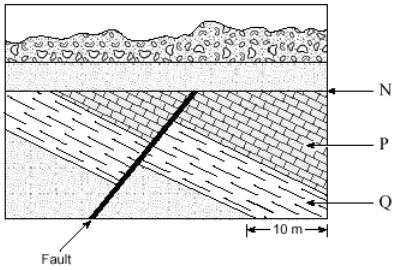
Answers to Section G: Time and the Fossil Record (Relative Dating)

Use the following sketch of a geological cross section to answer questions 1 to 3.



1. The **most important** principle used to determine the relative ages of layers **P** and **Q** is
   a) superposition.
   b) uniformitarianism.
   c) original horizontality.
   d) cross cutting relations.

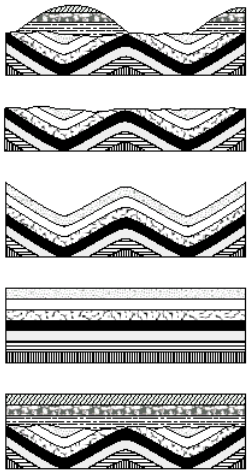
2. The break in the time sequence of layers at **N** is called a(n)
   a) normal fault.
   b) reverse fault.
   c) discontinuity.
   d) unconformity.

3. A correct sequence for some of the events in the cross section is
   a) deposit of P, erosion at N, tilting.
   b) erosion at N, deposit of P, tilting.
   c) tilting, deposit of P, erosion at N.
   d) deposit of P, tilting, erosion at N.

4. The statement "the granite is younger than the limestone" is an example of
   a) correlation.
   b) relative dating.
   c) absolute dating.
   d) uniformitarianism.

5. If a fault cuts across a sequence of beds, then the fault is younger than the beds. This is an example of the principle of
   a) cross-cutting relationships
   b) superposition
   c) original horizontality
   d) uncomformities

6. If a granite intrusion contains sandstone inclusions, the granite _____ the sandstone it contains
   a) is younger than
   b) is older than
   c) is the same age as
   d) cannot be compared to.

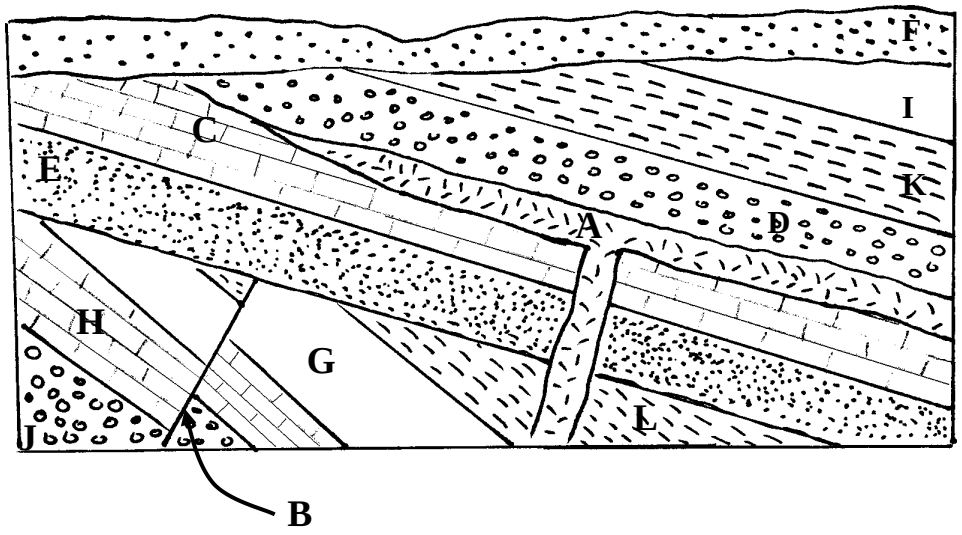


Use the following series of geological cross sections to answer question 7 and 8.

7. The geological cross sections above show all stages in the development of a section of the earth's crust. The correct sequence (from oldest to youngest) in the development of the crust is
   a) X, Y, V, W, Z
   b) Y, W, X, V, Z
   c) Y, X, W, Z, V
   d) X, W, Y, Z, V

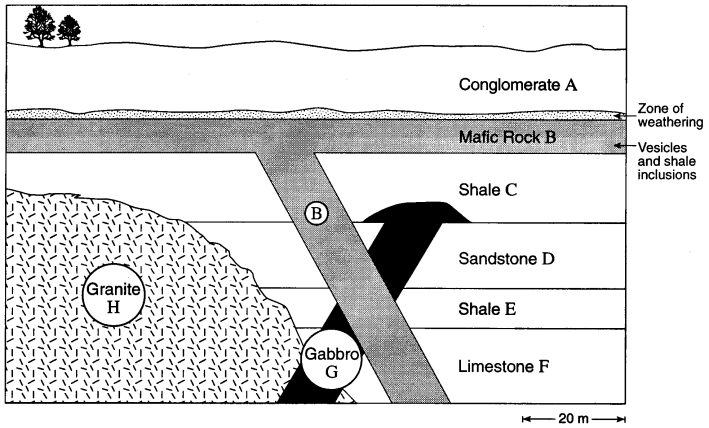
8. Explain your reasoning for question 7.
   Layers must be initially deposited horizontally (Y), then folded (X). Erosion occurs to flatten the surface (W), then new material can be deposited (Z), then further erosion of surface (V).

9. Use the following diagram and determine the relative age of each rock layer.



Youngest F
I
K
A
D
C
E
B
L
G
H
Oldest J

Use the following diagram to answer question 10.



10. The diagram shows a cross section of geological strata with igneous intrusions.
    a) Using appropriate geological principles, determine the geological order of the rock units. Organize your answer in the table below giving the letter of the rock unit. Order the rock units with the oldest at the bottom.

	Rock Unit
Youngest	*A*
	B
	G
	H
	C
	D
	E
Oldest	*F*

b) Describe how limestone **F** could have been formed.
The limestone is from marine organisms with shells. When they die the soft parts decay and the limestone remains.

c) Describe how gabbro **G** could have been formed.
The gabbro may have formed as a mafic dike intruded into the country rock but cooled very slowly, thus forming large crystals.

d) Is mafic rock **B** a sill or a lava flow? *Lava flow*

Give two pieces of evidence to support your answer.

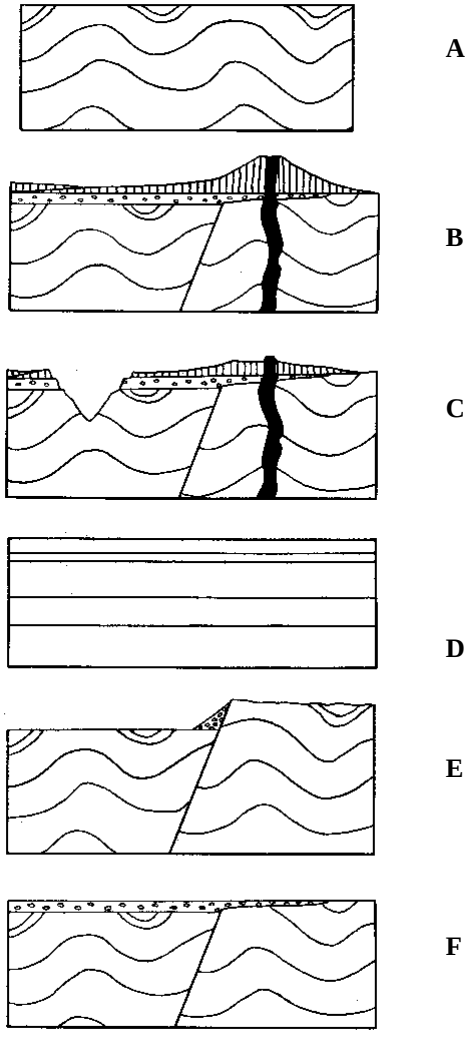
i. *There is a zone of weathering on top of the lava flow. When the lava was exposed at the earth's surface the top layer weathered. This would not happen if it were a sill.*

ii. *There are vesicles within the dike. This occurs when the gas within the lava can escape.*

Use the following series of geological cross sections to answer question 11.

11. The geological cross section to the right shows all stages in the development of a section of the Earth's crust. Using appropriate geological principles, determine the geological order of the events. Organize your answer in the table below giving the letter of the event. In addition, describe the event. Order the events with the oldest at the bottom.

	Event	Description
Youngest	***C***	*A river cuts through and erodes the land into a V shaped valley.*
	B	*Igneous intrusion in the form of a volcano*
	F	*Erosion of the land until it is flat.*
	E	*Faulting. A normal fault results as the land is pulled. An escarpment results as one side of the land rises against the other.*
	A	*Folding of the layers as the land is compressed and squeezed.*
Oldest	***D***	*Original horizontality. Layers are horizontal.*

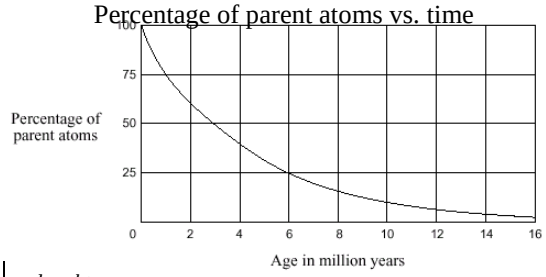


Answers for Section H: Time and the Fossil Record (Absolute Dating)

1. Explain how the half-lives of radioactive elements are used in estimating ages of materials

   Igneous rocks are the best class of rocks to use for radiometric dating. In a magma melt the concentration of uranium will be the same throughout the magma chamber. When the magma cools to become igneous rock, the concentration is no longer the same, because the uranium is decaying into its daughter product. The ratio of uranium to lead changes over time, and this ratio is used to determine the age of the rock.

Use the following decay curve graph to answer question 2 and 3.



2. A rock sample used for radiometric dating contained a ratio of 3 stable daughter atoms for 1 parent atom. The age of the sample is most likely
   a) 1 million years.
   b) 3 million years.
   c) 6 million years.
   d) 12 million years.

3. What is the half life of the sample?

   3 million years

   Half of the parent atoms are lost every half life, which is 3 million years

time (m.y.)	*parent (#of atoms)*	*daughter (#of atoms)*
0	*4*	*0*
3	*2*	*2*
6	*1*	*3*

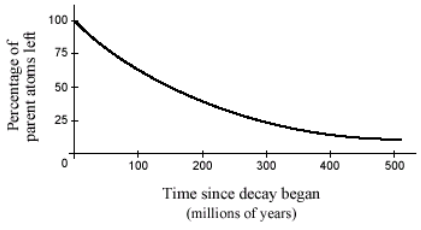
4. Radiometric dating of rock surrounding an igneous intrusion using potassium 40/argon 40 ($^{40}K - ^{40}Ar$) is unreliable because potassium 40
   a) has a long half-life.
   b) has no stable daughter product.
   c) has a gas as a daughter product.
   d) is in very small amounts in rock.

   Argon is a gas that can escape from the rock.

5. After a period of three half-lives, a sample of rock has 10 micro-grams of radioactive material left. How many micro-grams of radioactive material did it start with?
   a) 30 μg
   b) 40 μg
   c) 60 μg
   d) 80 μg

time (half lives)	*0*	*1*	*2*	*3*
amount (μg)	*80*	*40*	*20*	*10*

Use the following radioactive decay graph to answer questions 6 and 7.



6. The half-life of the element, for which the decay curve is graphed above, is
   a) 50 million years.
   b) 100 million years.
   c) 150 million years.
   d) 200 million years.

7. A rock sample is estimated to be approximately 3 000 million (3 billion) years old. The element, for which the decay curve is graphed above, would **not** be suitable for dating this rock sample because
   a) the half-life of the radioactive element would be too long.
   b) the radioactive element would not have decayed sufficiently.
   c) not enough of the daughter product would have accumulated.
   d) not enough of the parent element would be left to measure accurately.

8. The best group of rocks to choose for isotopic dating is
   a) igneous
   b) sedimentary
   c) metamorphic
   d) b and c

Igneous rocks are less likely to have lost daughter products.

9. Carbon 14 is used primarily to date which of the following?
   a) The oldest earth rocks.
   b) 200 to 65 million year old dinosaurs
   c) Geologically recent dead organic matter.
   d) The oldest fossils found on Earth

Carbon 14 has a very short half-life compared to the other radioisotopes used.

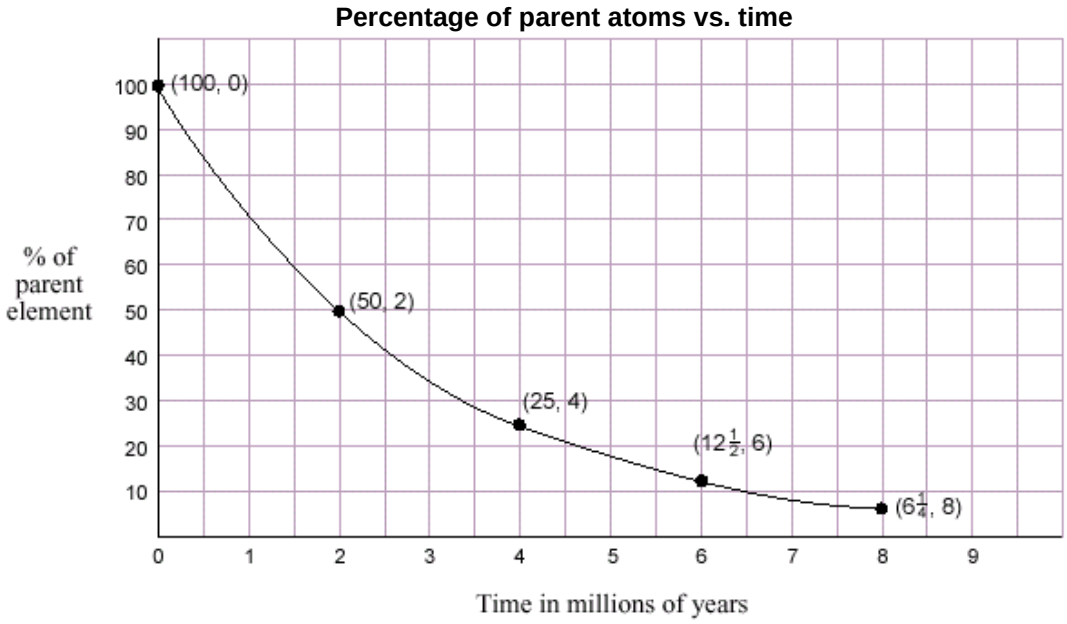
10. Of the four radiometric dating methods listed below, which would give the **most accurate** determination of the time when a shale layer was highly **metamorphose**d?
   a) carbon-14
   b) uranium-235 / lead-207
   c) potassium-40 / argon-40
   d) rubidium-87 / strontium-87

If a shale layer undergoes high metamorphism it will lose its accumulated argon. Under high metamorphism the isotopic clock can be reset to the time when metamorphism occurred.

Use the following diagram which represents the decay of carbon-14 atoms to answer question 11. The black area indicates the fraction of carbon-14 atoms remaining.

11. After 28 650 years, the fraction of carbon-14 atoms that would remain is
   a) 1/16
   b) 1/32
   c) 1/64
   d) 1/128

12. On the grid below, sketch a radioactive decay curve for an element with a half-life of 2 million years. Your sketch must contain:
   • Appropriately labeled vertical and horizontal axes.
   • Smooth and clearly drawn decay curve for four half-lives.



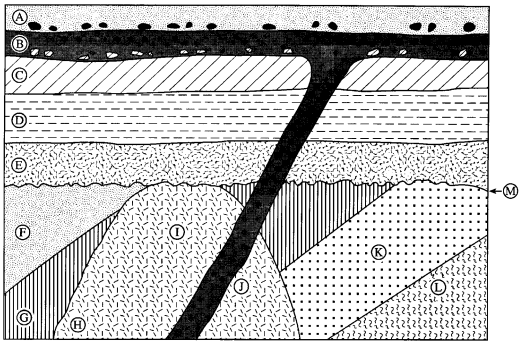
13. Describe **one** problem associated with radiometric dating of a heavily-weathered conglomerate.
The fragments that make up the conglomerate are older and not from the time of the formation of the rock. Weathering and erosion could bring in/take away parent and daughter material. (weathering adjusts parent/daughter ratio).

14. A Miocene (24 million to 5 million years ago) fossil of a clam is preserved as a cast. The age was determined using the rubidium–87/strontium–87 radiometric dating system technique. Give **two** reasons why the estimated radiometric age of the original organism might be inaccurate. The half-life of rubidium–87/strontium–87 is 49 billion years.

Reason 1: *Because of long half-life, there may not be enough daughter product to provide an accurate date.*

Reason 2: *Because it is a cast, one cannot date the original organism. Cast material may contain insufficient rubidium–87 to give an accurate date.*

Use the following cross-section diagram of the geology of a region to answer question 15.



15. The cross-section above shows many events that have occurred in a region over a vast period of time.
    a) Layer A is younger than layer B. Give two pieces of evidence that would indicate that this is so.
    Evidence #1: Using the principle of Superposition. The layer is on top, therefore it must be younger.
    Evidence #2: Layer A has included fragments from the lava flow below. The included fragments must be older than the layer. It does not make any sense for layer A to leave holes that are later filled in with a non-evaporate rock.

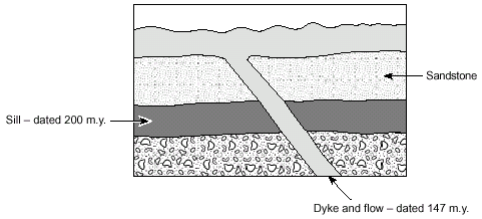
    b) What feature does the letter M indicate? Describe two processes that helped to form this feature.
    Feature M is an unconformity. It is formed when there is a break in the deposition of rock. The first process to form an unconformity is erosion. The second process at a much later time is new rock is laid down on top.

    c) The potassium – argon method is used to obtain radiometric dates from unweathered igneous rock at locations H and J. These dates are not the same. Explain how they are different and why.
    The date obtained at J is younger than at H due to contact metamorphism resetting the clock.

    d) The time taken to deposit layers C, D, and E was estimated by multiplying the modern sedimentation rate of 1 mm / year by the thickness of the beds. Why is the time estimate likely to be incorrect?
    Sedimentation rates vary and conditions in the past may have been different.
    Different rock types deposit at different rates.
    There may have been erosion between depositions.
    Compression and compaction thins layers.

Answers for Section I: Time and the Fossil Record (Geologic Time Scale)

Use the following diagram to answer question 1.



1. The period during which the sandstone layer would have been deposited is **most likely** the
   a) Cretaceous.
   b) Jurassic.
   c) Triassic.
   d) Permian.

   The age of the sandstone must between the sill and the dike.

2. The era during which all of the following events occurred is the

   a) Cenozoic
   b) Mesozoic.
   c) Paleozoic
   d) Precambrian.

3. Which of the following lists major events in Earth's history in the correct order?

a)	b)	c)	d)
Youngest	**Youngest**	**Youngest**	**Youngest**
amphibians dominated	invertebrates dominated	mammals dominated	amphibians dominated
first land plants	mammals dominated	amphibians dominated	invertebrates dominated
mammals dominated	amphibians dominated	first land plants	mammals dominated
invertebrates dominated	first land plants	invertebrates dominated	first land plants
Oldest		**Oldest**	**Oldest**

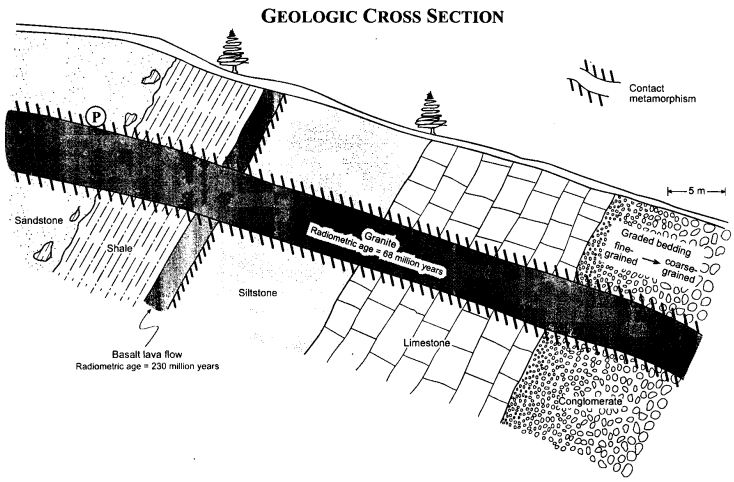
4. The first land plants were found on the Earth during which geologic period?
   a) Cambrian
   b) Silurian
   c) Permian
   d) Tertiary

5. Which of the following groups of animals were the first to appear on the Earth?
   a) Amphibians
   b) Dinosaurs
   c) Birds
   d) Humans

6. Primates evolved during which period?
   a) Devonian
   b) Triassic
   c) Tertiary
   d) Cambrian

Use the geologic cross section below to answer questions 7 and 8.

7. From the evidence shown in the cross section, which of the following could **not** be used to determine the relative ages of the sandstone and shale layers?
   a) correlation
   b) superposition
   c) included fragments
   d) original horizontality



8. In which geological era was the shale **likely** deposited?
   a) Cenozoic
   b) Mesozoic
   c) Paleozoic
   d) Precambrian

9. The era that means "middle life" is the
   a) Paleozoic
   b) Mesozoic
   c) Cenozoic
   d) Precambrian

10. Which kind of animal life was dominant during the Paleozoic era?
    a) Fishes
    b) Dinosaurs
    c) Birds
    d) Mammals

11. The era mammals came to dominate is the
    a) Paleozoic
    b) Mesozoic
    c) Cenozoic
    d) Neoproterozoic

Answers to Section J: Time and the Fossil Record (The Fossil Record)

1. Identify the conditions necessary for the preservation of fossils
   After the organism dies it undergoes a quick burial. This prevents the organism from decomposing at a fast rate, or being attacked by scavengers. Once buried, sediment compacts the fossil. A mold may form and can be replaced by minerals. Hard parts may be preserved. With time, lithification of the fossil and surrounding rock forms sedimentary rocks with preserved organic remains.

2. Differentiate between fossils and trace fossils
   Fossils are the remains of dead animal and plants, whereas trace fossils are the traces left behind to indicate that living organisms had once lived there, such as tracks, trails, burrows and borings etc.

3. Describe the processes of original preservation, carbonization, replacement, permineralization, and mould and cast formations

Original preservation	*Remains of the original body parts such as bone and teeth.*
Carbonization	*Soft tissue is preserved as thin films of carbon. When compressed, most of the oxygen, hydrogen and nitrogen are lost and the carbon remains behind as a black silhouette.*

Replacement	*The dead animal or plant has been replaced slowly by minerals.*
Permineralization	*When cavities and holes within the organism are filled in with mineral. The original composition remains but the organism is actually harder and more durable.*
Mold	*A plant or animal that has left an impression in the sediment and this has lithified.*
Cast	*If the mold is filled with material that lithifies.*

4. Analyse the characteristics of a fossil that would make a good index (or guide) fossil
   A good guide fossil is one that is short lived, a wide geographic range, abundant and easily identifiable. This greatly enables correlation of rock strata to determine the age of any rock exposure and outcrop.

5. Draw diagrams to illustrate the following evolutionary principles:
   - Punctuated equilibrium

   - Adaptive radiation

6. A dinosaur bone that has had its pores filled by calcium carbonate indicates the process of
   a) replacement
   b) carbonation
   c) permineralization
   d) original preservation

7. Which of the following sedimentary rocks would most likely contain traces of the soft parts of an animal?
   a) Marine shale
   b) Reef limestone
   c) Desert sandstone
   d) Shoreline sandstone

8. Which of the following would be considered a trace fossil?
   a) Shark tooth
   b) Mammoth tusk
   c) Sea urchin spine
   d) Dinosaur footprint

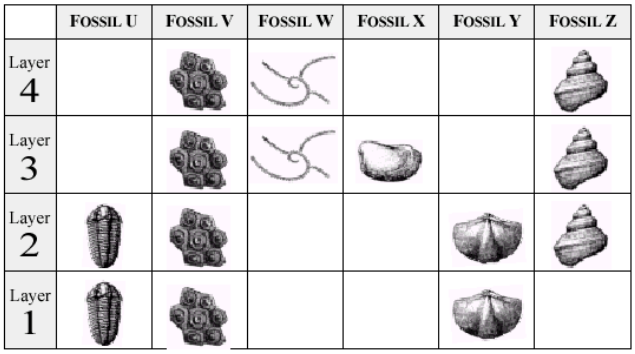
9. Charles Darwin proposed that organisms evolved through a process of natural selection. Natural selection means that a species may change over time by
   a) the best adapted organisms surviving.
   b) organisms being able to select their mates.
   c) groups of organisms selecting their environment.
   d) individual organisms changing to suit their environment.

10. The fossil record supports the principle of evolution by demonstrating that plant and animal species
    a) change over geologic time
    b) are the same all over the world
    c) remain the same until extinction
    d) have existed for a few thousand years

11. A plant leaf will most likely be fossilized through
    a) replacement
    b) carbonization
    c) mold and cast
    d) permineralization

12. A fossil that is useful for correlation is
    a) localized and with a long geological time range
    b) localized and with a short geological time range
    c) widespread and with a long geological time range
    d) widespread and with a short geologic time range

Use the following table to answer questions 13 to 16.
The table shows four layers of Silurian sedimentary rock found in a cliff section.



13. The best index (guide) fossil for layer 3 is
    a) V
    b) W
    c) X
    d) Z

    It is the only fossil that is found in only layer 3. Thus it has a short time-span

14. A geologist working at another cliff section has discovered a layer of similar sedimentary rock that contains fossils Y and Z. The newly-discovered layer **best** correlates with layer
    a) 4
    b) 3
    c) 2
    d) 1

15. In which of the following sedimentary environments were layers 1 to 4 **most likely** deposited?
    a) desert
    b) river bed
    c) shallow marine
    d) freshwater lake

16. What is the common name for fossil U?
    a) Trilobite
    b) Insect
    c) Gastropod
    d) Graptolite

17. A geologist has found the following assemblage of fossils in a shale layer: Graptolites, trilobites and brachiopods. The **most likely** age of the shale layer is
    a) Permian.
    b) Devonian.
    c) Ordovician.
    d) Precambrian.

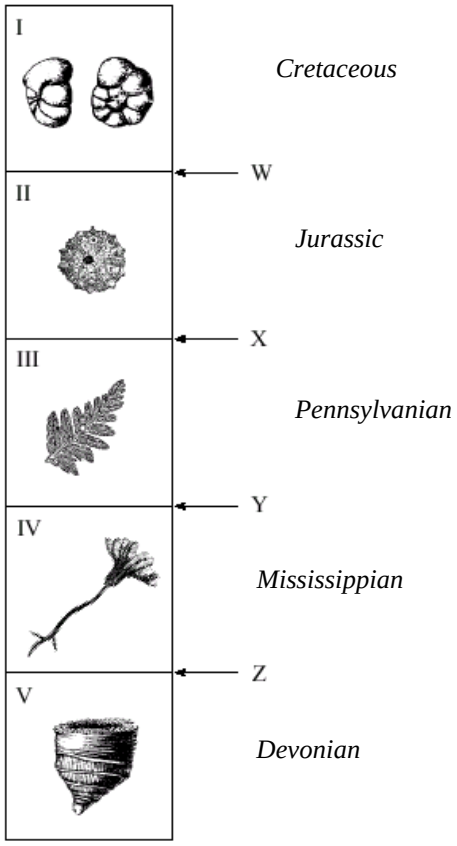
    Graptolites had a short time span, confined to the Ordovician

18. Which of the following life forms must have evolved before the others?
    a) coral
    b) algae
    c) trilobites
    d) brachiopods

Use the diagram to the right to answer questions 19 to 23.

19. An unconformity exists at
    a) W
    b) X
    c) Y
    d) Z

There is a large gap in the geologic record at X



20. The fossil in strata III of the column is **most typically** preserved by
    a) replacement.
    b) carbonization.
    c) mold and cast.
    d) permineralization.

21. The fossils in the column that were preserved from organisms that lived attached to the sea floor are shown in strata
    a) I and II
    b) I and IV
    c) II and III
    d) IV and V

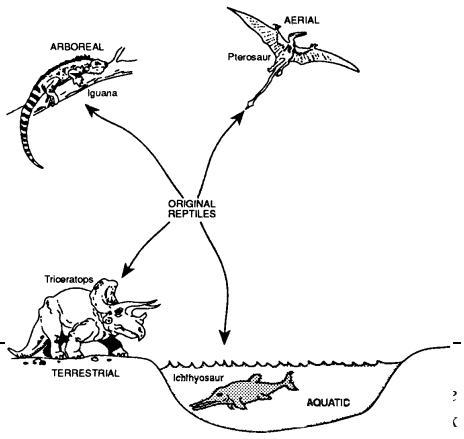
22. The fossil in strata V was formed from a(n)
    a) plant (ginkgo).
    b) mollusk (clam).
    c) coelenterate (coral).
    d) arthropod (eurypterid).

23. The fossil found in strata IV is a
    a) enchinoid
    b) crinoid
    c) coral
    d) plant leaf

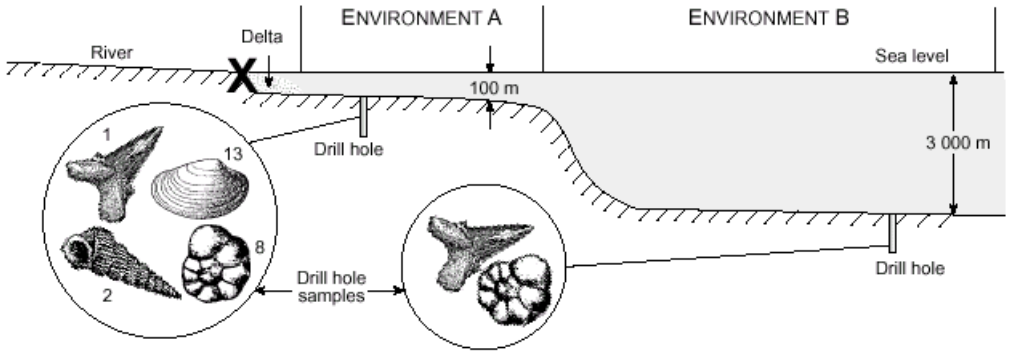
24. The fossil record changes dramatically due to mass extinctions that ended the Paleozoic and Mesozoic eras. These changes shown in the fossil record are known as
    a) punctuated equilibrium
    b) natural selection
    c) adaptive radiation
    d) uniformitarianism

Use the following diagram to answer question number 25.
The diagram shows how an original primitive reptile has, over millions of years, evolved into different types of Mesozoic reptiles, each living in a different environment.

25. Changes of the types shown in the diagram are known as
    a) convergence
    b) natural selection
    c) adaptive radiation
    d) punctuated equilibrium



Use the following diagram to answer question 26.



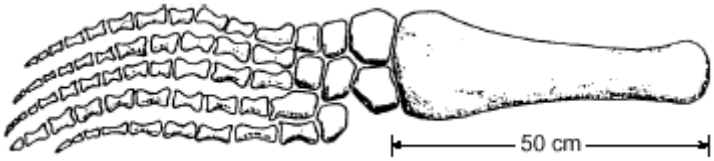
26. The sketch shows a profile of a river delta, continental shelf and abyssal plain, at the edge of a continent. Drill hole samples taken in environment A contain large quantities of fossils 1, 2, 8 and 13. Samples from drill holes in environment B contain large quantities of fossils 1 and 8.
    a) Give **one** reason why fossils 1 and 8 are found in both environments.
    Fossils 1 and 8, in both environments, are from free-swimming organisms and could have been preserved anywhere.

    b) Place an **X** on the profile where a ginkgo leaf (fossil 18) would **most likely** be preserved as a fossil. Explain why you have chosen that location.
    See diagram. X should be in the river or the delta, not a distance out on the shelf and certainly not on the abyssal plain.
    - *The leaf is delicate and would not survive much transport.*
    - *The leaf would probably rot quickly in the ocean.*
    - *The leaf is from a land plant and could not be transported further than the delta.*
    - *Fine sediments deposited in the delta would allow good preservation.*

    c) Give **two** conditions that favour the fossilization of marine organisms.
    - *Rapid burial.*
    - *Fine sediments.*
    - *Hard parts such as shell.*
    - *Large numbers of organisms.*

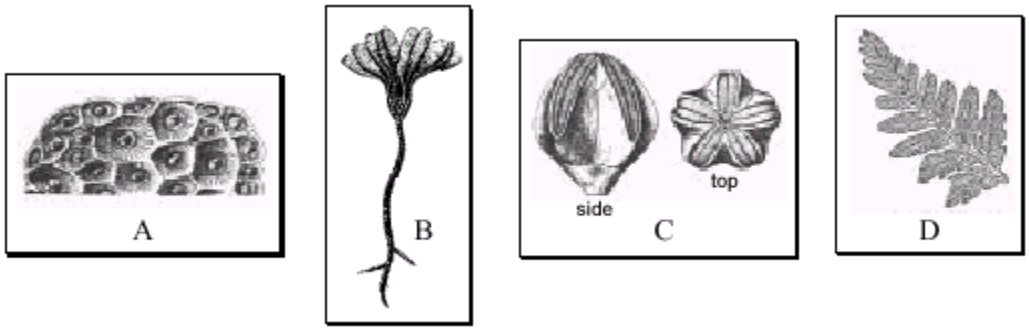
Use the following diagram of a fossilized forelimb to answer question 27.

27. Making reference to the fossil to the right, describe how the Principle of Uniformitarianism is used to discover the lifestyle of the organism.



On can assume that the fossil's lifestyle was similar to modern animals because the bone structure is similar to modern animals. The fossil looks like a flipper from a seal or similar animal because the finger-like bones do not look like grasping fingers, they look more paddle-like. It looks like a flipper so may be used for swimming.

28. The following four fossils are in a collection.



a) Which fossil seems out of place with the others?
Fossil D.

b) Give **two** reasons for your conclusion in a) above.
- *Fossil D is non-marine, and therefore it is unlikely to be located with ocean/marine fossils.*
- *Fossil D was not alive at the time of the other fossils, and not alive at the time of deposition.*
- *Fossil D is a plant.*
- *Fossil D probably carbonized while others did not.*

c) What is the maximum time-span, in millions of years, represented by this fossil collection?
74 million years. or 360 – 286 million years ago "Carboniferous" period

31. The Burgess Shale of Yoho National Park, B.C. is well known for the fine detail and the preservation of traces of soft parts in its fossils. List two factors that would lead to the occurrence of this type of preservation and for each explain how the factor promotes fossilization.

Factor 1*: Rapid burial prevents scavenging.*

Factor 2*: Exclusion of oxygen prevents decomposition.*

Factor 3: *The fine sediment because this allows for preservation of fine details.*