) the instructions in DNA and then translating them into a protein molecule using the cell's molecular machinery *[SEP-2]*. Can you think of an analogy for this process? Construct an explanation based on evidence for how the structure of DNA determines the structure of a protein *[SEP-6] [LS1.A] [CCC-6] [HS-LS1-1]*. 66 76

☐ 8 In groups, come up with a list of the roles that proteins carry out in our bodies. Use examples and models (e.g. molecular models or drawings) to elaborate on your previous investigations and explain how the shape of a protein determines its function *[SEP-2] [SEP-6] [LS1.A] [CCC-6]*. 67

☐ 9 Describe the structure of the plasma (cell surface) membrane, including the role that proteins play as part of its functional structure *[LS1.A] [CCC-6]*. Use a model to explain how different substances move through membranes by diffusion, osmosis, or active transport *[SEP-2] [SEP-6] [LS1.A] [CCC-6]*. Make the connection between these processes and the functioning of the cell and the organism as a whole *[CCC-6]*. 68

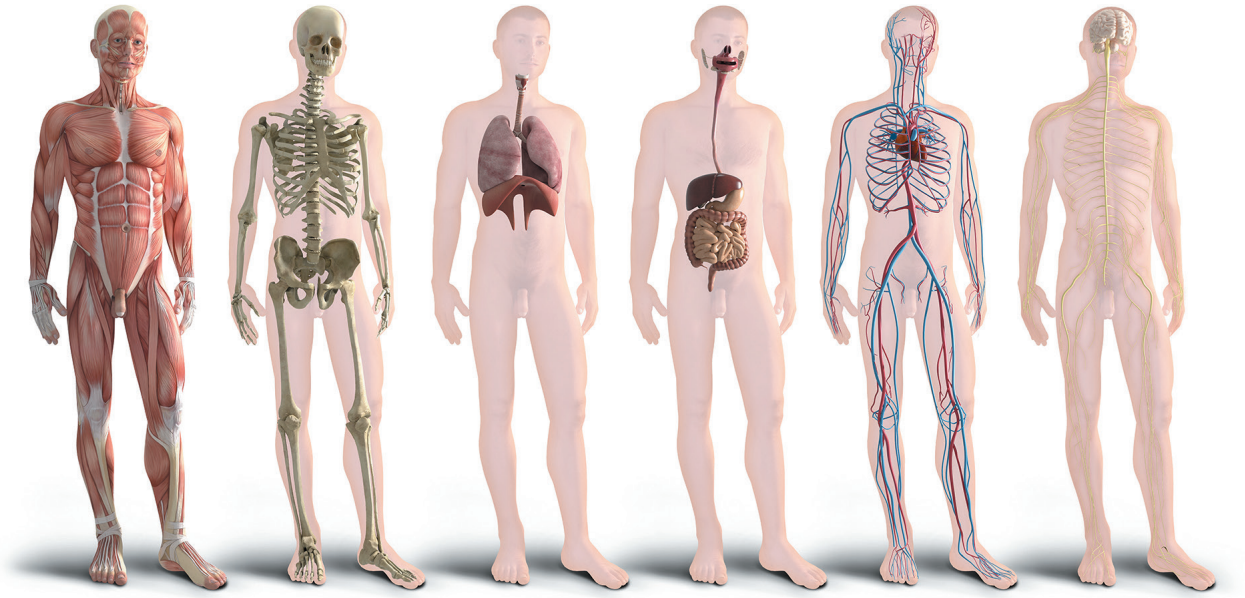
☐ 10 Recall that enzymes are proteins with catalytic roles in cells. Investigate *[SEP-3]* the way in which temperature affects the activity of an enzyme (e.g. salivary amylase). What is the enzyme's optimum temperature and why? *[LS1.A] [CCC-6]* 68

65 Interacting Systems

ENGAGE: How do body systems interact?

- How does Simone Biles perform her amazing gymnastic feats? They require balance, coordination, strength, and timing. Not all of us can achieve such athleticism, but everyday our body's systems work together to keep us functioning in our environment.
- An **organ system** is a group of organs that work together to perform a certain group of tasks.
- The body has 11 organ systems, six are pictured below. The skin (not shown) is the body's largest organ. Can you think why?

Simone Biles



Muscular system | Skeletal system | Gas exchange system | Digestive system | Circulatory system | Nervous system

1. The images above show six of the body's eleven organ systems. Using the images to help you, identify some of the important components of each of the systems pictured.

   (a) Muscular system: _____

   (b) Skeletal system: _____

   (c) Gas exchange (respiratory) system: _____

   (d) Digestive system: _____

   (e) Circulatory system: _____

   (f) Nervous system: _____

2. Think of two ways in which some of these six systems might interact to help the body function. Describe them:

   (a) _____

   _____

   (b) _____

   _____

LS1.A SF

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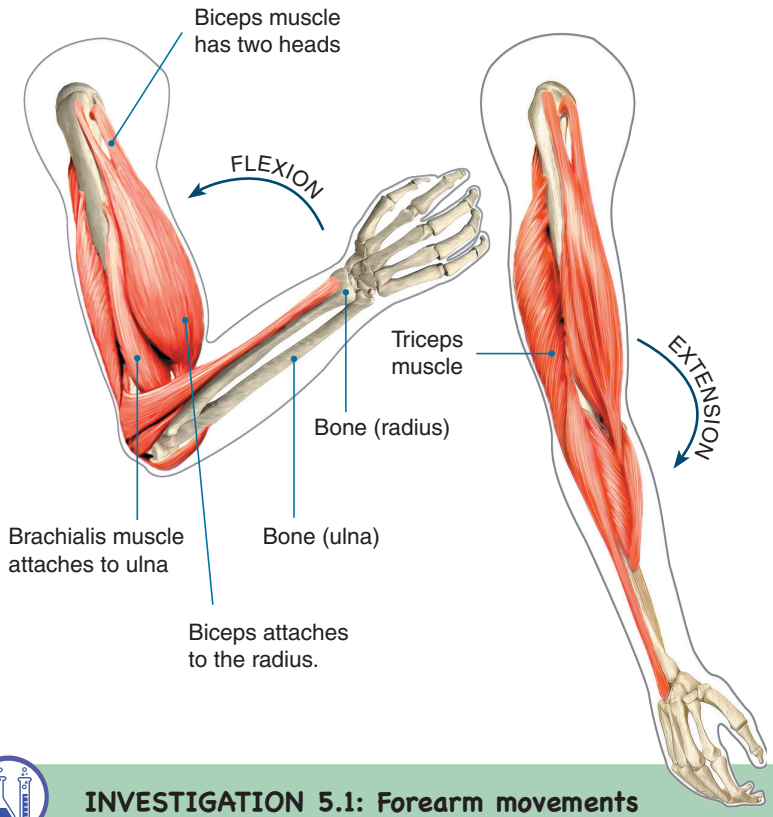
EXPLORE: Flex your muscles

Bones act with muscles to form levers that enable movement



INVESTIGATION 5.1: Forearm movements

No equipment required.

What makes different parts of your body move? Try this quick investigation to find out.

1. Hang the hand of your right arm down by your side, thumb forward. Put your left hand around the middle of your upper right arm so that you can feel the muscle underneath. Make a fist and bend your right arm at the elbow towards you (**forearm flexion**).

   Describe how the shape of the muscle on your upper arm changes as you do this:

   _____

   What do you think is happening to the muscle? _____

   _____

2. Now move your left hand around a bit more so that you can feel the muscle at the back of your upper right arm while it is in the flexed (bent) position. Make a fist and then straighten your arm from the elbow (**forearm extension**).

   What do you feel now? _____

   _____

3. Use the diagram above and your own investigation to explain how the interaction of body systems can generate movement of body parts:

_____

_____

_____

_____

_____

_____

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EXPLORE: Breathe!

- You know from earlier chapters that cellular respiration requires oxygen and produces carbon dioxide. How do these gases enter and leave our bodies?
- You will know that your chest rises and falls as air enters and leaves the lungs in your chest cavity. But what actions bring this about? In this simple investigation you will build and use a simple model to explore how you breathe.

INVESTIGATION 5.2a: A model for the gas exchange system

See appendix for equipment list.

Take care using a utility knife as they are very sharp.
Cut on a flat firm surface or cutting board.

You can work in pairs for this activity if you wish.

1. Take a 500 mL (approximately) plastic bottle and use a utility knife to cut the bottom off.
2. Hang one of the balloons inside the neck end of the bottle and stretch the open end of the balloon over the neck of the bottle. It should fit tightly, but secure with a rubber band if needed.
3. Cut the lower third off the second balloon and keep the two-thirds with the open end. Tie a knot in the neck of this balloon.
4. Stretch the wide opening of the cut balloon over the wide end of the cut bottle so that the knot hangs down. It should fit tightly over the bottle but secure with a rubber band if needed.
5. Pull and release the knot. What happens? _____

_____

What do you think happens to the pressure inside the bottle when you pull and release the knot?

_____

How does this explain what happens in the model? _____

_____

4. (a) What does the balloon in the bottle represent? _____

   (b) What does the cut balloon with the knot in it represent? _____

   (c) Pulling down on the knot is like breathing in / breathing out (delete one)

   (d) Releasing the knot is like breathing in / breathing out (delete one)

5. (a) How is your model like the human gas exchange system? _____

   _____

   (b) How is it different? _____

   _____

INVESTIGATION 5.2b: Refining your model

See appendix for equipment list.

1. Use the equipment provided to refine your model of a human gas exchange system. Draw a picture or take a photograph of your refined model and attach it to this page.

   How much better does your new model resemble the gas exchange system?

   _____

   _____

   What is still missing from your model? _____

   _____

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EXPLAIN: Circulation and gas exchange

- In humans and other vertebrates, the gas exchange (respiratory) system and circulatory system interact to supply oxygen and remove carbon dioxide from the body.

Circulatory system

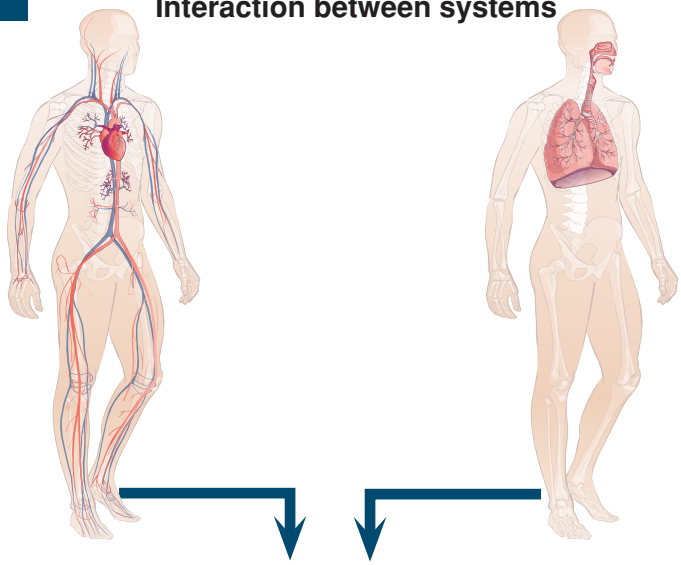
Function

Delivers oxygen (O_2) and nutrients to all cells and tissues. Removes carbon dioxide (CO_2) and other waste products of metabolism. CO_2 is transported to the lungs.

Components

- Heart
- Blood vessels:
  - Arteries
  - Veins
  - Capillaries
- Blood

Interaction between systems



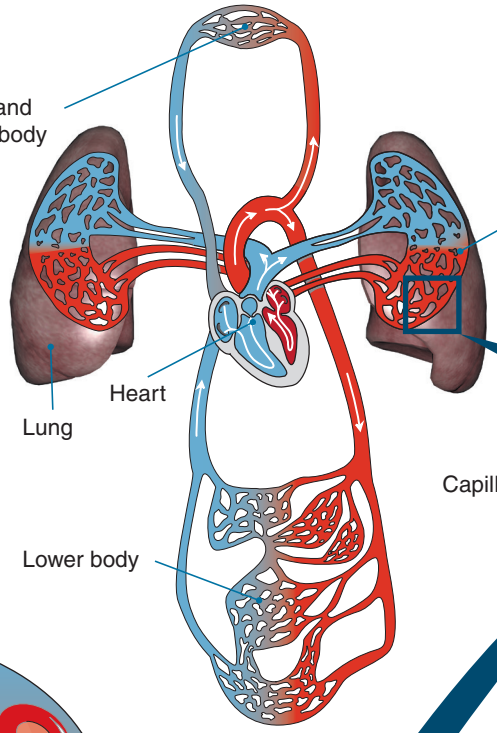
Gas exchange system

Function

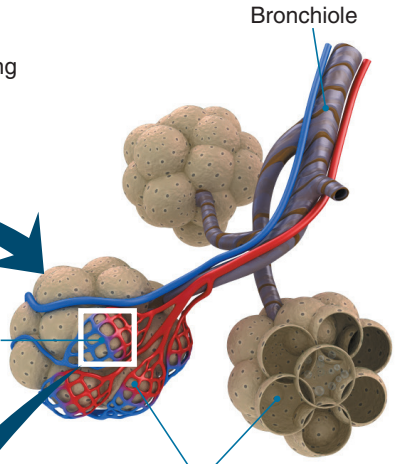
Provides surface for gas exchange. Moves fresh air into the body and stale air out.

Components

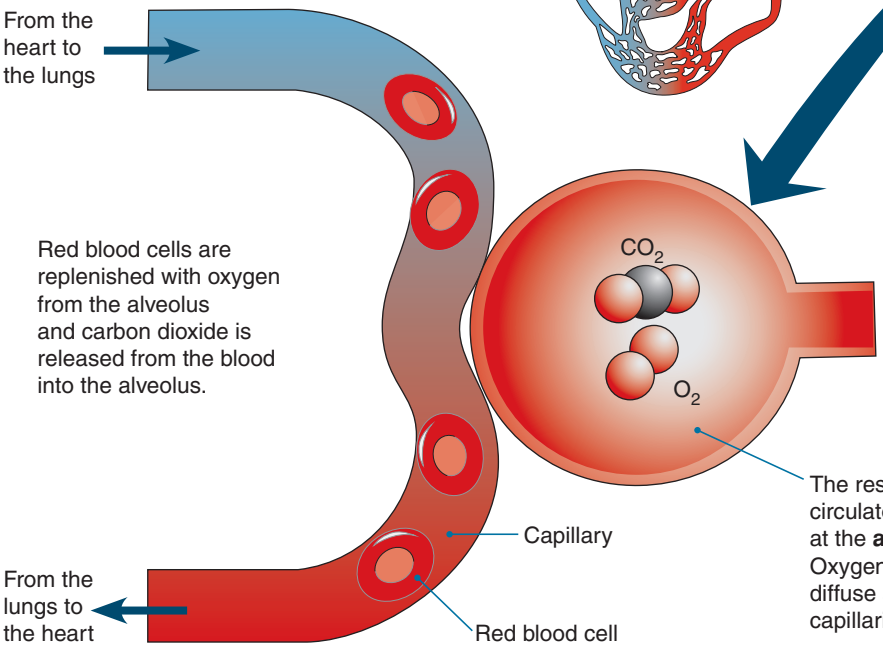
- Airways:
  - Pharynx
  - Larynx
  - Trachea
- Lungs:
  - Bronchi
  - Bronchioles
  - Alveoli
- Diaphragm



Oxygen (O_2) from inhaled air moves from the lungs into the blood of the circulatory system and is transported within red blood cells to the heart. The heart pumps the blood to the body where O_2 is released and carbon dioxide (CO_2) is picked up. The blood returns to the heart and is pumped to the lungs where CO_2 is released into the lungs to be breathed out.



The airways of the lungs end at the **alveoli**, which are microscopic air sacs that enable gas exchange.



Red blood cells are replenished with oxygen from the alveolus and carbon dioxide is released from the blood into the alveolus.

CO_2
O_2

The carbon dioxide released from the blood exits the body during breathing out. Breathing in brings in fresh air containing oxygen.

The respiratory system and the circulatory system come together at the **alveoli** (sing. alveolus). Oxygen and carbon dioxide diffuse across the thin walls of capillaries and alveoli.

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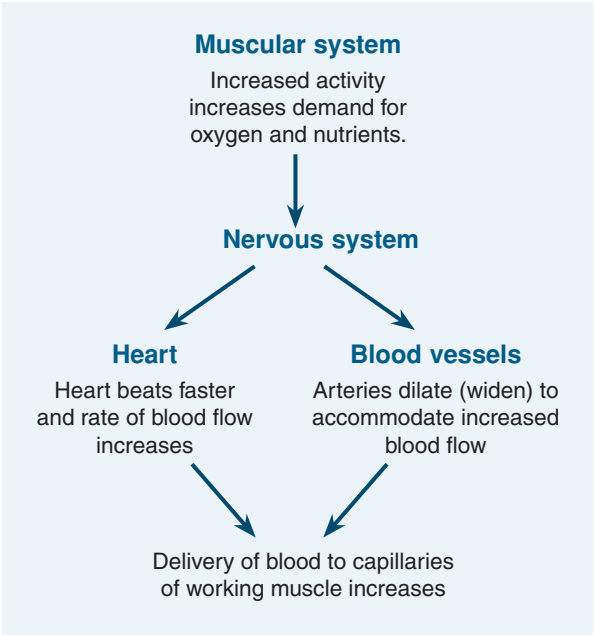
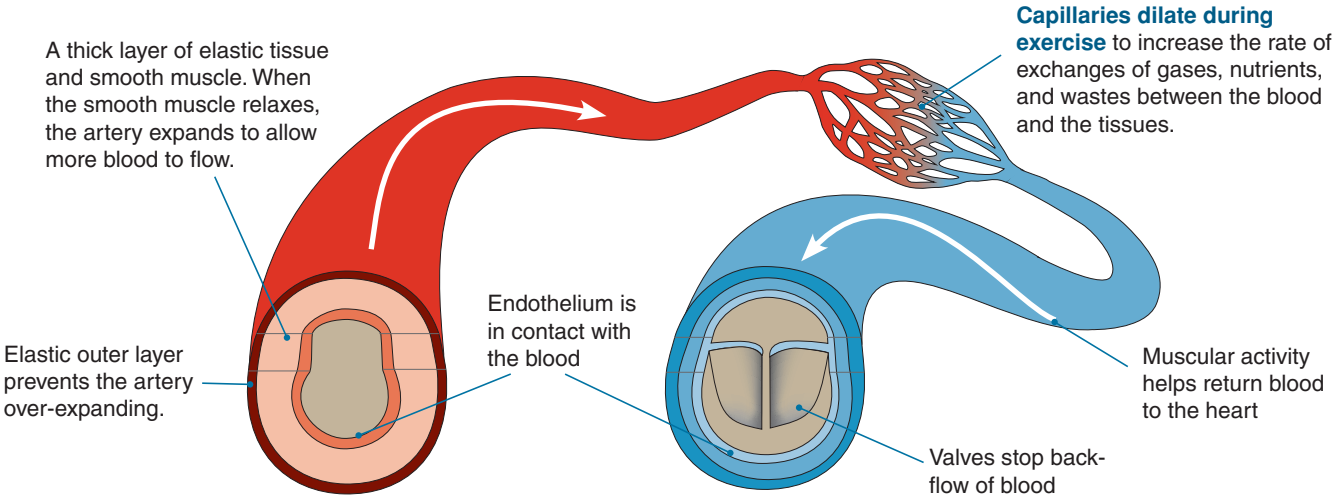
Responses to exercise

- During exercise, your body needs more oxygen to meet the extra demands placed on the muscles, heart, and lungs. At the same time, more carbon dioxide must be expelled. To meet these increased demands, blood flow must increase. This is achieved by increasing the rate of heart beat. As the heart beats faster, blood is circulated around the body more quickly, and exchanges between the blood and tissues increase.
- The arteries and veins must be able to resist the extra pressure of higher blood flow and must expand (dilate) to accommodate the higher blood volume. If they didn't, they could rupture (break). During exercise, the muscular, cardiovascular, and nervous systems interact to maintain the body's systems in spite of increased demands (right).





Artery

The strong stretchy structure of arteries enables them to respond to increases in blood flow and pressure as more blood is pumped from the heart.

Vein

Veins return blood to the heart. Veins are less muscular than arteries, but valves and the activity of skeletal muscles help the blood return to the heart.

3. In your own words, describe how the circulatory system and respiratory system work together to provide the body with oxygen and remove carbon dioxide:

4. (a) What happens to blood flow during exercise? _____

   (b) Explain how body systems interact to accommodate the extra blood flow needed when a person exercises?

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66 How Cells Make Proteins

ENGAGE: Go boil your egg!

- Eggs are 13% protein. They have a 'native' state and the loss of that native state is called denaturation. What happens when you subject the protein in egg white to heat or chemicals?

INVESTIGATION 5.3: Protein denaturation

See appendix for equipment list.

You can work in pairs for this activity if you wish.

1. Crack open an egg, separating the yolk from the white. Place the white in a 250 mL beaker that is about half full of water. Heat the water until it is nearly boiling. Record what the egg white looks like before and after boiling.

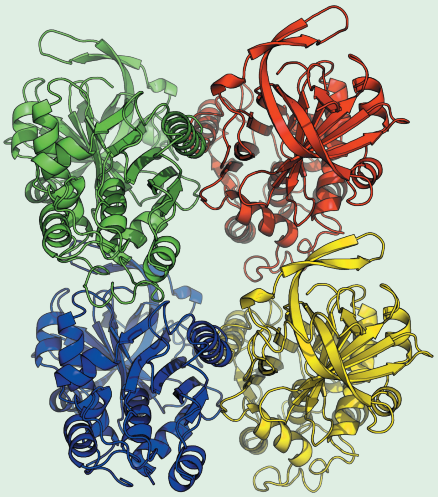
_____

_____

2. Place about 100 mL of isopropyl alcohol (propan-2-ol or rubbing alcohol) into a 250 mL beaker. Crack open an egg, separating the yolk from the white and place the white in the beaker. Stir the egg slowly and record the result.

_____

_____



Ovalbumin, the main protein in egg albumen

1. (a) What did the heat and the alcohol do to the egg white protein?: _____

_____

(b) Which one had the greatest effect on the egg white? _____

(c) Can you think of another common way egg whites are denatured? Describe it: _____

_____

2. Look at the complex shape of a molecule of ovalbumin, the main protein in egg white. What do think might be happening to the molecule when it is heated, mixed with alcohol, or beaten?

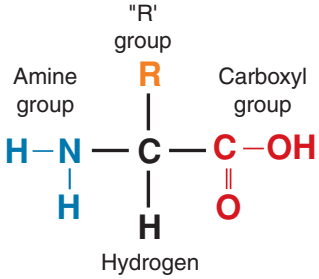
_____

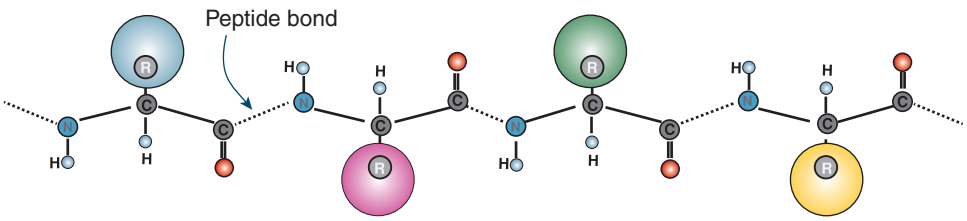
_____

_____

EXPLORE: Proteins are made of amino acids

- Proteins are large molecules made up of many smaller units called amino acids. The amino acids are joined together by peptide bonds (between the amine and carboxyl groups). A chain of amino acids is therefore called a **polypeptide**. The sequence of amino acids in a protein is determined by the order of nucleotides in DNA.
- All amino acids have a common structure (below 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.





The order of amino acids in a protein is directed by the code (the sequence of nucleotides) in the DNA. This is called the protein's **primary structure**.

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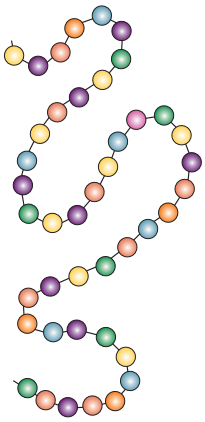
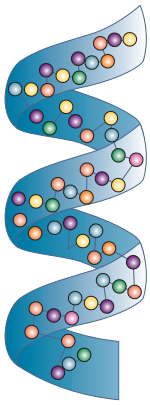
EXPLORE: Proteins fold up into a functional structure

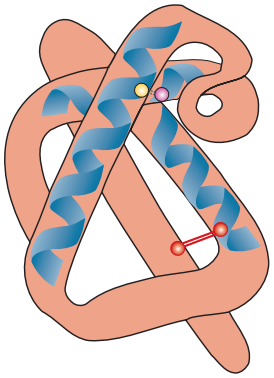
- The amino acid sequence of a protein is only the first step in making a functional protein. A protein must fold into a functional structure in order to carry out its biological role. This is where the 'R' groups become important.
- The amino acid chain will fold up into a specific shape depending on the interactions between the different 'R' groups (below). These interactions include hydrogen bonds, disulfide (S – S) bonds, and hydrophobic (water-hating) and hydrophilic (water-loving) interactions.
- First, the amino acid chain folds into coils (helices) and sheets to create a **secondary structure**. These shapes are created and maintained by hydrogen bonds between CO and NH groups.
- More distant parts of the folded chain can then interact to create a highly organized **tertiary structure**. Disulfide bridges are important in maintaining the folded tertiary structure.
- Some functional proteins, such as haemoglobin (below) consist of two or more polypeptide chains. When multiple polypeptides come together, the protein has a **quaternary structure**. The functional structure of hemoglobin also includes four iron atoms. These enable hemoglobin to bind oxygen.



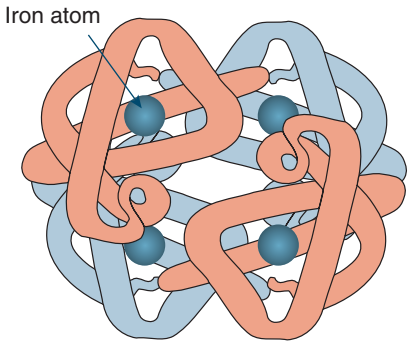
Primary structure
Amino acid chain



Secondary structure
Coiled helix



Tertiary structure
Folded helices



Quaternary structure
Multi-unit protein

INVESTIGATION 5.4: Modeling protein structure

See appendix for equipment list.

Work in pairs for this activity.

1. You will need pipe cleaners with four colors. We have used 2 white, 2 pink, 2 purple, and 4 blue but you can swap out for the colors you have. Each color represents a different amino acid.
2. Twist a loop in the center of each pipe cleaner (figure 1). The twist represents the amino acid's functional group.
3. Join the amino acids together (figure 2) by twisting their arms together in the following sequence: 1) white 2) pink 3) blue 4) purple 5) blue 6) pink 7) blue 8) white 9) blue 10) purple.

   What level of protein organization does the structure in figure 2 represent?

   _____

4. Attach sticky tape to the loops of the purple pipe cleaners and to one arm of each of the blue pipe cleaners. These represent places where hydrogen bonding can occur.

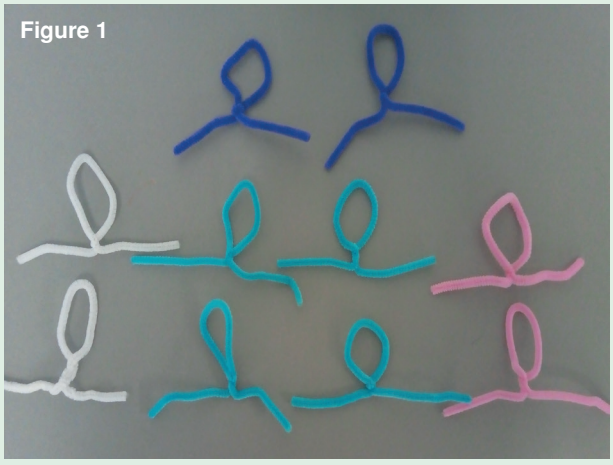


Figure 1


Figure 2

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5. Join the sticky tape together between amino acids 3 and 5 and also between amino acids 7 and 9 (figure 3).

   Describe what happens to the shape of the model when you do this: _____

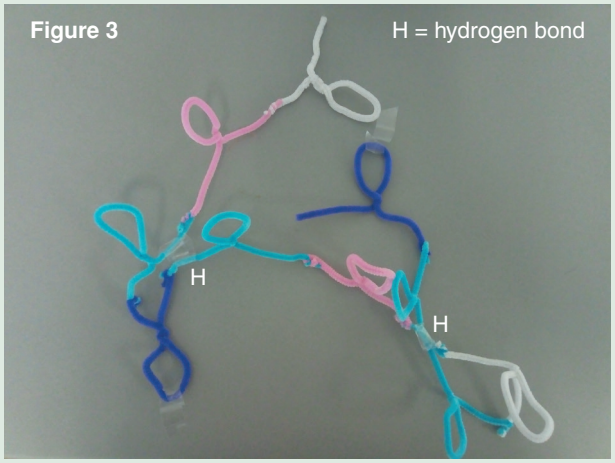
   _____

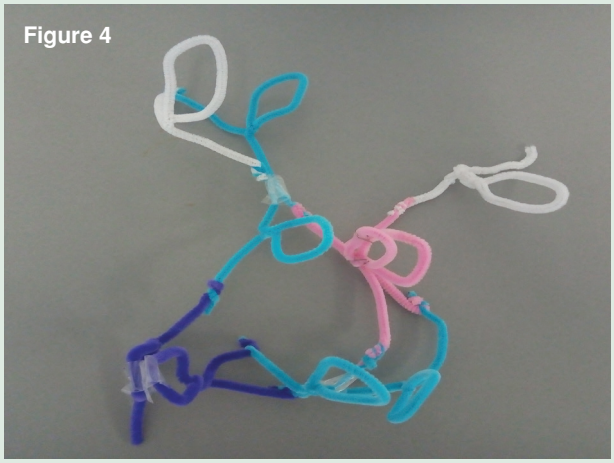
   _____

   What level of protein structure does this represent? _____

6. Attach binder clips or paper clips to the loops of the two pink amino acids and then use the clips to join the two pink amino acids together. The clips represent a disulfide bond.
7. Join the sticky tape together on the two purple amino acids (figure 4). Your protein has now formed its fully functional structure.

   What level of protein structure does this represent? _____





3. (a) Label figure 4 to show the location of all of the hydrogen bonds (H) and the disulfide bond (S).

   (b) Based on the properties of your model and its components which of these bonds is likely to be the strongest:

   _____

4. Break the hydrogen bonds between amino acids 3 and 5 and also between 7 and 9 in your molecule.

   (a) What happens to the shape of the protein? _____

   _____

   (b) What process does breaking these bonds represent? _____

   _____

   (c) What effect will this process have on the protein's ability to carry out its job? _____

   _____

   _____

   _____

5. How could you adapt your model to demonstrate quaternary structure? _____

   _____

   _____

   _____

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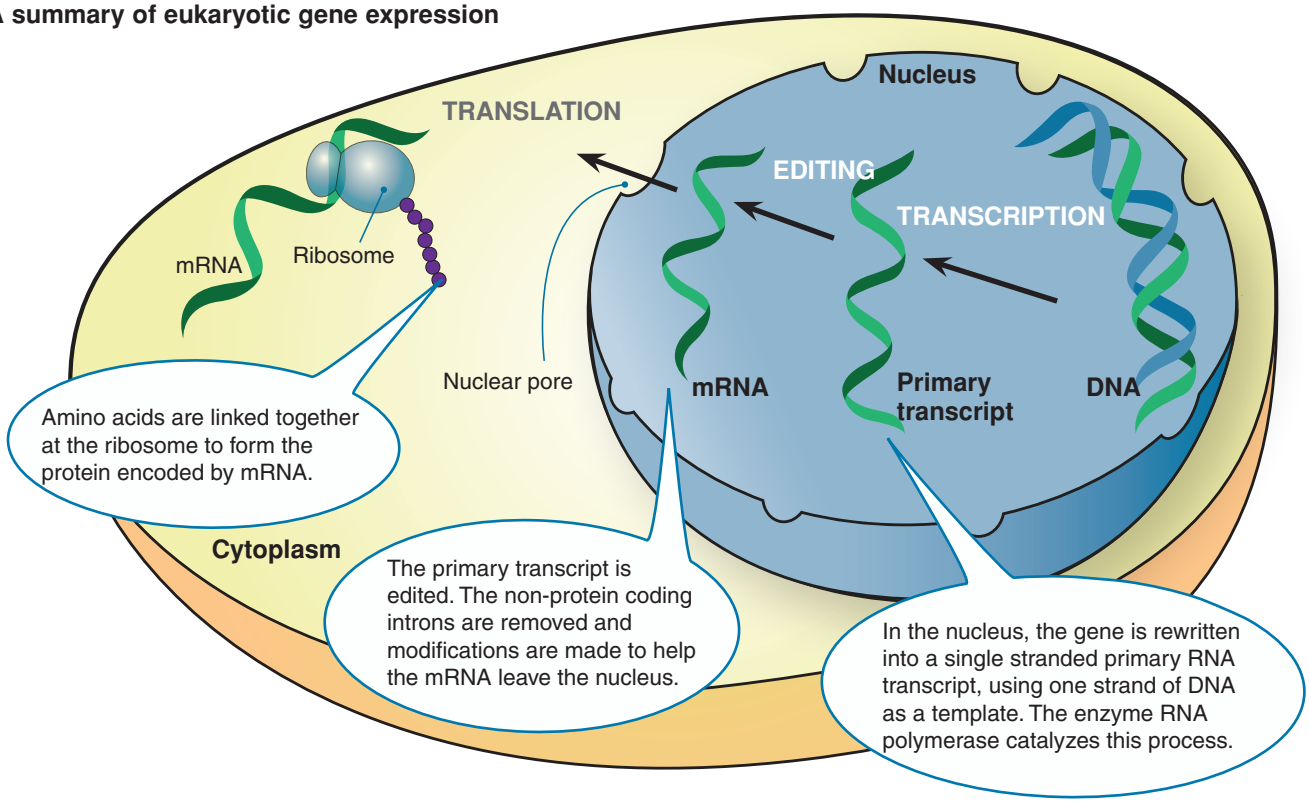
EXPLORE: Gene expression

- We have seen how the primary structure of a protein is the sequence of its amino acids and that this sequence is directed by the sequence of nucleotides in DNA. We can now ask ourselves, exactly how does this happen?
- Cells make proteins in a process called gene expression. It involves **transcription** (rewriting) of the DNA making up a gene into mRNA and **translation** of the mRNA into protein. Translation is the job of ribosomes.
- Eukaryotic genes include non protein-coding regions called introns. These regions of intronic DNA must be removed before the mRNA is translated. Transcription of the genes and editing that primary transcript to form the mature mRNA occurs in the nucleus. Translation of the protein by the ribosomes occurs in the cytoplasm.

A summary of eukaryotic gene expression



The diagram above shows a simple model of gene expression. Use it to answer the following questions:

6. (a) What are the three stages in gene expression in eukaryotes and where do they occur:

(i) _____

(ii) _____

(iii) _____

(b) What happens in each stage?

(i) _____

(ii) _____

(iii) _____

EXPLORE: The genetic code

- The genetic code is the set of rules by which the genetic information in DNA (or mRNA) is translated into proteins.
- The genetic information for the assembly of amino acids is stored as three-base sequence. These three letter codes on mRNA are called codons.
- Each codon represents one of 20 amino acids used to make proteins. The code is effectively universal, being the same in all living things (with a few minor exceptions).
- The code is degenerate, meaning there may be more than one codon for each amino acid. Most of this degeneracy is in the third nucleotide of a codon.

A triplet (three nucleotide bases) codes for a single amino acid. The triplet code on mRNA is called a codon.

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mRNA-amino acid table

- The genetic code is summarized in a mRNA-amino acid table, which identifies the amino acid encoded by each mRNA codon. The table lets you to decode the genetic code from a given mRNA sequence to give a sequence of amino acids in a polypeptide. Each amino acid has its own one or three letter abbreviation (below and next page).
- To work out which amino acid is coded for by a codon (triplet of bases) look for the first letter of the codon in the row label on the left hand side of the table. Then look for the column that intersects the same row from above matching the second base. Finally, locate the third base in the codon by looking along the row from the right hand side that matches your codon. The RNA base U (uracil) replaces the DNA base T (thymine) in RNA sequences. Example: Determine **CAG**: C on the left row, A on the top column, G on the right row. **CAG** is Gln (**glutamine**)

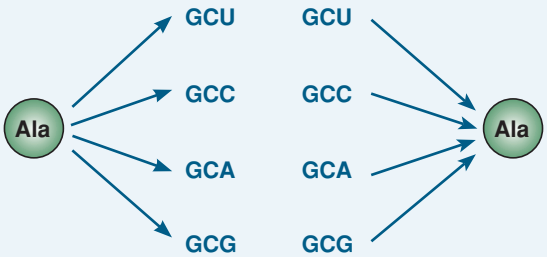
Read second letter here

Read first letter here

Read third letter here

First letter	Second letter: U	Second letter: C	Second letter: A	Second letter: G	Third letter
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA STOP	UGA STOP	A
	UUG Leu	UCG Ser	UAG STOP	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

The genetic code shows **degeneracy**. This means that a number of 3 base combinations specify one amino acid. The codons for the same amino acid often differ by only a single letter (often the second or third). For example, alanine is encoded by four different codons.



The degeneracy of the genetic code creates **redundancy**, so that several codons code for the same amino acid (e.g. GCU, GCC, GCA, and GCG code for alanine). Note that although there is redundancy, there is no ambiguity - none of the codons encodes any other amino acid.

Use the codon table above to answer the following questions:

7. What is the amino acid chain produced from the following mRNA sequences? Use abbreviations for the amino acids.

   (a) GAU CCG UAC GUA CGA ACA AUU ACC: _____

   (b) GGG UUU GCU UGG CAA AAC AGU GCA: _____

   (c) AAA CCC GGG GUA AUU CGC AAU GAU: _____

8. (a) If one RNA base (A, U, C, G) coded for one amino acid, how many amino acids could be coded for in total? _____

   (b) If two RNA bases coded for one amino acid, how many amino acids could be coded for in total? _____

9. (a) What is the effect (in general) of changing the last base in a codon? _____

   _____

   (b) How might this affect the chance of a mutation changing the final protein produced after gene expression?

   _____

   _____

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EXPLAIN: The steps in making a functional protein

10. Use the information in this activity to come up with **one possible** mRNA sequence and its corresponding double stranded DNA sequence for each of the following amino acid chains. The table of amino acid abbreviations is given right to help you.

(a) Histidine, isoleucine, threonine, proline, cysteine, alanine, serine, tyrosine

mRNA: _____

ds DNA:

_____

(b) Valine, leucine, valine, lysine, arginine, tryptophan, glycine, proline

mRNA: _____

ds DNA:

_____

(c) Serine, threonine, cysteine, valine, leucine, glutamic acid, proline, asparagine

mRNA: _____

ds DNA:

_____

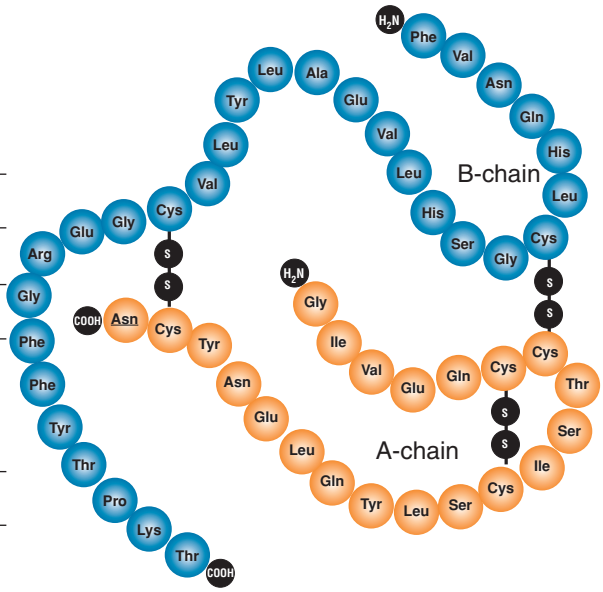
3-letter abbrev.	Amino acid	1-letter abbrev.
Gly	Glycine	G
Pro	Proline	P
Ala	Alanine	A
Val	Valine	V
Leu	Leucine	L
Ile	Isoleucine	I
Met	Methionine	M
Cys	Cysteine	C
Phe	Phenylalanine	F
Tyr	Tyrosine	Y
Trp	Tryptophan	W
His	Histidine	H
Lys	Lysine	K
Arg	Arginine	R
Gln	Glutamine	Q
Asn	Asparagine	N
Glu	Glutamic acid	E
Asp	Aspartic acid	D
Ser	Serine	S
Thr	Threonine	T

11. (a) What stage of the gene expression process is represented above?

_____

(b) What stage is not represented? _____

12. Insulin (pictured right) is a multi-unit protein. It is a hormone and has an important role in enabling cells to take up glucose.



(a) Does insulin show quaternary structure? Explain:

_____

_____

(b) How many amino acids are in the A-chain? _____

(c) How many amino acids are in the B-chain? _____

(d) What interactions can you see that stabilize the molecule's overall structure and where do they occur?

_____

_____

(e) Determine a mRNA sequence that will code for the A-chain of insulin (several sequences will give the right answer):

Gly - Ile - Val - Glu - Gln - Cys - Cys - Thr - Ser - Ile - Cys - Ser - Leu - Tyr - Gln - Leu - Glu - Asn - Tyr - Cys - Asn

_____

_____

(f) Now imagine a change (mutation) in the DNA sequence that causes a change in the sixth and seventh amino acids. What will be the effect of this change on the structure and function of insulin? Explain:

_____

_____

_____

_____

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