16) **ARTIFICIAL SELECTION** – The process by which humans breed other animals and plants for particular traits (aka selective breeding).
15) a) HEREDITY: Passing of traits from parent to offspring.
   b) GENETICS: The study of how traits are inherited.
17) EXTINCTION: The death and disappearance of a species. The fossil record shows that extinctions have been frequent in the history of life. Mass extinctions refer to the loss of a large number of species in a relatively short period of time. Episodes of mass extinction occur at times of rapid global environmental change; five such events are known from the fossil record of the past 600 million years. Human activity is causing extinctions on a scale comparable to the mass extinctions in the fossil record.
18) **Gregor Mendel** – Born 1822. The founder of modern genetics. Mendel’s experiments uncovered two principals in the science of heredity:

- Two factors determine traits
- Factors can be dominant or recessive
Arthropods: A success story

Almost any way you look at them, arthropods are successful:

- They have been around for more than 500 million years and are still evolving.
- They live on Earth in overwhelming numbers.
- They have come in all shapes and sizes.
- They have evolved to fill a variety of ecological niches — from tiny internal parasite to giant bird-eating predator.

But what is it about arthropods that has made them so successful? Let's begin our investigation by reviewing what an arthropod is.

Ecological niches
What is an arthropod?

We're going to take a closer look at this amazing group of animals called arthropods. You are familiar with a wide variety of arthropods from seeing them in your daily life. Have you thought about what they all have in common?

"I simply cannot eat with that disgusting arthropod there!!!"

Arthropods are a lot more than just delicious feasts and disgusting pests. Before we go too far, we need to figure out exactly what an arthropod is.
1. Bilateral symmetry
1. Bilateral symmetry
2. Segmented body
1. Bilateral symmetry
2. Segmented body
3. Hard exoskeleton
1. Bilateral symmetry
2. Segmented body
3. Hard exoskeleton
4. Jointed legs
1. Bilateral symmetry
2. Segmented body
3. Hard exoskeleton
4. Jointed legs
5. Many pairs of limbs
<table>
<thead>
<tr>
<th></th>
<th>bilateral symmetry</th>
<th>segmented body</th>
<th>hard exoskeleton</th>
<th>jointed legs</th>
<th>many pairs of legs</th>
</tr>
</thead>
<tbody>
<tr>
<td>scorpion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>moth</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>onychophoran</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>mouse</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td>millipede</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>jelly</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

✓ = has characteristic  
✗ = does not have characteristic

**Based on these data, check all of the following animals that are arthropods.**

- ✔ scorpion
- ✔ moth
- ✔ millipede
- □ onychophoran
- □ mouse
- □ jelly
Arthropods can be divided into five major groups, each with its own distinctive characteristics.

This tree reflects recent data, but the relationships among major groups of arthropods are still being debated.
Question #1

Which of the following is probably NOT a characteristic of the arthropod common ancestor?

- A. Large claws
- B. Jointed legs
- C. Exoskeleton
- D. Bilateral symmetry
Question #1

Which of the following is probably NOT a characteristic of the arthropod common ancestor?

- [ ] A. Large claws
- [ ] B. Jointed legs
- [ ] C. Exoskeleton
- [ ] D. Bilateral symmetry
Question #2

On this evolutionary tree, which point represents the common ancestor of Species 1, 2, and 3?

☐ point A
☐ point B
☐ point C
☐ D. None of the above
On this evolutionary tree, which point represents the common ancestor of Species 1, 2, and 3?

- point A
- point B
- point C
- D. None of the above
All of the groups shown here branched off during the Cambrian.
Question #1

Which of the following is a true statement about life during the Cambrian?

- A. Many major animal lineages got their starts during the Cambrian.
- B. "Complex" animals (like chordates, echinoderms, etc.) did not evolve until long after the Cambrian.
- C. All the animals alive during the Cambrian left modern descendents.
- D. All of the above are true.

Question #2

Studying fossils helps scientists learn about evolution and the history of life. Which of the following are true statements about fossils?

- A. Fossils often preserve the "hard parts" (e.g., exoskeletons, bones) of organisms.
- B. Fossils occasionally preserve the "soft parts", such as the guts or muscles, of organisms.
- C. An organism can sometimes be identified through the characters preserved in its fossils.
- D. All of the above are true.
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- D. All of the above are true.
Question #2

On this evolutionary tree, the ancestor of all chordates is identified. Which point on the tree represents a non-chordate that is closely related to the ancestral chordate?

- point A
- point B
- point C
- point D
Question #2

On this evolutionary tree, the ancestor of all chordates is identified. Which point on the tree represents a non-chordate that is closely related to the ancestral chordate?

- [ ] point A
- [x] point B
- [ ] point C
- [ ] point D
Question #1

Which of the following is a true statement about evolution?

- [ ] A. Evolution responds to organisms’ needs and gives them the perfect traits for survival.
- [ ] B. Evolution can only work with the variation that is present in a lineage.
- [ ] C. Evolution cannot shape an existing trait to serve a new function.
- [ ] D. None of the statements above are true.
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D. None of the statements above are true.
The Cambrian explosion
From about 570 to 530 million years ago, an evolutionary burst of life forms occurred, often referred to as the "Cambrian Explosion." This marks an important point in the history of life on earth, as most of the major lineages of animals got their starts during the Cambrian Period and have been evolving ever since. If we wound the clock back a little more than half a billion years to the Cambrian, we would find that life then was different from life today:

• All life was aquatic.
• Most life was relatively small.
• Many animals had unusual body layouts.

Many Cambrian animals seem bizarre at first glance, but are actually members of groups that are still around today — such as the arthropods.
Is Sanctacaris an Arthropod?

Click the magnifying glasses to look closer:

- Fossil
- Reconstruction

- Many pairs of jointed appendages
- This armor plating looks like exoskeleton
- Body segmentation
Is Opabinia an Arthropod?

Five strange, mushroom-shaped eyes

Weird proboscis

No jointed appendages

Click the magnifying glasses to look closer:

fossil

reconstruction

Does it look like Opabinia inherited all of the characters of an arthropod?

<table>
<thead>
<tr>
<th>arthropod characters</th>
<th>bilateral symmetry</th>
<th>segmented body</th>
<th>hard exoskeleton</th>
<th>jointed legs</th>
<th>many pairs of legs</th>
</tr>
</thead>
</table>
Is Hallucigenia an Arthropod?

Yes, it looks like Hallucigenia inherited all of the characters of an arthropod.

- No jointed legs
- No signs of exoskeleton
- No body segmentation
Is Naraola an Arthropod?

Does it look like *Naraola* inherited all of the characters of an arthropod?

**Arthropod characters**
- Bilateral symmetry
- Segmented body
- Hard exoskeleton
- Jointed legs
- Many pairs of legs

### Naraola

- Many pairs of jointed legs
- Exoskeleton
- Body segmentation (not visible from above)
1. Name at least four traits that are shared by all arthropods.

2. Which statement about fossil arthropods is the most accurate:
   a. Fossils of arthropods have never been found.
   b. Fossils of arthropods have been found that are more than 500 million years old.
   c. Fossils of arthropods are only one million years old or younger
   d. Fossil arthropods do not resemble arthropods of today.
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1) Bilateral symmetry,
   Segmented body
   Hard exoskeleton
   Jointed limbs
   Many legs
3. Examine the following diagram and the statements that follow.

**Dorsal view**  
**Ventral view**

Statements:
1. This animal has bilateral symmetry.
2. This animal has many legs.
3. This animal has an exoskeleton.
4. This animal is an arthropod.

Which of the statements are accurate?
- a. 1 and 3.
- b. 2 and 4.
- c. 3 and 4.
- d. 1, 2, 3, and 4.
3. Examine the following diagram and the statements that follow.

Statements:
1. This animal has bilateral symmetry.
2. This animal has many legs.
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4. This animal is an arthropod.

Which of the statements are accurate?

- a. 1 and 3.
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4. Which of the following is a true statement about evolution?
   a. Evolution responds to organisms’ needs and gives them the perfect traits for survival.
   b. Evolution can only work with the variation that is present in a lineage.
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   d. None of the statements above are true.

5. What is the definition of an evolutionary constraint?
   a. a key innovation that allows a lineage to diversify into new niches
   b. a mass extinction that wipes out more than 50% of the species alive, changing the outcome of evolution
   c. an aspect of a lineage’s inherited traits that prevents it from reaching a particular evolutionary outcome
   d. when a species is forced to live in a new environment with different selective pressures
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The four requirements of artificial selection/selective breeding = VIST

**Artificial Selection**

*Artificial selection* happens when people select individuals to mate that have features they hope the offspring will inherit. This is also called selective breeding.

Here is what is required:

**V = Variation**: The differences that exist among individuals. Many of these differences are determined by their genes.
Artificial Selection

*Artificial selection* happens when people select individuals to mate that have features they hope the offspring will inherit. This is also called selective breeding.

Here is what is required:

\[ I = \text{Inheritance:} \text{ Genetic traits are inherited from parents and are passed on to offspring.} \]
Artificial Selection

*Artificial selection* happens when people select individuals to mate that have features they hope the offspring will inherit. This is also called selective breeding.

Here is what is required:

**S = Selection:** In artificial selection, individuals with favorable traits are bred in the hopes that those traits will be passed on to the next generation.
The four requirements of artificial selection/selective breeding = VIST

**Artificial Selection**

*Artificial selection* happens when people select individuals to mate that have features they hope the offspring will inherit. This is also called selective breeding.

Here is what is required:

**T = Time:** Getting the desirable features does not usually happen in just one try. Often, you have to breed many generations to get a new breed established.
In your notebook - write a short summary paragraph about the process of artificial selection using the four VIST words:
Variation
Inheritance
Selection
Time
“You have been contacted by several farmers that want dogs that would be useful for controlling small rodents such as mice that tend to eat their stored crops in their granaries. These rodents often hide among the stacks of grain, invisible to those trying to find them. The granaries are often kept at very warm temperatures.”

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**Ownership Card**

**Breeders’ names:** ___________________________________________________________

**Date:** __________________

**Assignment:** “You are a dog breeder. You have been contacted by a scientist who wants dogs that could be used to see and retrieve waterfowl (ducks and geese) from lakes in the area so the birds can be tagged and re-released. The birds are very skittish (scare easily) and must be retrieved unharmed and with a minimum amount of stress.”

<table>
<thead>
<tr>
<th>Physical feature</th>
<th>above average</th>
<th>average</th>
<th>below average</th>
<th>any</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smell:</td>
<td>above average</td>
<td>average</td>
<td>below average</td>
<td>any</td>
</tr>
<tr>
<td>Sight:</td>
<td>above average</td>
<td>average</td>
<td>below average</td>
<td>any</td>
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<tr>
<td>Hearing:</td>
<td>above average</td>
<td>average</td>
<td>below average</td>
<td>any</td>
</tr>
<tr>
<td>Speed:</td>
<td>above average</td>
<td>average</td>
<td>below average</td>
<td>any</td>
</tr>
<tr>
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Use blank paper to draw one of the resulting puppies (draw how it would look as an adult)

When finished: Are the puppies identical?

Group drawings according to parents.

Variation will depend on which parents were chosen and traits randomly that were selected.
A Dog For Retrieving Waterfowl
Dog type 1 X Dog type 2

Our mixed breed has the following physical and behavioral features that will help it succeed in retrieving waterfowl: list one, list another, and another, keep going, ...
Peppered Moth

Early English industrial town, Staffordshire.
Survival of the fittest

Early giraffes had short necks

their offspring had longer necks

modern giraffes have longest necks
Coyote ADAPTATIONS:

- Long legs for running
- Keen sense of smell
- Fur to protect from elements
- Eat almost anything
- Travel in packs
- Dig dens to protect young
- Hunt day and night
The offspring of organisms often grow up to look like one or both of their parents. This is because offspring inherit information from their parents that directs their development.

The inherited information is located in the **Nucleus** of every cell in the organism. The information is coded in the huge **DNA** molecule. The huge molecules are coiled into compact hot dog–shaped structures called **Chromosomes**. **Chromosomes** are always present in almost identical pairs. Locations on chromosomes that affect features of organisms are called **Genes**. A gene is composed of **Paired alleles**.

An organism’s unique combination of genes is its **Genotype**. The traits produced by an organism’s genes is its **Phenotype**. Alleles that have more influence in determining traits are **Dominant** alleles. Alleles that have less influence in determining traits are **Recessive** alleles.
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The inherited information is located in the __________ of every cell in the organism. The information is coded in the huge _____ molecule. The huge molecules are coiled into compact hot dog–shaped structures called __________. _______________ are always present in almost identical pairs. Locations on chromosomes that affect features of organisms are called _____________. A gene is composed of _______________. An organism’s unique combination of genes is its ____________. The traits produced by an organism’s genes is its _____________. Alleles that have more influence in determining traits are __________ alleles. Alleles that have less influence in determining traits are ______________ alleles.
Chromosome
Gene
Nucleus
Allele
A clade is a grouping that includes a common ancestor and all the descendants (living and extinct) of that ancestor. Using a phylogeny, it is easy to tell if a group of lineages forms a clade. Imagine clipping a single branch off the phylogeny — all of the organisms on that pruned branch make up a clade.
Clades are nested within one another — they form a nested hierarchy. A clade may include many thousands of species or just a few. Some examples of clades at different levels are marked on the phylogenies below. Notice how clades are nested within larger clades.

In this highly simplified phylogeny, a speciation event occurred resulting in two lineages. One led to the mosses of today; the other led to the fern, pine, and rose. Since that speciation event, both lineages have had an equal amount of time to evolve. So, although mosses branch off early on the tree of life and share many features with the ancestor of all land plants, living moss species are not ancestral to other land plants. Nor are they more primitive. Mosses are the cousins of other land plants.
For any speciation event on a phylogeny, the choice of which lineage goes to the right and which goes to the left is arbitrary. The following phylogenies are equivalent:

MOSS  FERN  PINE  ROSE  FERN  PINE  ROSE  MOSS

\[ \text{Diagram of phylogenies} \]

**Misconceptions about humans**

The points described above cause the most problems when it comes to human evolution. The phylogeny of living species most closely related to us looks like this:

\[ \text{Diagram of phylogeny} \]

It is important to remember that:

1. Humans did not evolve from chimpanzees. Humans and chimpanzees are evolutionary cousins and share a recent common ancestor that was neither chimpanzee nor human.

2. Humans are not "higher" or "more evolved" than other living lineages. Since our lineages split, humans and chimpanzees have each evolved traits unique to their own lineages.
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