Oakland CUSD #5

BSAA

April 20-24, 2020

Jeff Coon

Week of April 20-24, 2020

All of these assignments are on google classroom. You must pick one of the 3 listed and complete by next Monday April 20 for credit. If you would like to use google docs to complete the work that would be most efficient, just remember to start a new copy with your own work please. Paper copies can be returned to the school.

Class	Choice 1	Choice 2	Choice 3 (Enrichment)
Ag Science	Common Breeding	Starting an sae	FFA Official dress
Ag Business Mang	MaInvestments	Life Insurance	Business Plan
BSAA	Advanced DNA	Animal Repro Systems	Domestic Animals
Landscape Design	Environment	Landscape tools	Landscape IPM
Intro To Ag	FFA Creed	Parly pro	World food supply
Ag Mech.	Profile Leveling	Power tools	Precision Ag

Choice 1

Mr. Coon BSAA Advanced DNA April 20 - 24

Matching Instructions: Match the word with the correct definition.

a. Cloning f. Ligation b. DNA profiling g. plasmid c. gel electrophoresis h. marker gene d. DNA cloning i. restriction enzyme e. genetically modified organism j. Vector

_______1. the process of making copies of specific DNA or segments of DNA (such as a gene).

_______2. a DNA molecule that is used as a vehicle to transfer DNA from one organism into another

_______3. a circular, double-stranded DNA found in the cytoplasm of bacteria that is capable of replicating independently of chromosomal DNA

_______4. the analysis of DNA for a specific gene

_______5. the production of a genetically identical biological entity

_______6. the process of joining two nucleic acid fragments through the action of an enzyme

_______7. a laboratory technique used to separate mixtures of DNA, RNA, and proteins according to their molecular size

_______8. an enzyme that can slice DNA molecules at, or near, a specific sequence of bases

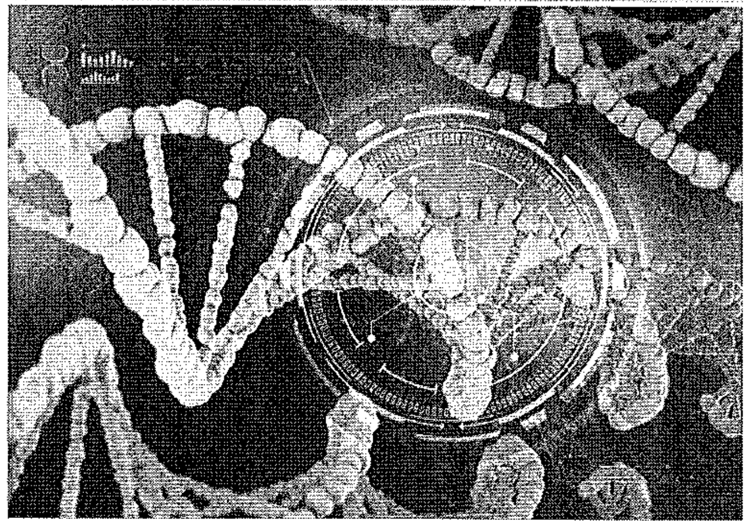
_______9. a gene that can be identified and tracked, can serve as a flag for the target gene, and can let researchers know if the transfection was successful

______10. any organism that has been genetically modified through mutation by natural or artificial means

April 20-24 Coon Choice 1

E-UNIT B1–4 Recombinant DNA Technology

For thousands of years, humans have bred animals, and in doing so, have slowly changed their genetic makeup. Today, humans have the technological tools to make genetic changes in animals in a short amount of time. How they go about recombining DNA is the subject of this e-unit.



Objective:

Describe how recombinant DNA techniques are applied to animals.

Key Terms:

- biotechnology
- blastocyst
- cloning
- DNA cloning
- DNA profiling
- gel electrophoresis
- genetic engineering (GE)
- genetically modified organism (GMO)
- ligation
- marker gene
- microinjection
- plasmid
- recombinant DNA (rDNA)
- recombinant DNA technology
- reporter gene
- reproductive cloning
- restriction enzyme
- screening
- somatic cell
- transformation
- transfection
- target gene
- transgene
- transgenic organism
- vector

Biotechnology

Since humans first began practicing agriculture, they relied on artificial selection to domesticate animals and to create breeds that better provide for human needs. However, selective breeding does have some disadvantages. It is time consuming, because it takes multiple generations of animals to obtain the desired results. Since it is a process of trial and error, offspring do not always show an improvement over their parents. Another disadvantage is that the gene pool (all the genes within a population of interbreeding animals) is limited to the species being bred. Animals can only be crossed with their related species (e.g., cattle with cattle and pigs with pigs).

Advances in biotechnology have changed agriculture in profound ways. **Biotechnology** is any application that uses living systems or organisms to make or modify technological products or processes for a specific use. Biotechnology comes from the words "biology" (the study of living organisms) and "technology" (the use of tools and crafts to adapt or control one's environment). Genetic engineering is at the forefront of biotechnologies.

GENETIC ENGINEERING AND PROCESSES

Since the 1970s, practices in modern biotechnology have centered around DNA. Instead of working with whole organisms, scientists work at the molecular level (cells and target genes) for the research and development of new products. **Genetic engineering (GE)** is the artificial manipulation of genetic material, which largely involves the creation of recombinant DNA.

The goals for the genetic engineering of animals are similar to the goals of selective breeding—a better efficiency for growth, a superior yield, higher milk production, a robust or more appealing appearance, a resistance to disease, and more nutritious, safer meat. The biggest difference lies in GE's ability to achieve goals in significantly less time than through selective breeding.

GMOs and Transgenic Organisms

Two organisms associated with genetic engineering are the genetically modified organism and the transgenic organism. Many sources mistakenly use the terms interchangeably. A **genetically modified organism (GMO)** is any organism that has been genetically modified through mutation by natural or artificial means. A **transgenic organism** is any organism whose DNA has been altered by having a foreign gene artificially inserted to express a new, desirable trait. The specific gene inserted into a transgenic organism from another organism is called a **transgene**. So, technically speaking, it is wrong to equate a genetically modified organism with a transgenic organism.

Recombinant DNA

Recombinant DNA technology is any technique used in genetic engineering that involves the identification, isolation, and insertion of a gene into a vector, such as a plasmid, and then introducing the DNA into a host cell. **Recombinant DNA (rDNA)** is a genetically-engineered DNA molecule formed from spliced fragments of DNA—from a different cell within the organism or from another organism altogether.

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Performing Genetic Engineering

In the laboratory, gene sequences can be combined and inserted into an organism, resulting in a transgenic organism. There are several steps in this process of genetic engineering—from locating the desired trait to breeding it into a population.

Identify and Locate a Desired Trait Gene

A desired trait must first be identified in an organism that possesses the trait. The next step is to locate the gene in the organism's chromosomes. Locating genes in chromosomes has become easier as biotechnologists have mapped the genomes of many organisms. A genome is the complete set of the genetic material from an organism.

DNA profiling is the analysis of DNA for a specific gene. This technology has enabled breeders to be very specific in which animals (or plants) are chosen for the next generation. In the laboratory, DNA profiling can find the DNA sequence that is needed to produce a protein related to a specific trait.

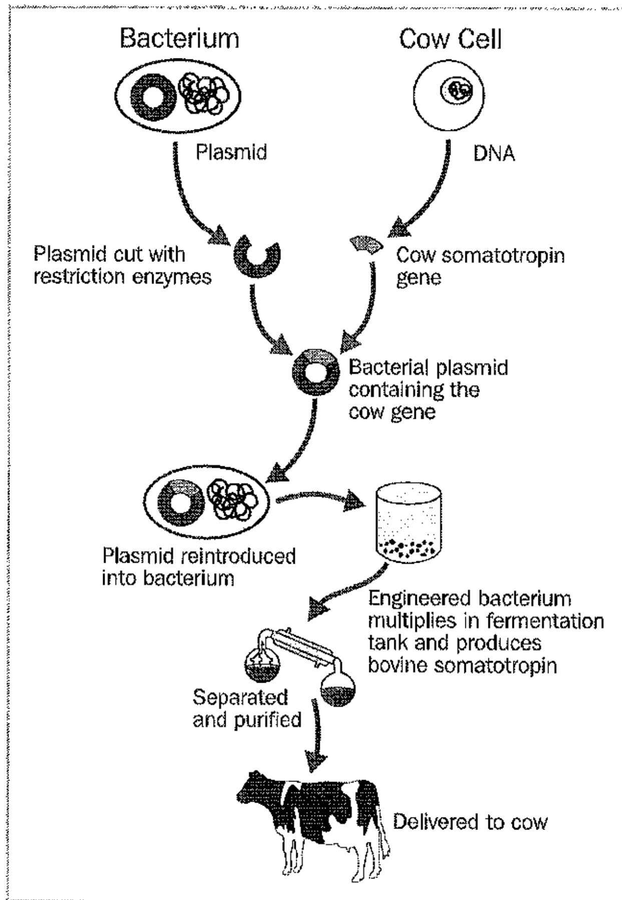

FIGURE 1. Recombinant DNA technology is used in the production of bovine somatotropin (bST). bST is used to increase milk production in dairy cows.

Scientists use rDNA technology to find target genes. A **target gene** is a segment of DNA coding for a trait. (This segment will be cut from one organism and pasted to another organism or cut and pasted from one part of an organism's DNA to another part.)

Clone the Desired Trait Gene

When you hear the term cloning, you may think of a science fiction scenario where humans are duplicates, or you may remember Dolly, the cloned sheep. Properly, **cloning** is the production of a genetically identical biological entity. The term comes from the Greek word for a twig or a plant cutting. In this sense, plant clones have been produced for almost as long as agriculture has been in existence. In rDNA technology, cloning relates to only a gene, or a specific DNA sequence, not the whole organism.

DNA cloning is the process of making copies of specific DNA or segments of DNA (such as a gene). In other words, DNA cloning may refer to one of two things. It can refer to the act of making many identical copies of a DNA molecule, or it can refer to isolating and making copies of only a segment of that DNA (like a target gene).

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Once the targeted DNA segment is isolated, the genetic information must be copied. A common method used for DNA cloning involves inserting DNA fragments into bacteria. As one bacterium divides and reproduces, it makes a copy of the DNA in its cell. The cloned DNA can then be used for modification, or it can be inserted into an organism.

Obtain the DNA

The desired DNA fragment can be cut out of a longer sequence using restriction enzymes on DNA isolated by gel electrophoresis. A **restriction enzyme** is an enzyme that can slice DNA molecules at, or near, a specific sequence of bases. **Gel electrophoresis** is a laboratory technique used to separate mixtures of DNA, RNA, and proteins according to their molecular size. Thus, a specific fragment of DNA is separated from other fragments by running the mixture through gel electrophoresis.

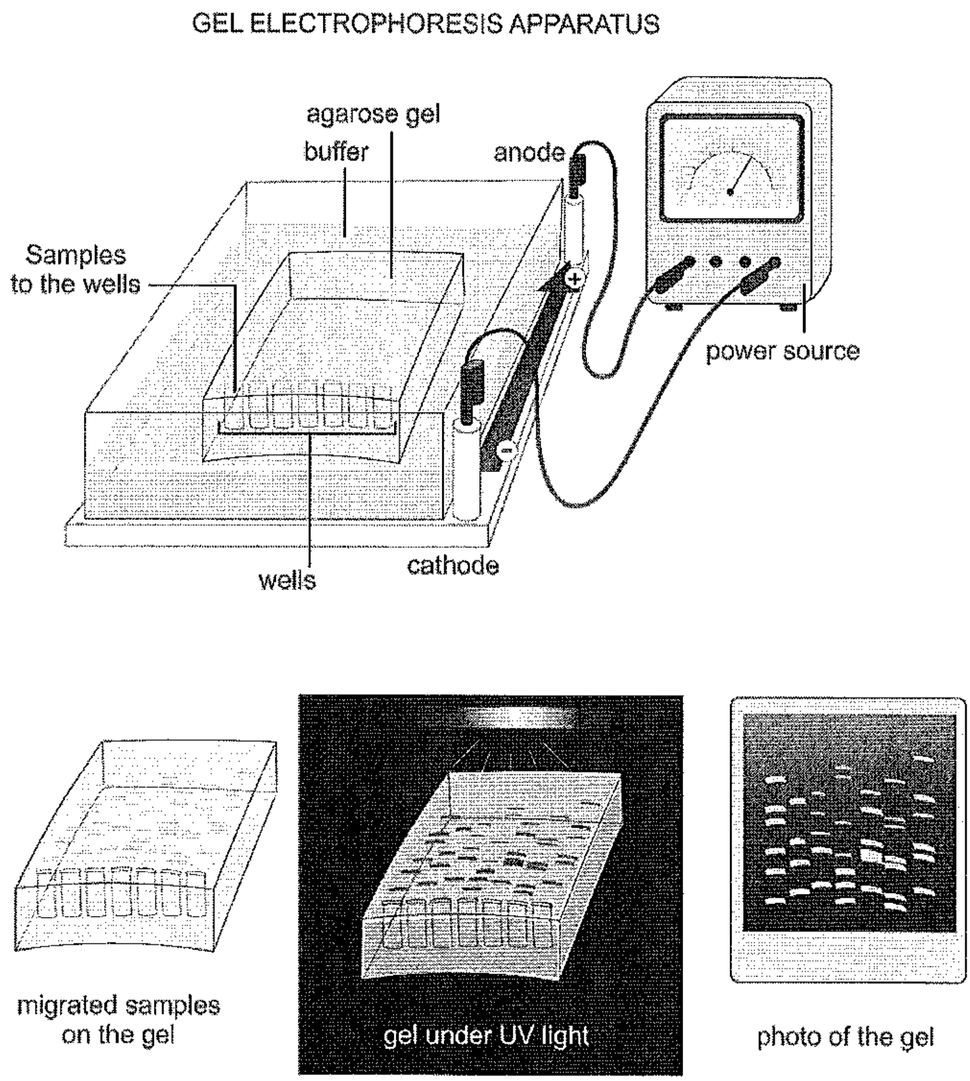

FIGURE 2. Gel electrophoresis is a laboratory technique used to separate mixtures of DNA, RNA, and proteins according to their molecular size.

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Link the DNA to a Vector

The next step is to biochemically insert the desired DNA fragment into a vector. A **vector** is a DNA molecule that is used as a vehicle to transfer DNA from one organism into another. This DNA segment (from the vector) must then be attached to the destination DNA. The process of joining two nucleic acid fragments through the action of an enzyme is called **ligation**.

A variety of vectors are used in the laboratory. The correct vector depends on the size of the DNA fragment being moved. The most commonly used vectors are viruses and plasmids. Typically, a **plasmid** is a circular, double-stranded DNA found in the cytoplasm of bacteria that is capable of replicating independently of chromosomal DNA.

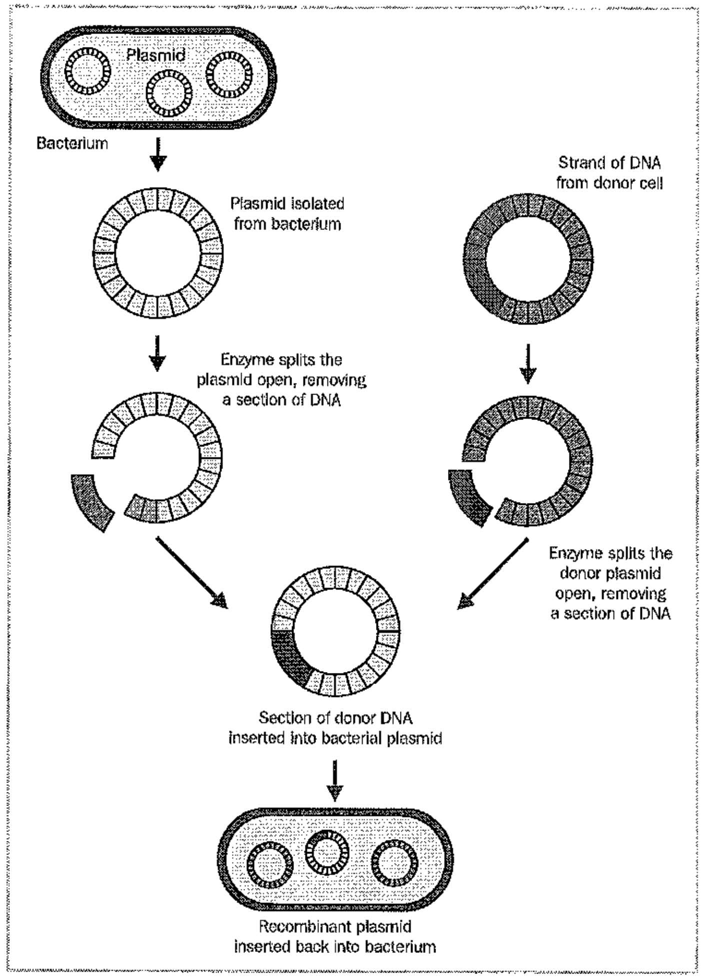

FIGURE 3. A desired DNA fragment is inserted into a plasmid.

Perform Transformation

The modified virus or plasmid is then introduced into a living cell in a process called transformation. **Transformation** is the uptake of the new DNA by the host cell, resulting in a change of the organism's original genetic makeup. **Transfection** is the occurrence of transformation in a eukaryotic cell, such as an animal or plant cell.

Transfection in animals can be accomplished in a number of ways. The simplest method involves inserting a desired fragment of DNA into a self-replicating, genetic element such as a virus or a plasmid. The plasmid (virus or the bacteria) carries the genetic material into the animal cell. For example, a DNA fragment containing a pig gene can be joined to the chromosome of a virus in a test tube, and then, the newly recombined DNA molecule can be introduced into a bacterial cell. The rapid multiplication of the virus can produce countless identical virus DNA molecules in less than a day, thereby amplifying the inserted pig DNA fragment.

A nonviral transfection method is microinjection. **Microinjection** is the injection of DNA into a cell using a fine-diameter glass needle and a microscope. It has a relatively low success rate. During this method, the chosen gene is directly microinjected into the pronucleus of a fertilized ovum. A pronucleus is the haploid nucleus of the sperm or the ovum just before their cells unite to form a zygote. Once a manipulated, fertilized ovum

Coon April 2024 Choice

enters the embryonic phase, it is transferred to the oviduct of a recipient female—where it will be carried to full term.

Screen the Clones

As soon as the transfection has taken place, it is necessary to find and select those cells that have successfully incorporated the desired DNA. This is the screening step. **Screening** is the process of selecting and isolating individual clones out of the mixture of clones.

Typically, in transformation, only one in several million (up to a billion) cells may receive new DNA. Not every cell can be checked to see if transformation occurred. So, a genetic sequence that will produce a detectable signal is incorporated within the target gene. A **marker gene** is a gene that can be identified and tracked, can serve as a flag for the target gene, and can let researchers know if the transfection was successful. A marker gene must be on the same chromosome as the target gene and close enough for the two genes to be genetically linked and inherited together. There are two types of marker genes, selectable markers and screenable markers.

A selectable marker protects the organism from a selective agent. Scientists use a selective agent to kill all cells that do not contain the foreign DNA, leaving only the desired ones. The most common selective agents are antibiotics. For example, researchers may insert an antibiotic gene along with the foreign gene into a plasmid. After insertion of the plasmid into the host cell, the cells are grown on an antibiotic medium. Only those cells that have the antibiotic-resistance gene can survive on the medium. Therefore, cells that survive must have the desired gene and the antibiotic-resistance marker gene.

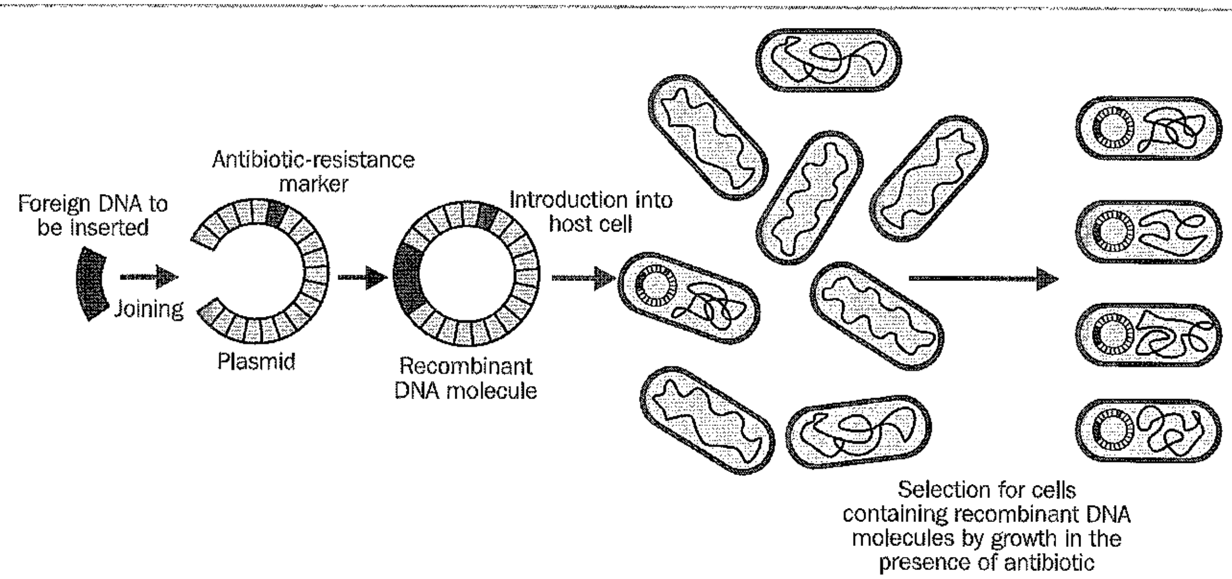

FIGURE 4. A marker gene is inserted for screening purposes.

A **reporter gene** is a type of screenable marker gene that is inserted for easy detection and diagnostic purposes. A commonly used reporter gene contains a GFP (green fluorescent protein). The GFP gene is derived from a jellyfish that glows green in UV light.

Corn April 20-24 Choice 1

Breed the Desired Trait

If the animal cell is successfully transformed, the cells are injected into a blastocyst. A **blastocyst** is an inner cell mass that was formed in early development and later forms the embryo. The resulting embryo is implanted in the womb of a recipient and allowed to develop. Scientists then verify that the animal responds with the desired trait. Successful transfection results in the desired gene becoming a constant part of the animal's genotype. Once the genotype consistently appears, the animal is used in traditional breeding programs.

REPRODUCTIVE CLONING

Reproductive cloning is the creation of the genetic duplicate of an existing organism. This is typically accomplished by using an individual adult cell.

SCNT Procedure

The most common cloning technique is a somatic cell nuclear transfer (SCNT). A **somatic cell** is any cell in a living organism that is not a reproductive cell. The SCNT procedure follows these steps:

- The nucleus is removed from an egg or oocyte—leaving the cytoplasm and mitochondria that belong to the mother.
- A somatic cell, such as a skin cell, is taken from an adult individual. The DNA is extracted from its nucleus and inserted into the prepared egg in two different ways. One method involves the removal of the DNA-containing nucleus with a needle and injecting it into the empty egg. The second method involves placing the somatic cell alongside the empty egg and using an electrical current to fuse the two.
- The new cell is made to divide within a test tube—using either

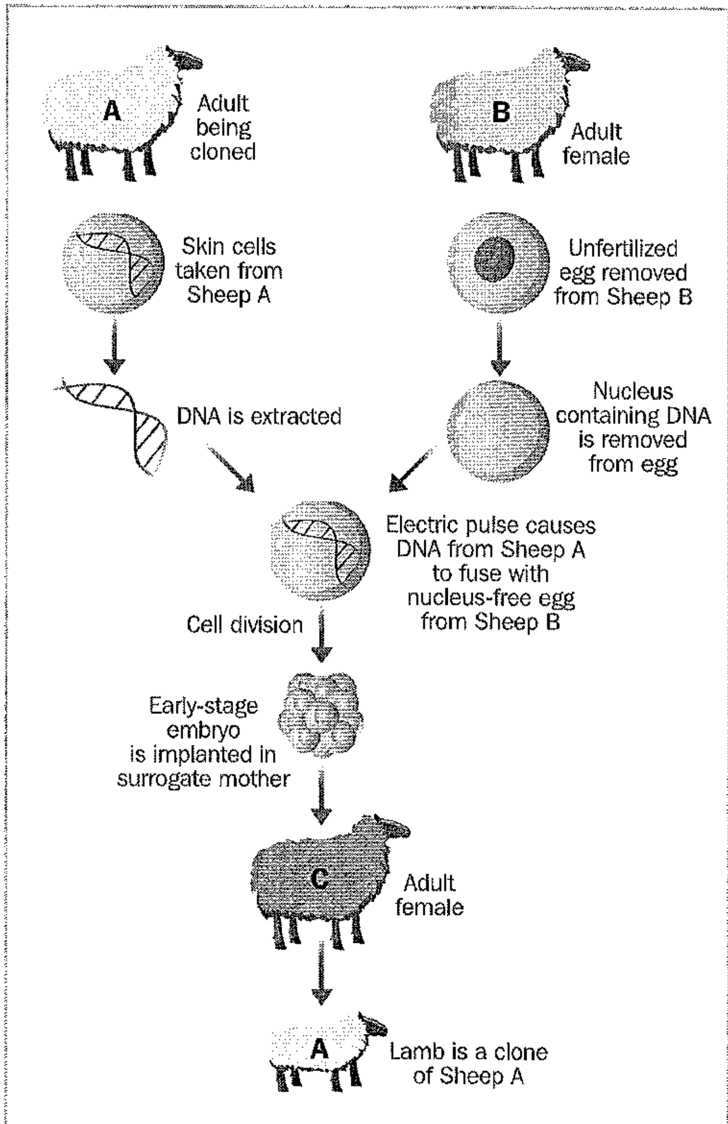

FIGURE 5. The process of reproductive cloning.

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chemical or electrical stimulation. This begins its development as an early-stage embryo.

- After several days, the embryo is inserted into the womb of the recipient and allowed to develop to term.
- Ultimately, the adult female gives birth to an animal that is a clone (a genetic duplicate) of the original individual (whose somatic cell was used). Currently, the most-famous clone is Dolly (a sheep).

Mortality Rates

Mortality rates for cloned animals are initially very high. Although not clear why, it is believed that the donor egg's nucleus holds on to a kind of genetic memory, and it resists the new genetic material. If animals cloned through SCNT survive the shock of birth, they generally grow into healthy adults.

REASONS FOR PRODUCING TRANSGENIC ANIMALS

Transgenic animals are useful for agricultural, medical, and industrial purposes.

Agricultural Applications

Traditional breeding is time consuming. Through recombinant DNA technologies, animals that possess improved traits can be produced in a much shorter period of time.

Transgenic animals provide high yields (without added hormones residing in the animal product). Cows can produce more milk, or milk with less lactose or cholesterol. Pigs and cattle can produce more (and leaner) meat. Sheep can grow more wool.

Through transgenics, scientists strive to produce disease-resistant animals, such as influenza-resistant pigs.

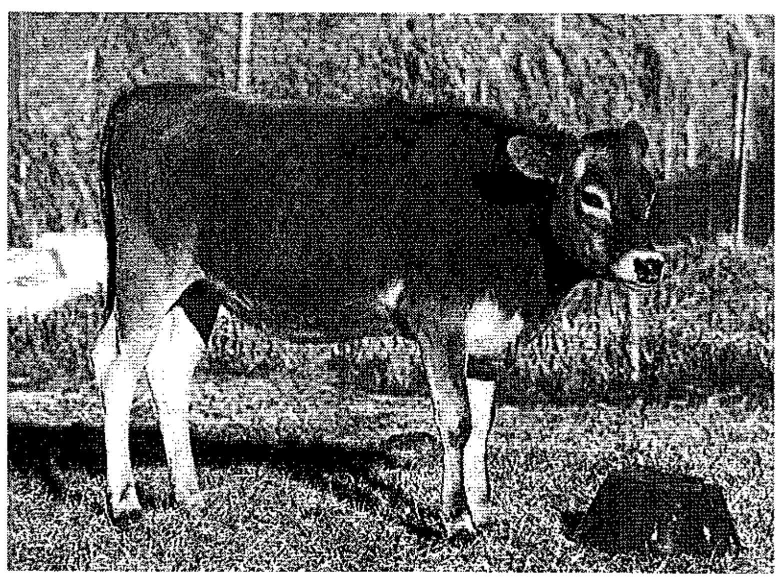

FIGURE 6. This is Annie, the first transgenic cow clone engineered to resist mastitis (a staphylococcus-related disease that costs the dairy industry more than $1 billion annually). (Photo by Scott Bauer. Courtesy of the USDA Agricultural Research Service.)

Medical Applications

Organs for human transplant may soon come from transgenic animals. Xenotransplantation is the transplantation of living cells, Com April 20-24 Choice/

tissues, or organs from one species to another. Many people die every year while waiting for a replacement heart, liver, or kidney. Transgenic pigs may provide the transplant organs needed to alleviate current shortfalls.

Milk-producing, transgenic animals are especially useful for nutritional supplements and pharmaceuticals. Products such as insulin, human growth hormones, and anti-clotting drugs may be obtained from the milk of transgenic cows, sheep, or goats. Research is also underway to manufacture milk for the treatment of debilitating diseases.

Transgenic animals can produce substances for human gene therapy. Human gene therapy includes the introduction of normal genes into the genomes of defective genes. For example, a calf's gene that makes a substance promoting the growth of red blood cells can be used in humans. Transgenic animals can also be used for testing chemical safety, biological products, and disease progression (usually in transgenic mice).

Industrial Applications

One industrial application of transgenic animals is material fabrication. For example, scientists have spliced spider genes into the cells of lactating goats. The transgenic goats manufactured silk along with their milk. The polymer strands are separated from the milk. They can be woven into a thread that is used to create a light, tough, flexible material. Military uniforms and medical microsutures are real-life applications of this product.

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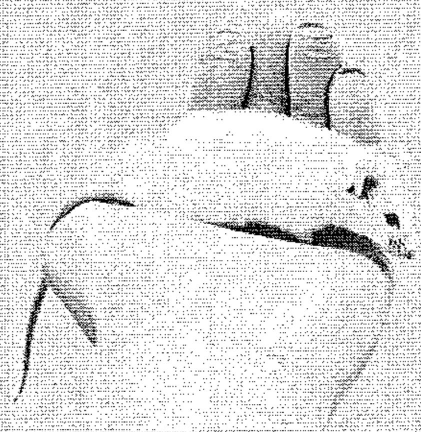
Knockout Mice

One widely used application of recombinant DNA technology involves genetically engineering knockout animals, usually mice. A knockout mouse has had an existing gene inactivated, or "knocked out," by replacing or disrupting it with a piece of foreign DNA. The response is often a change in a mouse's phenotype, including appearance, behavior, or other physical and biochemical characteristics.



Because humans share many genes with mice, knocking out the activity of a mouse gene gives researchers insight into what that gene normally does in humans. Observing the changes in knockout mice can provide a better understanding of how similar human genes cause or contribute to different diseases. Knockout mice have been useful in studying cancer, obesity, heart disease, diabetes, arthritis, substance abuse, anxiety, aging, and Parkinson disease.

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Summary:

Genetic engineering (GE) is the artificial manipulation of genetic material, which largely involves the creation of recombinant DNA. The goals of the genetic engineering of animals are similar to the goals of selective breeding—better efficiency for growth, better yield, higher milk production, a more appealing appearance, resistance to disease, and healthier meat. The biggest difference lies in GE's ability to achieve goals in significantly less time than through selective breeding.

A transgenic organism is any organism whose DNA has been altered by having a foreign gene artificially inserted to express a new, desirable trait. rDNA technology is any technique used in genetic engineering that involves the identification, isolation, and insertion of a gene into a vector, such as a plasmid, and then introducing the DNA into a host cell.

In the laboratory, gene sequences can be combined and inserted into an organism, resulting in a transgenic organism. There are several steps in this process of genetic engineering—from locating the desired trait to breeding it into a population.

Reproductive cloning is the creation of the genetic duplicate of an existing organism. This is typically accomplished by using an individual adult cell. The most common cloning technique is a somatic cell nuclear transfer (SCNT).

Transgenic animals are useful for agricultural, medical, and industrial purposes.

Expanding Your Knowledge:

To increase your understanding of rDNA, watch the YouTube video, "DNA cloning and recombinant DNA," on the Khan Academy channel at https://www.youtube.com/watch?v=5ffl-oOYVQU.

Checking Your Knowledge:

Part One: Matching

Instructions: Match the word with the correct definition.

a. cloning
b. DNA profiling
c. gel electrophoresis
d. DNA cloning
e. genetically modified organism
f. ligation
g. plasmid
h. marker gene
i. restriction enzyme
j. vector

_______1. the process of making copies of specific DNA or segments of DNA (such as a gene)

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_______2. a DNA molecule that is used as a vehicle to transfer DNA from one organism into another

_______3. a circular, double-stranded DNA found in the cytoplasm of bacteria that is capable of replicating independently of chromosomal DNA

_______4. the analysis of DNA for a specific gene

_______5. the production of a genetically identical biological entity

_______6. the process of joining two nucleic acid fragments through the action of an enzyme

_______7. a laboratory technique used to separate mixtures of DNA, RNA, and proteins according to their molecular size

_______8. an enzyme that can slice DNA molecules at, or near, a specific sequence of bases

_______9. a gene that can be identified and tracked, can serve as a flag for the target gene, and can let researchers know if the transfection was successful

_______10. any organism that has been genetically modified through mutation by natural or artificial means

Part Two: Completion

Instructions: Complete the following statements.

1. _______________________ is any application that uses living systems or organisms to make or modify technological products or processes for a specific use.
2. _______________________ is any technique used in genetic engineering that involves the identification, isolation, and insertion of a gene into a vector, such as a plasmid, and then introducing the DNA into a host cell.
3. A/an _______________________ is a segment of DNA coding for a trait.
4. A/an _______________________ is any organism whose DNA has been altered by having a foreign gene artificially inserted to express a new, desirable trait.
5. _______________________ is the artificial manipulation of genetic material, which largely involves the creation of recombinant DNA.
6. _______________________ is a genetically-engineered DNA molecule formed from spliced fragments of DNA—from a different cell within the organism or from another organism altogether.
7. _______________________ is the uptake of the new DNA by the host cell, resulting in a change of the organism's original genetic makeup.
8. The specific gene inserted into a transgenic organism from another organism is called a/an _______________________.

Coon April 20-24 Choice 1

9. If the transformation is in a eukaryotic cell, such as an animal or plant cell, it is called ____________________.

10. ____________________ is the process of selecting and isolating individual clones out of the mixture of clones.

Part Three: True/False

Instructions: Write *T* for true or *F* for false.

_______1. A disadvantage of genetic engineering is that the gene pool is limited to the species being bred.

_______2. Genetic engineering takes much less time to achieve desired goals than selective breeding.

_______3. Locating genes on chromosomes has become easier as biotechnologists have mapped the genomes of many organisms.

_______4. A common method used for gene cloning involves inserting DNA fragments into a eukaryote.

_______5. A specific DNA fragment can be separated from other fragments by running the mixture through ligation enzymes.

_______6. A microinjection is the preferred method of injecting DNA into a cell because of its high success rate.

_______7. The GFP gene is a reporter gene derived from a jellyfish that glows green in UV light.

_______8. A marker gene must be on the same chromosome as the target gene and close enough for the two genes to be genetically linked and inherited together.

_______9. The most common cloning technique is a somatic cell nuclear transfer (SCNT).

_______10. Although transgenic animals provide high yields, residuals of high hormone concentrations will remain within their products.

Choice 2

Mr. Coon BSAA Reproduction April 20 -24

Checking Your Knowledge: Part One: Matching Instructions: Match the word with the correct definition.

a. estrogen f. ovulation b. estrus g. parturition c. fertilization h. progesterone d. gestation i. spermatogenesis e. oogenesis j. Testosterone

_______1. giving birth
_______ 2. period of animal development from pregnancy to birth
_______3. the moment when a follicle ruptures and releases an egg
_______4. a period of sexual receptiveness—heat
_______5. the production of ova
_______6. a male developmental hormone
_______7. a female developmental hormone
_______8. a hormone that helps maintain gestation and assists in regulation of the estrous cycle
_______9. the penetration of a male's sperm into a female's egg
_______10. the production of sperm

Coon April 20-24 Choice 2

E-UNIT B2–1 Reproductive Systems and Processes

Reproductive success in farm animals is of significant, economic importance to producers, and ultimately, consumers. Reproduction can affect the consumer costs of multiple livestock products. Many consider this the most valuable part of the livestock industry, because of its higher interconnectivity with all areas of economic return. Regardless of its economic ramifications, understanding the mechanisms of sexual reproduction allows you to be a better breeder, livestock operator, or pet owner.

Objective:

Describe how the form and function of reproductive organs enable animals to reproduce.

Key Terms:

accessory sex glands
acrosome
ampulla
anestrus
bulbourethral gland (Cowper's gland)
cervix
clitoris
conception
copulation
corpus luteum (CL)
diestrus
diploid
epididymis
estrogen
estrous cycle
estrus
extender
fertilization
follicle-stimulating hormone (FSH)
follicles
gametes
gestation
glans penis
gonadotropin-releasing hormone (GnRH)
haploid
infundibulum

Coon April 20-24 Choice 2

luteinizing hormone (LH)	prostaglandin (PGF)	spermatogenesis
metestrus	prostate gland	spermatogonium
oogenesis	puberty	spermatozoa (sperm)
ova	reproduction	synapsis
ovary	reproductive efficiency	testicles (testes)
oviducts (fallopian tubes)	scrotum	testosterone
ovulation	semen	urethra
parturition	seminal vesicles	uterine horns
penis	seminiferous tubules	uterus (womb)
polar body	sheath	vagina
primordial germ cells	sigmoid flexure	vas deferens
proestrus	sperm morphology	vulva
progesterone	sperm motility	zygote

Animal Reproduction

Reproduction is the process of creating offspring. It is an essential, natural instinct of an animal to continue its species. Reproduction typically involves the male depositing his sperm into the female's reproductive tract during **copulation**, the act of mating. After **fertilization** (the penetration of a male's sperm into a female's egg), **conception** (the initial formation of a new organism through fertilization) occurs, and a new animal begins to develop. A fertilized egg is known as a **zygote**.

The newly formed zygote will develop during **gestation**, the period of animal development from pregnancy to birth. The length of gestation and the typical number of offspring born will vary among species—represented in TABLE 1.

TABLE 1. Average Gestation Length and Number of Offspring Born for Selected Mammals

Species	Gestation Length (Days)	Typical Offspring (Per Birth)
Cattle	283 days	1
Swine	114 days	6 to 14
Sheep	147 days	1 to 3
Goats	150 days	2 to 3
Horses	336 days	1
Dogs	65 days	7
Rabbits	31 days	4 to 8

Coon April 20-24 Choice 2

The gestation period will last until **parturition** (giving birth). It is essential for producers to understand proper management techniques during each of these stages. Knowing the functions of the reproductive system and sex-cell production will allow you to increase the reproductive efficiency of the herd. **Reproductive efficiency**, the number of offspring that can be born within a specific time, can play a critical role in determining whether livestock provide a profit during a given year.

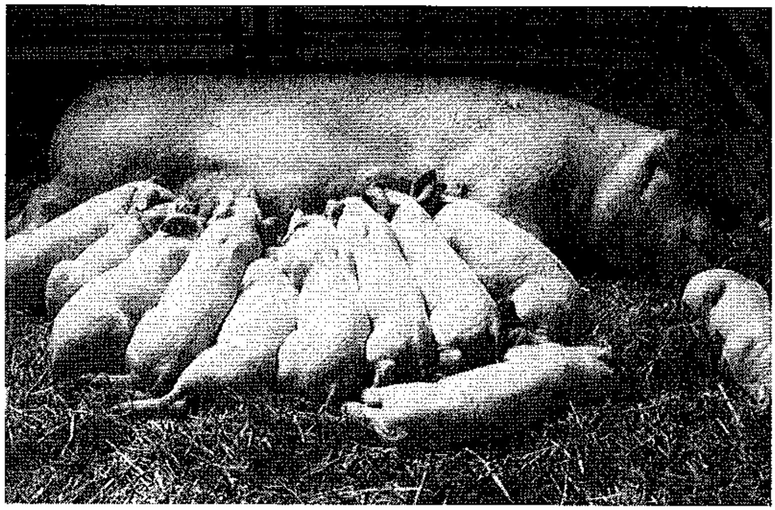


FIGURE 1. Reproductive efficiency is essential for profitability in the livestock industry.

REPRODUCTIVE SYSTEMS

For you to fully understand the reproductive processes of fertilization, gestation, and parturition, it is essential to have a basic understanding of both male and female reproductive anatomy and physiology.

Male Reproductive Organs and Functions

The male reproductive system has several interconnected, working parts that must function together for successful mating. In the reproductive system of a male mammal, the major organs are the testicles, epididymis, scrotum, vas deferens, accessory sex glands, urethra, and penis.

Testicles

Testicles (testes) are the male reproductive organs that produce hormones and sperm. **Spermatozoa (sperm)** are mature, male sex cells. The testes produce **testosterone**, a male developmental hormone. Testosterone triggers masculine traits in an animal's appearance and behavior. A typical male mammal has two testicles. Sperm leave through an **epididymis** (a duct connected to a testicle in which sperm mature and pass to the vas deferens) that is attached to a testicle. Through the epididymis, they mature, are stored, and eventually leave.

Scrotum

The **scrotum** is a two-lobed sac that contains and protects the testicles. It also regulates the temperature of the testicles, which must be maintained below body temperature. When the environmental temperature is lower than the desired temperature, the scrotum contracts, pulling the testicles toward the body for warmth. When the

Coon April 20-24 Choice 2

environmental temperature is higher than the desired temperature, the scrotum relaxes, permitting the testicles to drop away from the body. This temperature regulation is greatly important to the reproductive process, because heat can affect the production and vitality of sperm.

Vas Deferens

Another important organ of the male reproductive system is the **vas deferens**, a transportation tube that carries sperm from the epididymis to the urethra. The end of each vas deferens has an enlarged portion called the **ampulla**, a spherical cavity that serves as a temporary reservoir for sperm entering the urethra. The **urethra** is the large, muscular canal that transports semen (and urine) out of the body. It extends from the urinary bladder to the end of the penis.

Accessory Sex Glands

The **accessory sex glands** are the glands that grow along the genital tract of mammals. They add volume and nutrients to the sperm-rich fluid coming from the epididymis. The **seminal vesicles** are two tubular glands that produce fluids that help transport sperm. They open into the urethra. The **prostate gland** is a walnut-sized gland between the bladder and the penis. It produces a fluid that mixes with the sperm fluid, and has some smooth muscles that help to expel the semen. **Semen** is a mixture of sperm and the fluids produced by the vesicles and prostate. The **bulbourethral gland (Cowper's gland)**, is a pea-sized sex gland behind (and to the side) of the urethra. It produces a fluid that moves down the urethra ahead of the seminal fluid. This fluid cleans and neutralizes the urethra, helping to protect the sperm as they move through.

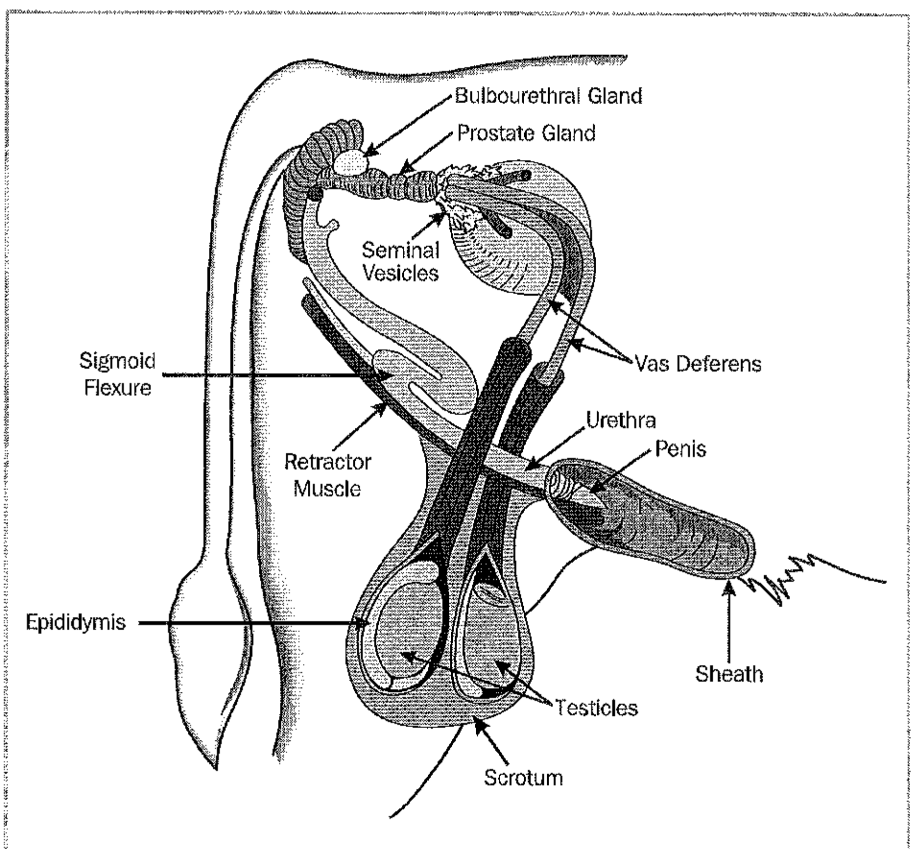


FIGURE 2. The male reproductive organs of a bull.

Penis

The **penis** is the external, male sex organ that semen travels through

Coon April 20-24 Choice 2

during copulation. It deposits the semen within the female reproductive system. In a penis, the urethra is surrounded by spongy tissue that fills with blood when the male is aroused. This causes an erection, which is necessary for mating to occur. The **sigmoid flexure**, an s-shaped curvature of the penis, is commonly found in bulls, rams, and boars. An animal penis also has a retractor muscle that extends or retracts the penis from the **sheath**, a tubular fold of skin that covers the penis. When the penis is erect, the sigmoid flexure straightens. The **glans penis** is the sensitive tip of the penis. It is homologous to the female clitoris.

TABLE 2: Summary of the Major Organs and Primary Functions in the Male Reproductive System

Organ	Primary Functions in the Reproductive System
Testicles	• Production of sperm and testosterone
Epididymis	• Concentrates, stores, transports, and aids in maturation of sperm
Scrotum	• Protects testicles and aids in temperature regulation
Vas deferens	• Transportation of sperm • Addition of fluid
Accessory sex glands	• Add volume, nutrients, and fluid to sperm (creates semen)
Urethra	• Transportation of semen
Penis	• Deposits semen into female reproductive tract

Female Reproductive Organs and Functions

Like the male, the female mammal has a complex system of organs that compose the reproductive system. The major organs that make up the female reproductive tract are the ovaries, oviducts, uterus, vulva, clitoris, and vagina.

Ovaries

A female mammal typically has two ovaries. An **ovary** is a female reproductive organ that produces ova, estrogen, and progesterone. Within each ovary are hundreds of tiny **follicles** (fluid-filled ovum sacs) in which the **ova**, female reproductive cells (unfertilized eggs), are produced. Each ovum (singular form of ova) is the largest single cell in the body. The ovaries also produce the sex hormones estrogen and progesterone. **Estrogen** is a female developmental hormone. It triggers feminine traits and appearances in the female body and aids in the initiation of **estrus** (a period of sexual receptiveness—heat). **Progesterone** is a hormone that helps maintain gestation and assists in regulation of the estrous cycle.

Coon April 20-24 Choice 2

Oviducts

Oviducts (fallopian tubes) are the two tubes (each connected to an ovary) that carry the ova to the uterus. They reside close to the ovaries but are not attached to them. The funnel-shaped end of each oviduct nearest an ovary is called the **infundibulum**. At **ovulation**, the moment when a follicle ruptures and releases an egg, the fingerlike projections of the infundibulum catch the ova and guide it into the oviduct.

After copulation, sperm move through the uterus to the oviduct. Fertilization of the ovum occurs in the upper end of the oviduct. The fertilized ovum moves to the uterus about three days after fertilization.

Uterus

In mammals, the **uterus (womb)** is a Y-shaped organ that holds the embryo. It consists of the body, the two uterine horns, and the cervix. The size and shape of the uterus vary with the species. The upper part of the uterus consists of two **uterine horns**, the two horn-shaped extensions of the uterus that connect to the oviducts. In most species, except horses, pregnancy occurs in the uterine horns. In the horse, however, pregnancy occurs in the body of the uterus. The uterus is the site where the fetus grows until parturition. The **cervix** is the lower outlet of the uterus. It is composed primarily of connective tissue, and it constitutes a gateway between the uterus and the vagina. It helps facilitate sperm transport and prevent uterine contamination. It also tightens, or closes, during pregnancy to keep the fetus in place. At birth, the cervix opens.

Vulva, Clitoris, and Vagina

The **vulva** is the external opening of the female reproductive and urinary systems. The vulva has three major functions—a passage for urine, an opening for mating, and the final part of the birth canal.

The **clitoris** is the sensory, erectile organ of the female—located just inside the vulva. The clitoris develops from the same embryonic tissue as the male penis, and it produces sexual stimulation during copulation.

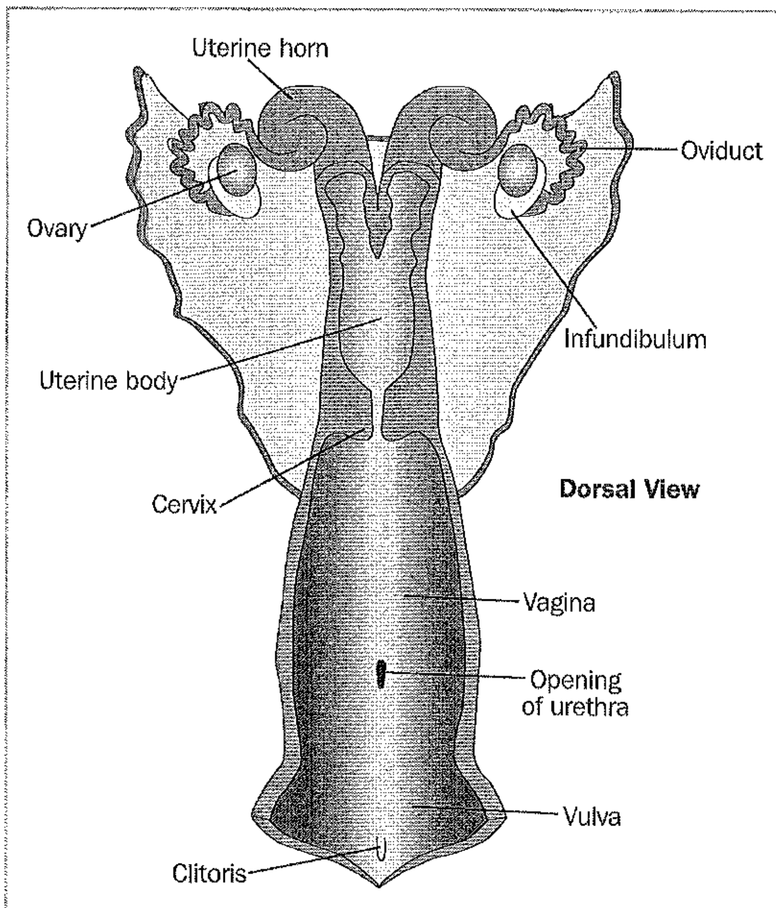


FIGURE 3. The female reproductive organs of a cow.

Com April 20-24 Choice 2

Lastly, the **vagina** is the tube-like sex organ that connects the vulva to the cervix (lower end of uterus). It is used as a receptacle for the penis during copulation and as the birth canal at parturition. The lining is moist during estrus and dry when not in heat.

TABLE 3. Summary of the Major Organs and Primary Functions in the Female Reproductive System

Organ	Primary Functions in the Reproductive System
Ovary	• Production of eggs and hormones (estrogen, progesterone)
Oviduct	• Transportation of eggs • Site of fertilization
Uterus	• Site of pregnancy • Womb
Vulva	• Opening for mating • Part of the birth canal
Clitoris	• Sensory organ during copulation
Vagina	• Reproductive organ for copulation • Birth canal during parturition

ESTRUS

Puberty is the time at which an animal reaches sexual maturity and has the ability to reproduce. Several factors influence the timing of puberty, including breed, genetics, and environmental factors. Typically, a female reaches puberty when estrus and ovulation occur. During estrus (or when in heat), a female animal will allow copulation. To fully understand estrus, you will need to understand the processes of female sex-cell production, ovarian function, and the estrous cycle.

Female Sex-Cell Production

In the last section you learned that ova are produced in the ovaries. Ova are female **gametes** (sex cells) responsible for the formation of cells that can become a new organism. (Sperm are male gametes.) The production of ova is known as **oogenesis**. The process begins with meiosis, which occurs

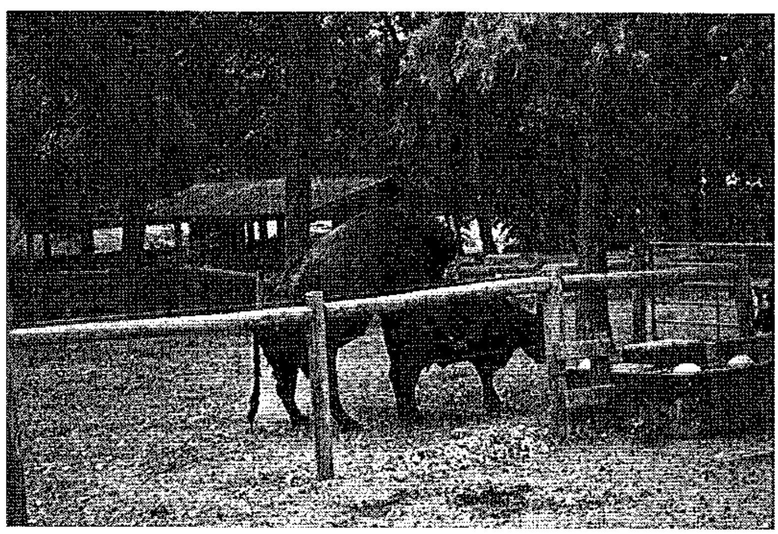


FIGURE 4. The cow allowing the bull to mount her is an indication of estrus. (Courtesy, USDA)

Coon April 20-24 Choice 2

in the **primordial germ cells** (the diploid, origin cells of gametes that are capable of undergoing meiosis). They are found near the surface of the ovary. To begin meiosis (the process of sex-cell division), the germ-cell chromosomes double themselves, then each pair of chromosomes fuse together. This pairing of duplicate chromosomes is called **synapsis**. This synapsis results in a primary oocyte (immature ovum). From there, the first meiotic division occurs, leading to one relatively large cell, the secondary oocyte, and a smaller cell—the first polar body. A **polar body** is a small cell formed from meiosis that does not become an oocyte. Next, the second meiotic division produces the mature ovum and additional, smaller polar bodies. Polar bodies nourish the ovum until eventually disintegrating, leaving only one ovum from each primary oocyte. Oogenesis will normally begin during puberty, and it will continue with each estrous cycle of an animal's reproductive life.

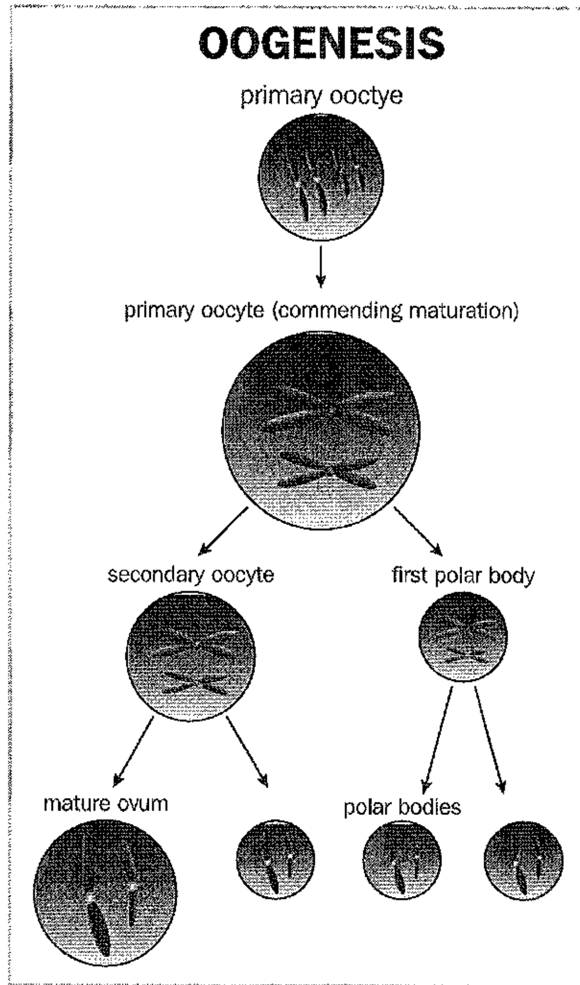


FIGURE 5. The process of oogenesis.

Ovarian Function

As mentioned earlier, estrus is triggered by the release of ovarian hormones. Other areas of the body release hormones to regulate egg production in the ovaries, including the hypothalamus and the anterior pituitary gland (AP). The **follicle-stimulating hormone (FSH)** is an AP-secreted hormone that stimulates egg formation in females (and sperm formation in males). The **luteinizing hormone (LH)** is a hormone secreted from the AP that stimulates ovulation. Both AP hormones help stimulate follicular development in the ovaries. The **gonadotropin-releasing hormone (GnRH)** is a hormone produced in the hypothalamus that stimulates the AP to release the LH and FSH. Upon egg maturation and ovulation, estrogen is released, and the female will experience a period of estrus.

The time frame for estrus varies between species, but hormonal changes can be visually identified. For example, besides standing to be ridden, a cow in estrus may display restlessness, a swollen vulva, or a thick, fluid discharge. This is a natural response to ovulation in a majority of species.

The Estrous Cycle

The **estrous cycle** is the time between and during reproductive cycles, including estrus, ovulation, and uterine-wall discharge. In many mammals, the estrous cycle of

Coon April 20-24 Choice 2

Species	Estrous Cycle (days)	Length of Estrus (heat)	Ovulation
Cow	21	12–18 hours	10–14 hours after estrus
Mare	22	6–8 days	1–2 days before estrus ends
Doe (goat)	21	30–40 hours	at the end of or just after estrus
Doe (rabbit)	Constant	Constant	8–10 hours after mating
Sow	20–21	40–72 hours	mid estrus
Ewe	17	24–36 hours	late estrus
Bitch (dog)	—	9 days	1–2 days after estrus begins
Queen (cat)	14–21*	5 days	24 hours after mating

*Estrous cycle influenced by length of daylight, with mating season typically when there are more than 12 hours of daylight in one day.

FIGURE 6. Duration of estrous cycle, length of estrus, and time of ovulation.

reproductively healthy females is continuous, except during pregnancy. However, it is not continuous in species that are classified as seasonal breeders, such as sheep and horses. The estrous cycle progresses through four phases if pregnancy does not occur. Related to the estrous cycle, other phases of the cyclical process include anestrus, metestrus, diestrus, and proestrus.

Anestrus

Some animals will experience periods of **anestrus** (a time of estrous cycle inactivity), even when a female is not pregnant. This is usually a biological response to environmental cues, and it allows the animal a respite from reproductive urges. Seasonal breeders go through long periods of anestrus. They only mate once or twice a year (during a specific "season").

Metestrus

Metestrus (the cycle stage after estrus in which the corpus luteum is formed) occurs following estrus. In this phase, the female is no longer sexually receptive to the male and may show no signs of previously being in estrus. However, hormonal effects continue within the female. The LH stimulates the development of the **corpus luteum (CL)**, a hormonal mass that forms after a follicle releases an ovum; it secretes progesterone. The CL develops at the point where the ovum was released. Its purpose is to produce progesterone to either maintain the pregnancy or regulate the estrous cycle if not pregnant. If there is no pregnancy, it should dissipate. In some species, this is the phase during which ovulation will occur.

Coon April 20-24 Choice 2

Diestrus

Diestrus is the short interval of the estrous cycle in which there is sexual inactivity and the animal's body prepares for pregnancy. The CL produces high levels of progesterone to maintain a pregnancy. It sends signals to prepare the uterus for the development of an embryo. If an animal is pregnant, the CL will continue to function, producing more progesterone and preventing further cycling. If it is not pregnant, the estrous cycle continues.

Proestrus

Proestrus is the last stage of the estrous cycle, where the follicles become active and the body prepares for estrus. This occurs if an embryo does not attach to the uterus (no pregnancy). The uterus releases the hormone **prostaglandin (PGF)**, a hormone that signals a decrease in progesterone, the disintegration of the CL, and the contraction of the uterus. The uterus is no longer prepared to accept the attachment of an embryo, and the sex organs begin preparing again for estrus. Proestrus is the last phase of the continuous cycle, assuming the animal does not become pregnant and is not a seasonal breeder. Seasonal breeders will go through only a few estrous phases during their time of year, with the ultimate goal of becoming pregnant.

Estrous Cycle in Cattle

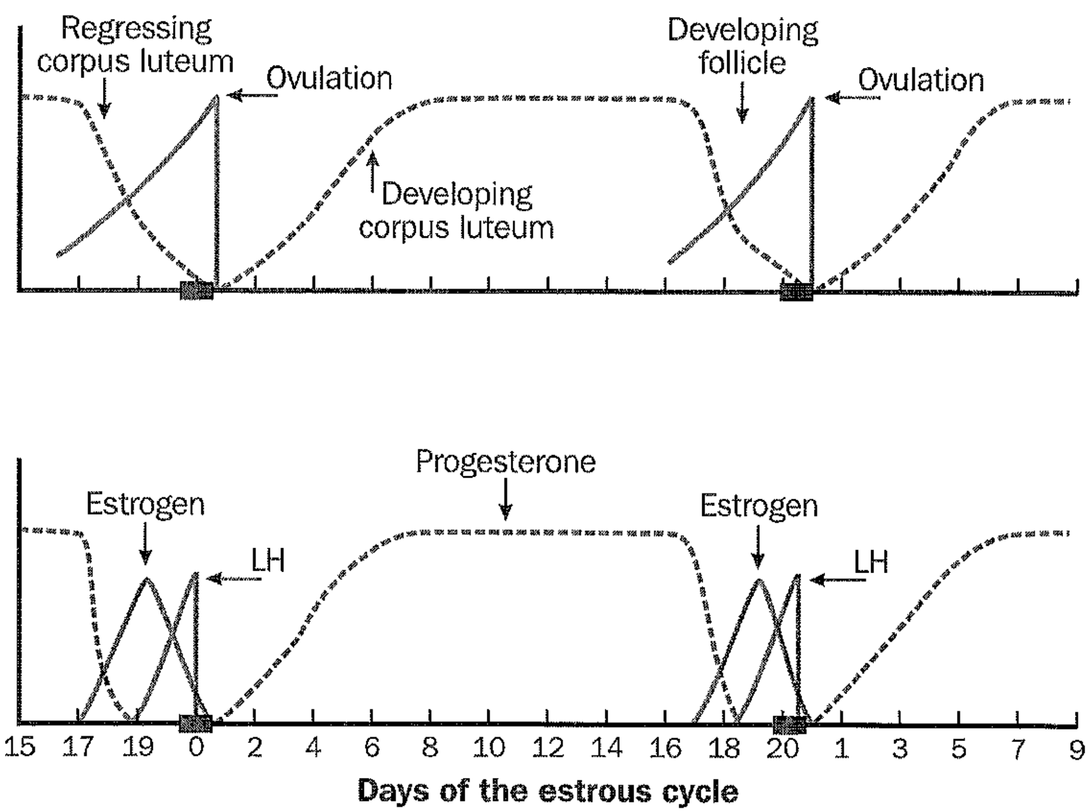


FIGURE 7. Timeline of events and hormone changes during the estrous cycle in cattle.

Coon April 20-24 Choice 2

SPERM DEVELOPMENT

As with females, males reach a point of reproductive maturity that allows for the production of offspring. For a male animal, this is when their ejaculations contain fertile sperm. This section will focus on a male's sex-cell production, testicular function, and sperm health.

Male Sex Cell Production

The male gamete is the sperm cell. The **seminiferous tubules** are the tube-like structures within testes that produce sperm cells through meiosis. These tiny tubules contain

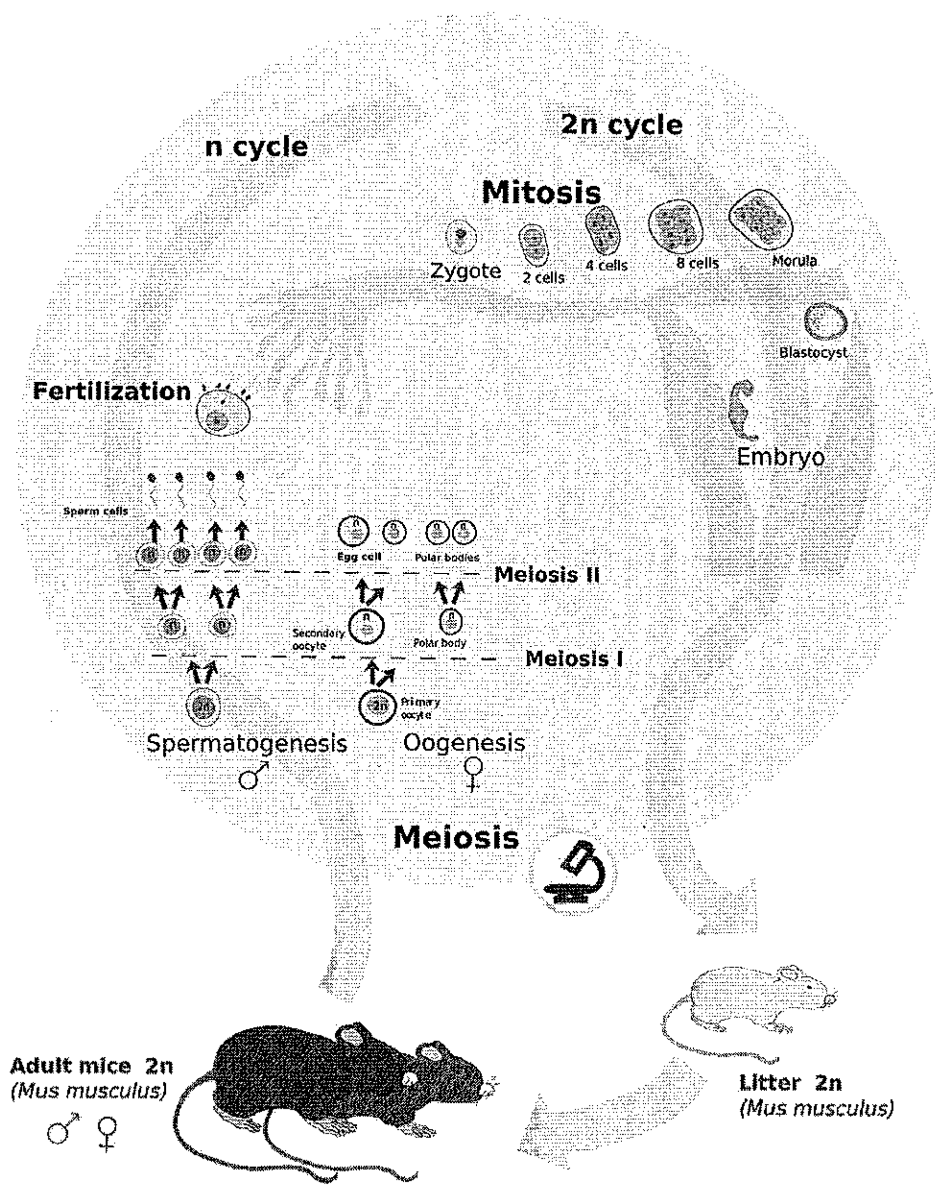


FIGURE 8. The processes of spermatogenesis, oogenesis, and reproduction in mice. (Courtesy of NuriaWrite. Licensing at https://creativecommons.org/licenses/by-sa/3.0/deed.en.)

Coon April 20-24 Choice 2

spermatogonium (an undifferentiated, male germ cell that lines the seminiferous tubes, awaiting spermatogenesis). They are **diploid** (containing two sets of chromosomes), and eventually, they become sperm cells. The production of sperm is called **spermatogenesis**. During the process of spermatogenesis, four mature sperm are formed from a primordial germ cell.

The initial, male-meiosis steps are the same as in oogenesis. The chromosomes replicate themselves and pair together during synapsis. Once the primary spermatocyte is formed, meiosis continues, and the cells continue to divide. During the final step, the cells and chromosomes separate, resulting in four **haploid** (containing a single set of chromosomes) sperm cells. The primary function of spermatogenesis is to turn each diploid spermatogonium into four sperm.

Testicular Function

As with the female, male reproduction is regulated by a series of hormonal signals from the endocrine system in the AP. In fact, the LH and FSH (which help stimulate development of follicles and eggs in females) are both essential in a male's reproductive performance. The LH is crucial to testosterone production, and the FSH encourages cells in the seminiferous tubules to develop sperm. It is imperative that these hormones are present for proper testicular function and sperm development.

Evaluating Sperm Health

Most livestock producers often have a limited number of reproductive males in their herd. Utilizing healthy, reproductive males that are fertile, efficient, and productive is key in the breeding success of a livestock operation. Poor semen will typically result in lost time, wasted resources (such as feed and housing), and reproductive failure. There are many common reasons for poor reproductive health in males. These may include genetics, extreme temperatures, stress, illness, and improper nutrition.

Before using a male, you can evaluate semen to determine fertility potential. Several indicators can be used to evaluate semen viability—volume, abnormalities, and motility in a given semen sample.

Volume

The volume of ejaculated semen varies greatly between species. Interestingly, one bull can ejaculate enough sperm to inseminate hundreds of cows. Even a stallion can produce enough semen for about 17 mares. Because of this, a semen sample can be extended and frozen for later use. Nutrients, pH adjustment, and protection from freezing are benefits of adding an **extender** (semen diluter).

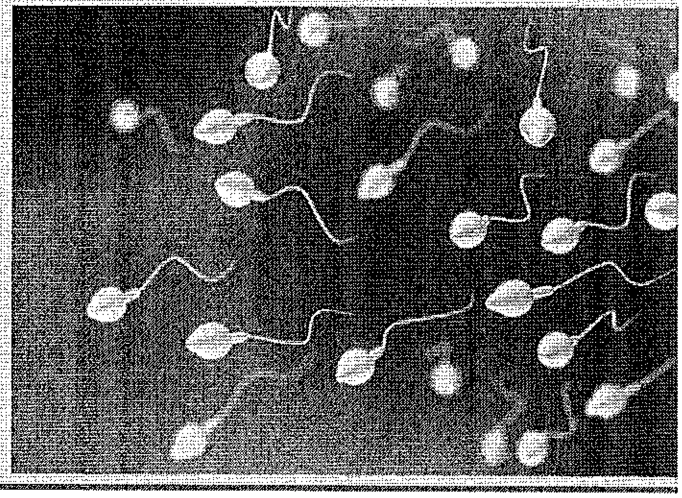
After the semen is diluted, it is placed in a small, plastic straw (or syringe) and slowly cooled. After the semen reaches 0°C, it is rapidly cooled to –320°F with liquid nitrogen. The metabolism of the sperm cells immediately stops, ending all motility. There are several benefits to using liquid nitrogen, such as a consistent temperature and easy transport; however, only 50% to 65% of the sperm cells will survive.

Coon April 20-24 Choice

Further Exploration... *ONLINE CONNECTION*

Semen Evaluation

So, now that you know the importance of semen health, what do you look for under a microscope? We've discussed volume, concentration, motility, and structure, but what are the acceptable levels? How does a lab technician actually evaluate these samples? To learn more about semen evaluation parameters, complete the University of Wisconsin's online simulation at http://www.ansci.wisc.edu/jjp1/pig_case/html/semeneval1.html.



Sperm Morphology and Abnormalities

Sperm morphology, the size and shape of the sperm cell, is another fertility factor. A sperm cell typically consists of a head, body, and tail. A membrane cap covering the sperm head is called the **acrosome**. The acrosome contains enzymes that help break through the ovum for fertilization.

Using a microscope, you can identify abnormalities in a sperm sample. Frequent morphological problems include an abnormal shaped head or tail, multiple tails or heads, and a ruffled or incomplete acrosome.

Sperm Motility

Sperm motility (sperm movement) can also be evaluated with a microscope. The tail is primarily responsible for motility. Without proper motility, the sperm cannot make the journey to the ova for fertilization.

After ejaculation, the sperm must swim out of the semen. In order to do so, they must swim quickly and in a straight line. This is known as "rapid and linear" movement. If they swim slowly, in circles, or in a curved manner, few of them will make it out of the semen and to the egg.

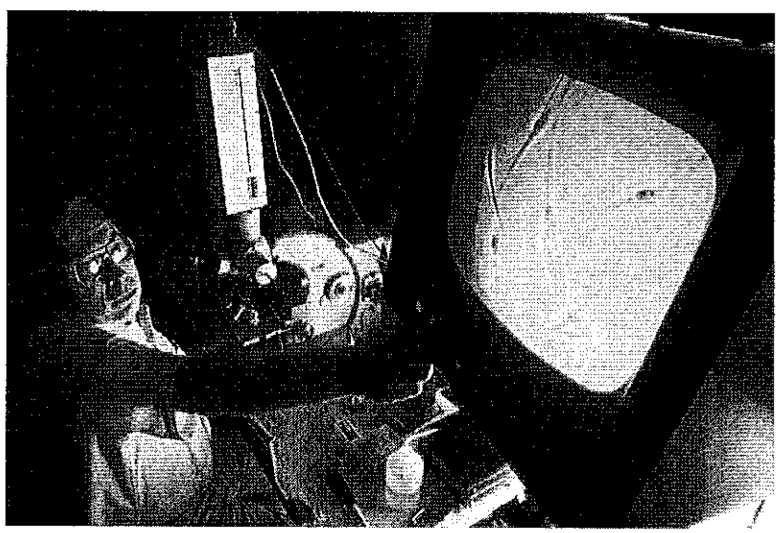


FIGURE 9. Evaluating sperm motility. (Photo by Keith Weller. Courtesy of Agricultural Research Service, USDA.)

Corn April 20-24 Choice 2

The sperm must travel to the egg, which is in the upper part of the oviduct. Tiny hairs (cilia) in the uterine wall, as well as uterine contractions, help the sperm travel to the egg. Once the sperm reaches the egg, it must pass through two layers of the ovum—the cumulus and the zona pellucida. Sperm must swim in a fast, spiraling path in order to penetrate the cumulus. This is known as a "capacitating motility pattern." When the sperm gets to the zona pellucida, enzymes from the acrosome must create a small opening for entry. Finally, the sperm must swim in a "hyperactivation" manner, bending their tail sharply back and forth in a rapid and random manner to enter the egg. Sperm with low motility percentages often fail to swim in a way (or travel the distance) that allows egg entry.

TABLE 4. Typical Ejaculate Characteristics of Common Livestock Species

Species	Ejaculate Volume (ml)	Sperm Concentration ($x10^9$/ml)	Total Sperm ($x10^9$)/ Ejaculate	Percentage Motility	Percentage Normal
Cattle	5.0	1.2	4–5	30+	70+
Swine	200	.30	60	80+	80+
Sheep	1.0	2.5	3	70+	50+
Equine	70	.12	7–10	60+	60+

Note. These are approximate figures based on averages.

Summary:

Reproduction is the process of creating offspring. It is an essential, natural instinct of an animal to continue its species. Reproduction typically involves the male depositing his sperm into the female's reproductive tract during copulation. After fertilization, conception occurs, and a new animal begins to develop. The fertilized egg is known as a zygote.

In the male reproductive system, the major organs are the testicles, epididymis, scrotum, vas deferens, accessory sex glands, urethra, and penis. In the female reproductive system, the major organs are the ovaries, oviducts, uterus, vulva, clitoris, and vagina. Each reproductive organ has a specific function to attain fertilization and reproduction. A successful livestock producer must be knowledgeable in the reproductive process, especially how male and female sex cells are produced and function.

A female must produce fertile ova that are inseminated at the appropriate phase of the estrous cycle. During estrus, her body becomes sexually responsive, ovulates, and prepares for attachment of the embryo. If not pregnant, her body prepares to begin the cycle again. The estrous cycle occurs throughout the year when the female is not pregnant, except in seasonal breeders, such as sheep and horses, who only ovulate a few times per year.

Coon April 20-24 Choice 2

To determine reproductive health in males, you have to evaluate sperm health. For a breeding male to be effective, their body must produce sperm that are the right size and shape, motile, and free of abnormalities. These attributes can be found through microscopic evaluation of the extended (diluted) sperm.

Expanding Your Knowledge:

Create a three-dimensional model of a female reproductive tract for livestock or a companion animal. When finished, compare and contrast your model with others in the class.

Checking Your Knowledge:

Part One: Matching

Instructions: Match the word with the correct definition.

a. estrogen
b. estrus
c. fertilization
d. gestation
e. oogenesis
f. ovulation
g. parturition
h. progesterone
i. spermatogenesis
j. testosterone

_______ 1. giving birth

_______ 2. period of animal development from pregnancy to birth

_______ 3. the moment when a follicle ruptures and releases an egg

_______ 4. a period of sexual receptiveness—heat

_______ 5. the production of ova

_______ 6. a male developmental hormone

_______ 7. a female developmental hormone

_______ 8. a hormone that helps maintain gestation and assists in regulation of the estrous cycle

_______ 9. the penetration of a male's sperm into a female's egg

_______ 10. the production of sperm

Part Two: Completion

Instructions: Complete the following statements.

1. ___________________________ is the number of offspring that can be born within a specific time.

Coon April 20-24 Choice 2

2. The average gestation length for swine is ________________ days.
3. The ________________ is a two-lobed sac that regulates the temperature of testicles.
4. The process of chromosome pairs fusing together is called ________________.
5. The two AP hormones that are essential to testicular and ovarian function are the ________________ and the ________________.
6. The four phases of the estrous cycle are ________________, ________________, ________________, and ________________.
7. The estrous cycle will normally last for ________________ days in a cow.
8. During the process of spermatogenesis, the meiosis should end with the formation of ________________ mature sperm.
9. Semen health can be evaluated by examining ________________, ________________, and ________________ in a semen sample.
10. The membrane cap of a sperm is called a/an ________________.

Part Three: True/False

Instructions: Write *T* for true or *F* for false.

_______1. Reproduction is the process of producing offspring.

_______2. Meiosis produces gametes.

_______3. The site of fertilization in a female is the vagina.

_______4. The fertilized ovum will typically move to the uterus about three days after fertilization.

_______5. The function of the epididymis is to add volume and nutrients to sperm.

_______6. Sperm morphology, or the movement of sperm, is often a factor in male fertility.

_______7. Seasonal breeders, such a sheep or horses, may experience periods of anestrus during their reproductive life.

_______8. A diploid cell has a single set of chromosomes.

_______9. Common reasons for poor reproductive health in male animals include poor genetics, extreme temperatures, stress, illness, or improper nutrition.

_______10. Proestrus is the last phase of the estrous cycle.

Choice 3

Mr. Coon BSAA Animal Domestication April 20-24

Matching Instructions: Match the word with the correct definition.

a. adaptation f. genetic diversity b. breed g. inbreeding c. artificial selection
h. natural selection d. Evolution i. outbreeding e. gene pool j. purebred

_______1. the survival process in which better-adapted individuals are more likely to make it to a reproductive age than less-fit individuals

_______2. the ability of any organism to adjust or change its physiology or structure to become more suited to their environment

_______3. a group of animals that, as a result of breeding and selection, have certain distinguishable characteristics

_______4. a collection of all the genes within a freely interbreeding population

_______5. the variety of genes within a species

_______6. the cumulative, genetic change in a population of organisms from generation to generation

_______7. the mating of genetically similar (related) individuals

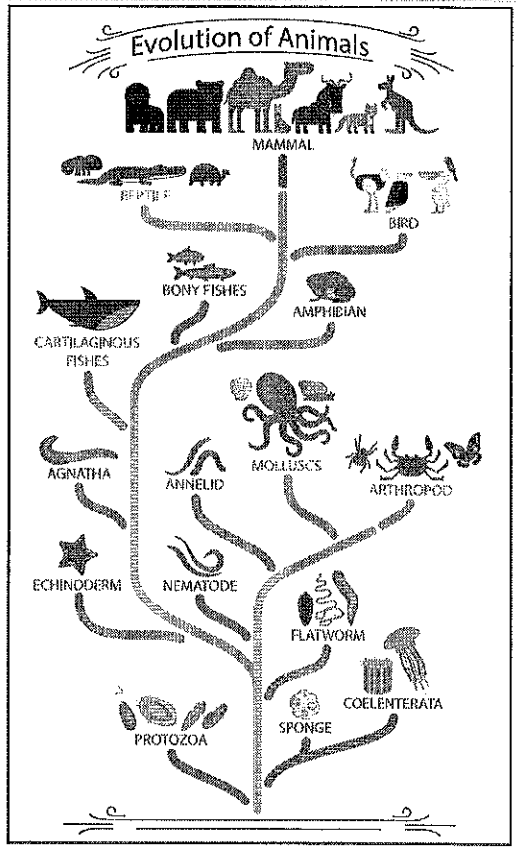
_______8. the practice of intentionally breeding animals (or other organisms) with one or more desirable traits to produce offspring with similar desirable or improved traits

_______9. an animal whose parental lineage (on both sides) is from members of a recognized breed

______10. the mating of unrelated individuals

E-UNIT B1–3

Evolution and Animal Domestication



The theory of evolution has sparked debate since it was first presented by Charles Darwin in 1858. This debate, often very spirited, has taken place on political, theological, and cultural levels. This unit offers scientific insight into the mechanisms behind evolution and the evolution that led to the domestication of animals.

Objective:

Explain the mechanisms for biological evolution and how evolution applies to animal domestication.

Key Terms:

adaptation
analogous structure
artificial selection (selective breeding)
breed
comparative anatomy
convergent evolution
crossbreeding
domestication
evolution
gene pool
genetic diversity
homologous structure
hybrid vigor (heterosis)
inbreeding
inbreeding depression
interspecific hybridization
natural selection
outbreeding
outcrossing
purebred
taming

Com April 26-24 Choice 3

The Genetics of Evolution and Animal Breeding

In a biological sense, **evolution** is the cumulative, genetic change in a population of organisms from generation to generation. Charles Darwin expressed evolution as "descent with modification."

Evolution is both a theory and a fact. Unlike the meaning of the word theory in everyday conversation, in science, theory refers to an explanation of some aspect of nature that is supported by a vast body of evidence. The theory of evolution is based on overwhelming evidence from observations and confirming experiments. Scientists can state, with confidence, that no new evidence will surface to change the concepts of the theory. Evolution is a fact, because the evidence supporting it is so great that its occurrence is no longer in doubt (in the scientific community).

One of the greatest forms of evidence in support of evolution is comparative anatomy. **Comparative anatomy** is the comparison of the structural similarities of organisms to determine their evolutionary relationships. Organisms with more-similar anatomical features are more closely related than organisms with less-similar structures. Those with similarities are assumed to share a common ancestor. Scientists study anatomical similarities and differences to classify organisms and to determine evolutionary lines. Two common concepts of comparative anatomy are homologous structures and analogous structures.

A **homologous structure** is a part of an organism which is similar in different species, because the species have common ancestry (but the similar part may or may not perform the same function). For instance, the bones of vertebrate species are an example. A horse's leg and a chicken's wing are homologous structures.

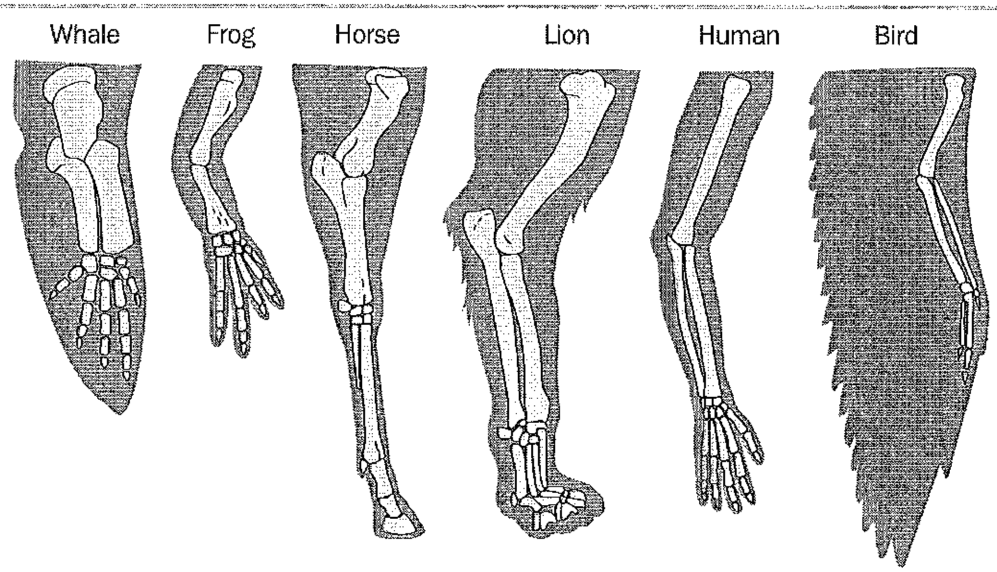


FIGURE 1. Homologous structures.

Coon April 20-24 Choice 3

An **analogous structure** is a part of an organism that serves a similar function in different species, but the species have evolved separately (they do not share a common ancestor). Analogous structures are a result of convergent evolution. **Convergent evolution** is the independent evolution of similar structural or functional traits, resulting from an adaptation to similar environments. In other words, these traits evolved in a similar environment, rather than being inherited from a common ancestor. These structures usually serve the same, or similar, purposes. Examples of analogous structures are the wings of bats, insects, and birds (for flight). Additionally, it could be the fins of fish or wings of penguins (for swimming).

NATURAL AND ARTIFICIAL SELECTION

The evolution of animals happens naturally or artificially. Within these two processes, certain principles are universally observed.

Natural Selection: Mechanisms

Natural selection is the mechanism by which evolution proceeds. **Natural selection** is the survival process in which better-adapted individuals are more likely to make it to a reproductive age than less-fit individuals. These stronger individuals would then create more offspring and make a larger gene-pool contribution than those less fit. A **gene pool** is a collection of all the genes within a freely interbreeding population.

The mechanism of natural selection operates on four observations of the natural world.

- Each species produces more offspring than can be supported—not all will survive to maturity.
- Offspring vary from one another genetically.
- Organisms compete with one another for limited resources.
- Individuals that have the most-favorable combination of characteristics are most likely to survive and reproduce.

Natural Selection: Adaptations for Survival

Through natural selection, different species have evolved mechanisms that better enable them to survive and to perpetuate the species. The ability of any organism to adjust or change its physiology or structure to become more suited to their environment is called **adaptation**. All species have adaptations for survival in certain ecosystems, whether it is in a rainforest, desert, arctic region, or temperate environment. An organism must have both functional and reproductive adaptations in order to ensure that its genes are passed on to the next generation. Adaptations can be anatomical, behavioral, or physiological.

Coor April 20-24 Choice 3

Anatomical Adaptations

Anatomical adaptations involve physical structures (or morphology) such as body size, fur, and teeth. Ruminants are able to acquire nutrients from plant-based food by fermenting it in a specialized stomach. This is accomplished prior to digestion, and, principally, it occurs through microbial actions. Cattle, sheep, goats, and bison are very successful herbivores because of this anatomical adaptation.

FIGURE 2. Sheep have the anatomical features that allow them to acquire nourishment from grass.

Behavioral Adaptations

Behavioral adaptations can be inherited or learned. Chickens establish a pecking order to determine which chickens have first access to food, water, and dust-bathing areas. It also determines who gets the most comfortable nesting boxes and the best spots on the roosting bar. Sheep flock together, and cattle herd for safety. Caribou migrate hundreds of miles to reach birthing grounds. Whales will migrate thousands of miles to feed and breed.

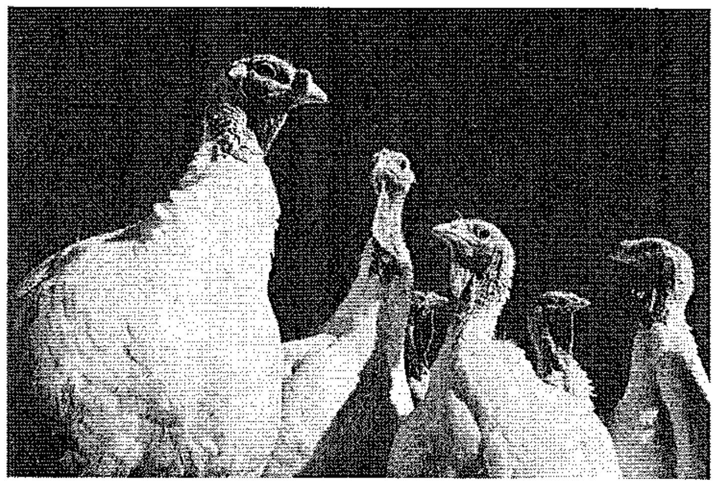


FIGURE 3. The pecking order established in poultry is a behavioral adaptation.

Physiological Adaptations

A physiological adaptation includes the ability to tolerate climatic conditions. For instance, tropical breeds of cattle (*Bos indicus*) evolved from domesticated Asian aurochs and adapted to hot, tropical climates. They are tolerant of intense heat, sun, and humidity. The Brahman breed (*Bos taurus*) is a tropical breed that evolved in Europe and in the Fertile Crescent

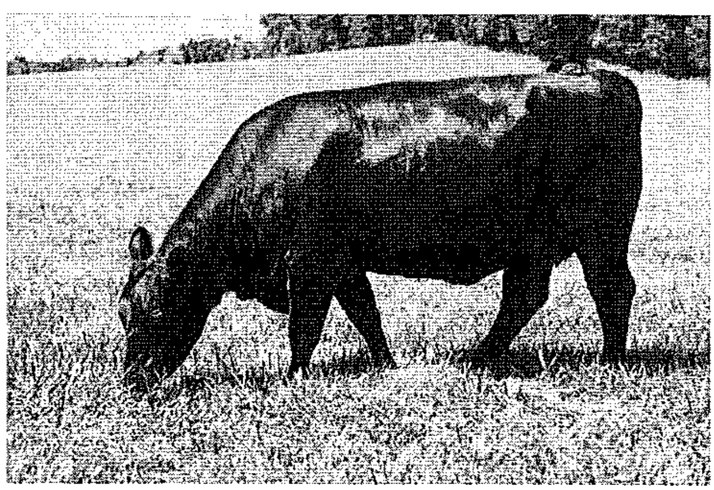


FIGURE 4. The Angus breed is adapted to temperate climates.

Corn April 20-24 Choice 3

(some are bred in the United States). The European beef-cattle breeds are adapted to temperate climates. Most breeds commonly found in the United States belong to this group (Angus, Charolais, Hereford, Simmental, Senepol, and dairy breeds).

Artificial Selection

Understanding the mechanisms of evolution has helped in the development of agricultural animals through artificial selection. **Artificial selection (selective breeding)** is the practice of intentionally breeding animals (or other organisms) with one or more desirable traits to produce offspring with similar desirable or improved traits.

Artificial selection is the change of a domesticated species by human intervention, as opposed to the "natural environment." The mechanisms of artificial and natural selection are essentially the same. However, with artificial selection, farmers or breeders choose the variants to be used in producing the succeeding generations. Modern breeds of pigs, sheep, and cattle are excellent examples of animals that have been altered through artificial selection.

Artificial Versus Natural Selection

TABLE 1. A Comparison of Natural Selection to Artificial Selection

	Natural Selection	Artificial Selection
The Meaning:	The process in nature by which only the organisms that are best adapted to their environment tend to survive and reproduce, transmitting their genetic traits to the next generation.	Artificial selection is when humans act as the "environmental pressure" that shapes populations.
Where It Occurs:	Natural populations	Domestic populations
Controlled by:	Nature	Humans
Rate of Process:	Slow	Much faster
Produces:	Great biological diversity	Varieties of organisms very different from native generations

ANIMAL DOMESTICATION

Domestication is the process by which wild plants and animals are genetically modified over time for traits that are more advantageous or desirable for human use.

The domestication of plants and animals led to humans abandoning a nomadic lifestyle and forming urban communities thousands of years ago. Domestication allowed fewer people to cultivate more food. With more predictable food supplies, people were able to spend more time on crafts, travel, and trade.

Coon April 20-24 Choice 3

Early Domestication

The first incident of the domestication of an animal was that of the gray wolf, occurring around 15,000 years ago. Modern dogs (*Canis lupus familiaris*) are the result of the domestication of the gray wolf (*Canis lupus*). Over years of artificial selection, dogs became a distinct species.

Around 10,000 years ago, people in Mesopotamia began to domesticate goats and sheep for meat, milk, and hides. At about the same time, chickens were domesticated in Southeast Asia. Shortly thereafter, humans began domesticating larger animals, such as oxen and horses, for plowing and transportation. Five species of wild cattle have been domesticated within the last 10,500 years.

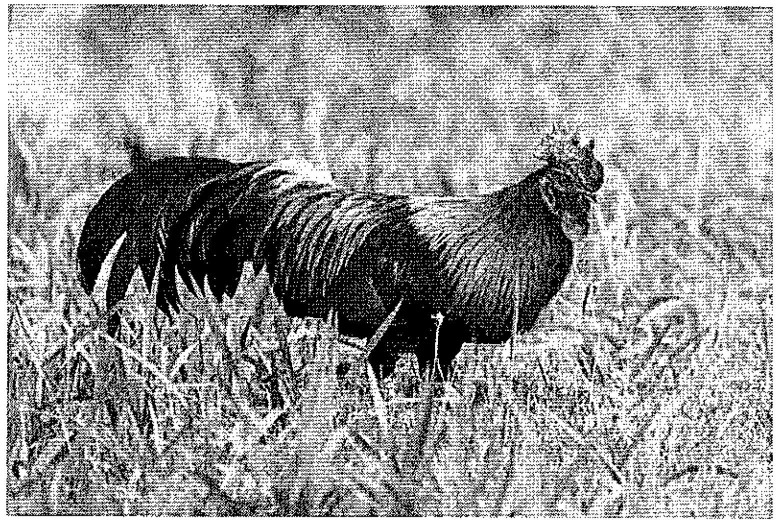


FIGURE 5. The red jungle fowl is believed to have been domesticated about 10,000 years ago.

Domesticated animals can look very different from their wild ancestors. Think of the many modern breeds of dogs and how they differ in appearance to wolves. Also, domesticated chickens look very different from wild chickens. Wild chickens generally weigh about two pounds. Through domestication and selective breeding to yield more meat, they have become much larger. Today, domestic chickens weigh as much as 17 pounds. Wild chickens lay a small number of eggs once a year, while domestic chickens may lay 200 or more eggs each year.

Animals Used in Domestication

Certain animal species proved easier to domesticate than others. This is why only a few animal species out of the thousands that exist have been domesticated. According to professor and biologist Jared Diamond, there are six criteria that animals must meet for domestication. Many species qualify for some of the criteria, but very few species meet all six criteria.

1. A domesticated species must be able to eat a variety of foods and to find enough food in and around human settlements for survival. For instance, cows and sheep forage on grass and eat surplus grains. Dogs and cats scavenge on human leftovers or waste.
2. A domesticated species must reach maturity quickly, especially in relation to the human life. Humans can't afford to devote too much time feeding and caring for an animal before it grows large enough to be put to work or slaughtered.

Coor April 20-24 Choice 3

3. A domesticated species must be willing to breed in captivity. Species such as antelope will not breed in crowded enclosures.
4. A domesticated species must be docile by nature. Cows and sheep are generally submissive. In contrast, the African buffalo and American bison are both unpredictable and very dangerous to humans. Similarly, the zebra, though closely related to the horse, is aggressive and resistant to human interaction.
5. A domesticated species must lack a tendency to panic and flee when startled. Deer and gazelles have flighty temperaments that make them impossible to domesticate. Although sheep are panicky, they have a flocking instinct that activates when they are nervous. This flocking instinct makes herding possible.
6. A domesticated species must conform to a social hierarchy dominated by strong leadership. They should recognize their human caretaker as the group leader. One exception to this criterion is the cat.

Domestication Verses Taming

There is a distinction between domestication and taming. Domestication involves the permanent genetic modification of an animal, which leads to an inherited tolerance toward humans. **Taming** is the training of a wild-born animal through behavioral modification to reduce its natural tendency for avoiding or attacking humans. The goal of taming is tolerance to the presence of humans. There is no genetic modification (through breeding) associated with taming.

Digging Deeper... *UNCOVERING ADDITIONAL FACTS*

Where Animals Were Originally Domesticated

- The first domesticated sheep and goats appeared in Southwest Asia.
- Chickens were first domesticated in Southeast Asia.
- All cattle are descended from as few as 80 animals that were domesticated from wild oxen in Western Asia.
- The domestication of hogs occurred independently from wild-boar subspecies in Europe and Asia.
- Dogs were domesticated separately in Eastern and Western Eurasia.
- The Arabian or dromedary camel was domesticated in Arabia.
- Water buffalo were domesticated in China.
- Wild tarpan horses, believed to be the ancestors of modern horses, were domesticated in Ukraine.
- The donkey was domesticated in Egypt.
- The domestication of llamas and the alpacas occurred in South America. Some historians believe South Americans saved these species from the brink of extinction.

Coon April 20-24 Choice 3

GENETIC BASIS OF ANIMAL BREEDING

The domestication of animals has produced breeds. A **breed** is a group of animals that, as a result of breeding and selection, have certain distinguishable characteristics. Animals of a breed share a phenotype, or they have a homogeneous appearance and behavior. These shared characteristics distinguish the breed from other organisms of the same species. Breeds are developed through genetic isolation or a natural adaptation to the environment, selective breeding (artificial) for the environment, or a combination of the two.

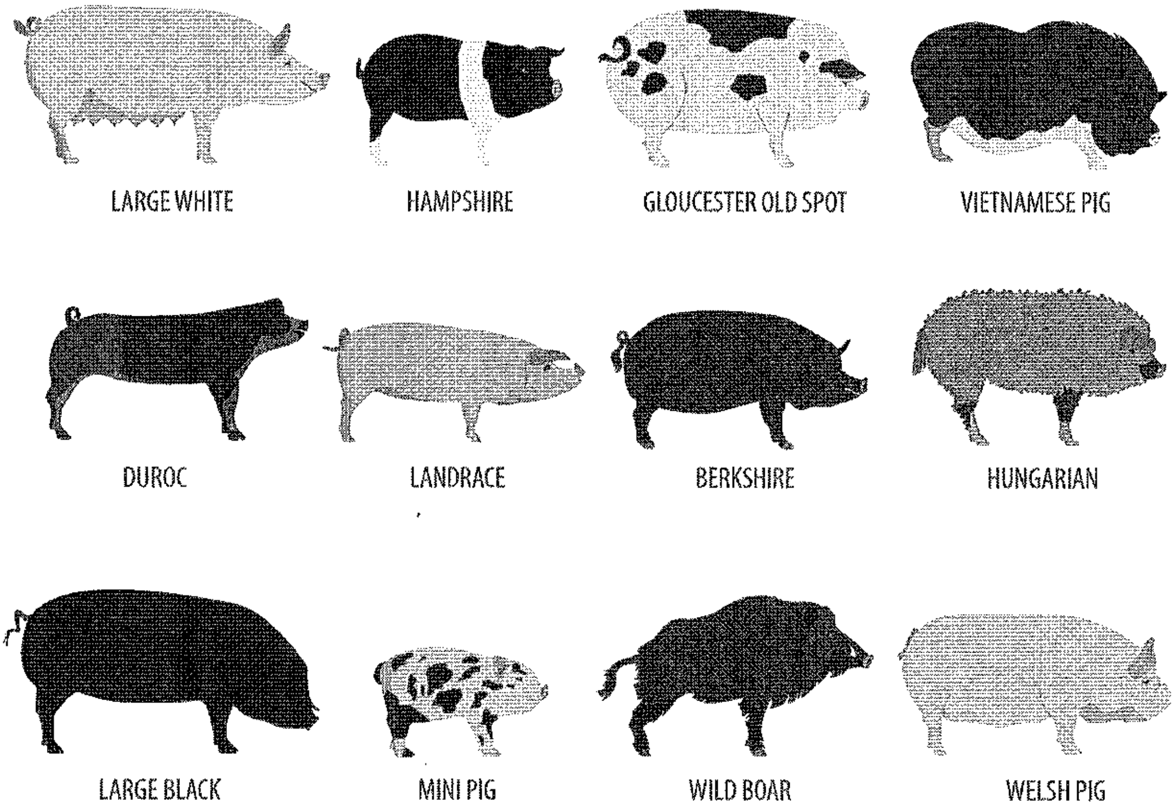


FIGURE 6. Hog breeds are distinguished by certain characteristics.

Objectives of Animal Breeding

The main objectives of animal breeding are:

1. To improve the growth rate of the breed
2. To increase the production of milk, meat, eggs, wool, etc.
3. To produce superior quality of milk, meat, eggs, wool, etc.
4. To improve animal resistance to various diseases
5. To increase the productive life of an animal
6. To increase or improve the rate of reproduction

Coon April 20-24 Choice 3

Methods of Animal Breeding

Inbreeding, outbreeding, outcrossing, crossbreeding, and interspecific hybridization are all forms of animal breeding.

Inbreeding

Inbreeding is the mating of genetically similar (related) individuals. Inbreeding increases the number of individuals that are homozygous for a trait with each successive generation. Therefore, it increases the expression of recessive traits. In practice, a superior cow and a superior bull of the same breed are identified and mated. The offspring are evaluated, and from these, a superior male and female are identified for further mating. This process is followed for four to six generations.

Purebred animals are a result of inbreeding. A **purebred** is an animal whose parental lineage (on both sides) is from members of a recognized breed. The parents are homozygous for certain traits. In other words, a purebred animal is the result of mating by animals with the same breed that have had an unmixed lineage over many generations. For example, the mating of dogs of the same breed results in offspring with traits that are very predictable.

Inbreeding can lead to inbreeding depression. **Inbreeding depression** is the lowered ability of a population to survive and reproduce—a result of mating between close relatives. Fertility and productivity can be restored in the population through the mating of superior, unrelated animals from the same breed. Inbreeding depression occurs in wild animals, plant populations, and in humans.

Outbreeding

Outbreeding is the mating of unrelated individuals. Outbreeding often leads to offspring that are better adapted for survival than their parents (inciting hybrid vigor). **Hybrid vigor (heterosis)** is a tendency of an organism to have superior qualities over those of the parents, such as size, growth rate, yield, disease resistance, and fertility. Animal breeders achieve hybrid vigor by mating two different purebred lines that have advantageous traits. Outbreeding may occur as outcrossing, crossbreeding, or interspecific hybridization.

OUTCROSSING

Outcrossing is the mating of animals of the same breed that have had no common ancestors in the parental lineage for up to four to six generations. Outcrossing introduces unrelated genetic material into a breeding line, and it increases genetic diversity. In some cases, only one outcross is required to overcome inbreeding depression.

CROSSBREEDING

Crossbreeding is the process of producing offspring through the mating of two purebred individuals that come from different breeds, varieties, or species. Superior males of one breed are mated with superior females of another breed. As an example, the

Coon April 20-24 Choice 3

Hisardale sheep is a new breed (from Punjab) created by crossing Bikaneri ewes and Marino rams.

INTERSPECIFIC HYBRIDIZATION

Interspecific hybridization is the mating of animals from two different species. The progeny obtained from such a mating are usually different from both the parental species. The offspring may exhibit desirable characters from both parents. For example, a mule is produced from a cross between a female horse and a male donkey. Mules are reputed to be more patient, hardier, and live longer than horses. They are also less obstinate and more intelligent than a donkey.

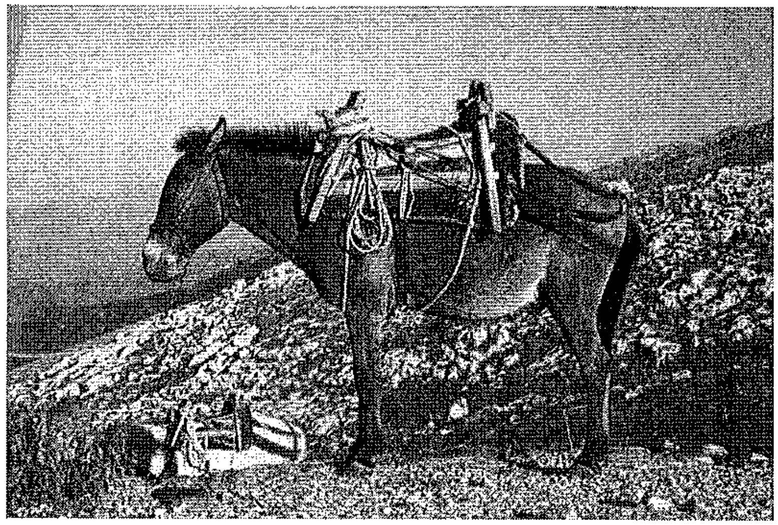


FIGURE 7. A mule is the result of interspecific hybridization.

Genetic Diversity

Genetic diversity is the variety of genes within a species. Over hundreds and thousands of years, farmers have found ways to improve the quality and yield of livestock and poultry through artificial selection. However, one of the major problems with artificial selection is its effect on genetic diversity.

Genetic diversity is important in agriculture. Many local breeds have gone extinct in the past 100 years. During that time, people have favored more-productive breeds produced on an industrial scale. Even individuals of industrial breeds have been decreasing in genetic diversity. The loss of breeds to extinction also means a loss of genetic diversity, and this loss reduces a species' capacity to adapt to new diseases, climate changes, or food sources.

Summary:

Evolution is the cumulative, genetic change in a population of organisms from generation to generation. Evolution is both a theory and a fact. One of the greatest forms of evidence in support of evolution is comparative anatomy.

Natural selection is the survival process in which better-adapted individuals are more likely to make it to a reproductive age than less-fit individuals. These stronger individuals

Coon April 26, 24 Choice 3

would then create more offspring and make a larger gene-pool contribution than those less fit.

Artificial selection (selective breeding) is the practice of intentionally breeding animals (or other organisms) with one or more desirable traits to produce offspring with similar desirable or improved traits. With artificial selection, farmers or breeders choose the variants to be used in producing the succeeding generations.

Domestication is the process by which wild plants and animals are genetically modified over time for traits that are more advantageous or desirable for human use.

The domestication of animals has produced breeds. A breed is a group of animals that, as a result of breeding and selection, have certain distinguishable characteristics. Breeds are developed through genetic isolation or a natural adaptation to the environment, selective breeding (artificial) for the environment, or a combination of the two. Inbreeding and outbreeding are the two main methods of animal breeding.

Genetic diversity is the variety of genes within a species. A loss of genetic diversity reduces a species' capacity to adapt to new diseases, climate changes, or food sources.

Expanding Your Knowledge:

Learn more about how evolution relates to agriculture by going on YouTube to watch the BrainStuff video, "Why Don't Humans Ride Zebras?," at https://www.youtube.com/watch?v=RMpMxaX3Kdg.

Checking Your Knowledge:

Part One: Matching

Instructions: Match the word with the correct definition.

a. adaptation
b. breed
c. artificial selection
d. evolution
e. gene pool
f. genetic diversity
g. inbreeding
h. natural selection
i. outbreeding
j. purebred

________1. the survival process in which better-adapted individuals are more likely to make it to a reproductive age than less-fit individuals

________2. the ability of any organism to adjust or change its physiology or structure to become more suited to their environment

________3. a group of animals that, as a result of breeding and selection, have certain distinguishable characteristics

________4. a collection of all the genes within a freely interbreeding population

Coon April 20-24 Choice 3

________5. the variety of genes within a species

________6. the cumulative, genetic change in a population of organisms from generation to generation

________7. the mating of genetically similar (related) individuals

________8. the practice of intentionally breeding animals (or other organisms) with one or more desirable traits to produce offspring with similar desirable or improved traits

________9. an animal whose parental lineage (on both sides) is from members of a recognized breed

________10. the mating of unrelated individuals

Part Two: Completion

Instructions: Complete the following statements.

1. ____________________ is the comparison of the structural similarities of organisms to determine their evolutionary relationships.
2. A/an ____________________ is a part of an organism which is similar in different species, because the species have common ancestry (but the similar part may or may not perform the same function).
3. A/an ____________________ is a part of an organism that serves a similar function in different species, but the species have evolved separately (they do not share a common ancestor).
4. ____________________ is the independent evolution of similar structural or functional traits, resulting from an adaptation to similar environments.
5. ____________________ is a tendency of an organism to have superior qualities over those of the parents, such as size, growth rate, yield, disease resistance, and fertility.
6. ____________________ is the process of producing offspring through the mating of two purebred individuals that come from different breeds, varieties, or species.
7. ____________________ is the training of a wild-born animal through behavioral modification to reduce its natural tendency for avoiding or attacking humans.
8. ____________________ is the process by which wild plants and animals are genetically modified over time for traits that are more advantageous or desirable for human use.
9. ____________________ is the lowered ability of a population to survive and reproduce—a result of mating between close relatives.
10. ____________________ is the mating of animals of two different species.

Coon April 20-24 Choice 3

Part Three: True/False

Instructions: Write *T* for true or *F* for false.

_______1. Evolution is both a theory and a fact.

_______2. An observation of the natural world (related to natural selection) is that each species produces more offspring than can be supported—not all will survive to maturity.

_______3. Artificial selection is also known as selective breeding.

_______4. One criterion for domestication is that the animal must be a herbivore.

_______5. The mechanisms of natural and artificial selection are essentially the same.

_______6. Behavioral adaptations include the ability to tolerate climatic conditions.

_______7. Individuals of industrial breeds have been increasing in genetic diversity.

_______8. Analogous structures are a result of convergent evolution.

_______9. Animals of a breed share a phenotype, and they have a homogeneous behavior.

_______10. Hybrid vigor lowers a population's ability to survive and reproduce.