NATIONAL OPEN UNIVERSITY OF NIGERIA

FACULTY OF AGRICUTURAL SCIENCES

COURSE CODE: AGR207

COURSE TITLE: ANATOMY AND PHYSIOLOGY OF FARM ANIMALS

COURSE MATERIAL WRITER/DEVELOPER: DR. C. E. ISIDAHOMEN

Department of Animal Science

Faculty of Agriculture

Ambrose Alli University Ekpoma

Introduction

The course AGR207 (anatomy and physiology of farm animals), is a two (2) credit unit course designed for 200 level undergraduate students pursuing a degree in Agricultural Science. The course is expected to provide a good knowledge base for the future manpower for animal towards a sustainable production of livestock. It explains the rudimentary of Anatomy and physiological traits, Parts of the beef and dairy cattle, sheep, goats, pigs, rabbits and poultry, fundamentals of cell biology, anatomy and physiology of the cell, cell types. anatomy and physiology of animal tissues, nervous system, skeletal system, muscle, bone, circulatory system, reproductive, digestive, special senses and other systems of farm animals. Physiological functions of animals – homeostatic, nutrition and digestion, respiration. Temperature regulation, excretion and reproduction, endocrinology, the blood and circulation, lactation, milk let down and egg production, water balance. The course will provide a basic foundation for students intending to take up Animal science as a Career in the future. The course is divided into four (4) modules with unit one to eleven units. Each unit begins with a clear introduction and statement of objectives followed by the main content. The conclusion, summary and references (for further reading) were also provided for each unit. Tutor marked assignments were provided for each unit to enable you attempt some questions on the topics treated for onward submission to your tutor. The Course Guide provides you with access to brief information and overview of the course content, course duration, what you are expected to know in each unit, what course material you need to use and how you can systematically go through the course materials.. Thus, we intend to achieve the above through the following broad aim and other specific objectives.

Course Aim

Anatomy and Physiology of Farm Animals is designed to provide you with the knowledge of different types of farm animals, various physiological functions and structures. It also enlighten the students on the different types of animals and their adaptive features.

Course Objectives

On successful completion of the course, you should be able to:

- Explain the different parts of livestock andfundamentals of cell biology
- Explain the different anatomy andphysiologyof the cell, cell types

- Explain anatomy and physiology of animal tissues, nervous system, skeletal system, muscle, bone, circulatory system, reproductive, digestive, special senses and other systems of farm animals.
- Mention the different Physiological functions of farm animal.

Working through this Course

You are expected to study and understand the content of this course. Each unit must be properly studied for good comprehension of the contents. By the end of each unit, you are expected to answer the questions therein and submit as appropriate when directed by the administration of the University. These questions are like continuous assessment. You are expected to sit for an examination on completion of the course. The course duration shall take about 17 weeks of learning. Therefore, you must be able to organize your time to achieve this successfully. Tutorial session will be available and it is advisable for you to attend in order to be able to assess and compared yourself with your peers and clarify any area that you do not properly understand.

The Course Material

Major components of the course material are:

- The Course Guide
- Study Units
- The References/Further Reading, that will be provided at the end of each unit are necessary supplements to the course material.

The term anatomy has come to refer to the science that deals with the form and structure of all organisms. Literally, the word means to cut apart; it was used by early anatomists when speaking of complete dissection of a cadaver. In contrast to anatomy, which deals primarily with structure, physiology is the study of the integrated functions of the body and the functions of all its parts (systems, organs, tissues, cells, and cell components), including biophysical and biochemical processes. When anatomy and physiology courses are taught separately, the approach to the laboratory portion of each course is considerably different. Study in a typical gross anatomy laboratory is based primarily on dissection of animal cadavers. These usually have been preserved by embalming, and one or more parts of the vascular system have been injected with a colored material to facilitate identification of the vessels. Careful dissection coupled with close observation gives the student a concept of the shape, texture, location, and relations of structures visible to the unaided eye that can be gained in no other way. Similarly, the use of the micro-scope with properly prepared tissue sections on slides is essential for understanding structures that are so small they cannot be seen without optical or electron microscopic assistance. In the physiology laboratory, the student studies the response of whole animals, isolated Descriptive Terms Useful in the Study of Anatomy Microscopic Anatomy: Animal Cells and Tissues Epithelial Tissues Connective Tissues Muscle Tissue Nervous Tissue the General Plan of the Animal Body

MODULE 1: Different parts of livestock

Unit 1: Different parts of livestock

- 1.1 Parts of cattle(beef and dairy)
- 1.2 Parts of sheep
- 1.3 Parts of goats
- 1.4Parts of rabbits
- 1.5 Parts of poultry

MODULE 2: Fundamentals of cell biology,Anatomy and physiology of cellandcell types.

Unit 1: Types cell

Unit 2: Cell theory

Unit 3: Function of Cell

Unit 4: Characteristic of a cell

Unit 5: Cell structure

Unit 6: Cell membrane

Unit 7: Cytoplasm

Unit 8: Cell division

Unit 9:Cell as a factor

MODULE 3: Anatomy and physiology of farm animals

Unit 1: Animal tissue

Unit 2: Nervous system

Unit 3: Skeletal systems

Unit 4: Muscles

Unit 5: Circulatory systems

Unit 6: Reproductive systems

Unit 7: Digestive systems

MODULE 4: Physiology functions of farm animals

Unit 1: Homeostasis

Unit 2: Nutrition and digestion

Unit 3: Respiratoryand thermoregulation

Unit 4: Physiology and temperature regulation

Unit 5: Excretion and reproduction

Unit 6: Endocrinology

Unit 7: The blood and circulation

Unit 8: Lactation

Unit 9: Milk let down and egg production

Unit 10: Physiology of egg production

Unit 11: Water balance

Assessment

The assessment of the course shall be in two parts. The Tutor-Marked Assignments (TMAs) will take a part while the end of course written examination takes the second part. As a result, you must do the TMAs applying the knowledge and techniques learnt in each unit. The assignment must be submitted to your tutor/facilitator for assessment in accordance with the set time in the presentation schedule. The TMAs assessment will constitute 30% while the written examination account for 70% of the total mark for the course.

Tutor-Marked Assignment

The TMA is a continuous assessment component of your course. It carries 30% of the total score. You will be given four TMAs to answer. Three of these must be answered before you are allowed to sit for the end of the course examination. The TMA would be given to you by your facilitator and you should submit after you have done the assignment.

End of Course Examination

The examination concludes the assessment for this course. It constitutes 70% of the mark for the whole course. You will be informed of the time for the examination.

Summary

Feed formulation is a course that gives you a good understanding of the different kind of feedstuffs for livestock, raw materials for processing, different methods for compounding feeds. It teaches the skills of handling, processing storing feeds and also feeds availability for livestock. Other information inclusive are ant nutritional factors in livestock feeds, law governing establishing of feed mill

Best wishes.

The study of the bones that make up the skeleton, or framework of the body, is osteology. The skeleton gives a basis for the external structure and appearance of most vertebrate animals as we know them. All mammals share a basic body plan with striking similarities in skeletal structure. Differences reflect adaptations to specific lifestyles .The skeleton of a living animal is made up of bones that are themselves living structures. They have blood vessels, lymphatic vessels, and nerves; they are subject to disease; they can undergo repair; and they adjust to changes in stress. The functions of bones include providing protection, giving rigidity and form to the body, acting as levers, storing minerals, and forming the cellular elements of blood.

Functions of Bones

Protection of vital organs is one of the important functions of bones. The central nervous system is protected by the skull and vertebral column; the heart and lungs, by the rib cage; and internal parts of the urogenital system, by the pelvis. In the vertebrates, locomotion, defense, offense, grasping, and other activities of this type depend largely upon the action of muscles that attach to levers. Almost without exception, these levers are made of bone and are integral parts of the skeleton.

MODULE 1: DIFFERENT PARTS OF LIVESTOCK

UNIT 1: PARTS OF LIVESTOCK

CONTENTS

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Know the different parts of livestock
- Identify the function of the skeletal system
- Know the different types of bones and functions

3.0 MAIN CONTENT

- 3.1 Parts of the beef and dairy cattle
- 3.1.1 Parts of the sheep
- 3.1.2 Parts of the goats

- 3.1.1.3 Parts of the pigs
- 3.1.4 Parts of the rabbits
- 3.1.5 Parts of the poultry

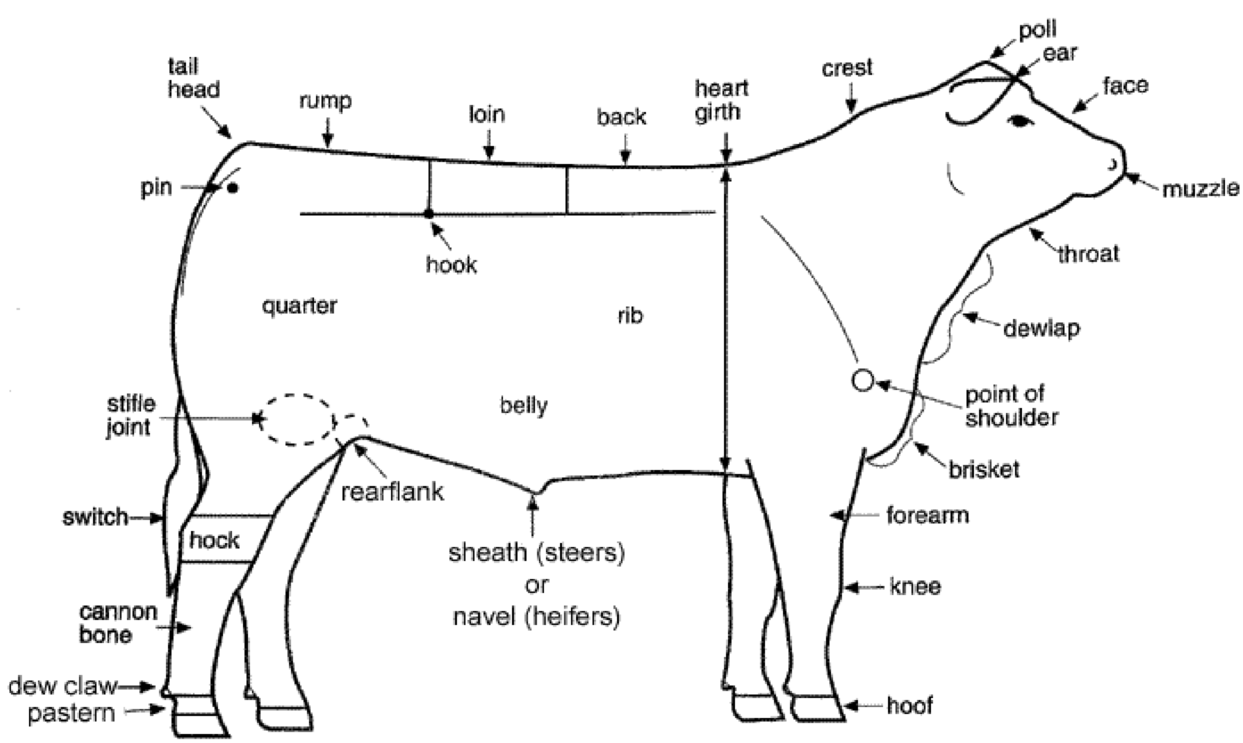
INTRODUCTION

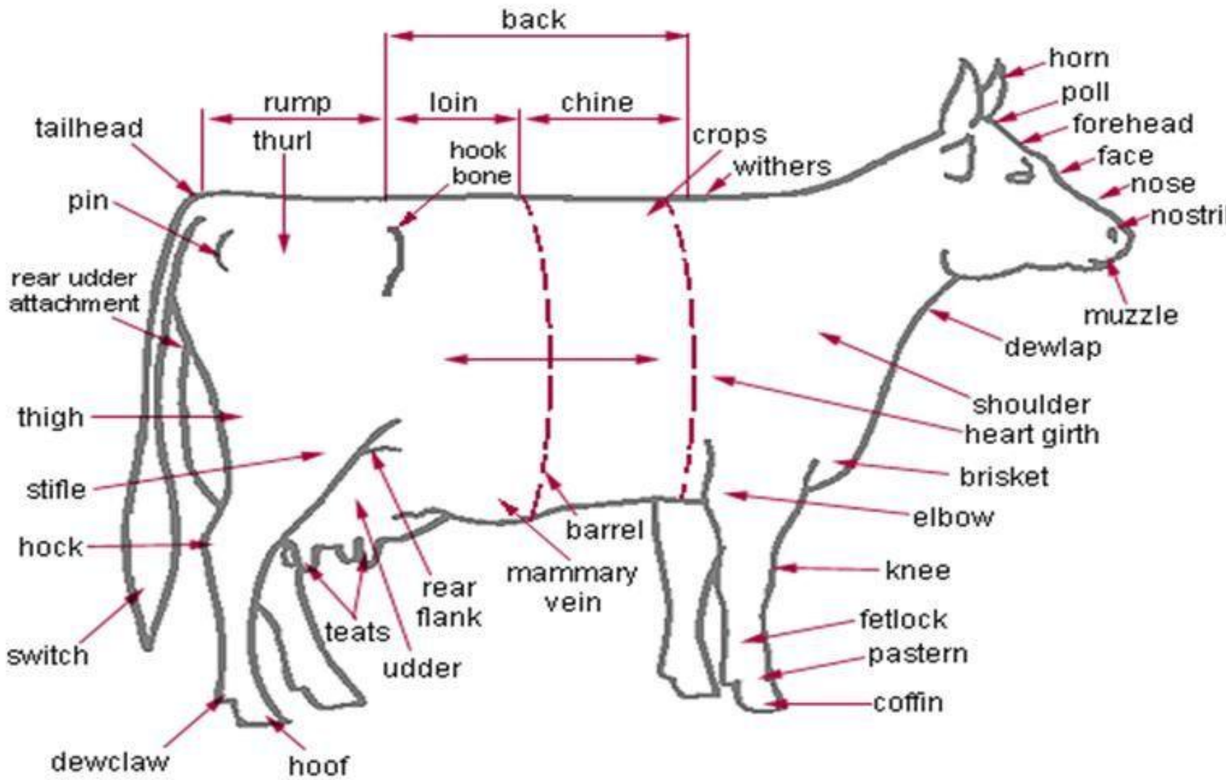
The skeleton act as the protection of vital organs is one of the important functions of bones. The central nervous system is protected by the skull and vertebral column; the heart and lungs, by the rib cage; and internal parts of the urogenital system, by the pelvis. In the vertebrates, locomotion, defense, offense, grasping, and other activities of this type depend largely upon the action of muscles that attach to levers. Almost without exception, these levers are made of bone and are integral parts of the skeleton.

Unit 1: Parts of the beef and dairy cattle, sheep, goats, pigs, rabbits and poultry

Parts of the Beef and Dairy Cattle,

3.1 Bovine Skeletal System

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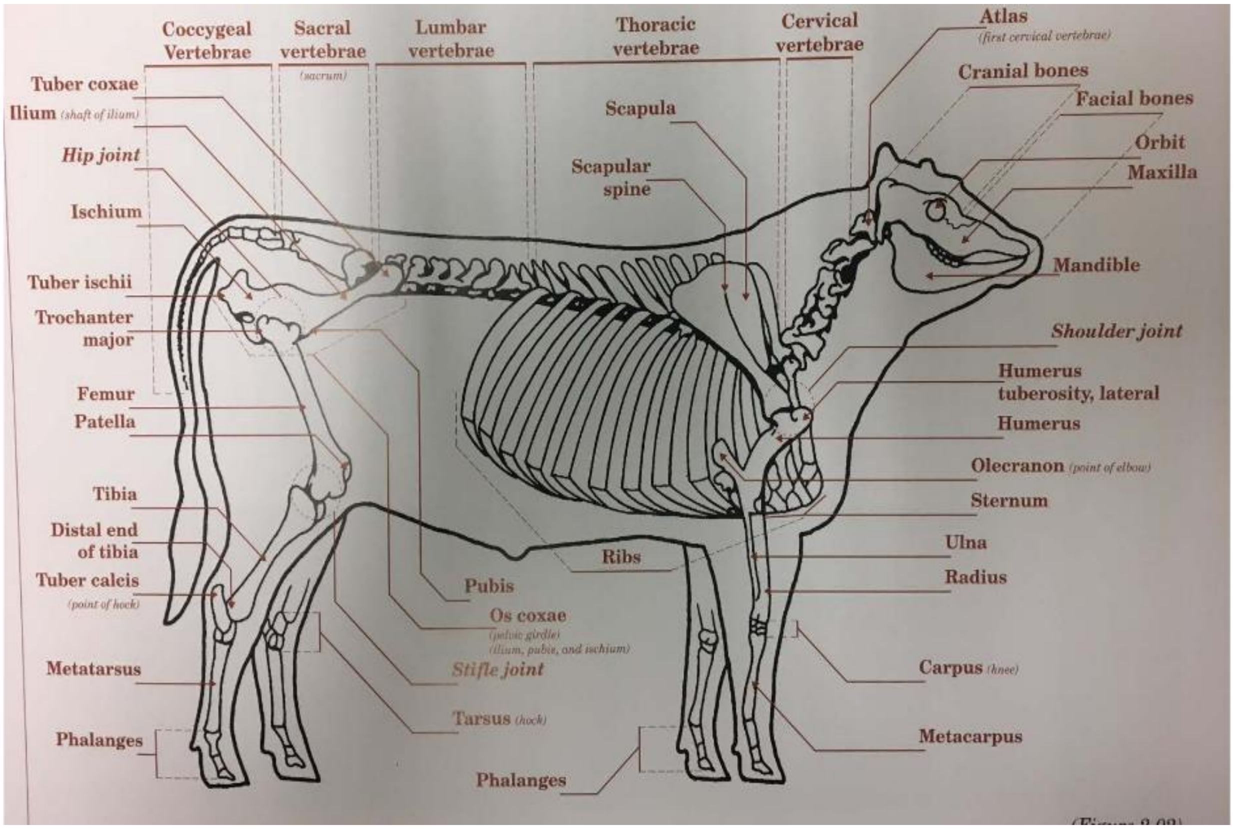
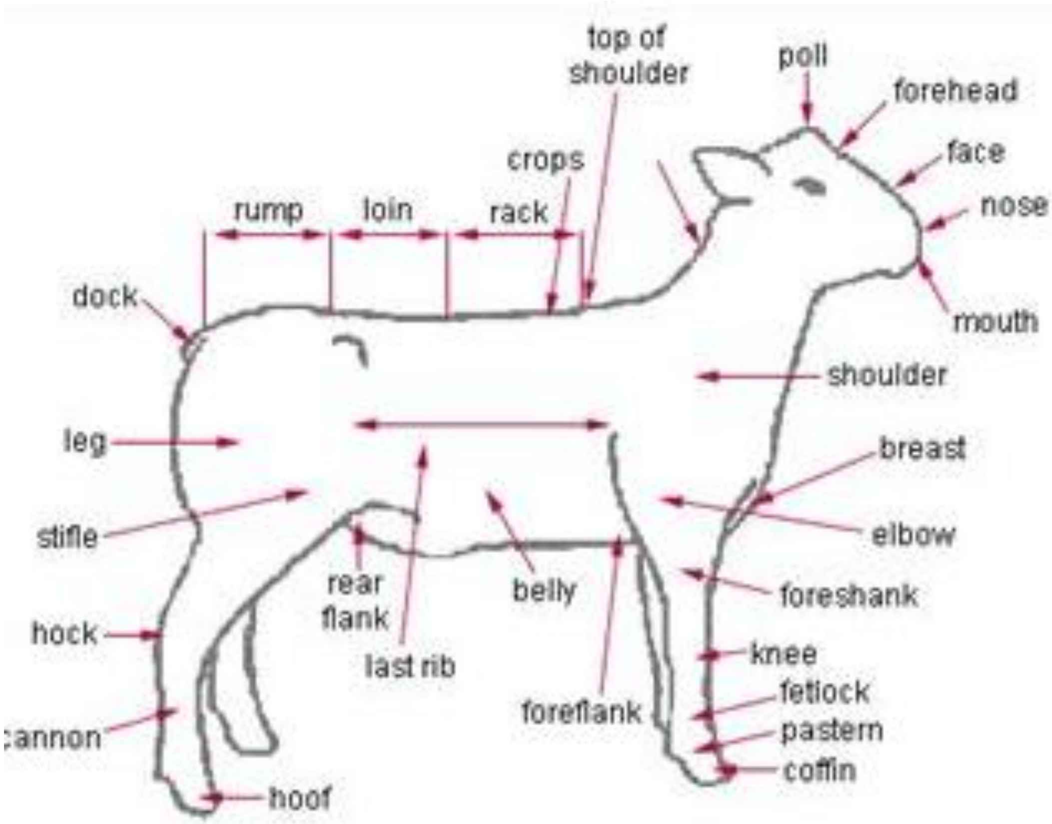


3.1.1Parts of Sheep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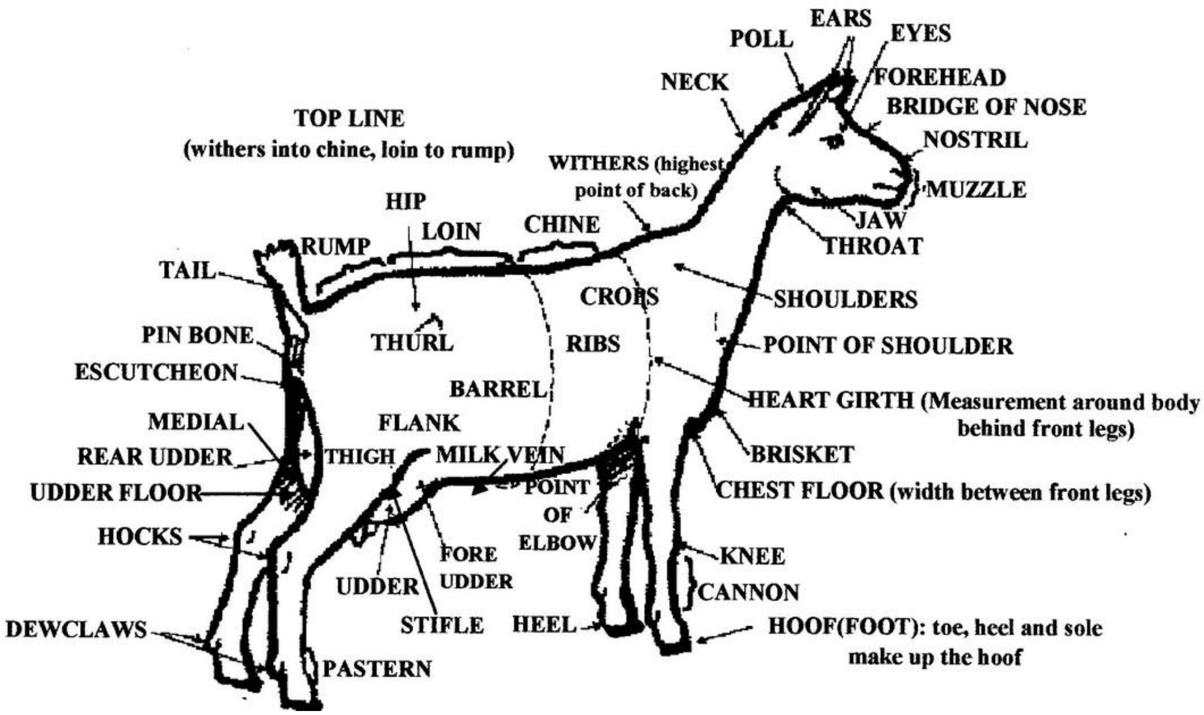
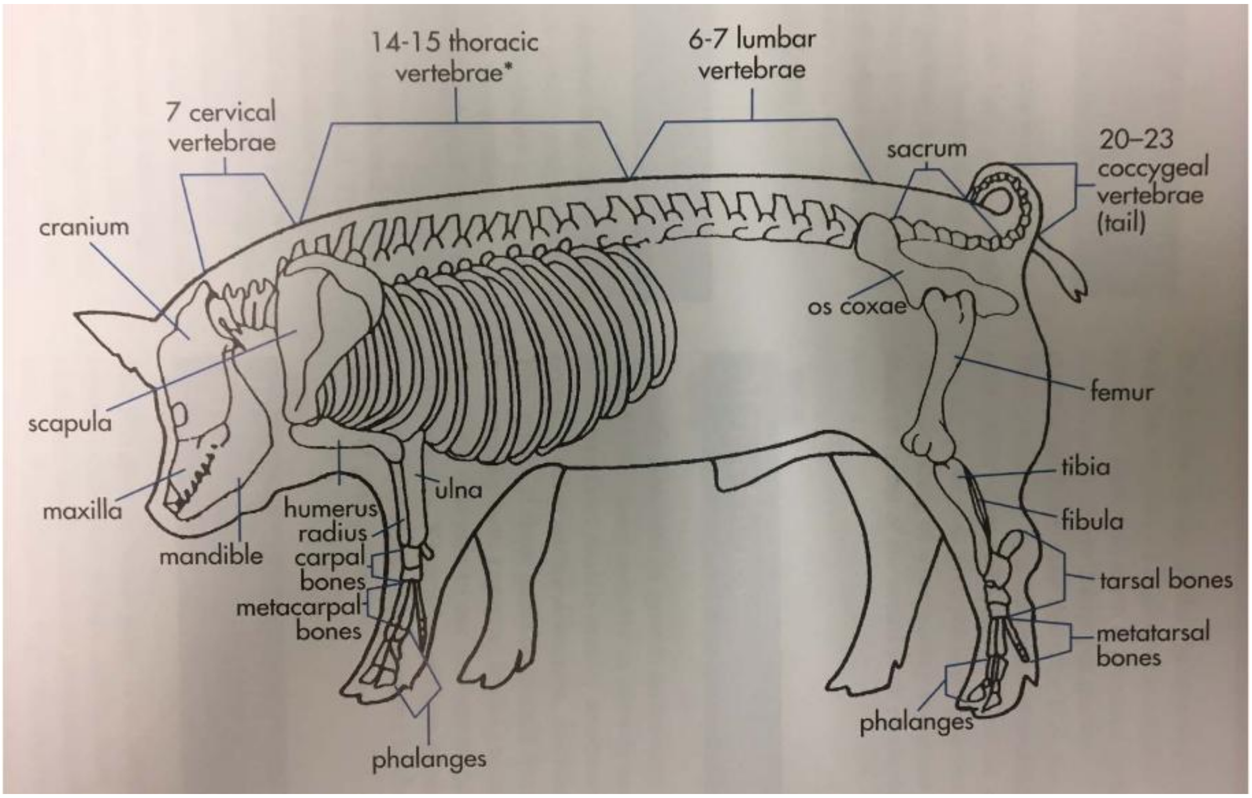
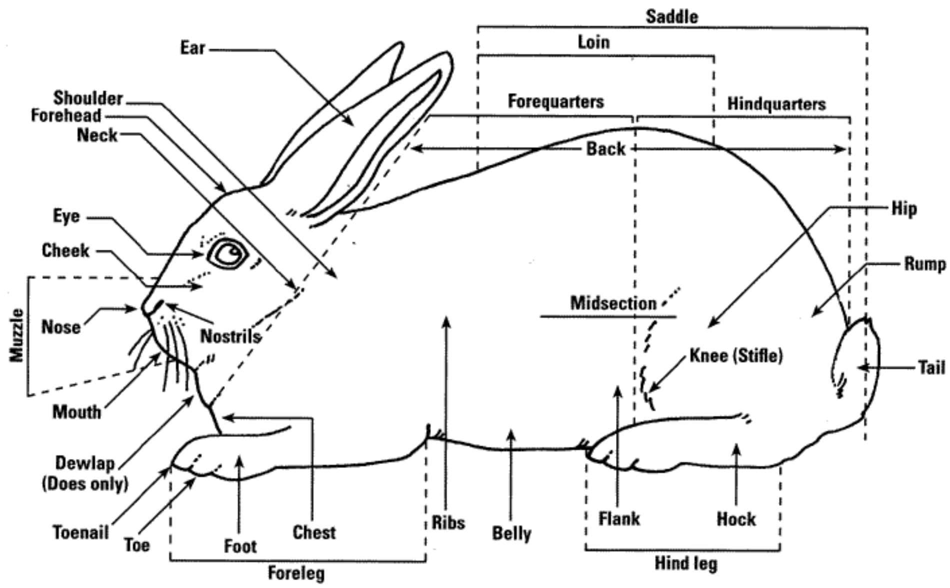


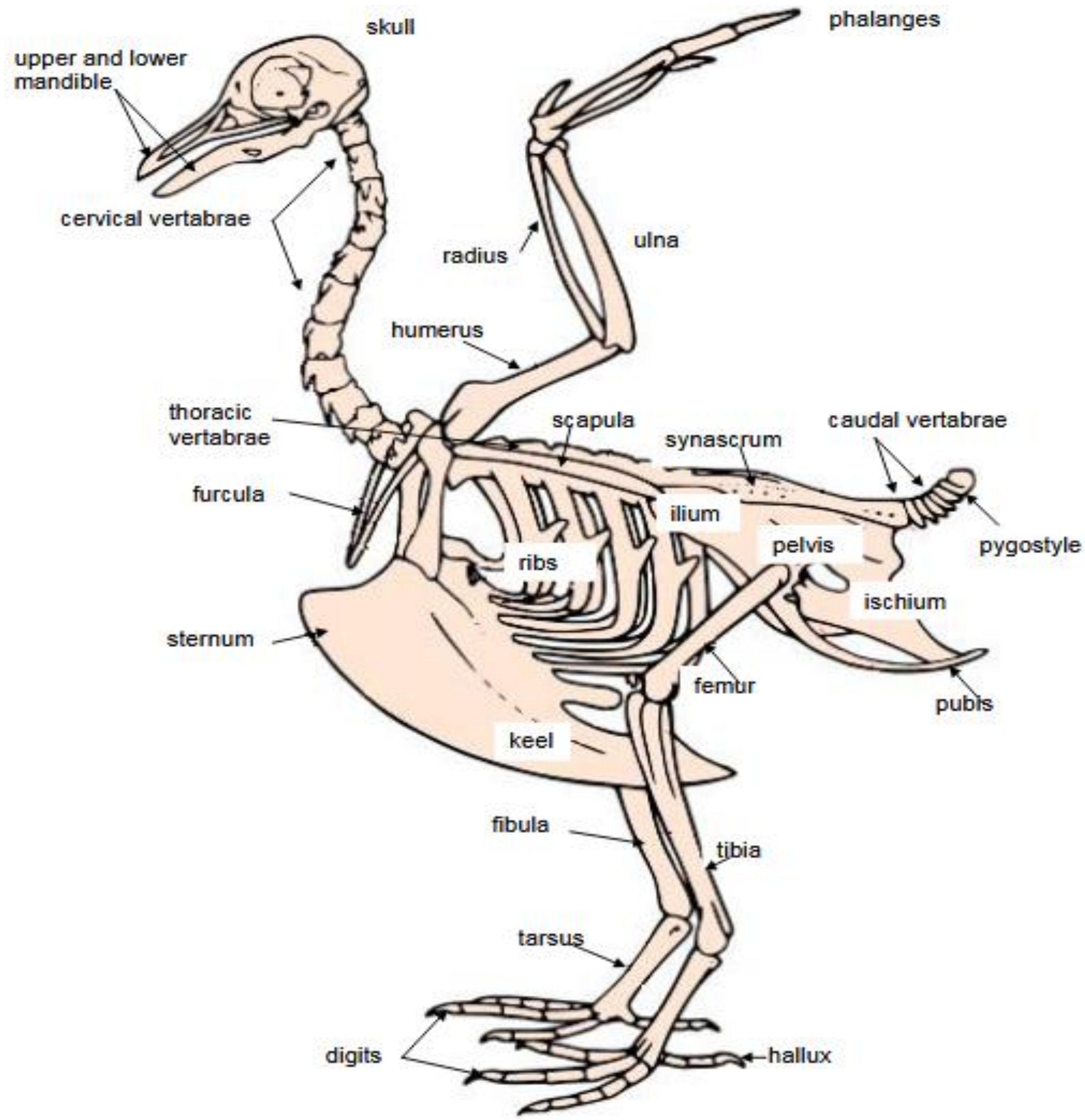
3.1.3: Parts of goats



3.1.4: Parts of Pigs



3.1.5: Parts of Rabbits



3.1.6: Parts of Poultry

3.1: Skeleton

The study of the bones that make up the skeleton, or framework of the body, is osteology. The skeleton gives a basis for the external structure and appearance of most vertebrate animals as we know them. All mammals share a basic body plan with striking similarities in skeletal structure. Differences reflect adaptations to specific lifestyles .The skeleton of a living animal is made up of bones that are themselves living structures. They have blood vessels, lymphatic vessels, and nerves; they are subject to disease; they can undergo repair; and they adjust to changes in stress. The functions of bones include providing protection, giving rigidity and form to the body, acting as levers, storing minerals, and forming the cellular elements of blood.

3.2: Functions of Bones

Protection of vital organs is one of the important functions of bones. The central nervous system is protected by the skull and vertebral column; the heart and lungs, by the rib cage; and internal parts of the urogenital system, by the pelvis. In the vertebrates, locomotion, defense, offense, grasping, and other activities of this type depend largely upon the action of muscles that attach to levers. Almost without exception, these levers are made of bone and are integral parts of the skeleton.

4.0: Conclusion

Decades of documented evidence demonstrates that Protection of vital organs is one of the important functions of bones.

5.0: Summary

The skeleton gives a basis for the external structure and appearance of most vertebrate animals as we know them. All mammals share a basic body plan with striking similarities in skeletal structure. Differences reflect adaptations to specific lifestyles .The skeleton of a living animal is made up of bones that are themselves living structures.

6.0: Tutor marked assignment

- Define skeletal systems and give example of how it is being used
- What are the functions of bones

1.7 References/ Further Reading

Babayemi,Olaniyi J, Abu,Okhiomah, A and Opakunbi, Ayotunde(2014). INTEGRATED ANIMAL HUSBANDRY for schools and colleges.ISBN978-978-52033-3-3-2

MODULE 2: FUNDAMENTALS OF CELL BIOLOGY.

CONTENTS

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Know the different parts of livestock
- Identify the function of the skeletal system
- Know the different types of bones and functions

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3.0 MAIN CONTENT

3.1: Types **of Cells**

Cells are similar to small factories with different labourers and departments that work all the time to make life possible. Various types of cells perform different functions.

There are two major kinds of living organisms based on their cellular structure namely:

- Prokaryotes
- Eukaryotes

Prokaryotes

1. Prokaryotes are made up of cells with no nucleus.
2. They all are single-celled microorganisms including archaea, bacteria and photosynthetic blue-green algae known as cyan bacteria.
3. The cell size ranges from 0.1 to 0.5 μm in diameter.
4. The hereditary material DNA is found in the nucleoid present in the central part of the cell.
5. They reproduce by binary fission.

Eukaryotes

1. Eukaryotes are made up of cells consisting of a true nucleus.
2. This large category involves all plants, fungi (such as moulds, yeast, and mushrooms), protozoa (Plasmodium falciparum and parasite that cause malaria) and animals.
3. The plasma membrane is responsible for monitoring the transport of nutrients and electrolytes in and out of the cell and also responsible for cell to cell communication.
4. Cellular life is entirely dependent on the various chemical process for survival. These chemical reactions mainly occur in a watery solution within the cell known as cytoplasm.
5. They reproduce sexually as well as asexually.

6. There are some contrasting features between plant and animal cell. For eg., the plant cell contains chloroplast, central vacuoles, and other plastids, whereas the animal cell does not.

3.1.1: Cell Theory

Cell Theory was proposed by the German scientists, Theodor Schwann, Matthias Schleiden, and Rudolf Virchow. The cell theory states that:

1. All living species on Earth are composed of cells.
2. A cell is the basic unit of life.
3. All cells arise from pre-existing cells.

A **modern version of the cell theory** was eventually formulated and it contains the following postulates:

1. Energy flows within the cells.
2. Hereditary information is passed on from one cell to the other.
3. The chemical composition of all the cells is the same.

3.1.2: Functions of a Cell

A cell performs six major functions essential for the growth and development of an organism. The functions of a cell include:

Provides Support and Structure

All the organisms are made up of cells. They form the structural basis of all the organisms. The cell wall and the cell membrane are the main components that function to provide support and structure to the organism. For eg., the skin is made up of a large number of cells. Xylem present in the vascular plants is made of cells that provide structural support to the plants.

Facilitate Growth Mitosis

In the process of mitosis, the parent cell divides into the daughter cells. Thus, the cells multiply and facilitate the growth in an organism.

Allows Transport of Substances

Various nutrients are imported by the cells to carry out various chemical processes going on inside the cells. The waste produced by the chemical processes is eliminated from the cells by active and passive transport.

Small molecules such as oxygen, carbon dioxide, and ethanol diffuse across the cell membrane along the concentration gradient. This is known as passive transport.

The larger molecules diffuse across the cell membrane through active transport where the cells require a lot of energy to transport the substances.

Energy Production

Cells require energy to carry out various chemical processes. This energy is produced by the cells through a process called photosynthesis in plants and respiration in animals.

Aids in Reproduction

A cell aids in reproduction through the processes called mitosis and meiosis. Mitosis is termed as the asexual reproduction where the parent cell divides to form daughter cells. Meiosis causes the daughter cells to be genetically different from the parent cells.

Thus, we see why cells are known as the structural and functional unit of life. This is because they are responsible for providing structure to the organisms and performs several functions necessary for carrying out life’s processes.

Important Questions about Cells

1.Definecell

A cell is defined as the basic, structural and functional unit of all life.

2. State the characteristics of cells

- Cells provide the necessary structural support for an organism.
- The genetic information necessary for reproduction is present within the nucleus.
- Structurally, the cell has cell organelles which are suspended in the cytoplasm.
- Mitochondria is the organelle responsible for fulfilling the cell’s energy requirements
- Lysosomes digest metabolic wastes and foreign particles in the cell.
- Endoplasmic reticulum synthesizes selective molecules and processes them, eventually directing them to their appropriate locations.

3. State the cellular components.

- Cell membrane
- Cell wall
- Cell organelles
  - Nucleolus
  - Nuclear membrane
  - Endoplasmic reticulum
  - Golgi Bodies
  - Ribosome
  - Mitochondria
  - Lysosomes
  - Chloroplast
  - Vacuoles

4. State the types of cells

Cells are primarily classified into two types, namely

- Prokaryotic cells
- Eukaryotic cells

5. ElaborateonCellTheory

Cell Theory was proposed by Matthias Schleiden, Theodor Schwann, and Rudolf Virchow, who were German scientists. The cell theory states that:

- All living species on Earth are composed of cells.
- A cell is the basic unit of life.
- All cells arise from pre-existing cells.

Cell Theory: All known living things are made up of cells. All cells come from preexisting cells by division. The cell is structural and functional unit of all living things.

Cell Structural Overview: The major parts of a cell are the nucleus, cytoplasm, and cell membrane.

Nucleus:

- The nucleus contains a nucleolus and is separated from the cytoplasm by the nuclear envelope.
- The nucleus contains the cell's DNA, a type of nucleic acid.
- The nucleolus is like a "tiny nucleus" inside the actual nucleus. It contains RNA, a type of nucleic acid.
- The nucleus communicates through holes in the envelope called nuclear pores.
- The nucleus decides what the cell needs and uses DNA to print out instructions for the rest of the cell to produce that need.

Chromosomes:

- Hold the cell's DNA in the nucleus.
- The nucleus contains genetic information in the form of DNA (the universal genetic code).
- The DNA does not hang around loosely in the nucleus. The DNA is packaged with proteins and wound up.
- Recall that the role of nucleic acids is to carry genetic information, which is inherited by

an organism's offspring.

- These wound up DNAprotein structures are called chromosomes.

Cytoplasmic Organelles: Are compartmentalized structures that perform a specialized function within a cell.

Golgi apparatus: ships packages around the cell.

- The golgi is made up of flattened, folded sacs.
- Packages (e.g. containing proteins) are carried to the golgi in vesicles.
- The golgi receives an incoming vesicle, tags the package, and sends the vesicle to its final destination.

Lysosome: destroy waste to clean up the cell.

- Lysosomes contain an environment made to destroy waste.
- Vesicles carry the waste (bacteria, old organelles, etc.) into the lysosome. Once inside, the waste is destroyed and its parts recycled.

Smooth endoplasmic reticulum: The two types of ER make different building blocks for the cell.

- Smooth ER is NOT attached to the nucleus and DOES NOT have attached ribosomes (thus smooth).
- Smooth ER synthesizes carbohydrates (sugars) and lipids (fats).

Mitochondria: produce energy to power the cell.

- The mitochondria convert carbohydrates (sugar) taken from food into ATP.
- The mitochondria are unique in that it has two protective shells.

Ribosomes: make proteins for the cell.

- The ribosome reads the DNA strand instructions to make proteins for the cell to use in its normal activities.
- The units clasp around a strand of nucleic acid instructions from the nucleus. Each ribosome is made of two protein subunits.

Rough endoplasmic reticulum: The two types of ER make different building blocks for the cell.

- Rough ER is found attached to the outside of the nucleus. It appears rough because of the ribosomes on its surface.
- Rough ER helps the attached ribosomes in finishing protein synthesis.

3.1.6: Cell membrane: A selectively permeable structure that envelops the cell and protects the cell's internal environment.

- Plasma Membrane, the cell's membrane is made of phospholipids, which have carbohydrate heads and lipid tails.
- Embedded proteins are anchored to the cell membrane.
- Exterior of the plasma membrane touches water; polar heads touch water on the inside of the cell and water on the outside of the cell.
- Interior Blocks Passage However, water and other molecules cannot pass through to either side because of the nonpolar tails.
- Provides a stabilized environment, which protects and maintains the cell's internal environment, separate from the environment outside.
- Proteins embedded into the membrane send and receive signals to communicate with other cells.

Transport across the cell membrane: The cell exchanges materials through the cell membrane using passive and active transport.

Three types of passive transport are osmosis, diffusion, and facilitated diffusion. Osmosis is the natural movement of water from a high concentration of water to a lower concentration of water. Diffusion is the natural movement of molecules from a higher concentration to a lower concentration. Facilitated Diffusion is the natural movement of molecules from a higher concentration to a lower concentration with the help of a transporter protein embedded on the cell membrane.

Active transport requires energy to occur. Active transport is “forced” movement of molecules from a lower concentration to a higher concentration. The most common type of active transport is a pump. Pumps are proteins embedded in the cell membrane, which use ATP energy to work.

Different Cell Types: Prokaryote and Eukaryote.

- **Prokaryotic**: Bacteria and other microscopic organisms are made up of prokaryotic cells. Prokaryotic cells do not have any complex organelles (not even a nucleus). However, prokaryotes do have ribosomes.
- **Eukaryotic:** Two types of eukaryotic cells are plant and animal cells.

3.1.5: The Cell structure

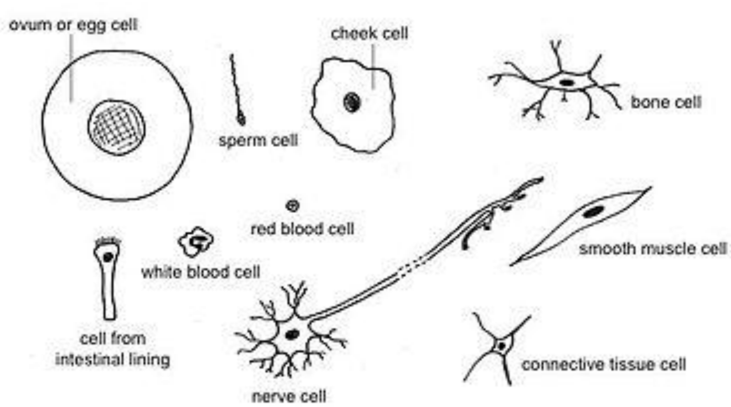


Diagram 3.1: A variety of animal cells

The cell is the basic building block of living organisms. Bacteria and the parasite that causes malaria consist of single cells, while plants and animals are made up of trillions of cells. Most cells are spherical or cube shaped but some are a range of different shapes (see diagram 3.1).

Most cells are so small that a microscope is needed to see them, although a few cells, e.g. the ostrich's egg, are so large that they could make a meal for several people.

A normal cell is about 0.02 of a millimetre (0.02mm) in diameter. (Small distances like this are normally expressed in micrometres or microns (µm). Note there are 1000 µms in every mm).

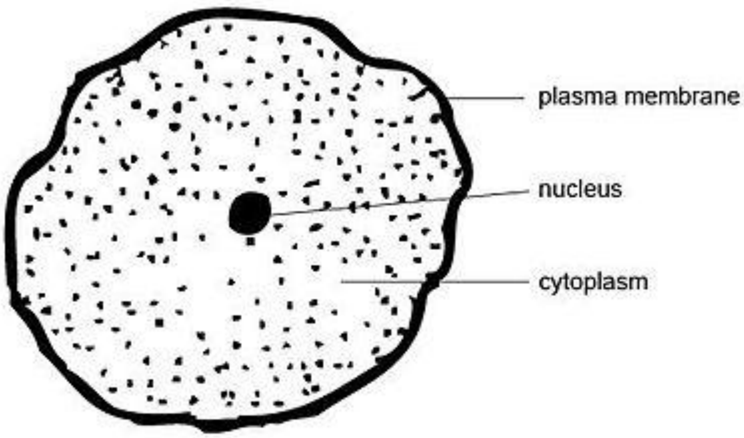


Diagram 3.2: An animal cell

When you look at a typical animal cell with a light microscope it seems quite simple with only a few structures visible (see diagram 3.2).

Three main parts can be seen:

- an outer cell membrane (plasma membrane),
- an inner region called the cytoplasm and
- the nucleus

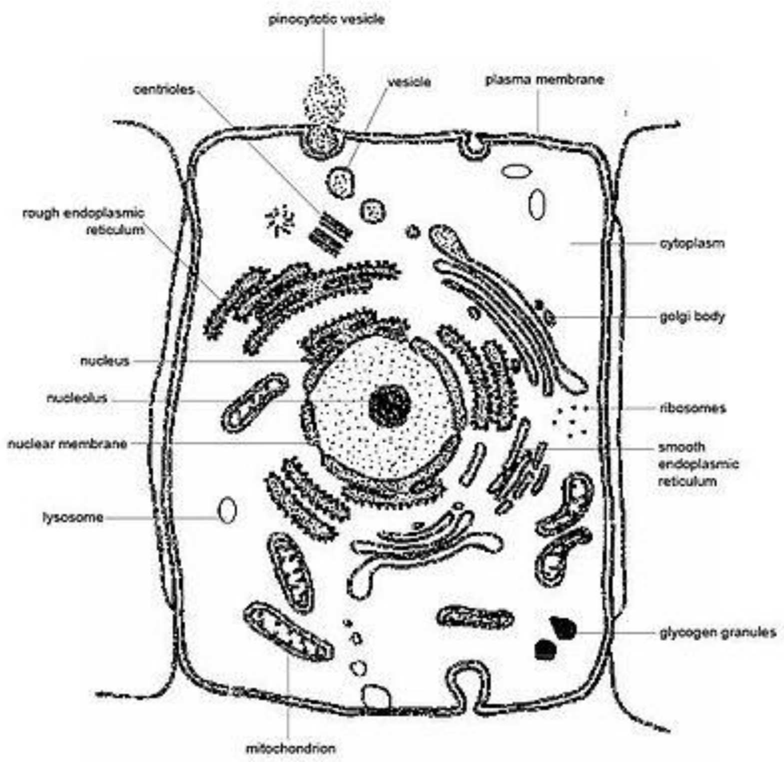


Diagram 3.3: An animal cell as seen with an electron microscope

However, when you use an electron microscope to increase the magnification many thousands of times you see that these seemingly simple structures are incredibly complex, each with its own specialized function. For example the plasma membrane is seen to be a double layer and the cytoplasm contains many special structures called **organelles** (meaning little organs) which are described below. A drawing of the cell as seen with an electron microscope is shown in diagram 3.3.

The Plasma Membrane

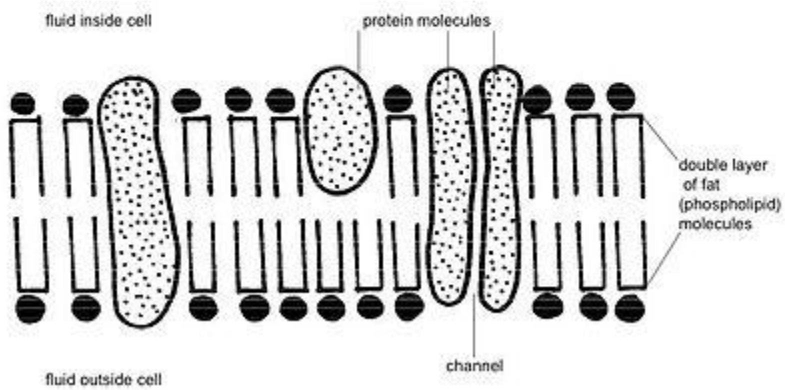


Diagram 3.4: The structure of the plasma membrane

The thin plasma membrane surrounds the cell, separating its contents from the surroundings and controlling what enters and leaves the cell. The plasma membrane is composed of two main molecules,phospholipids(fats) and proteins. The phospholipids are arranged in a double layer with the large protein molecules dotted about in the membrane (see diagram 3.4). Some of the protein molecules form tiny channels in the membrane while others help transport substances from one side of the membrane to the other.

How substances move across the Plasma Membrane

Substances need to pass through the membrane to enter or leave the cell and they do so in a number of ways. Some of these processes require no energy i.e. they are passive, while others require energy i.e. they are **active**.

Passive processes include: a) diffusion and b) osmosis, while active processes include: c) active transport, d) phagocytosis, e) pinocytosis and f) exocytosis. These will be described below.

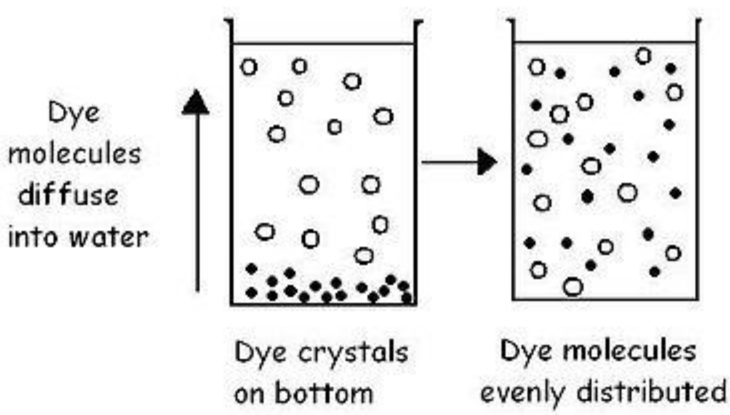


Diagram 3.5: Diffusion in a liquid

a) Diffusion

Although you may not know it, you are already familiar with the process of diffusion. It is diffusion that causes a smell (expensive perfume or smelly socks) in one part of the room to gradually move through the room so it can be smelt on the other side. Diffusion occurs in the air and in liquids.

Diagram 3.5 shows what happens when a few crystals of a dark purple dye called potassium permanganate are dropped into a beaker of water. The dye molecules diffuse into the water moving from high to low concentrations so they become evenly distributed throughout the beaker.

In the body, diffusion causes molecules that are in a high concentration on one side of the cell membrane to move across the membrane until they are present in equal concentrations on both sides. It takes place because all molecules have an in-built vibration that causes them to move and collide until they are evenly distributed. It is an absolutely natural process that requires no added energy.

Small molecules like oxygen, carbon dioxide, water and ammonia as well as fats, diffuse directly through the double fat layer of the membrane. The small molecules named above as well as a variety of charged particles (ions) also diffuse through the protein-lined channels. Larger molecules like glucose attach to a carrier molecule that aids their diffusion through the membrane. This is called **facilitated diffusion**.

In the animal's body diffusion is important for moving oxygen and carbon dioxide between the lungs and the blood, for moving digested food molecules from the gut into the blood and for the removal of waste products from the cell.

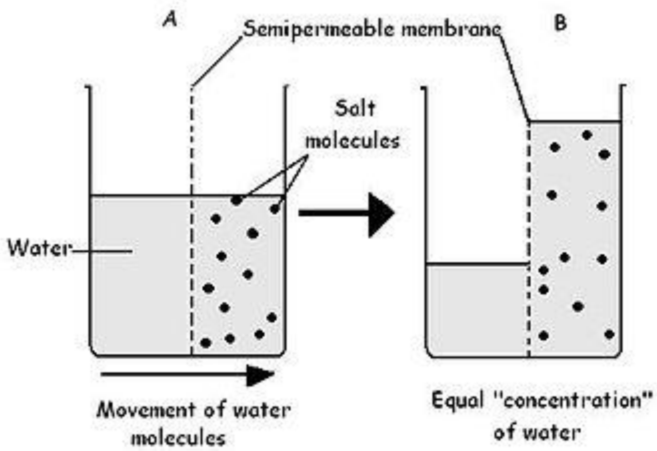


Diagram 3.6: Osmosis

b) Osmosis

Although the word may be unfamiliar, you are almost certainly acquainted with the effects of osmosis. It is osmosis that plumps out dried fruit when you soak it before making a fruit cake or makes that wizened old carrot look almost like new when you soak it in water. Osmosis is in fact the diffusion of water across a membrane that allows water across but not larger molecules. This kind of membrane is called a **semi-permeable membrane**.

Take a look at side **A** of diagram 3.6. It shows a container divided into two parts by an artificial semi-permeable membrane. Water is poured into one part while a solution containing salt is poured into the other part. Water can cross the membrane but the salt cannot. The water crosses the semi-permeable membrane by diffusion until there is an equal amount of water on both sides of the membrane. The effect of this would be to make the salt solution more diluted and cause the level of the liquid in the right-hand side of the container to rise so it looked like side **B** of diagram 3.6. This movement of water across the semi-permeable membrane is called osmosis. It is a completely natural process that requires no outside energy.

Although it would be difficult to do in practice, imagine that you could now take a plunger and push down on the fluid in the right-hand side of container **B** so that it flowed back across the semi-permeable membrane until the level of fluid on both sides was equal again. If you could measure the pressure required to do this, this would be equal to the **osmotic pressure** of the salt solution. (This is a rather advanced concept at this stage but you will meet this term again when you study fluid balance later in the course).

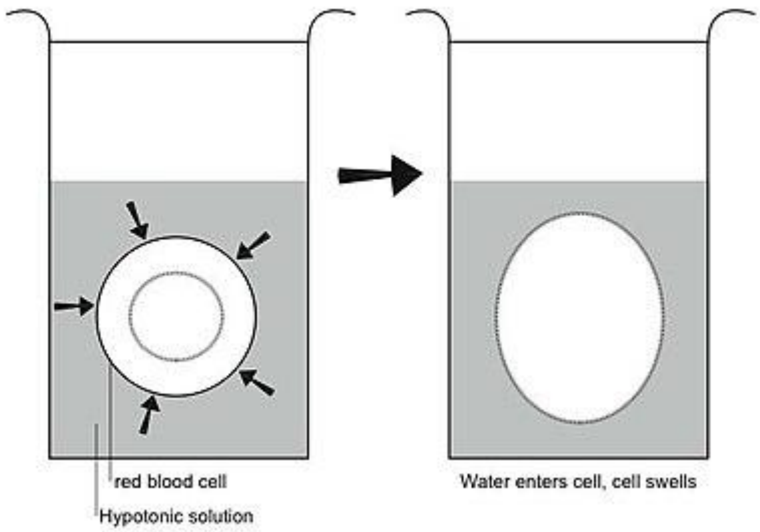


Diagram 3.7: Osmosis in red cells placed in a hypotonic solution

The plasma membrane of cells acts as a semi-permeable membrane. If red blood cells, for example, are placed in water, the water crosses the membrane to make the amount of water on both sides of it equal (see diagram 3.7). This means that the water moves into the cell causing it to swell. This can occur to such an extent that the cell actually bursts to release its contents. This bursting of red blood cells is called **haemolysis**. In a situation such as this when the solution on one side of a semi-permeable membrane has a lower concentration than that on the other side, the first solution is said to be **hypotonic** to the second.

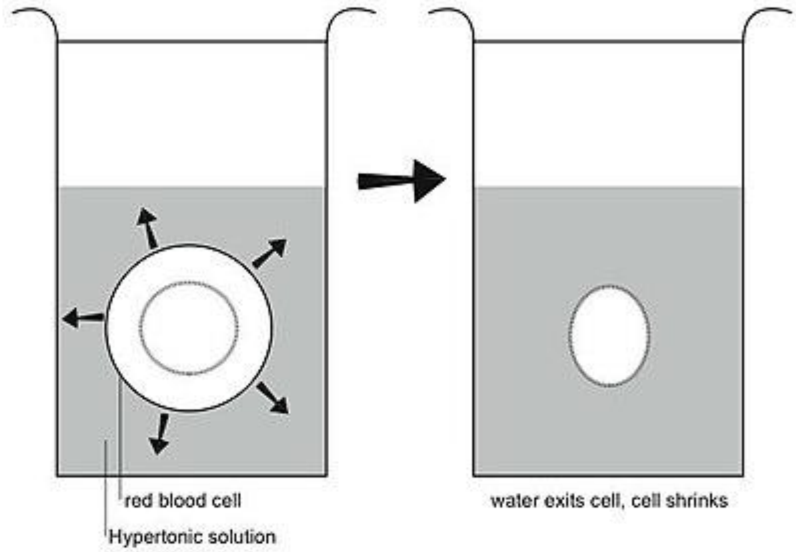


Diagram 3.8: Osmosis in red cells placed in a hypertonic solution

Now think what would happen if red blood cells were placed in a salt solution that has a higher salt concentration than the solution within the cells (see diagram 3.8). Such a bathing solution is called a **hypertonic** solution. In this situation the “concentration” of water within the cells would be higher than that outside the cells. Osmosis (diffusion of water) would then occur from the inside of the cells to the outside solution, causing the cells to shrink.

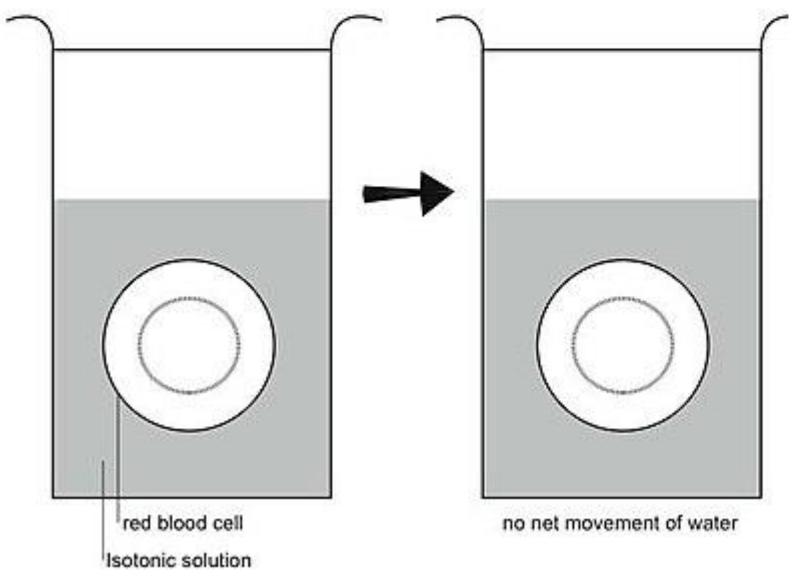


Diagram 3.9: Red cells placed in an isotonic solution

A solution that contains 0.9% salt has the same concentration as body fluids and the solution within red cells. Cells placed in such a solution would neither swell nor shrink (see diagram 3.9). This solution is called an **isotonic** solution. This strength of salt solution is often called **normal saline** and is used when replacing an animal's body fluids or when cells like red blood cells have to be suspended in fluid.

Remember - osmosis is a special kind of diffusion. It is the diffusion of water molecules across a semi-permeable membrane. It is a completely passive process and requires no energy.

Sometimes it is difficult to remember which way the water molecules move. Although it is not strictly true in a biological sense, many students use the phrase **"SALT SUCKS"** to help them remember which way water moves across the membrane when there are two solutions of different salt concentrations on either side.

As we have seen water moves in and out of the cell by osmosis. All water movement from the intestine into the blood system and between the blood capillaries and the fluid around the cells (tissue or extra cellular fluid) takes place by osmosis. Osmosis is also important in the production of concentrated urine by the kidney.

c) Active transport

When a substance is transported from a low concentration to a high concentration i.e. uphill against the concentration gradient, energy has to be used. This is called **active transport**.

Active transport is important in maintaining different concentrations of the ions sodium and potassium on either side of the nerve cell membrane. It is also important for removing valuable molecules such as glucose, amino acids and sodium ions from the urine.

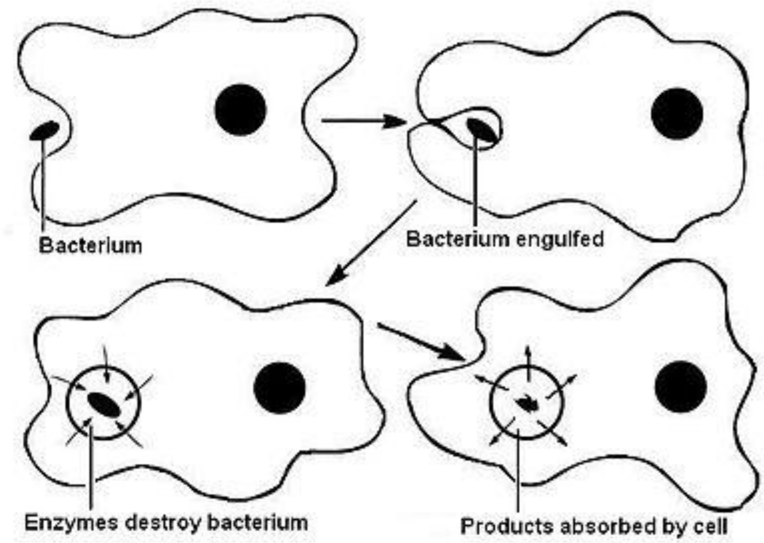


Diagram 3.10: Phagocytosis

d) Phagocytosis

Phagocytosis is sometimes called “cell eating”. It is a process that requires energy and is used by cells to move solid particles like bacteria across the plasma membrane. Finger-like projections from the plasma membrane surround the bacteria and engulf them as shown in diagram 3.10. Once within the cell, enzymes produced by the lysosomes of the cell (described later) destroy the bacteria.

The destruction of bacteria and other foreign substance by white blood cells by the process of phagocytosis is a vital part of the defense mechanisms of the body.

e) Pinocytosis

Pinocytosis or “cell drinking” is a very similar process to phagocytosis but is used by cells to move fluids across the plasma membrane. Most cells carry out pinocytosis (note the pinocytotic vesicle in diagram 3.3).

f) Exocytosis

Exocytosis is the process by means of which substances formed in the cell are moved through the plasma membrane into the fluid outside the cell (or extra-cellular fluid). It occurs in all cells but is most important in secretory cells (e.g. cells that produce digestive enzymes) and nerve cells.

3.1.7: The Cytoplasm

Within the plasma membrane is the **cytoplasm**. It consists of a clear jelly-like fluid called the a) **cytosol** or **intracellular fluid** in which b) **cell inclusions**, c) **organelles** and d) **microfilaments** and **microtubules** are found.

a) Cytosol

The cytosol consists mainly of water in which various molecules are dissolved or suspended. These molecules include proteins, fats and carbohydrates as well as sodium, potassium, calcium and chloride ions. Many of the reactions that take place in the cell occur in the cytosol.

b) Cell inclusions

These are large particles of fat, glycogen and melanin that have been produced by the cell. They are often large enough to be seen with the light microscope. For example the cells of adipose tissue (as in the insulating fat layer under the skin) contain fat that takes up most of the cell.

c) Organelles

Organelles are the "little organs" of the cell - like the heart, kidney and liver are the organs of the body. They are structures with characteristic appearances and specific "jobs" in the cell. Most can not be seen with the light microscope and so it was only when the electron microscope was developed that they were discovered. The main organelles in the cell are the **ribosomes, endoplasmic reticulum, mitochondrion, Golgi complex** and **lysosomes**. A cell containing these organelles as seen with the electron microscope is shown in diagram 3.3.

Ribosomes

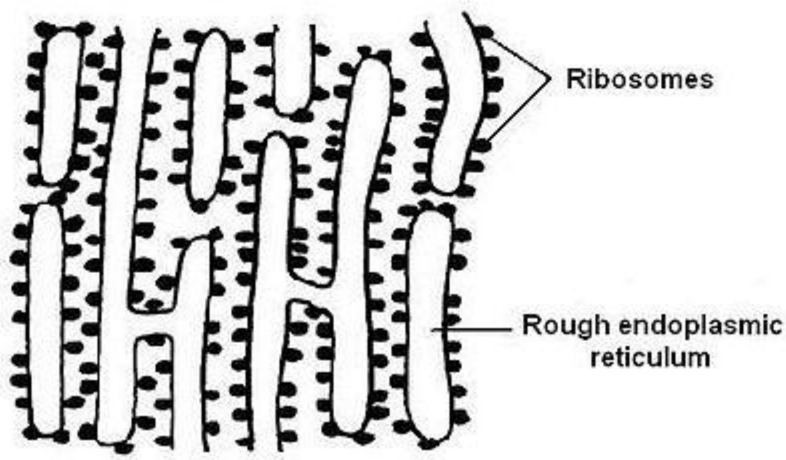


Diagram 3.11: Rough endoplasmic reticulum

Ribosomes are tiny spherical organelles that make proteins by joining amino acids together. Many ribosomes are found free in the cytosol, while others are attached to the rough endoplasmic reticulum.

Endoplasmic reticulum

The **endoplasmic reticulum (ER)** is a network of membranes that form channels throughout the cytoplasm from the nucleus to the plasma membrane. Various molecules are made in the ER and transported around the cell in its channels. There are two types of ER: smooth ER and rough ER.

> **Smooth ER** is where the fats in the cell are made and in some cells, where chemicals like alcohol, pesticides and carcinogenic molecules are inactivated.
> The **Rough ER** has ribosomes attached to its surface. The function of the Rough ER is therefore to make proteins that are modified stored and transported by the ER (Diagram 3.11).

Mitochondria

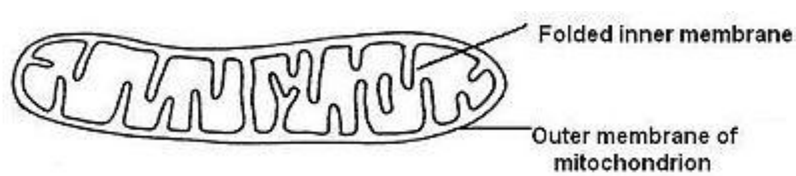


Diagram 3.12: A mitochondrion

Mitochondria (singular mitochondrion) are oval or rod shaped organelles scattered throughout the cytoplasm. They consist of two membranes, the inner one of which is folded to increase its surface area. (Diagram 3.12)

Mitochondria are the "power stations" of the cell. They make energy by "burning" food molecules like glucose. This process is called **cellular respiration**. The reaction requires oxygen and produces carbon dioxide which is a waste product. The process is very complex and takes place in a large number of steps but the overall word equation for cellular respiration is-

Glucose + oxygen = carbon dioxide + water + energy

or $C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O$ + **energy**

Note that cellular respiration is different from respiration or breathing. Breathing is the means by which air is drawn into and expelled from the lungs. Breathing is necessary to supply the cells with the oxygen required by the mitochondria and to remove the carbon dioxide produced as a waste product of cellular respiration.

Active cells like muscle, liver, kidney and sperm cells have large numbers of mitochondria.

Golgi Apparatus

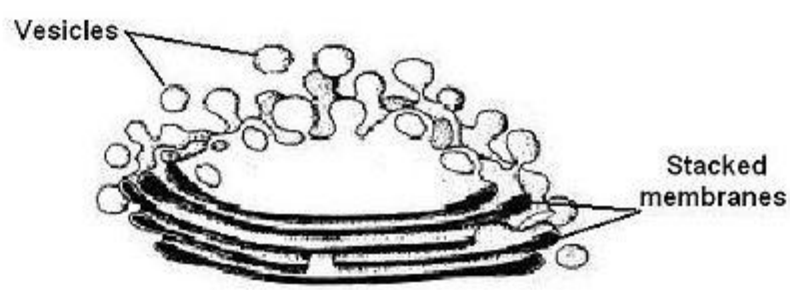


Diagram 3.13: A Golgi body

The **Golgi bodies** in a cell together make up the **Golgi apparatus**. Golgi bodies are found near the nucleus and consist of flattened membranes stacked on top of each other rather like a pile of plates (see diagram 3.13). The Golgi apparatus modifies and sorts the proteins and fats made by the ER, then surrounds them in a membrane as **vesicles** so they can be moved to other parts of the cell.

Lysosomes

Lysosomes are large vesicles that contain digestive enzymes. These break down bacteria and other substances that are brought into the cell by phagocytosis or pinocytosis. They also digest worn-out or damaged organelles, the components of which can then be recycled by the cell to make new structures.

d) Microfilaments and Microtubules

Some cells can move and change shape and organelles and chemicals are moved around the cell. Threadlike structures called **microfilaments** and **microtubules** that can contract are responsible for this movement.

These structures also form the projections from the plasma membrane known as **flagella** (singular flagellum) as in the sperm tail, and **cilia** found lining the respiratory tract and used to remove mucus that has trapped dust particles (see chapter 4).

Microtubules also form the pair of cylindrical structures called **centrioles** found near the nucleus. These help organise the spindle used in cell division.

The Nucleus

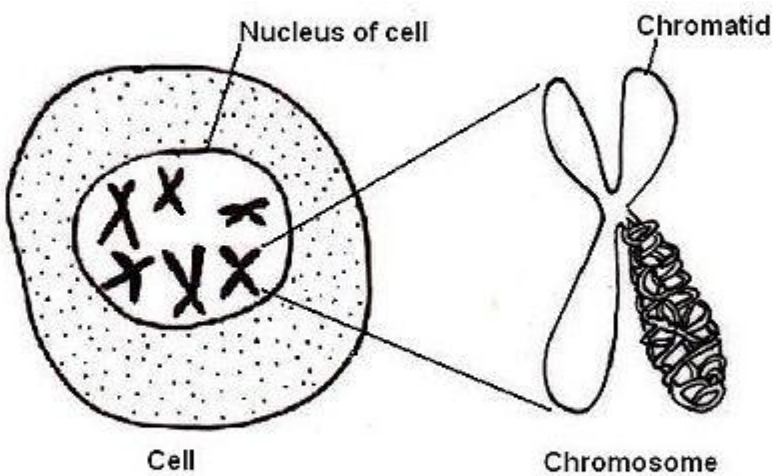


Diagram 3.14: A cell with an enlarged chromosome

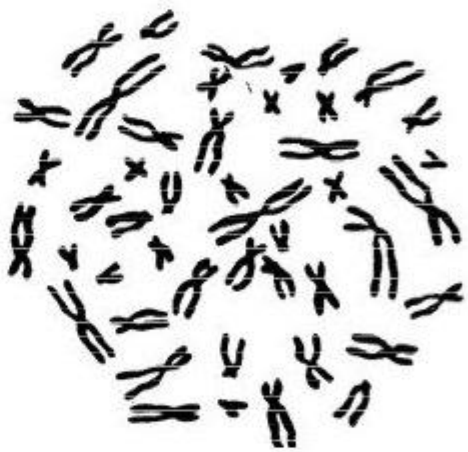


Diagram 3.15: A full set of human chromosomes

The **nucleus** is the largest structure in a cell and can be seen with the light microscope. It is a spherical or oval body that contains the **chromosomes**. The nucleus controls the development and activity of the cell. Most cells contain a nucleus although mature red blood cells have lost theirs during development and some muscle cells have several nuclei.

A double membrane similar in structure to the plasma membrane surrounds the nucleus (now called the nuclear envelope). Pores in this nuclear membrane allow communication between the nucleus and the cytoplasm.

Within the nucleus one or more spherical bodies of darker material can be seen, even with the light microscope. These are called **nucleoli** and are made of RNA. Their role is to make new ribosomes.

Chromosomes

Inside the nucleus are the chromosomes which:

- contain DNA;
- control the activity of the cell;
- are transmitted from cell to cell when cells divide;
- are passed to a new individual when sex cells fuse together in sexual reproduction.

In cells that are not dividing the chromosomes are very long and thin and appear as dark grainy material. They become visible just before a cell divides when they shorten and thicken and can then be counted (see diagram 3.14).

The number of chromosomes in the cells of different species varies but is constant in the cells of any one species (e.g. horses have 64 chromosomes, cats have 38 and humans 46). Chromosomes occur in pairs (i.e. 32 pairs in the horse nucleus and 19 in that of the cat). Members of each pair are identical in length and shape and if you look carefully at diagram 3.15, you may be able to see some of the pairs in the human set of chromosomes.

3.1.8: Cell Division

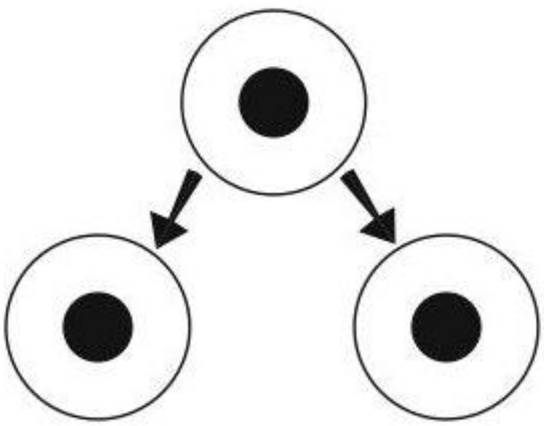


Diagram 3.16: Division by mitosis results in 2 new cells identical to each other and to parent cell

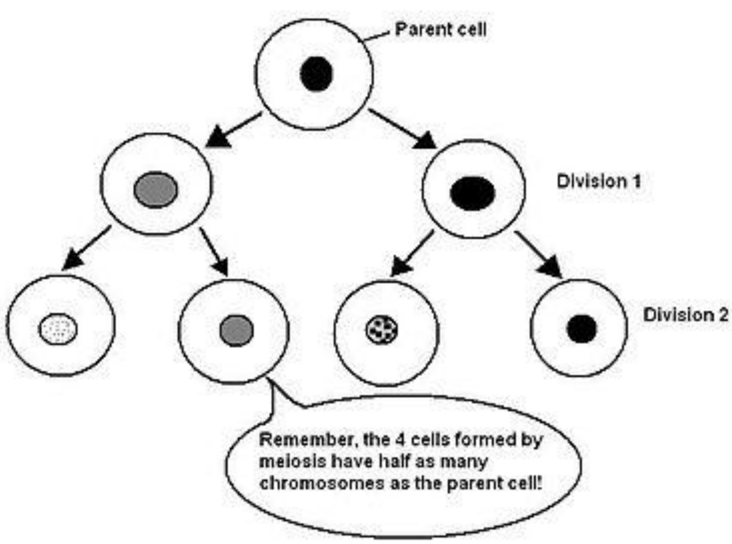


Diagram 3.17: Division by meiosis results in 4 new cells that are genetically different to each other

Cells divide when an animal grows, when its body repairs an injury and when it produces sperm and eggs (or ova). There are two types of cell division: **Mitosis** and **meiosis**.

Mitosis. This is the cell division that occurs when an animal grows and when tissues are repaired or replaced. It produces two new cells (daughter cells) each with a full set of chromosomes that are identical to each other and to the parent cell. All the cells of an animal's body therefore contain identical DNA.

Meiosis. This is the cell division that produces the ova and sperm necessary for sexual reproduction. It only occurs in the ovary and testis.

The most important function of meiosis it to half the number of chromosomes so that when the sperm fertilises the ovum the normal number is regained. Body cells with the full set of chromosomes are called **diploid** cells, while **gametes** (sperm and ova) with half the chromosomes are called **haploid** cells.

Meiosis is a more complex process than mitosis as it involves two divisions one after the other and the four cells produced are all genetically different from each other and from the parent cell.

This fact that the cells formed by meiosis are all genetically different from each other and from the parent cell can be seen in litters of kittens where all the members of the litter are different from each other as well as being different from the parents although they display characteristics of both.

3.1.9: The Cell asa Factory

To make the function of the parts of the cell easier to understand and remember you can compare them to a factory. For example:

- The nucleus (1) is the managing director of the factory consulting the blueprint (the chromosomes) (2);

- The mitochondria (3) supply the power
- The ribosomes (4) make the products;
- The chloroplasts of plant cells (5) supply the fuel (food)
- The Golgi apparatus (6) packages the products ready for dispatch;
- The ER (7) modifies, stores and transports the products around the factory;
- The plasma membrane is the factory wall and the gates (8);
- The lysosomes dispose of the waste and worn-out machinery.

The cell compared to a factory

Summary

- Cells consist of three parts: the **plasma membrane, cytoplasm** and **nucleus**.
- Substances pass through the plasma membrane by **diffusion** (gases, lipids), **osmosis** (water), **active transport** (glucose, ions), **phagocytosis** (particles), **pinocytosis** (fluids) and **exocytosis** (particles and fluids).
- **Osmosis** is the diffusion of **water** through a **semipermeable membrane**. Water diffuses from high water "concentration" to low water "concentration".
- The cytoplasm consists of **cytosol** in which are suspended **cell inclusions** and **organelles**.
- organelles include **ribosomes, endoplasmic reticulum, mitochondria, Golgi bodies** and **lysosomes**.
- The **nucleus** controls the activity of the cell. It contains the **chromosomes** that are composed of **DNA**.
- The cell divides by **mitosis** and **meiosis**

1.6 Tutor marked assignment

- Define cell and it composition
- Define genetic and cell
- Define genes and comment on its importance

Reference/ further reading

Extreme skewing of X chromosome inactivation in mothers of homosexual men. Human Genetics118:6 (691) 2006.

[(1) Department of Human Genetics, University of California, Los Angeles, CA, USA; (2) Department of Biostatistics, University of California, Los Angeles, CA, USA;
(3)Laboratory of Biochemistry, National Cancer Institute, Bethesda, MD, USA;
(4)Gonda 5524, 695 Charles Young Drive South, Los Angeles, CA90095-7088, USA
97 mothers of homosexual men; 103 age-matched control women without gay sons.

MODULE 3: Anatomy and physiology of farm animals

INTRODUCTION

The term **tissue** is used to describe a group of cells found together in the body. The cells within a tissue share a common embryonic origin. Microscopic observation reveals that the cells in a tissue share morphological features and are arranged in an orderly pattern that achieves the tissue's functions. From the evolutionary perspective, tissues appear in more complex organisms. For example, multicellular protists, ancient eukaryotes, do not have cells organized into tissues.

Although there are many types of cells in the human body, they are organized into four broad categories of tissues: epithelial, connective, muscle, and nervous. Each of these categories is characterized by specific functions that contribute to the overall health and maintenance of the body. A disruption of the structure is a sign of injury or disease. Such changes can be detected through **histology**, the microscopic study of tissue appearance, organization, and function.

2.0: Learning Objectives

By the end of this section, you will be able to:

- Identify the four main tissue types
- Discuss the functions of each tissue type
- Relate the structure of each tissue type to their function
- Discuss the embryonic origin of tissue
- Identify the three major germ layers
- Identify the main types of tissue membranes

3.0 MAIN CONTENT

3.1: Animal tissue

3.2: Nervous system

3.3: Skeletal systems

3.4: Muscles

3.5: Circulatory systems

3.6: Reproductive systems

3. 7: Digestive systems

3.1: Animal Tissues-The Four Types of Tissues

Types of Tissues

Epithelial tissue, also referred to as epithelium, refers to the sheets of cells that cover exterior surfaces of the body, lines internal cavities and passageways, and forms certain glands. **Connective tissue**, as its name implies, binds the cells and organs of the body together and functions in the protection, support, and integration of all parts of the body. **Muscle tissue** is excitable, responding to stimulation and contracting to provide movement, and occurs as three major types: skeletal (voluntary) muscle, smooth muscle, and cardiac muscle in the heart. **Nervous tissue** is also excitable, allowing the propagation of electrochemical signals in the form of nerve impulses that communicate between different regions of the body .

The next level of organization is the organ, where several types of tissues come together to form a working unit. Just as knowing the structure and function of cells helps you in your study of tissues, knowledge of tissues will help you understand how organs function. The epithelial and connective tissues are discussed in detail in this chapter. Muscle and nervous tissues will be discussed only briefly in this chapter.

Embryonic Origin of Tissues

The zygote, or fertilized egg, is a single cell formed by the fusion of an egg and sperm. After fertilization the zygote gives rise to rapid mitotic cycles, generating many cells to form the embryo. The first embryonic cells generated have the ability to differentiate into any type of cell in the body and, as such, are called **totipotent**, meaning each has the capacity to divide, differentiate, and develop into a new organism. As cell proliferation progresses, three major cell lineages are established within the embryo. Each of these lineages of embryonic cells forms the distinct germ layers from which all the tissues and organs of the human body eventually form. Each germ layer is identified by its relative position: **ectoderm** (ecto- = “outer”), **mesoderm** (meso- = “middle”), and **endoderm** (endo- = “inner”).shows the types of tissues and organs associated with the each of the three germ layers. Note that epithelial tissue originates in all three layers, whereas nervous tissue derives primarily from the ectoderm and muscle tissue from mesoderm.

Tissue Membranes

A **tissue membrane** is a thin layer or sheet of cells that covers the outside of the body (for example, skin), the organs (for example, pericardium), internal passageways that lead to the exterior of the body (for example, abdominal mesenteries), and the lining of the moveable joint cavities. There are two basic types of tissue membranes: connective tissue and epithelial membranes. The two broad categories of tissue membranes in the body are (1) connective tissue membranes, which include synovial membranes, and (2) epithelial membranes, which include mucous membranes, serous membranes, and the cutaneous membrane, in other words, the skin.

Connective Tissue Membranes

The **connective tissue membrane** is formed solely from connective tissue. These membranes encapsulate organs, such as the kidneys, and line our movable joints. A **synovial membrane** is a type of connective tissue membrane that lines the cavity of a freely movable joint. For example, synovial membranes surround the joints of the shoulder, elbow, and knee. Fibroblasts in the inner layer of the synovial membrane release hyaluronan into the joint cavity. The hyaluronan effectively traps available water to form the synovial fluid, a natural lubricant that enables the bones of a joint to move freely against one another without much friction. This synovial fluid readily exchanges water and nutrients with blood, as do all body fluids.

Epithelial Membranes

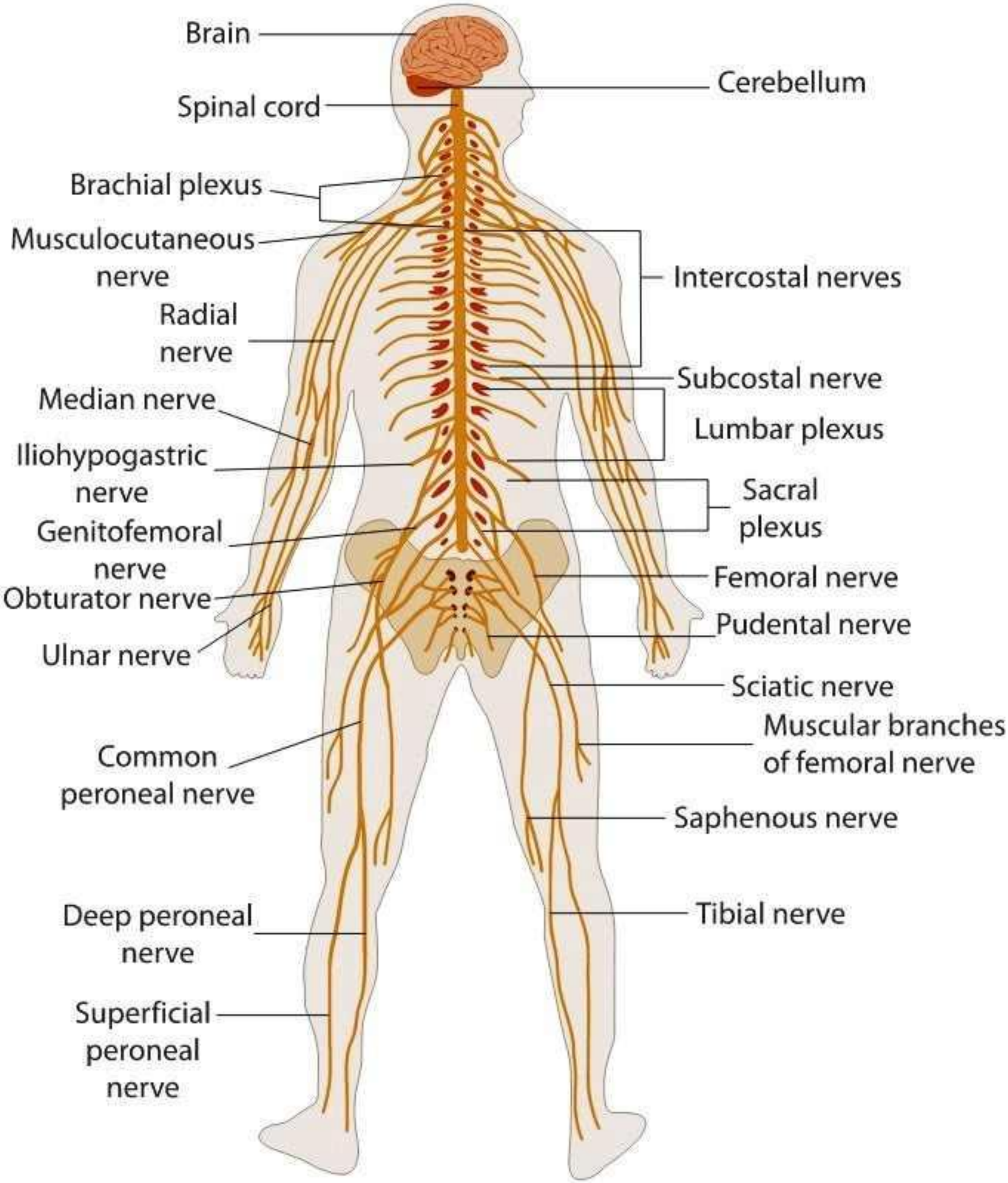
The **epithelial membrane** is composed of epithelium attached to a layer of connective tissue, for example, your skin. The **mucous membrane** is also a composite of connective and epithelial tissues. Sometimes called mucosae, these epithelial membranes line the body cavities and hollow passageways that open to the external environment, and include the digestive, respiratory, excretory, and reproductive tracts. Mucous, produced by the epithelial exocrine glands, covers the epithelial layer. The underlying connective tissue, called the **lamina propria** (literally "own layer"), help support the fragile epithelial layer.

A **serous membrane** is an epithelial membrane composed of mesodermally derived epithelium called the mesothelium that is supported by connective tissue. These membranes line the coelomic cavities of the body, that is, those cavities that do not open to the outside, and they cover the organs located within those cavities. They are essentially membranous bags, with mesothelium lining the inside and connective tissue on the outside. Serous fluid secreted by the cells of the thin squamous mesothelium lubricates the membrane and reduces abrasion and friction between organs. Serous membranes are identified according locations. Three serous membranes line the thoracic cavity; the two pleura that cover the lungs and the pericardium that covers the heart. A fourth, the peritoneum, is the serous membrane in the abdominal cavity that covers abdominal organs and forms double sheets of mesenteries that suspend many of the digestive organs.

The skin is an epithelial membrane also called the **cutaneous membrane**. It is a stratified squamous epithelial membrane resting on top of connective tissue. The apical surface of this membrane is exposed to the external environment and is covered with dead, keratinized cells that help protect the body from desiccation and pathogens.

3.1.2: Nervous System

The nervous system is the part of the body that coordinates voluntary and involuntary actions and transmits signals to and from different parts of its body. It detects and responds to changes inside and outside the body. Along with the endocrine system, the nervous system controls the vital functions of the body and maintains homeostasis. The response of the nervous system is much faster than that of the endocrine system.


Brain
Cerebellum
Spinal cord
Brachial plexus
Musculocutaneous nerve
Intercostal nerves
Radial nerve
Subcostal nerve
Median nerve
Lumbar plexus
Iliohypogastric nerve
Sacral plexus
Genitofemoral nerve
Femoral nerve
Obturator nerve
Pudental nerve
Ulnar nerve
Sciatic nerve
Muscular branches of femoral nerve
Common peroneal nerve
Saphenous nerve
Tibial nerve
Deep peroneal nerve
Superficial peroneal nerve

The nervous system consists of:

- Brain
- Spinal cord
- Peripheral nerves

The nervous system can be divided into:

- **The central nervous system (CNS):** Consisting of brain and spinal cord
- **The peripheral nervous system (PNS):** Consisting all the nerves outside brain and spinal cord

The central nervous system receives sensory information through afferent nerves. It then processes this information and responds appropriately by sending impulses through motor nerves to the effector organs. For example, responses to changes in the internal environment regulate important functions such as respiration and blood pressure. Similarly, responses to changes in the external environment result in voluntary actions such as change in posture or other activities.

The peripheral nervous system (PNS) consists of paired cranial and sacral nerves. Some of these nerves are sensory (afferent) i.e. transmit impulses to the CNS. Some are motor nerves (efferent) i.e. transmit impulses from the CNS. Some others are mixed.

The PNS can be divided into two functional parts:

- Sensory division
- Motor division

The motor division has two parts:

- **Somatic nervous system:** Controls voluntary movements of skeletal muscles
- **Autonomic nervous system:** Controls involuntary functions such as heart rate, digestion, respiratory rate, pupillary response, urination, and sexual arousal

The autonomic nervous system has two divisions:

- **Sympathetic:** Stimulates the body's "fight-or-flight" response
- **Parasympathetic:** Stimulates "rest-and-digest" or "feed and breed" activities that occur when the body is at rest

Topics in this Section

- Neurons
    - Properties of neurons
    - Cell bodies
    - Axons and dendrites
    - The nerve impulse (action potential)
    - Types of nerves
    - The synapse and neurotransmitters
- Central nervous system
    - Neuroglia
    - Membranes covering the brain and spinal cord (the meninges)
    - Ventricles of the brain and the cerebrospinal fluid
- Brain
    - Blood supply to the brain
    - Cerebrum
    - Brain stem
    - Cerebellum
- Spinal cord
    - Grey matter
    - White matter
- Peripheral nervous system
    - Spinal nerves
    - Thoracic nerves
    - Cranial nerves
- Autonomic nervous system
    - Sympathetic nervous system
    - Parasympathetic nervous system

    - Functions of the autonomic nervous system
        - Effects of autonomic stimulation
        - Afferent impulses from viscera
- Response of nervous tissue to injury
    - Neuron damage
    - Neuron regeneration
    - Neuroglia damage
    - Effects of poisons on the central nervous system
- Disorders of the brain
    - Increased intracranial pressure
        - Effects of increased ICP
        - Cerebral edema
        - Hydrocephalus
    - Head injuries
        - Blow to the head
        - Acceleration-deceleration injuries
        - Complications of head injury
    - Circulatory disturbances affecting the brain
        - Cerebral hypoxia
        - Stroke (cerebrovascular disease)
    - Dementia
    - Parkinson's disease
- Infections of the central nervous system
    - Pyogenic infection
    - Viral infections
    - Creutzfeldt-Jakob disease
    - Myalgic encephalitis (ME)
- Demyelinating diseases
    - Multiple (disseminated) sclerosis (MS)
    - Acute disseminating encephalomyelitis
- Phenylketonuria

- Diseases of the spinal cord
    - Motor neurons
    - Sensory neurons
    - Mixed motor and sensory conditions
- Diseases of peripheral nerves
    - Neuropathies
    - Neuritis
- Developmental abnormalities of the nervous system
    - Spina bifida
    - Hydrocephalus
- Tumors of the nervous system

3.1.3:The Functions of the Skeletal System

2.0. Learning Objectives

By the end of this section, you will be able to:

- Define bone, cartilage, and the skeletal system
- List and describe the functions of the skeletal system

Bone, or osseous tissue, is a hard, dense connective tissue that forms most of the adult skeleton, the support structure of the body. In the areas of the skeleton where bones move (for example, the ribcage and joints), cartilage, a semi-rigid form of connective tissue, provides flexibility and smooth surfaces for movement. The skeletal system is the body system composed of bones and cartilage and performs the following critical functions for the human body:

- supports the body
- facilitates movement
- protects internal organs
- produces blood cells
- stores and releases minerals and fat

Support, Movement, and Protection

The most apparent functions of the skeletal system are the gross functions—those visible by observation. Simply by looking at a person, you can see how the bones support, facilitate movement, and protect the human body.

Just as the steel beams of a building provide a scaffold to support its weight, the bones and cartilage of your skeletal system compose the scaffold that supports the rest of your body. Without the skeletal system, you would be a limp mass of organs, muscle, and skin.

Bones also facilitate movement by serving as points of attachment for your muscles. While some bones only serve as a support for the muscles, others also transmit the forces produced when your muscles contract. From a mechanical point of view, bones act as levers and joints serve as fulcrums . Unless a muscle spans a joint and contracts, a bone is not going to move. For information on the interaction of the skeletal and muscular systems, that is, the musculoskeletal system, seek additional contentBones also protect internal organs from injury by covering or surrounding them. For example, your ribs protect your lungs and heart, the bones of your vertebral column (spine) protect your spinal cord, and the bones of your cranium (skull) protect your brain.

Orthopedist

An orthopedist is a doctor who specializes in diagnosing and treating disorders and injuries related to the musculoskeletal system. Some orthopedic problems can be treated with medications, exercises, braces, and other devices, but others may be best treated with surgery

Orthopedists commonly treat bone and joint injuries but they also treat other bone conditions including curvature of the spine. Lateral curvatures (scoliosis) can be severe enough to slip under the shoulder blade (scapula) forcing it up as a hump. Spinal curvatures can also be excessive dorsoventrally (kyphosis) causing a hunch back and thoracic compression. These curvatures often appear in preteens as the result of poor posture, abnormal growth, or indeterminate causes. Mostly, they are readily treated by orthopedists. As people age, accumulated spinal column injuries and diseases like osteoporosis can also lead to curvatures of the spine, hence the stooping you sometimes see in the elderly.

Some orthopedists sub-specialize in sports medicine, which addresses both simple injuries, such as a sprained ankle, and complex injuries, such as a torn rotator cuff in the shoulder. Treatment can range from exercise to surgery.

Mineral Storage, Energy Storage, and Hematopoiesis

On a metabolic level, bone tissue performs several critical functions. For one, the bone matrix acts as a reservoir for a number of minerals important to the functioning of the body, especially calcium, and phosphorus. These minerals, incorporated into bone tissue, can be released back into the bloodstream to maintain levels needed to support physiological processes. Calcium ions, for example, are essential for muscle contractions and controlling the flow of other ions involved in the transmission of nerve impulses.

Bone also serves as a site for fat storage and blood cell production. The softer connective tissue that fills the interior of most bone is referred to as bone marrow . There are two types of bone marrow: yellow marrow and red marrow. Yellow marrow contains adipose tissue; the triglycerides stored in the adipocytes of the tissue can serve as a source of energy. Red marrow is where hematopoiesis—the production of blood cells—takes place. Red blood cells, white blood cells, and platelets are all produced in the red marrow.

The major functions of the bones are body support, facilitation of movement, protection of internal organs, storage of minerals and fat, and hematopoiesis. Together, the muscular system and skeletal system are known as the musculoskeletal system.

Critical Thinking Questions

The skeletal system is composed of bone and cartilage and has many functions. Choose three of these functions and discuss what features of the skeletal system allow it to accomplish these functions.

Glossary

bone

hard, dense connective tissue that forms the structural elements of the skeleton cartilage

semi-rigid connective tissue found on the skeleton in areas where flexibility and smooth surfaces support movement

hematopoiesis

production of blood cells, which occurs in the red marrow of the bones

orthopedist

doctor who specializes in diagnosing and treating musculoskeletal disorders and injuries

osseous tissue

bone tissue; a hard, dense connective tissue that forms the structural elements of the skeleton

red marrow

connective tissue in the interior cavity of a bone where hematopoiesis takes place

skeletal system

organ system composed of bones and cartilage that provides for movement, support, and protection

yellow marrow

connective tissue in the interior cavity of a bone where fat is stored

3.1.4: Muscles

2.0. Objectives

After completing this section, you should know:

- The structure of smooth, cardiac and skeletal muscle and where they are found.
- What the insertion and origin of a muscle is.
- What flexion and extension of a muscle means.
- That muscles usually operate as antagonistic pairs.
- What tendons attach muscles to bones.

Muscles

Muscles make up the bulk of an animal's body and account for about half its weight. The meat on the chop or roast is muscle and is composed mainly of protein. The cells that make up muscle tissue are elongated and able to contract to a half or even a third of their length when at rest. There are three different kinds of muscle based on appearance and function: smooth, cardiac and skeletal muscle.

Types of Muscle

- Smooth muscle

Smooth or Involuntary muscle carries out the unconscious routine tasks of the body such as moving food down the digestive system, keeping the eyes in focus and adjusting the diameter of blood vessels. The individual cells are spindle-shaped, being fatter in the middle and tapering off towards the ends with a nucleus in the centre of the cell. They are usually found in sheets and are stimulated by the non-conscious or autonomic nervous system as well as by hormones (see Chapter 3).

- Cardiac muscle

Cardiac muscle is only found in the wall of the heart. It is composed of branching fibres that form a three-dimensional network. When examined under the microscope, a central nucleus and faint stripes or striations can be seen in the cells. Cardiac muscle cells contract spontaneously and rhythmically without outside stimulation, but the sinoatrial node (natural pacemaker) coordinates the heart beat. Nerves and hormones modify this rhythm (see Chapter 3).

- Skeletal muscle

Skeletal muscle is the muscle that is attached to and moves the skeleton, and is under voluntary control. It is composed of elongated cells or fibres lying parallel to each other. Each cell is unusual in that it has several nuclei and when examined under the microscope appears striped or striated. This appearance gives the muscle its names of striped or striated muscle. Each cell of striated muscle contains hundreds, or even thousands, of microscopic fibres each one with its own striped appearance. The stripes are formed by two different sorts of protein that slide over each other making the cell contract (see diagram 7.1).

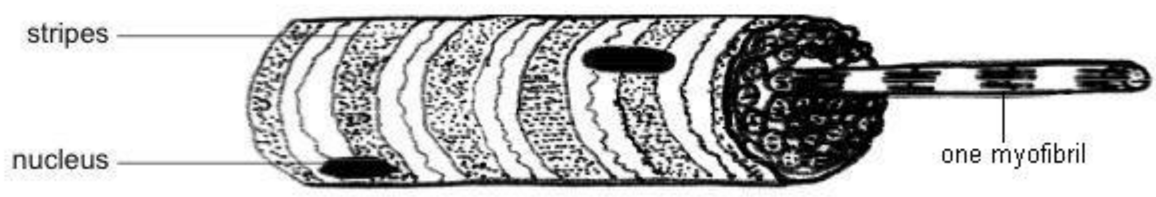


Diagram 7.1 - A striped muscle cell

Muscle contraction

Muscle contraction requires energy and muscle cells have numerous mitochondria. However, only about 15% of the energy released by the mitochondria is used to fuel muscle contraction. The rest is released as heat. This is why exercise increases body temperature and makes animals sweat or pant to rid themselves of this heat.

What we refer to as a muscle is made up of groups of muscle fibers surrounded by connective tissue. The connective tissue sheaths join together at the ends of the muscle to form tough white bands of fiber called **tendons**. These attach the muscles to the bones. Tendons are similar in structure to the **ligaments** that attach bones together across a joint (see diagrams 7.2a and b).

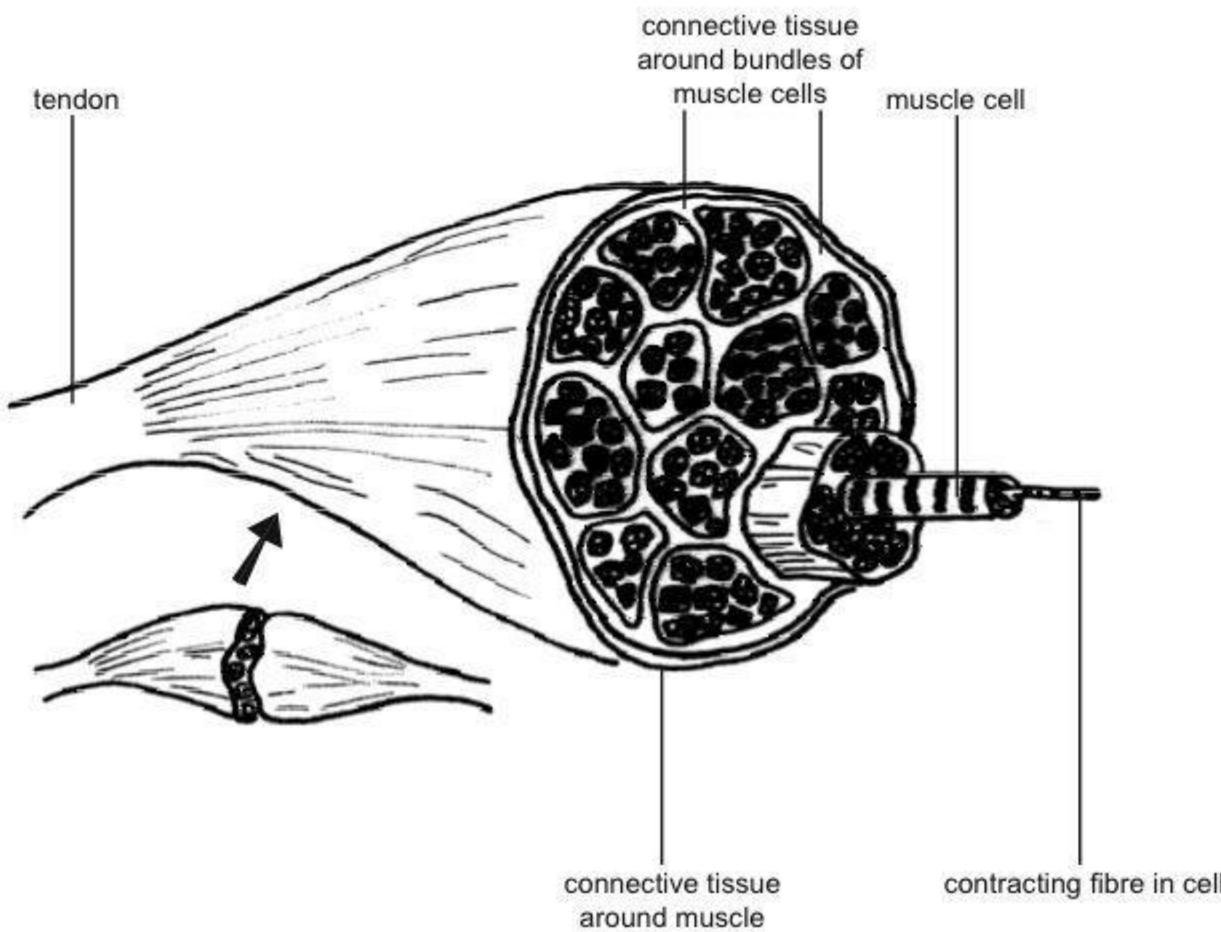


Diagram 7.2 a and b - The structure of a muscle

Remember:

Tendons Tie muscles to bones

and

Ligaments Link bones at joints

Structure of a muscle

A single muscle is fat in the middle and tapers towards the ends. The middle part, which gets fatter when the muscle contracts, is called the **belly** of the muscle. If you contract your biceps muscle in your upper arm you may feel it getting fatter in the middle. You may also notice that the biceps is attached at its top end to bones in your shoulder while at the bottom it is attached to bones in your lower arm. Notice that the bones at only one end move when you contract the biceps. This end of the muscle is called the **insertion**. The other end of the muscle, the **origin**, is attached to the bone that moves the least (see diagram 7.3).

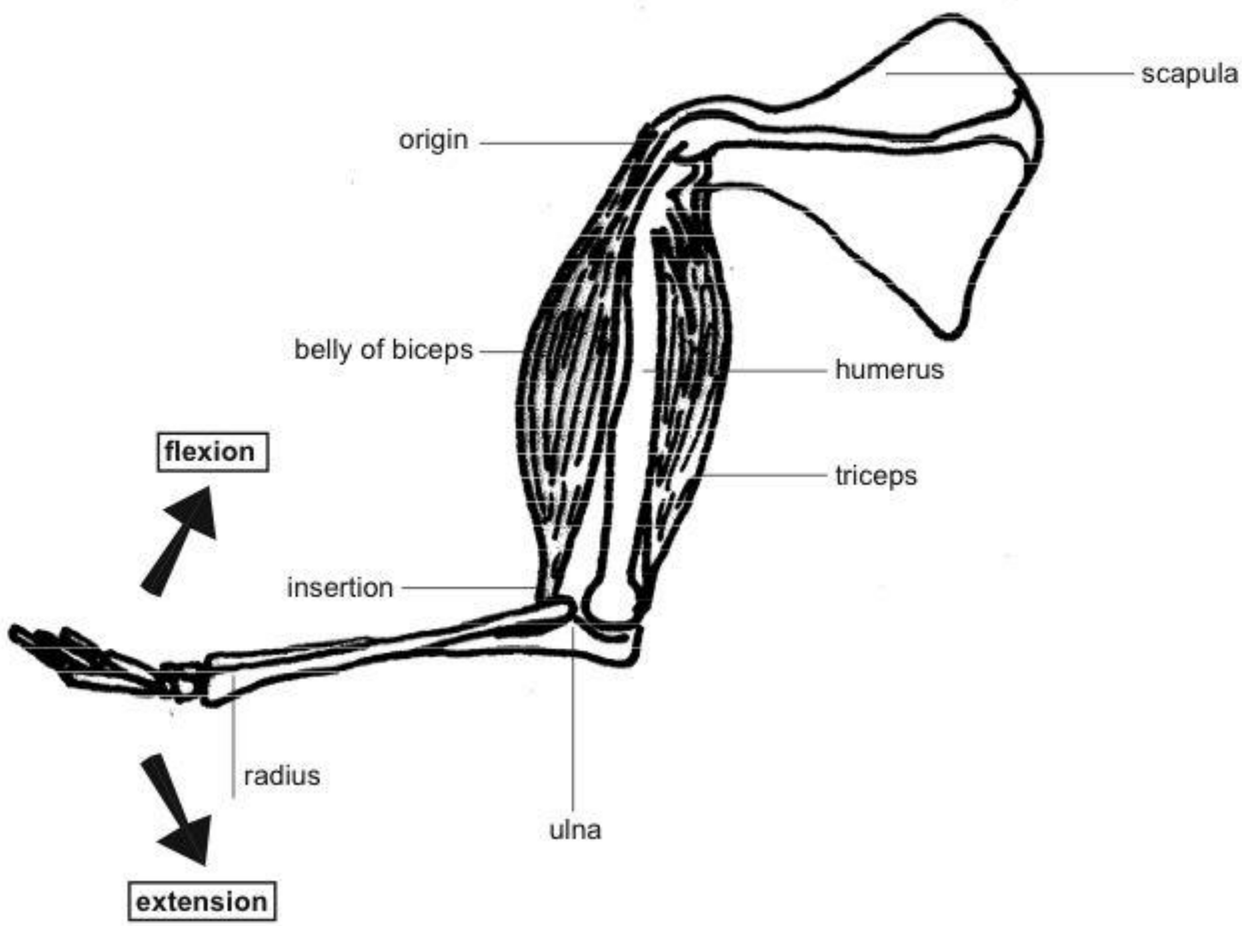


Diagram 7.3 - Antagonistic muscles, flexion and extension

Antagonistic muscles

Skeletal muscles usually work in pairs. When one contracts the other relaxes and vice versa. Pairs of muscles that work like this are called **antagonistic muscles**. For example the muscles in the upper forearm are the biceps and triceps (see diagram 7.3). Together they bend the elbow.

When the biceps contracts (and the triceps relaxes) the lower forearm is raised and the angle of the joint is reduced. This kind of movement is called **flexion**. When the triceps is contracted (and the biceps relaxes), the angle of the elbow increases. The term for this movement is **extension**.

When you or animals contract skeletal muscle it is a voluntary action. For example, you make a conscious decision to walk across the room, raise the spoon to your mouth, or smile. There is however, another way in which contraction of muscles attached to the skeleton happens that is not under voluntary control. This is during a **reflex action**, such as jerking your hand away from the hot stove you have touched by accident. This is called a **reflex arc** and will be described in detail in chapter 14-15.

Summary

- There are three different kinds of muscle tissue: **smooth muscle** in the walls of the gut and blood

  vessels; **cardiac muscle** in the heart and **skeletal muscle** attached to the skeleton.

- **Tendons** attach skeletal muscles to the skeleton.
- **Ligaments** link bones together at a joint.
- Skeletal muscles work in pairs known as **antagonistic pairs.** As one contracts the other in the

  pair relaxes.

- **Flexion** is the movement that reduces the angle of a joint. **Extension** increases the angle

  of a joint.

Test Yourself

1. What kind of muscle tissue:

   a) moves bones
   b) makes the heart pump blood:

c) pushes food along the intestine:

d) makes your mouth form a smile:

e) makes the hair stand up when cold:

f) makes the diaphragm contract for breathing in:

2. What structure connects a muscle to a bone?

3. What is the insertion of a muscle?

4. Which muscle is antagonistic to the biceps?

5. Name 3 other antagonistic pairs and tell what they do.

6. When you bend your knee what movement are you making?

7. When you straighten your ankle joint what movement happens?

8. What organelles provide the energy that muscles need?

9. State the difference between a tendon and a ligament.

10.In the section "Skeletal Muscle" there are 2 proteins mentioned. Name these proteins, state their size difference, and tell what they actually do to help produce movement.

Website

- http://health.howstuffworks.com/muscle.htm How muscles work

Description of the three types of muscles and how skeletal muscles work.

3.1.5: The Circulatory System

You might remember that blood is a form of connective tissue (widely spaced cells in a matrix, in this case a fluid matrix). In this section, you will start to understand how blood might better be called *the* connective tissue. Most people grow up thinking of blood as part of the "circulatory" system, but as you shall see, there are in fact two systems involved in circulation: the cardiovascular system and the lymphatic system. In terms of transport, the cardiovascular system takes the top spot, but in terms of defending against bacteria and viruses, the lymphatic system gets top billing. In this section, I explore the connection between these two parallel systems.

Blood is the giver of life, the provider of food, water, and air, the waste remover (with the help of the kidneys; see The Excretory System), but it can also be the harbinger of death, if an infection makes its way into the blood and we become septic. Adult females have an average of four to five liters of blood, and adult males average about five to six liters. How the blood manages to get from place to place is the subject of The Heart and Cardiovascular and Lymphatic Circulation. Here I discuss what blood actually *does*.

Function Junction

With apologies to Tina Turner, what's blood got to do with it? Blood does many wondrous things:

- Blood (plus vessels and the heart) is the primary transportation system for materials (the lymphatic system, as you will see, is the secondary transportation system): nutrients, water, wastes, O_2, and CO_2.
- Blood, which is slightly alkaline (7.35 to 7.45), regulates pH levels by absorbing acids from the interstitial fluid and neutralizing them.
- Blood regulates body temperature by transferring (via the plasma) heat generated by muscles (hemopoiesis; see The Muscles) to tissues throughout the body; heat can also be retained or lost through the constriction and dilation of vessels in the skin. As such, the average temperature of blood is higher than body temperature (38ºC, or 100.4ºF).
- Blood protects from fluid loss by clotting at the site of injuries.
- Blood protects from toxins and pathogens, through the action of white blood cells and antibodies.

3.1.6:Reproductive System

In biological terms sexual reproduction involves the union of **gametes** - the sperm and the ovum - produced by two parents. Each gamete is formed by **meiosis** (see Chapter 3). This means each contains only half the chromosomes of the body cells (**haploid**). Fertilization results in the joining of the male and female gametes to form a **zygote** which contains the full number of chromosomes (**diploid**). The zygote then starts to divide by **mitosis** (see Chapter 3) to form a new animal with all its body cells containing chromosomes that are identical to those of the original zygote

Sexual reproduction

The offspring formed by sexual reproduction contain genes from both parents and show considerable variation. For example, kittens in a litter are all different although they (usually) have the same mother and father. In the wild this variation is important because it means that when the environment changes some individuals may be better adapted to survive than others. These survivors pass their "superior" genes on to their offspring. In this way the characteristics of a group of animals can gradually change over time to keep pace with the changing environment. This "survival of the fittest" or "**natural selection**" is the mechanism behind the theory of **evolution**.

Fertilization

In most fish and amphibia (frogs and toads) fertilisation of the egg cells takes place outside the body. The female lays the eggs and then the male deposits his sperm on or at least near them.

In reptiles and birds, eggs are fertilized inside the body when the male deposits the sperm inside the **egg duct** of the female. The egg is then surrounded by a resistant shell, "laid" by the female and the embryo completes its development inside the egg.

In mammals the sperm are placed in the body of the female and the eggs are fertilized internally. They then develop to quite an advanced stage inside the body of the female.

Sexual Reproduction In Mammals

The reproductive organs of mammals produce the **gametes** (sperm and egg cells), help them fertilize and then support the developing embryo.

The Male Reproductive System

The male reproductive system consists of a pair of testes that produce **sperm** (or **spermatozoa**), ducts that transport the sperm to the penis and glands that add secretions to the sperm to make **semen** (see diagram 13.2).

The various parts of the male reproductive system with a summary of their functions are shown in diagram 13.3.

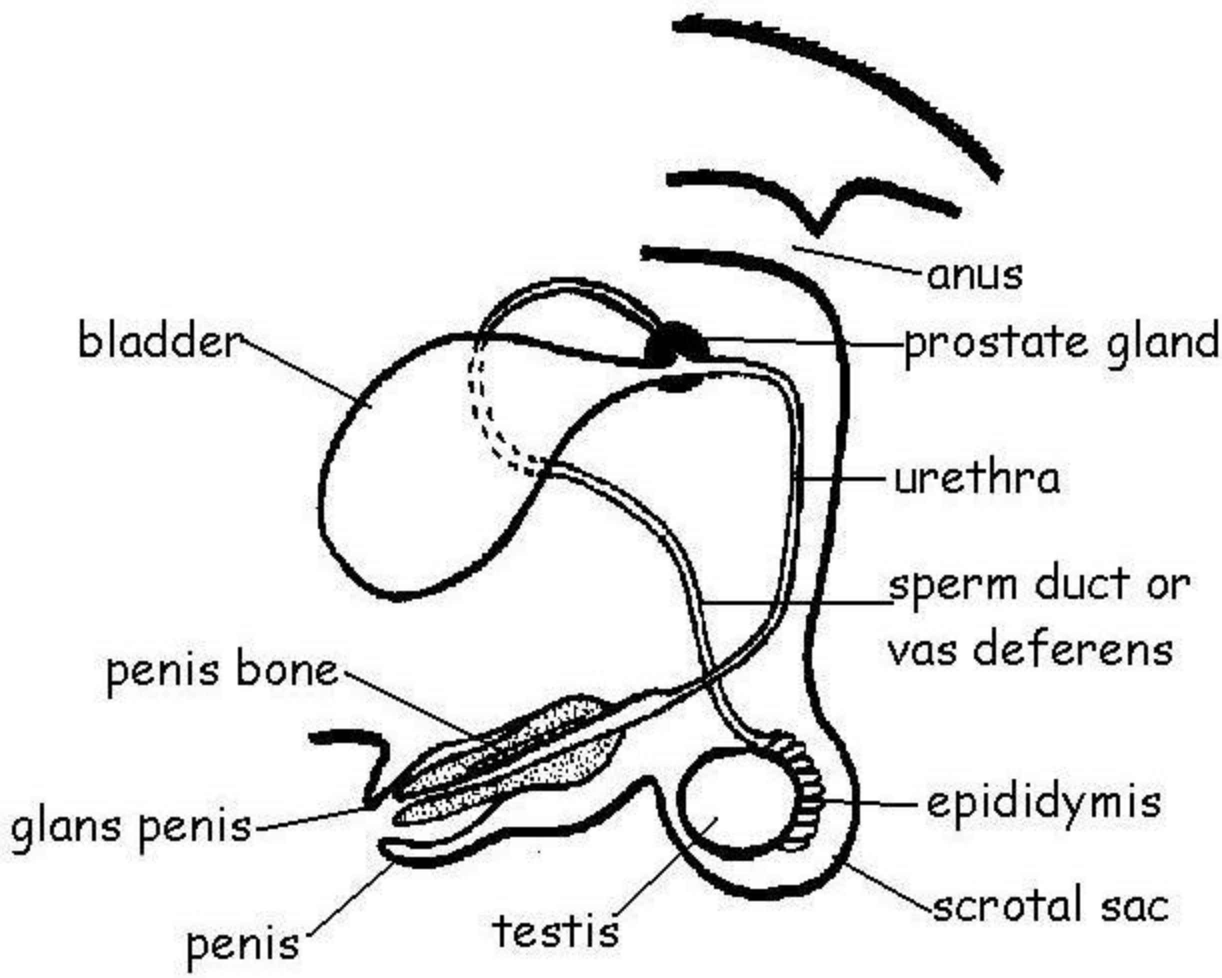


Diagram 13.2. The reproductive organs of a male dog

File:Anatomy and physiology of animals Diagram summarizing the functions of the male reproductive organs.jpg

Diagram 13.3 - Diagram summarizing the functions of the male reproductive organs

The Testes

Sperm need temperatures between 2 to 10 degrees Centigrade lower and then the body temperature to develop. This is the reason why the testes are located in a bag of skin called the

scrotal sacs (or **scrotum**) that hangs below the body and where the evaporation of secretions from special glands can further reduce the temperature. In many animals (including humans) the testes descend into the scrotal sacs at birth but in some animals they do not descend until sexual maturity and in others they only descend temporarily during the breeding season. A mature animal in which one or both testes have not descended is called a **cryptorchid** and is usually infertile.

The problem of keeping sperm at a low enough temperature is even greater in birds that have a higher body temperature than mammals. For this reason bird's sperm are usually produced at night when the body temperature is lower and the sperm themselves are more resistant to heat.

The testes consist of a mass of coiled tubes (the **seminiferous** or **sperm producing tubules**) in which the sperm are formed by meiosis (see diagram 13.4). Cells lying between the seminiferous tubules produce the male sex hormone **testosterone**.

When the sperm are mature they accumulate in the **collecting ducts** and then pass to the **epididymis**before moving to the **sperm duct** or **vas deferens**. The two sperm ducts join the **urethra** just below the bladder, which passes through the **penis** and transports both sperm and urine.

Ejaculation discharges the semen from the erect penis. It is brought about by the contraction of the epididymis, vas deferens, prostate gland and urethra.

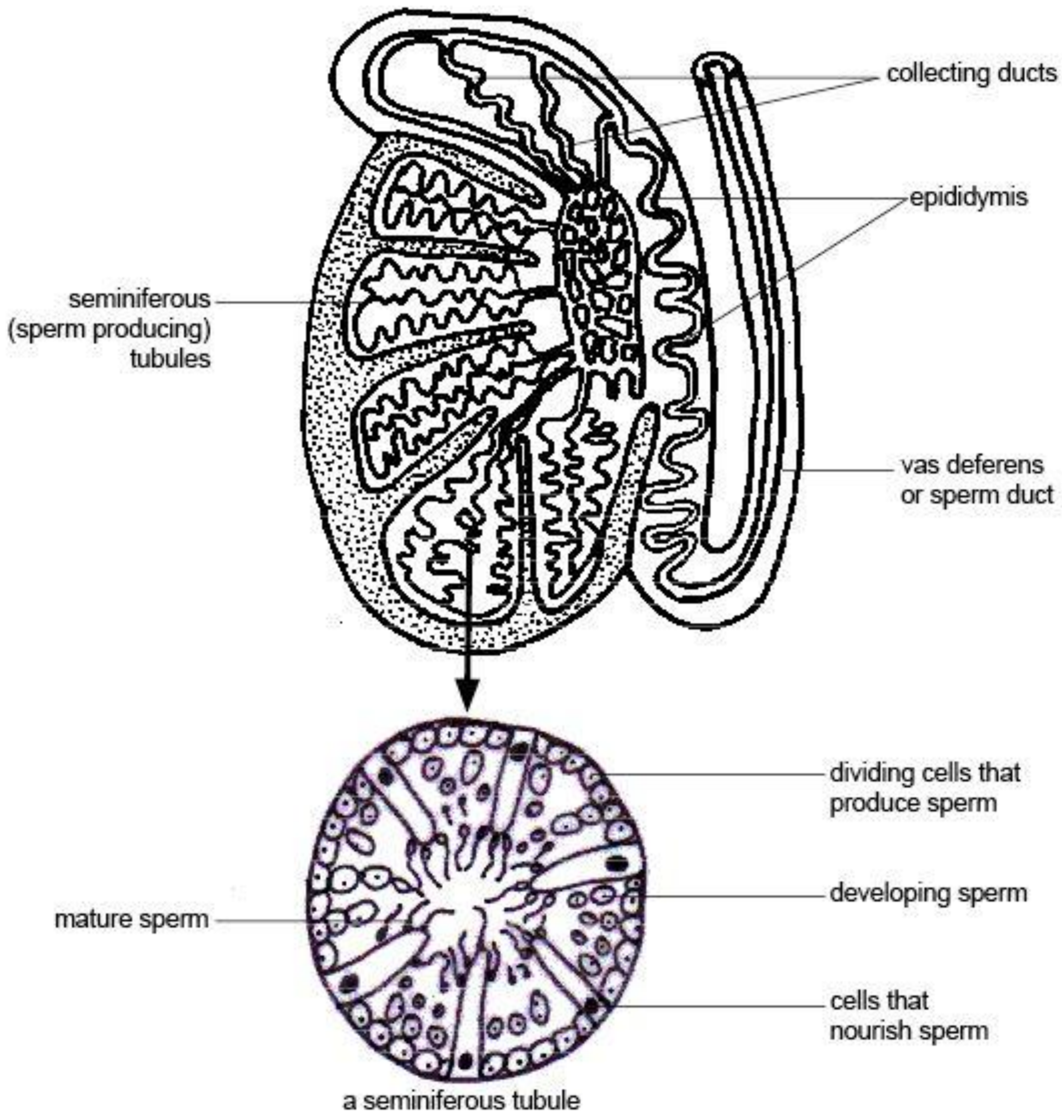


Diagram 13.4 - The testis and a magnified seminiferous tubule

Semen

Semen consists of 10% sperm and 90% fluid and as sperm pass down the ducts from testis to penis, (accessory) glands add various secretion...

Accessory Glands

Three different glands may be involved in producing the secretions in which sperm are suspended, although the number and type of glands varies from species to species.

Seminal vesicles are important in rats, bulls, boars and stallions but are absent in cats and dogs. When present they produce secretions that make up much of the volume of the semen, and transport and provide nutrients for the sperm.

The **prostate gland** is important in dogs and humans. It produces an alkaline secretion that neutralizes the acidity of the male urethra and female vagina.

Cowper's glands (bulbourethral glands) have various functions in different species. The secretions may lubricate, flush out urine or form a gelatinous plug that traps the semen in the female reproductive system after copulation and prevents other males of the same species fertilizing an already mated female. Cowper's glands are absent in bears and aquatic mammals.

The Penis

The penis consists of connective tissue with numerous small blood spaces in it. These fill with blood during sexual excitement causing erection.

Penis Form And Shape

Dogs, bears, seals, bats and rodents have a special bone in the penis which helps maintain the erection (see diagram 13.2). In some animals (e.g. the bull, ram and boar) the penis has an "S" shaped bend that allows it to fold up when not in use. In many animals the shape of the penis is adapted to match that of the vagina. For example, the boar has a corkscrew shaped penis, there is a pronounced twist in bulls' and it is forked in marsupials like the opossum. Some have spines, warts or hooks on them to help keep them in the vagina and copulation may be extended to help retain the semen in the female system. Mating can last up to three hours in minks, and dogs may "knot" or "tie" during mating and can not separate until the erection has subsided.

Sperm

Sperm are made up of three parts: a **head** consisting mainly of the nucleus, a **midpiece** containing many mitochondria to provide the energy and a **tail** that provides propulsion (see diagram 13.5).

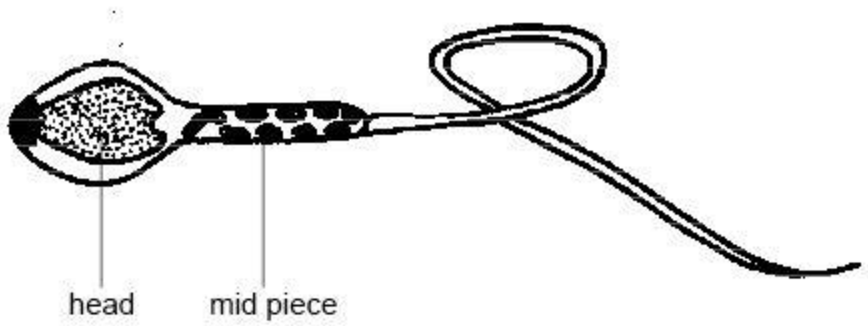


Diagram 13.5 - A sperm

A single ejaculation may contain 2-3 hundred million sperm but even in normal semen as many as 10% of these sperm may be abnormal and infertile. Some may be dead while others are inactive or deformed with double, giant or small heads or tails that are coiled or absent altogether.

When there are too many abnormal sperm or when the sperm concentration is low, the semen may not be able to fertilize an egg and the animal is infertile. Make sure you don't confuse infertility with impotence, which is the inability to copulate successfully.

Sperm do not live forever. They have a definite life span that varies from species to species. They survive for between 20 days (guinea pig) to 60 days (bull) in the epididymis but once ejaculated into the female tract they only live from 12 to 48 hours. When semen is used for artificial insemination, storage under the right conditions can extend the life span of some species.

Artificial Insemination

In many species the male can be artificially stimulated to ejaculate and the semen collected. It can then be diluted, stored and used to **inseminate** females. For example bull semen can be diluted and stored for up to 3 weeks at room temperature. If mixed with an antifreeze solution and stored in "straws" in liquid nitrogen at minus 79^{o}C it will keep for much longer. Unfortunately the semen of chickens, stallions and boars can only be stored for up to 2 days.

Dilution of the semen means that one male can be used to fertilise many more females than would occur under natural conditions. There are also advantages in the male and female not having to make physical contact. It means that owners of females do not have to buy expensive males and the possibility of transmitting sexually transmitted diseases is reduced. Routine examination of the semen for sperm concentration, quality and activity allows only the highest quality semen to be used so a high success rate is ensured.

Since the lifespan of sperm in the female tract is so short and ova only survive from 8 to 10 hours the timing of the artificial insemination is critical. Successful conception depends upon detecting the time that the animal is "on heat" and when ovulation occurs.

The Female Reproductive Organs

The female reproductive system consists of a pair of **ovaries** that produce egg cells or **ova** and **fallopian tubes** where fertilisation occurs and which carry the fertilised ovum to the **uterus**. Growth of the foetus takes place here. The **cervix** separates the uterus from the **vagina** or birth canal, where the sperm are deposited (see diagram 13.6).

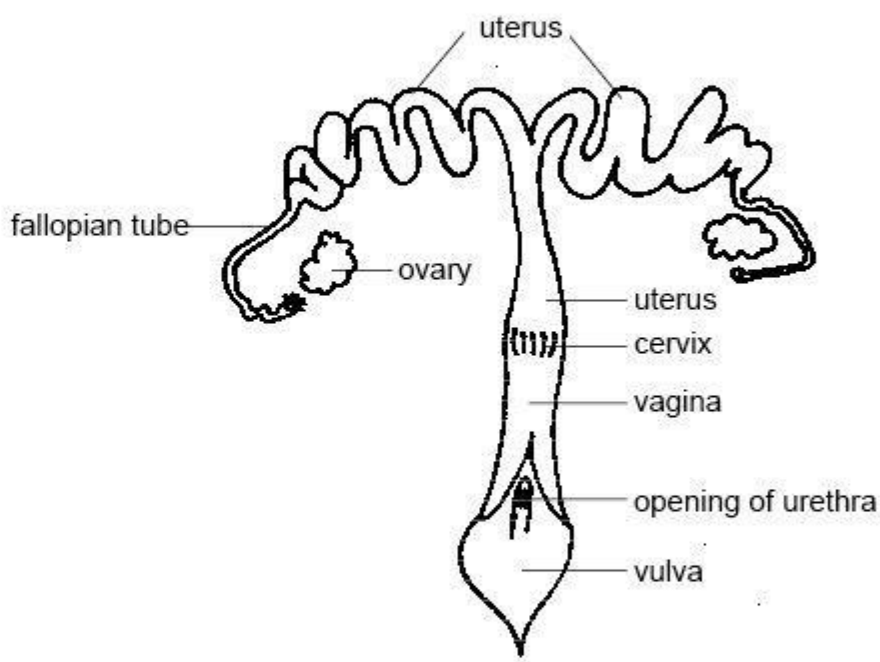


Diagram 13.6. - The reproductive system of a female rabbit

Note that primates like humans have a uterus with a single compartment but in most mammals the uterus is divided into two separate parts or **horns** as shown in diagram 13.6.

The Ovaries

Ovaries are small oval organs situated in the abdominal cavity just ventral to the kidneys. Most animals have a pair of ovaries but in birds only the left one is functional to reduce weight (see below).

The ovary consists of an inner region (**medulla**) and an outer region (**cortex**) containing egg cells or ova. These are formed in large numbers around the time of birth and start to develop after the animal becomes sexually mature. A cluster of cells called the **follicle** surrounds and nourishes each ovum.

The Ovarian Cycle

The **ovarian cycle** refers to the series of changes in the ovary during which the follicle matures, the ovum is shed and the **corpus luteum** develops (see diagram 13.7).

Numerous undeveloped ovarian follicles are present at birth but they start to mature after sexual maturity. In animals that normally have only one baby at a time only one ovum will mature at once but in litter animals several will. The mature follicle consists of outer cells that provide nourishment. Inside this is a fluid-filled space that contains the ovum.

A mature follicle can be quite large, ranging from a few millimetres in small mammals to the size of a golf ball in large animals. It bulges out from the surface of the ovary before eventually rupturing to release the ovum into the abdominal cavity. Once the ovum has been shed, a blood clot forms in the empty follicle. This develops into a tissue called the **corpus luteum** that produces the hormone **progesterone** (see diagram 13.9). If the animal becomes pregnant the corpus luteum persists, but if there is no pregnancy it degenerates and a new ovarian cycle usually.

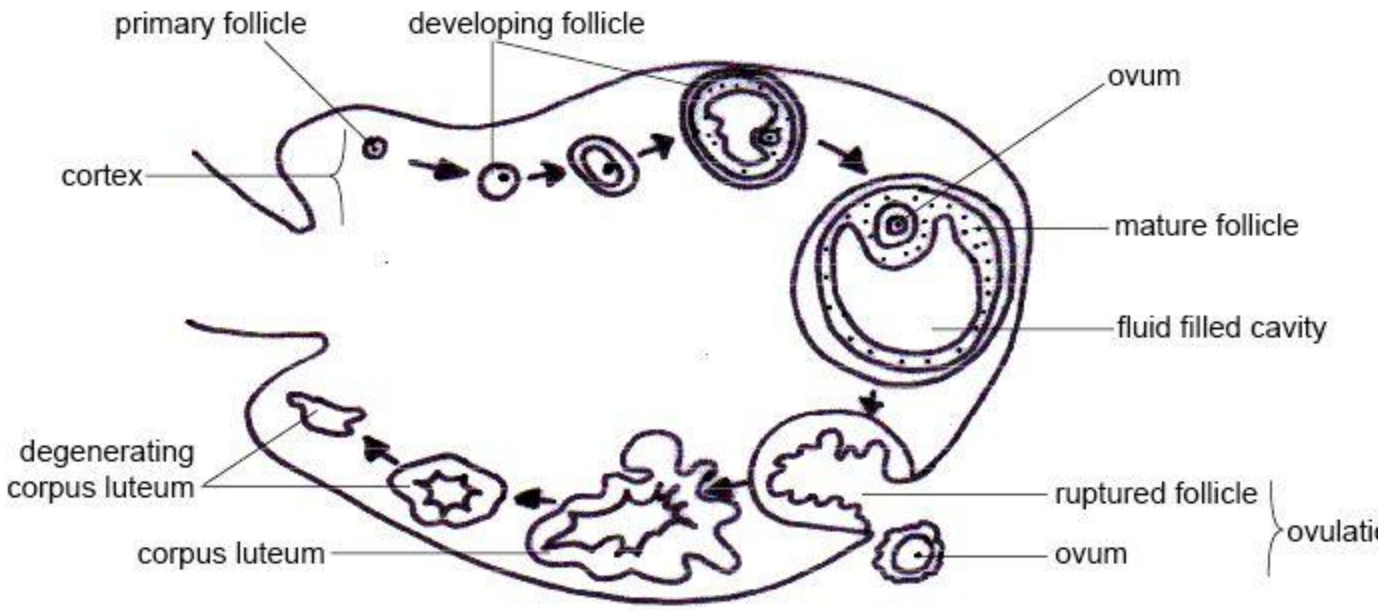


Diagram 13.7 - The ovarian cycle showing from the top left clockwise: the maturation of the ovum over time, followed by ovulation and the development of the corpus luteum in the empty follicle

The Ovum

When the ovum is shed the nucleus is in the final stages of meiosis (cell division). It is surrounded by few layers of follicle cells and a tough membrane called the **zona pelluc**ida (see diagram 13.8).

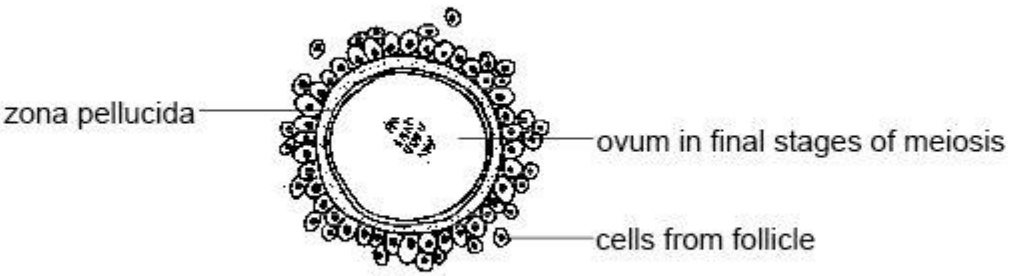


Diagram 13.8 - An ovum

The Oestrous Cycle

The **oestrous cycle** is the sequence of hormonal changes that occurs through the **ovarian cycle**. These changes influence the behaviour and body changes of the female (see diagram 13.9).

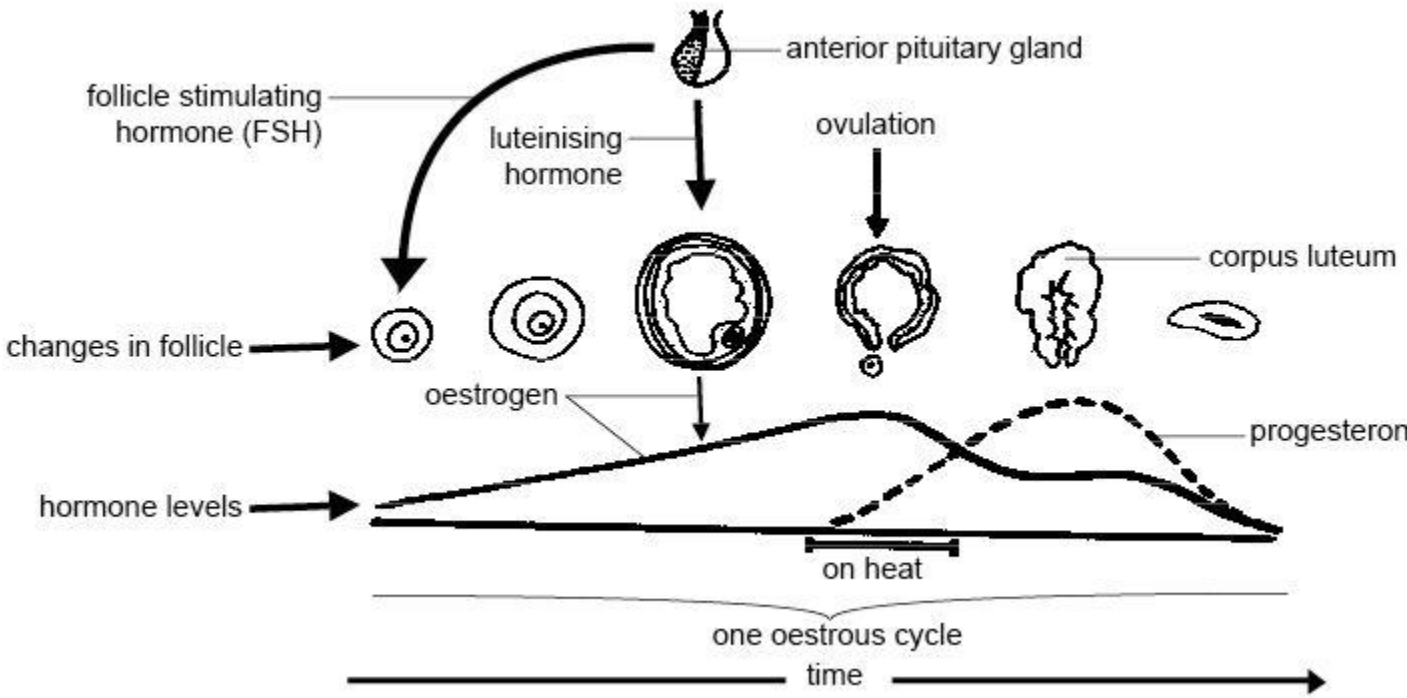


Diagram 13.9 - The oestrous cycle

The first hormone involved in the oestrous cycle is **follicle stimulating hormone (F.S.H.),** secreted by the **anterior pituitary gland** (see chapter 16). It stimulates the follicle to develop. As the follicle matures the outer cells begin to secrete the hormone **oestrogen** and this stimulates the mammary glands to develop. It also prepares the lining of the uterus to receive a fertilised egg. Ovulation is initiated by a surge of another hormone from the anterior pituitary, **luteinising hormone (L.H.).** This hormone also influences the development of the corpus luteum, which produces **progesterone**, a hormone that prepares the lining of the uterus for the fertilised ovum and readies the mammary glands for milk production. If no pregnancy takes place the corpus luteum shrinks and the production of progesterone decreases. This causes FSH to be produced again and a new oestrous cycle begins.

For fertilisation of the ovum by the sperm to occur, the female must be receptive to the male at around the time of ovulation. This is when the hormones turn on the signs of "**heat**", and she is "**in season**" or "**in oestrous**". These signs are turned off again at the end of the oestrous cycle.

During the oestrous cycle the lining of the uterus (**endometrium**) thickens ready for the fertilised ovum to be implanted. If no pregnancy occurs this thickened tissue is absorbed and the next cycle starts. In humans and other higher primates, however, the endometrium is shed as a flow of blood and instead of an oestrous cycle there is a **menstrual cycle**.

The length of the oestrous cycle varies from species to species. In rats the cycle only lasts 4–5 days and they are sexually receptive for about 14 hours. Dogs have a cycle that lasts 60–70 days and heat lasts 7–9 days and horses have a 21-day cycle and heat lasts an average of 6 days.

Ovulation is spontaneous in most animals but in some, e.g. the cat, and the rabbit, ovulation is stimulated by mating. This is called **induced ovulation**.

Signs of Oestrous or Heat

- When on heat a bitch has a blood stained discharge from the **vulva** that changes a little later to a straw coloured one that attracts all the dogs in the neighbourhood.
- Female cats "call" at night, roll and tread the carpet and are generally restless but will "stand" firm when pressure is placed on the pelvic region (this is the lordosis response).
- A female rat shows the lordosis response when on heat. It will "mount" other females and be more active than normal.
- A cow mounts other cows (bulling), bellows, is restless and has a discharge from the vulva.

Breeding Seasons and Breeding Cycles

Only a few animals breed throughout the year. This includes the higher primates (humans, gorillas and chimpanzees etc.), pigs, mice and rabbits. These are known as **continuous breeders**.

Most other animals restrict reproduction to one or two seasons in the year-**seasonal breeders** (see diagram 13.10). There are several reasons for this. It means the young can be born at the time (usually spring) when feed is most abundant and temperatures are favourable. It is also sensible to restrict the breeding season because courtship, mating, gestation and the rearing of young can exhaust the energy resources of an animal as well as make them more vulnerable to predators.

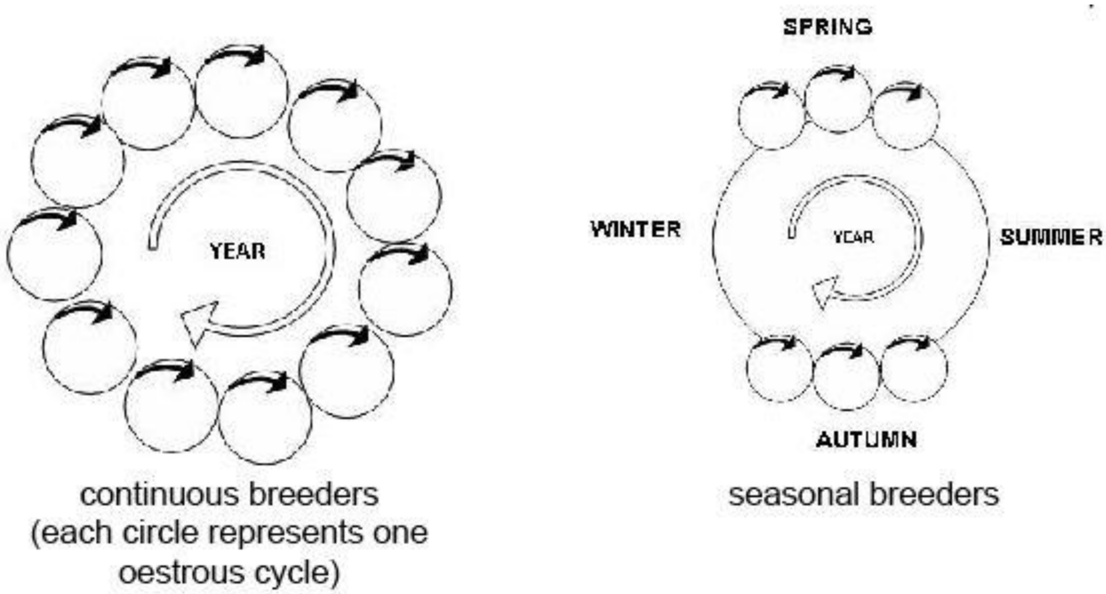


Diagram 13.10 - Breeding cycles

The timing of the breeding cycle is often determined by day length. For example the shortening day length in autumn will bring sheep and cows into season so the foetus can gestate through the winter and be born in spring. In cats the increasing day length after the winter solstice (shortest day) stimulates breeding. The number of times an animal comes into season during the year varies, as does the number of oestrous cycles during each season. For example a dog usually has 2-3 seasons per year, each usually consisting of just one oestrous cycle. In contrast ewes usually restrict breeding to one season and can continue to cycle as many as 20 times if they fail to become pregnant.

Fertilisation and Implantation

Fertilisation

The opening of the fallopian tube lies close to the ovary and after ovulation the ovum is swept into its funnel-like opening and is moved along it by the action of cilia and wave-like contractions of the wall.

Copulation deposits several hundred million sperm in the vagina. They swim through the cervix and uterus to the fallopian tubes moved along by whip-like movements of their tails and contractions of the uterus. During this journey the sperm undergo their final phase of maturation so they are ready to fertilise the ovum by the time they reach it in the upper fallopian tube.

High mortality means only a small proportion of those deposited actually reach the ovum. The sperm attach to the outer **zona pellucida** and enzymes secreted from a gland in the head of the sperm dissolve this membrane so it can enter. Once one sperm has entered, changes in the **zona pellucida** prevent further sperm from penetrating. The sperm loses its tail and the two nuclei fuse to form a **zygote** with the full set of paired chromosomes restored.

Development Of The Morula And Blastocyst

As the fertilised egg travels down the fallopian tube it starts to divide by mitosis. First two cells are formed and then four, eight, sixteen, etc. until there is a solid ball of cells. This is called a **morula**. As division continues a hollow ball of cells develops. This is a **blastocyst** (see diagram 13.11).

Implantation

Implantation involves the blastocyst attaching to, and in some species, completely sinking into the wall of the uterus.

Pregnancy

The Placenta And Foetal Membranes

As the **embryo** increases in size, the **placenta**, **umbilical cord** and **foetal membranes** (often known collectively as the **placenta**) develop to provide it with nutrients and remove waste products (see diagram 13.12). In later stages of development the embryo becomes known as a **foetus**.

The placenta is the organ that attaches the foetus to the wall of the uterus. In it the blood of the foetus and mother flow close to each other but never mix (see diagram 13.13). The closeness of the maternal and foetal blood systems allows diffusion between them. Oxygen and nutrients diffuse from the mother's blood into that of the foetus and carbon dioxide and excretory products diffuse in the other direction. Most maternal hormones (except adrenaline), antibodies, almost all drugs (including alcohol), lead and DDT also pass across the placenta. However, it protects the foetus from infection with bacteria and most viruses.

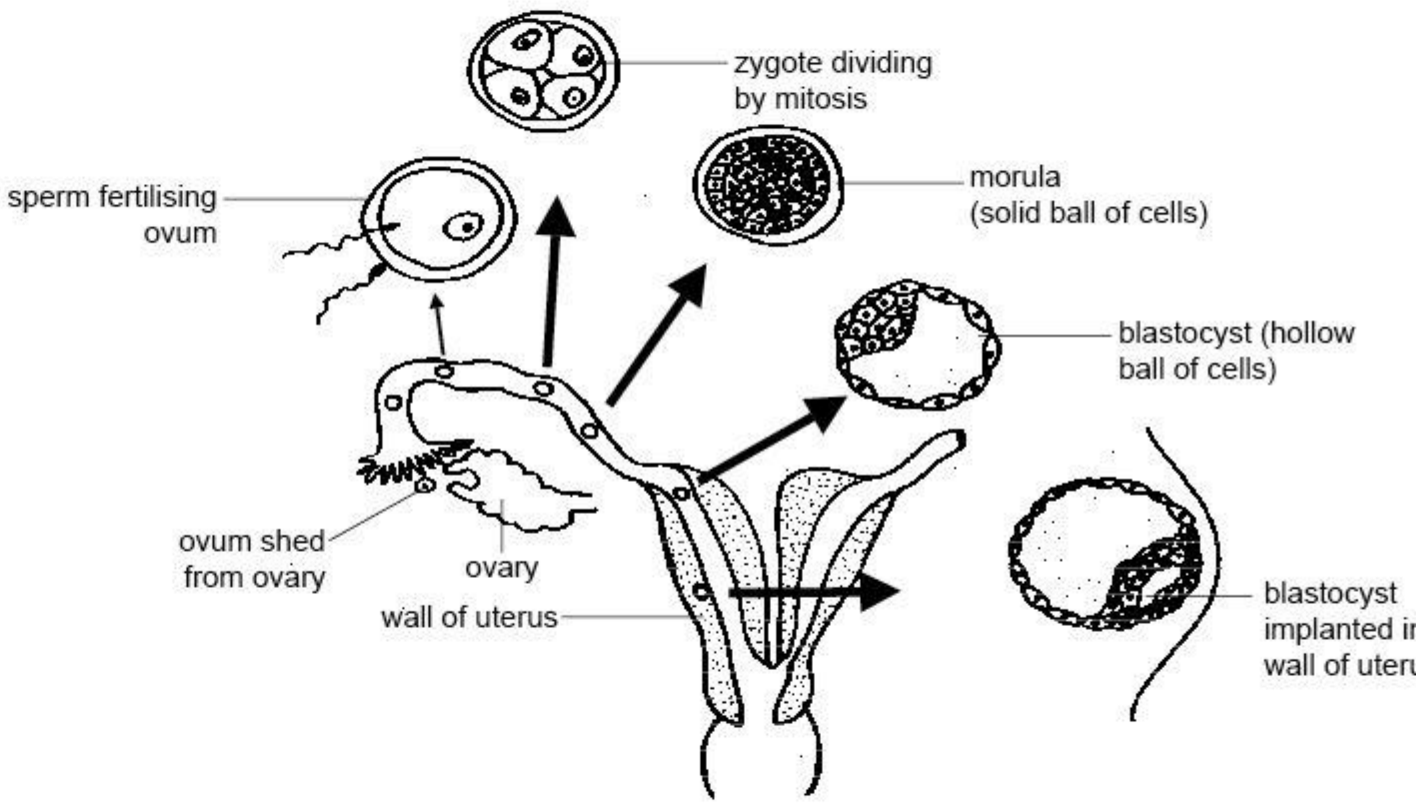


Diagram 13.11 - Development and implantation of the embryo

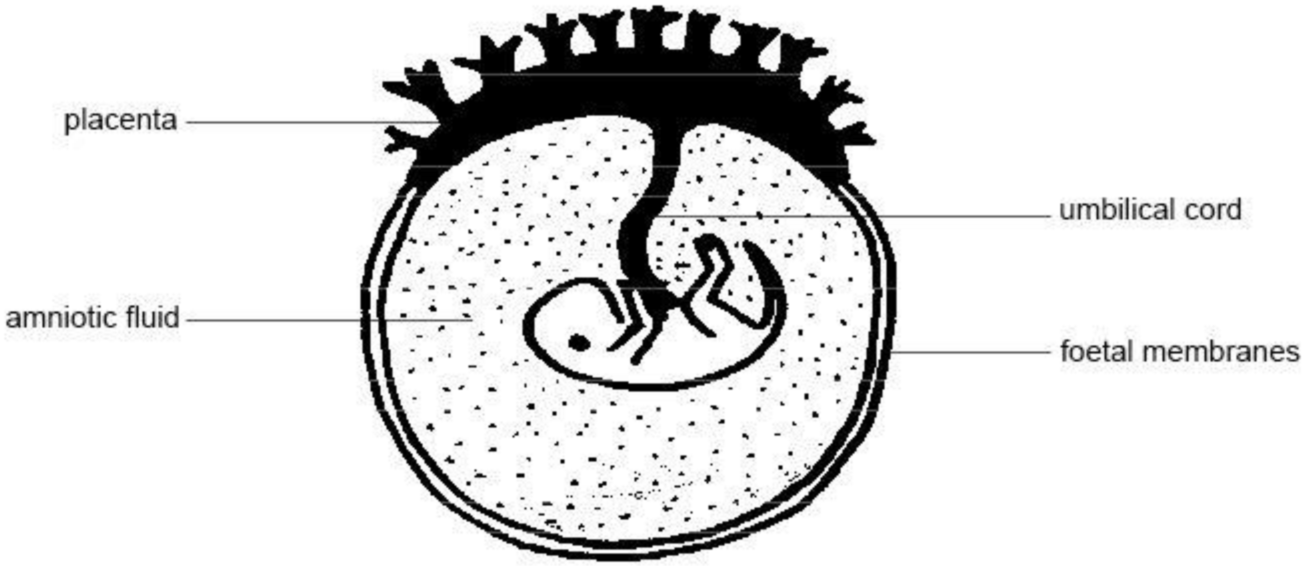


Diagram 13.12. The foetus and placenta

The foetus is attached to the placenta by the **umbilical cord**. It contains arteries that carry blood to the placenta and a vein that returns blood to the foetus. The developing foetus becomes surrounded by membranes. These enclose the amniotic fluid that protects the foetus from knocks and other trauma (see diagram 13.12).

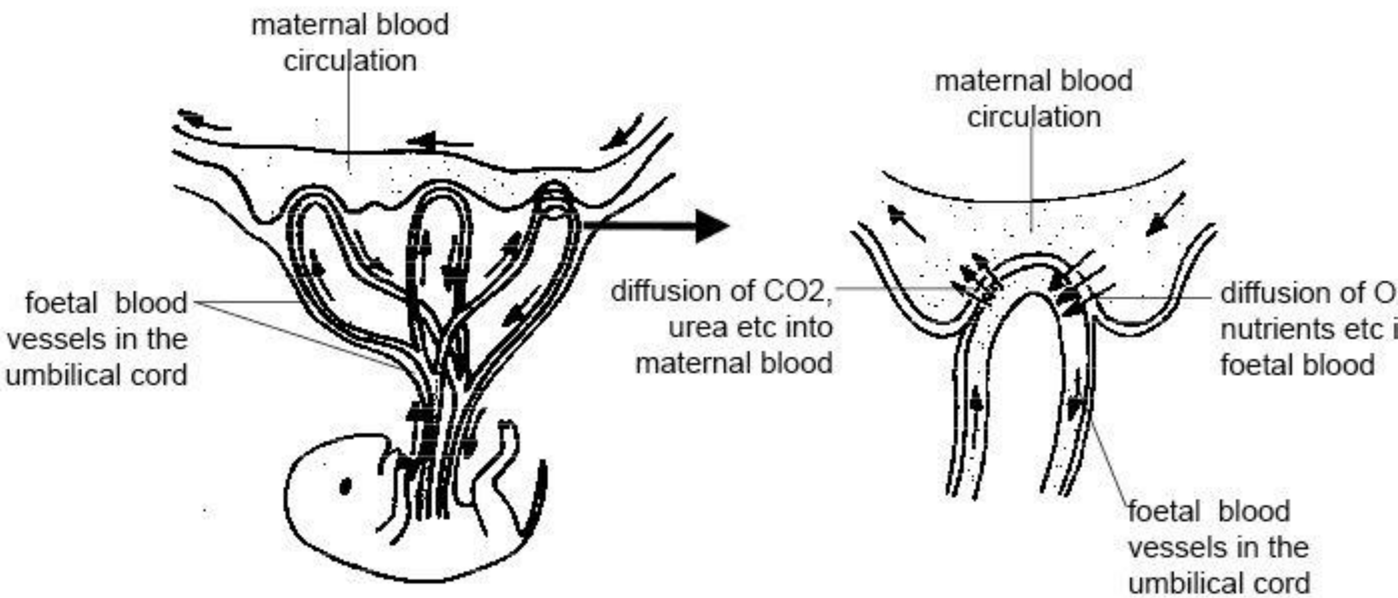


Diagram 13.13 - Maternal and foetal blood flow in the placenta

Hormones during Pregnancy

The corpus luteum continues to secrete progesterone and oestrogen during pregnancy. These maintain the lining of the uterus and prepare the mammary glands for milk secretion. Later in the pregnancy the placenta itself takes over the secretion of these hormones.

Chorionic gonadotrophin is another hormone secreted by the placenta and placental membranes. It prevents uterine contractions before labour and prepares the mammary glands for lactation. Towards the end of pregnancy the placenta and ovaries secrete **relaxin**, a hormone that eases the joint between the two parts of the pelvis and helps dilate the cervix ready for birth.

Pregnancy Testing

The easiest method of pregnancy detection is ultrasound which is noninvasive and very reliable Later in gestation pregnancy can be detected by taking x-rays.

In dogs and cats a blood test can be used to detect the hormone **relaxin**.

In mares and cows palpation of the uterus via the rectum is the classic way to determine pregnancy. It can also be done by detecting the hormones **progesterone** or **equine chorionic gonagotrophin** (**eCG**) in the urine. A new sensitive test measures the amount of the hormone, **oestrone sulphate**, present in a sample of faeces. The hormone is produced by the foal and placenta, and is only present when there is a living foal.

In most animals, once pregnancy is advanced, there is a window of time during which an experienced veterinarian can determine pregnancy by feeling the abdomen.

Gestation Period

The young of many animals (e.g. pigs, horses and elephants) are born at an advanced state of development, able to stand and even run to escape predators soon after they are born. These animals have a relatively long gestation period that varies with their size e.g. from 114 days in the pig to 640 days in the elephant.

In contrast, cats, dogs, mice, rabbits and higher primates are relatively immature when born and totally dependent on their parents for survival. Their gestation period is shorter and varies from 25 days in the mouse to 31 days in rabbits and 258 days in the gorilla.

The babies of marsupials are born at an extremely immature stage and migrate to the pouch where they attach to a teat to complete their development. Kangaroo joeys, for example, are born 33 days after conception and opossums after only 8 days.

Birth

Signs Of Imminent Birth

As the pregnancy continues, the mammary glands enlarge and may secrete a milky substance a few days before birth occurs. The vulva may swell and produce thick mucus and there is sometimes a visible change in the position of the foetus. Just before birth the mother often becomes restless, lying down and getting up frequently. Many animals seek a secluded place where they may build a nest in which to give birth.

Labour

Labour involves waves of uterine contractions that press the foetus against the cervix causing it to dilate. The foetus is then pushed through the cervix and along the vagina before being delivered. In the final stage of labour the placenta or "afterbirth" is expelled.

Adaptations Of The Foetus To Life Outside The Uterus

The foetus grows in the watery, protected environment of the uterus where the mother supplies oxygen and nutrients, and waste products pass to her blood circulation for excretion. Once the baby animal is born it must start to breathe for itself, digest food and excrete its own waste. To allow these functions to occur blood is re-routed to the lungs and the glands associated with the gut start to secrete. Note that newborn animals can not control their own body temperature. They need to be kept warm by the mother, littermates and insulating nest materials.

Milk Production

Cows, manatees and primates have two mammary glands but animals like pigs that give birth to large litters may have as many as 12 pairs. Ducts from the gland lead to a nipple or teat and there may be a sinus where the milk collects before being suckled (see diagram 13.14).

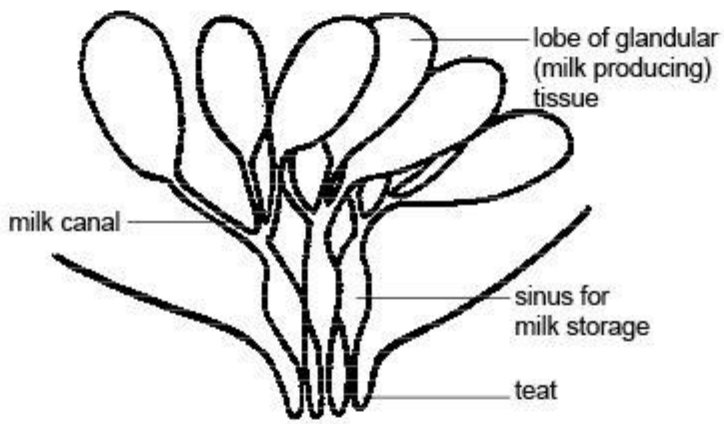


Diagram 13.14 - A mammary gland

The hormones **oestrogen** and **progesterone** stimulate the mammary glands to develop and **prolactin** promotes the secretion of the milk. **Oxytocin** from the pituitary gland releases the milk when the baby suckles. The first milk is called **colostrum**. It is a rich in nutrients and contains protective antibodies from the mother. Milk contains fat, protein and milk sugar as well as vitamins and most minerals although it contains little iron. Its actual composition varies widely from species to species. For example whale’s and seal’s milk has twelve times more fat and four times more protein than cow’s milk. Cow’s milk has far less protein in it than cat’s or dog’s milk. This is why orphan kittens and puppies cannot be fed cow’s milk.

Reproduction In Birds

Male birds have testes and sperm ducts and male swans, ducks, geese and ostriches have a penis. However, most birds make do with a small amount of erectile tissue known as a **papilla**. To reduce weight for flight most female birds only have one ovary - usually the left, which produces extremely yolky eggs. The eggs are fertilised in the upper part of the oviduct (equivalent to the fallopian tube and uterus of mammals) and as they pass down it **albumin** (the white of the egg), the membrane beneath the shell and the shell are laid down over the yolk. Finally the egg is covered in a layer of mucus to help the bird lay it (see diagram 13.15).

Most birds lay their eggs in a nest and the hen sits on them until they hatch. Ducklings and chicks are relatively well developed when they hatch and able to forage for their own food. Most other nestlings need their parents to keep them warm, clean and fed. Young birds grow rapidly and have voracious appetites that may involve the parents making up to 1000 trips a day to supply their need for food.

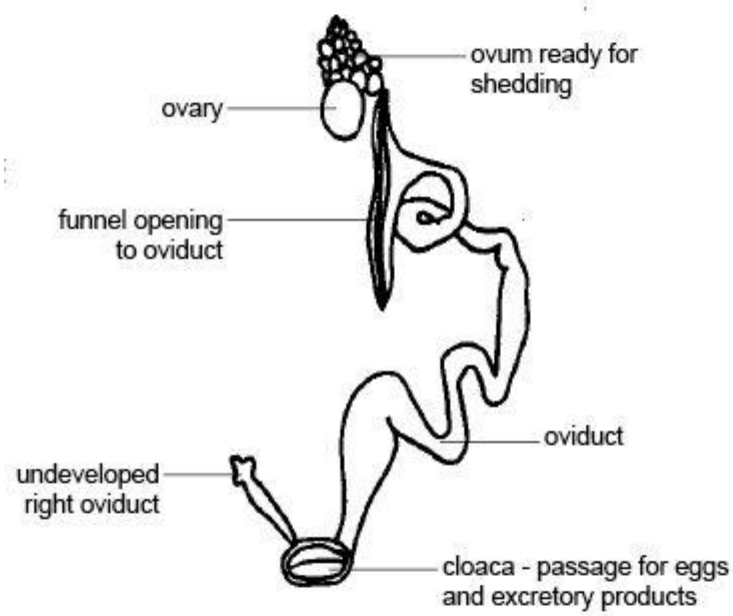


Diagram 13.15 - Female reproductive organs of a bird

Summary

- **Haploid** gametes (sperm and ova) are produced by meiosis in the **gonads** (testes and ovaries).
- Fertilisation involves the fusing of the gametes to form a diploid **zygote**.

- The male reproductive system consists of a pair of **testes** that produce sperm (or **spermatozoa**), ducts that transport the sperm to the penis and glands that add secretions to the sperm to make semen.
- Sperm are produced in the **seminiferous tubules**, are stored in the **epididymis** and travel via the **vas deferens** or **sperm duct** to the junction of the bladder and the **urethra** where various accessory glands add secretions. The fluid is now called **semen** and is ejaculated into the female system down the **urethra** that runs down the centre of the penis.
- Sperm consist of a head, a midpiece and a tail.
- **Infertility** is the inability of sperm to fertilize an egg while **impotence** is the inability to copulate successfully.
- The female reproductive system consists of a pair of **ovaries** that produce **ova** and **fallopian tubes** where fertilisation occurs and which carry the fertilised ovum to the **uterus**. Growth of the foetus takes place here. The **cervix** separates the uterus from the **vagina**, the birth canal and where the sperm are deposited.
- The **ovarian cycle** refers to the series of changes in the ovary during which the follicle matures, the ovum is shed and the **corpus luteum** develops.
- The **oestrous cycle** is the sequence of hormonal changes that occurs through the ovarian cycle. It is initiated by the secretion of **follicle stimulating hormone (F.S.H.),** by the **anterior pituitary gland** which stimulates the **follicle** to develop. The follicle secretes **oestrogen** which stimulates **mammary gland** development. **luteinising hormone (L.H.)** from the anterior pituitary initiates **ovulation** and stimulates the **corpus luteum** to develop. The corpus luteum produces **progesterone** that prepares the lining of the uterus for the fertilised ovum.
- **Signs of oestrous** or heat differ. A bitch has a blood stained discharge, female cats and rats are restless and show the lordosis response, while cows mount other cows, bellow and have a discharge from the vulva.
- After fertilisation in the fallopian tube the **zygote** divides over and over by mitosis to become a ball of cells called a **morula**. Division continues to form a hollow ball of cells called the **blastocyst**. This is the stage that **implants** in the uterus.
- The **placenta, umbilical cord** and **foetal membranes** (known as the **placenta**) protect and provide the developing foetus with nutrients and remove waste products.

Websites

- http://www.anatomicaltravel.com/CB_site/Conception_to_birth3.htm Anatomical travel. Images of fertilisation and the development of the (human) embryo through to birth.
- http://www.uchsc.edu/ltc/fert.swf Fertilisation. A great animation of fertilisation, formation of the zygote and first mitotic division. A bit advanced but still worth watching.
- http://www.uclan.ac.uk/facs/health/nursing/sonic/scenarios/salfordanim/heart.swf Sonic. An animation showing the foetal blood circulation through the placenta to the changes allowing circulation through the lungs after birth.
- http://en.wikipedia.org/wiki/Estrus Wikipedia. As always, good interesting information although some terms and concepts are beyond the requirements of this level.

3.1.7: Digestion

2.0: Objectives

After completing this section, you should know:

- what is meant by the terms: ingestion, digestion, absorption, assimilation, egestion, peristalsis and chyme
- the characteristics, advantages and disadvantages of a herbivorous, carnivorous and omnivorous diet
- the 4 main functions of the gut
- the parts of the gut in the order in which the food passes down

The Gut and Digestion

Plant cells are made of organic molecules using energy from the sun. This process is called **photosynthesis**. Animals rely on these ready-made organic molecules to supply them with their food. Some animals (herbivores) eat plants; some (carnivores) eat the herbivores.

Herbivores

Herbivores *eat plant material. While no animal produces the digestive enzymes to break down the large **cellulose** molecules in the plant cell walls, micro-organisms' like bacteria, on the other hand, can break them down. Therefore herbivores employ micro-organisms to do the job for them.*

There are two types of herbivore:

> The first, **ruminants** like cattle, sheep and goats, house these bacteria in a special compartment in the enlarged stomach called the **rumen**.
>
> The second group has an enlarged large intestine and caecum, called a **functional caecum**, occupied by cellulose digesting micro-organisms. These non-ruminant herbivores include the horse, rabbit and rat.

Plants are a primary pure and good source of nutrients, however they aren't digested very easily and therefore herbivores have to eat large quantities of food to obtain all they require. Herbivores like cows, horses and rabbits typically spend much of their day feeding. To give the micro-organisms access to the cellulose molecules, the plant cell walls need to be broken down. This is why herbivores have teeth that are adapted to crush and grind. Their guts also tend to be lengthy and the food takes a long time to pass through it.

Eating plants have other advantages. Plants are immobile so herbivores normally have to spend little energy collecting them. This contrasts with another main group of animals - the carnivores that often have to chase their prey.

Carnivores

Carnivorous animals like those in the cat and dog families, polar bears, seals, crocodiles and birds of prey catch and eat other animals. They often have to use large amounts of energy finding, stalking, catching and killing their prey. However, they are rewarded by the fact that meat provides a very concentrated source of nutrients. Carnivores in the wild therefore tend to eat distinct meals often with long and irregular intervals between them. Time after feeding is spent digesting and absorbing the food.

The guts of carnivores are usually shorter and less complex than those of herbivores because meat is easier to digest than plant material. Carnivores usually have teeth that are specialised for dealing with flesh, gristle and bone. They have sleek bodies, strong, sharp claws and keen senses of smell, hearing and sight. They are also often cunning, alert and have an aggressive nature.

Omnivores

Many animals feed on both animal and vegetable material – they are **omnivorous.** There are currently two similar definitions of omnivorism:

1. Having the ability to derive energy from plant and animal material.

2. Having characteristics which are optimized for acquiring and eating both plants and animals.

Some animals fit both definitions of omnivorism, including bears, raccoons, dogs, and hedgehogs. Their food is diverse, ranging from plant material to animals they have either killed themselves or scavenged from other carnivores. They are well equipped to hunt and tear flesh (claws, sharp teeth, and a strong, non-rotational jaw hinge), but they also have slightly longer intestines than carnivores, which has been found to facilitate plant digestion. The examples also retain an ability to taste amino acids, making unseasoned flesh palatable to most members of the species.

Classically, humans and chimpanzees are classified as omnivores. However, further research has shown chimpanzees typically consume 95% plant matter (the remaining mass is largely termites), and their teeth, jaw hinge, stomach pH, and intestinal length closely matches herbivores, which many suggest classified them as herbivores. Humans, conversely, have chosen to eat meat for much of the archaeological record, although their teeth, jaw hinge, and stomach pH, and intestinal lengths also closely match other herbivores.

The dispute of human/ chimps classifications is caused by two things. First, there is research that both plant-only and some-animal diets promote health (longevity and freedom from disease) in humans. Second, well-off humans have often chosen to eat meat and dairy products throughout written history, which some argue shows that we prefer meat and dairy by latent instinct.

Per the classical definition, omnivores lack the specialized teeth and guts of carnivores and herbivores but are often highly intelligent and adaptable reflecting their varied diet.

Treatment of Food

Whether an animal eats plants or flesh, the **carbohydrates**, **fats** and **proteins** in the food it eats are generally giant molecules (see chapter 1). These need to be split up into smaller ones before they can pass into the blood and enter the cells to be used for energy or to make new cell constituents.

For example:

> **Carbohydrates** like cellulose, starch, and glycogen need to be split into **glucose** and other **monosaccharides**;
> **Proteins** need to be split into **amino acids**;
> **Fats** or **lipids** need to be split into **fatty acids** and **glycerol**.

The Gut

The **digestive tract, alimentary canal** or **gut** is a hollow tube stretching from the mouth to the anus. It is the organ system concerned with the treatment of foods.

At the mouth the large food molecules are taken into the gut **-** this is called **ingestion**. They must then be broken down into smaller ones by digestive enzymes **- digestion**, before they can be taken from the gut into the blood stream **- absorption**. The cells of the body can then use these small molecules **- assimilation**. The indigestible waste products are eliminated from the body by the act of **egestion** (see diagram 11.1).

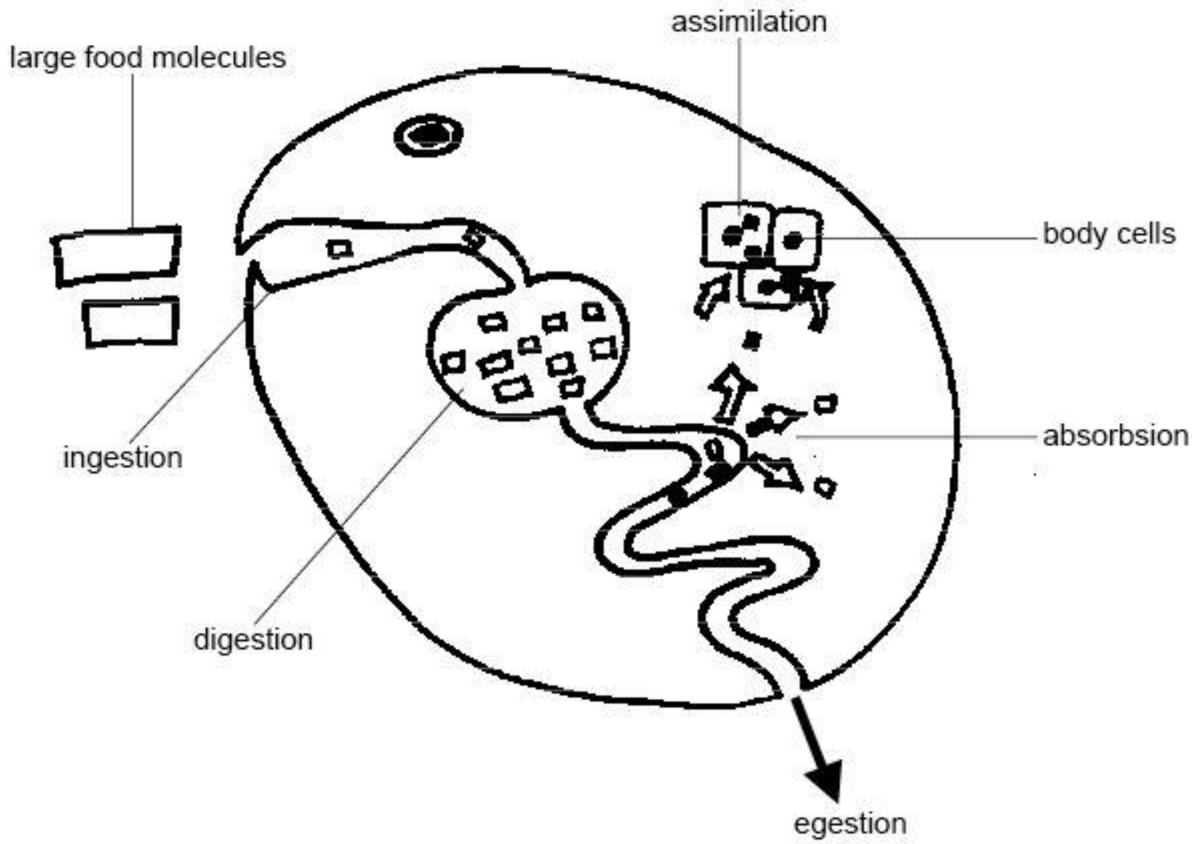


Diagram 11.1 - From ingestion to egestion

The 4 major functions of the gut are:

1. Transporting the food;
2. Processing the food physically by breaking it up (chewing), mixing, adding fluid etc.
3. Processing the food chemically by adding digestive enzymes to split large food molecules into smaller ones.
4. Absorbing these small molecules into the blood stream so the body can use them.

The regions of a typical mammals gut (for example a cat or dog) are shown in diagram 11.2.

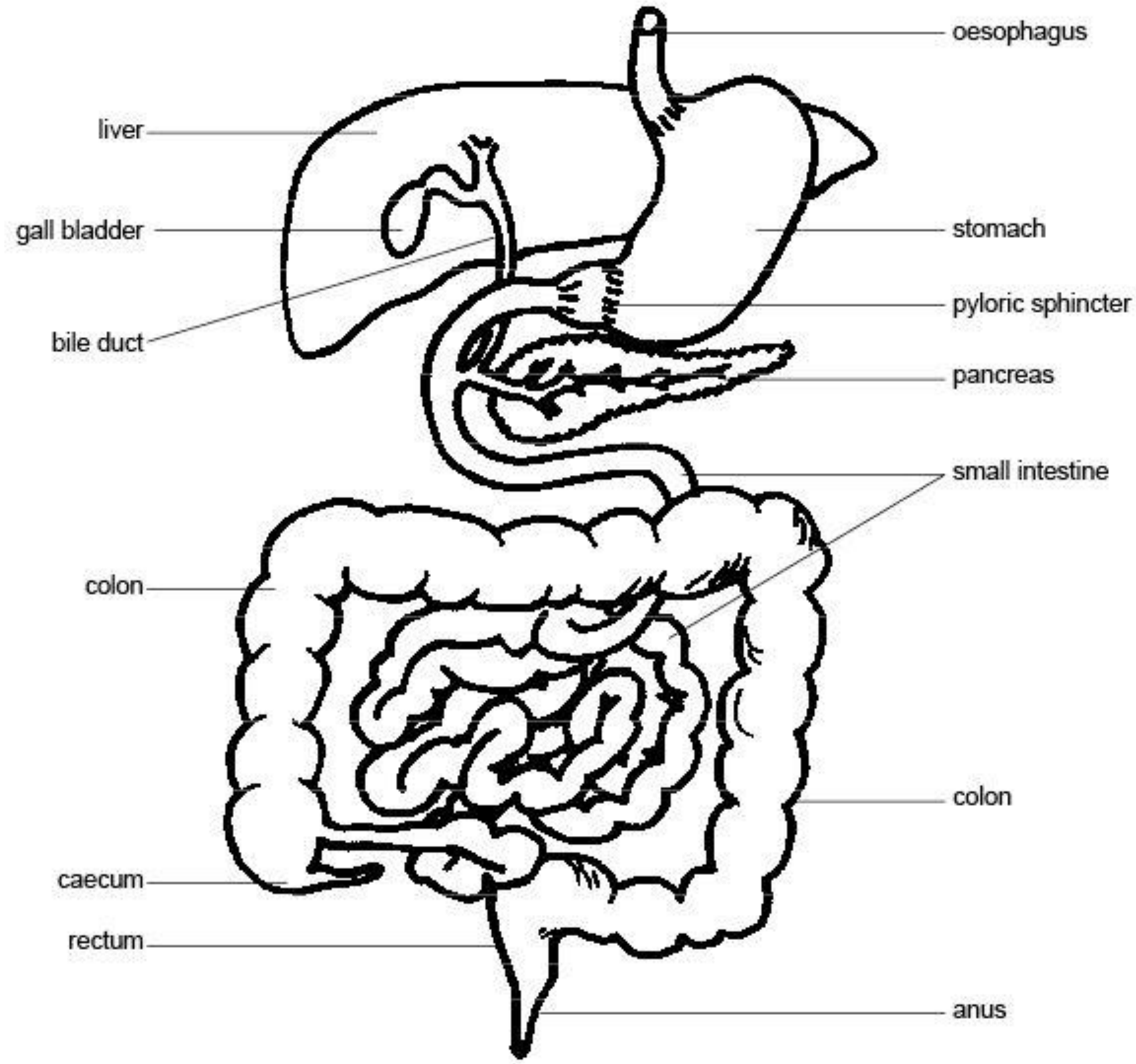


Diagram 11.2 - A typical mammalian gut

The food that enters the **mouth** passes to the **oesophagus**, then to the **stomach**, **small intestine**, **cecum**, **large intestine**, **rectum** and finally undigested material exits at the **anus**. The **liver** and **pancreas** produce secretions that aid digestion and the **gall bladder** stores **bile**. Herbivores have an appendix which they use for the digestion of cellulose. A carnivore has an appendix but is not of any function anymore due to the fact that their diet is not based on cellulose anymore.

Mouth

The mouth takes food into the body. The lips hold the food inside the mouth during chewing and allow the baby animal to suck on its mother's teat. In elephants the lips (and nose) have developed into the trunk which is the main food collecting tool. Some mammals, e.g. hamsters, have stretchy cheek pouches that they use to carry food or material to make their nests.

The sight or smell of food and its presence in the mouth stimulates the **salivary glands** to secrete **saliva**. There are four pairs of these glands in cats and dogs (see diagram 11.3). The fluid they produce moistens and softens the food making it easier to swallow. It also contains the enzyme, **salivary amylase**, which starts the digestion of starch.

The **tongue** moves food around the mouth and rolls it into a ball called a bolus for swallowing. **Taste buds** are located on the tongue and in dogs and cats it is covered with spiny projections used for grooming and lapping. The cow's tongue is prehensile and wraps around grass to graze it.

Swallowing is a complex reflex involving 25 different muscles. It pushes food into the oesophagus and at the same time a small flap of tissue called the **epiglottis** closes off the windpipe so food doesn't enter the trachea and choke the animal (see diagram 11.4).

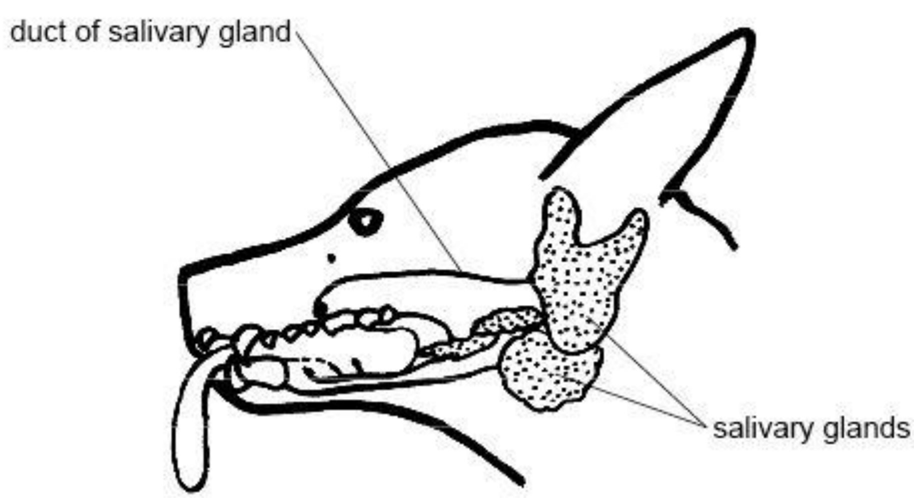


Diagram 11.3 - Salivary glands

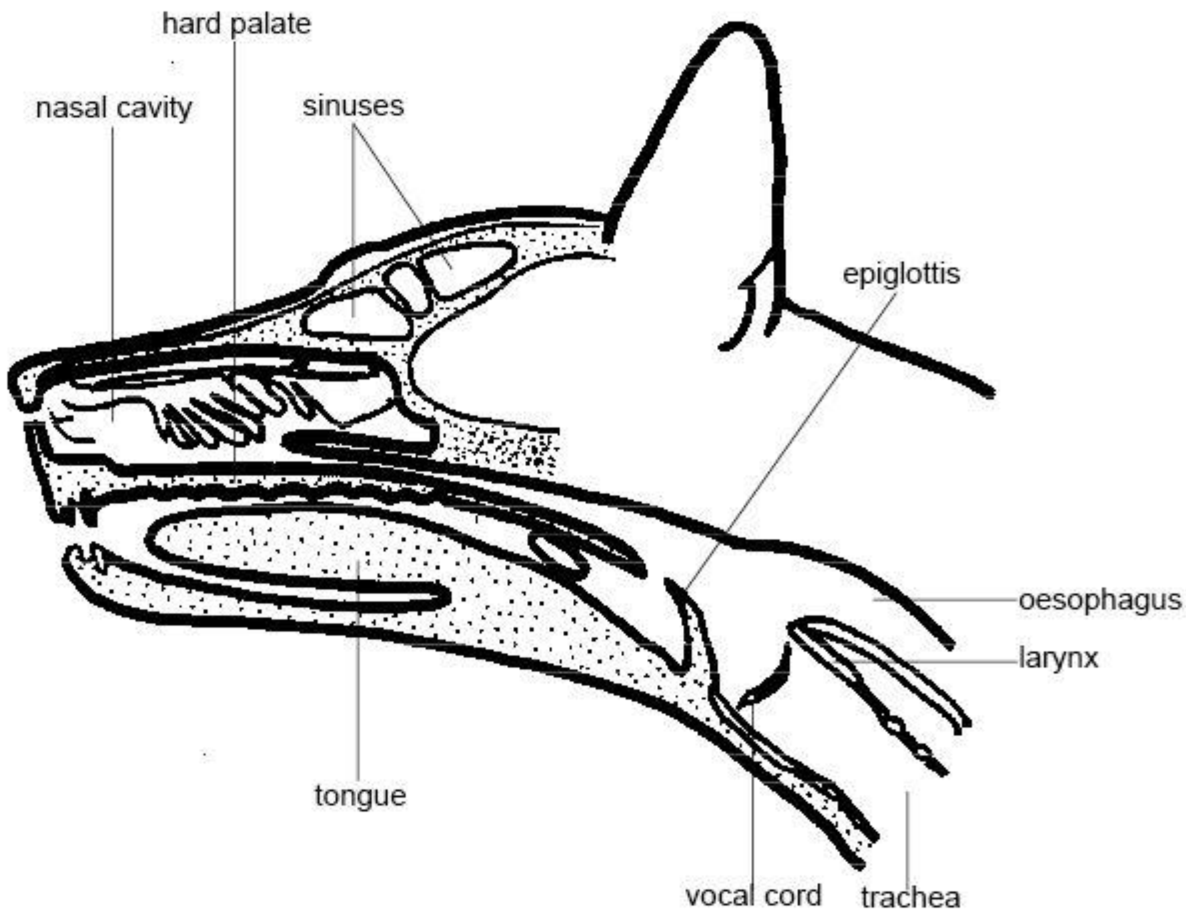


Diagram 11.4 - Section through the head of a dog

Teeth

Teeth seize, tear and grind food. They are inserted into sockets in the bone and consist of a crown above the gum and root below. The crown is covered with a layer of **enamel**, the hardest substance in the body. Below this is the **dentine**, a softer but tough and shock resistant material. At the centre of the tooth is a space filled with **pulp** which contains blood vessels and nerves. The tooth is cemented into the **socket** and in most teeth the tip of the root is quite narrow with a small opening for the blood vessels and nerves (see diagram 11.5).

In teeth that grow continuously, like the incisors of rodents, the opening remains large and these teeth are called **open rooted teeth**. Mammals have 2 distinct sets of teeth. The first set, the **milk teeth**, are replaced by the **permanent teeth**.

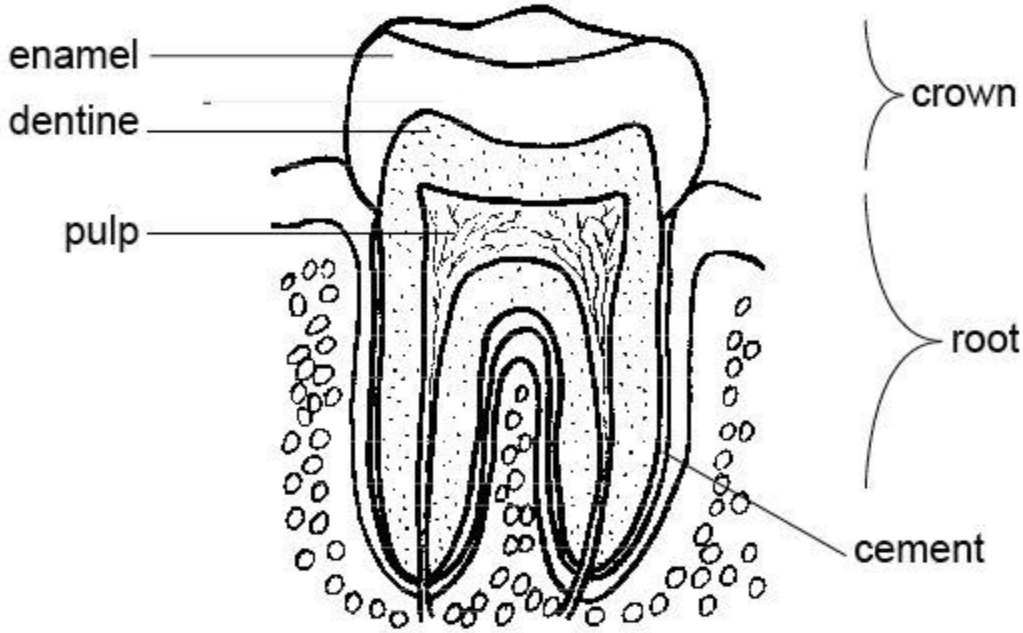


Diagram 11.5 - Structure of a tooth

Types Of Teeth

All the teeth of fish and reptiles are similar but mammals usually have four different types of teeth.

The **incisors** are the chisel-shaped ‘biting off’ teeth at the front of the mouth. In rodents and rabbits the incisors never stop growing (open-rooted teeth). They must be worn or ground down continuously by gnawing. They have hard enamel on one surface only so they wear unevenly and maintain their sharp cutting edge.

The largest incisors in the animal kingdom are found in elephants, for tusks are actually giant incisors. Sloths have no incisors at all, and sheep have no incisors in the upper jaw (see diagram 11.6). Instead there is a horny pad against which the bottom incisors cut.

The **canines** or ‘wolf-teeth’ are long, cone-shaped teeth situated just behind the incisors. They are particularly well developed in the dog and cat families where they are used to hold, stab and kill the prey (see diagram 11.7).

The tusks of boars and walruses are large canines while rodents and herbivores like sheep have no (or reduced) canines. In these animals the space where the canines would normally be is called the **diastema**. In rodents like the rat and beaver it allows the debris from gnawing to be expelled easily.

The cheek teeth or **premolars** and **molars** crush and grind the food. They are particularly well developed in herbivores where they have complex ridges that form broad grinding surfaces (see diagram 11.6). These are created from alternating bands of hard enamel and softer dentine that wear at different rates.

In carnivores the premolars and molars slice against each other like scissors and are called **carnassial** teeth see diagram 11.7). They are used for shearing flesh and bone.

Dental Formula

The numbers of the different kinds of teeth can be expressed in a **dental formula**. This gives the numbers of incisors, canines, premolars and molars in **one half** of the mouth. The numbers of these four types of teeth in the left **or** right **half of the upper jaw** are written above a horizontal line and the four types of teeth in the right **or** left **half of the lower jaw** are written below it.

Thus the dental formula for the sheep is:

0.0.3.3
3.1.3.3

It indicates that in the upper right (or left) **half** of the jaw there are no incisors or canines (i.e. there is a **diastema**), three premolars and three molars. In the lower right (or left) **half** of the jaws are three incisors, one canine, three premolars and three molars (see diagram 11.6).

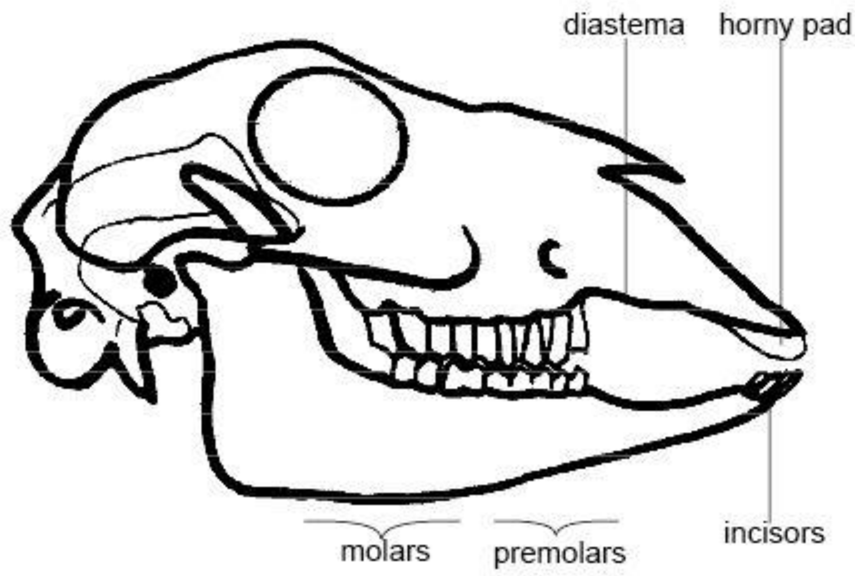


Diagram 11.6 - A sheep's skull

The dental formula for a dog is:

3.1.4.2
3.1.4.3

The formula indicates that in the right (or left) **half** of the upper jaw there are three incisors, one canine, four premolars and two molars. In the right (or left) **half** of the lower jaw there are three incisors, one canine, four premolars and three molars (see diagram 11.7).

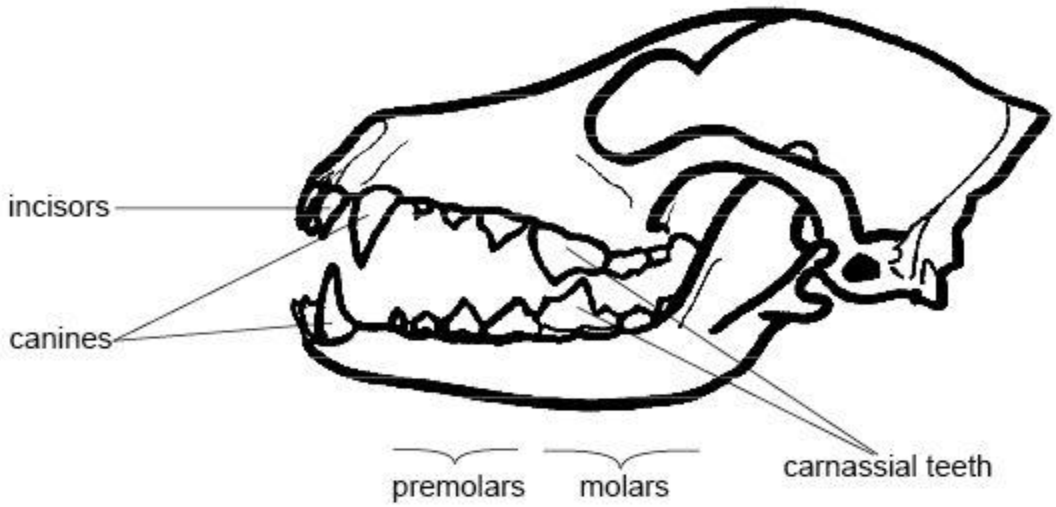


Diagram 11.7 - A dog's skull

Oesophagus

The **oesophagus** transports food to the stomach. Food is moved along the oesophagus, as it is along the small and large intestines, by contraction of the smooth muscles in the walls that push the food along rather like toothpaste along a tube. This movement is called **peristalsis** (see diagram 11.8).

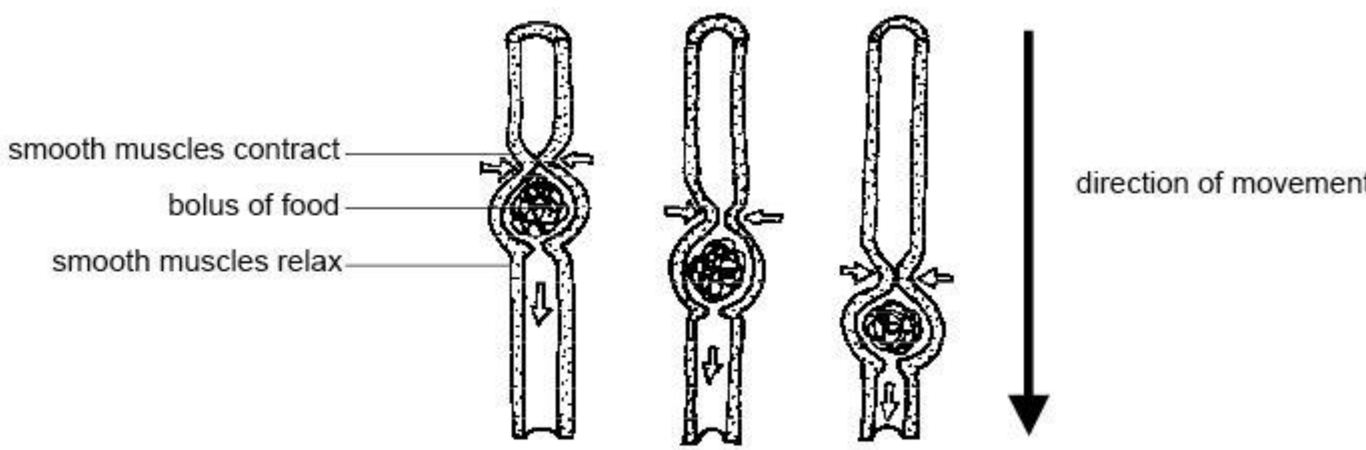


Diagram 11.8 - Peristalsis

Stomach

The **stomach** stores and mixes the food. Glands in the wall secrete **gastric juice** that contains enzymes to digest protein and fats as well as **hydrochloric acid** to make the contents very acidic. The walls of the stomach are very muscular and churn and mix the food with the gastric juice to form a watery mixture called **chyme** (pronounced kime). Rings of muscle called **sphincters** at the entrance and exit to the stomach control the movement of food into and out of it (see diagram 11.9).

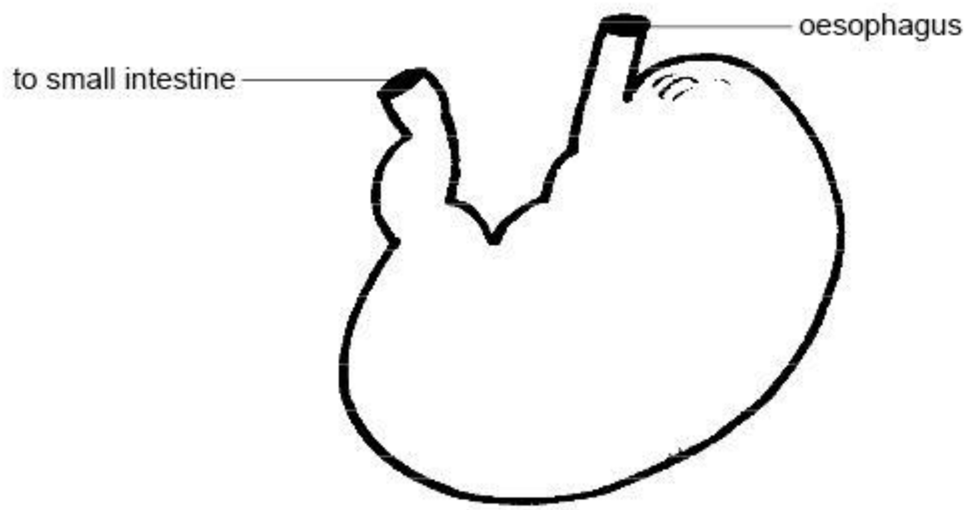


Diagram 11.9 - The stomach

Small Intestine

Most of the breakdown of the large food molecules and absorption of the smaller molecules take place in the long and narrow small intestine. The total length varies but it is about 6.5 metres in humans, 21 metres in the horse, 40 metres in the ox and over 150 metres in the blue whale.

It is divided into 3 sections: the duodenum (after the stomach), jejunum and ileum. The duodenum receives 3 different secretions:

1) **Bile** from the liver;
2) **Pancreatic juice** from the pancreas and
3) **Intestinal juice** from glands in the intestinal wall.

These complete the digestion of starch, fats and protein. The products of digestion are absorbed into the blood and lymphatic system through the wall of the intestine, which is lined with tiny finger-like projections called **villi** that increase the surface area for more efficient absorption (see diagram 11.10).

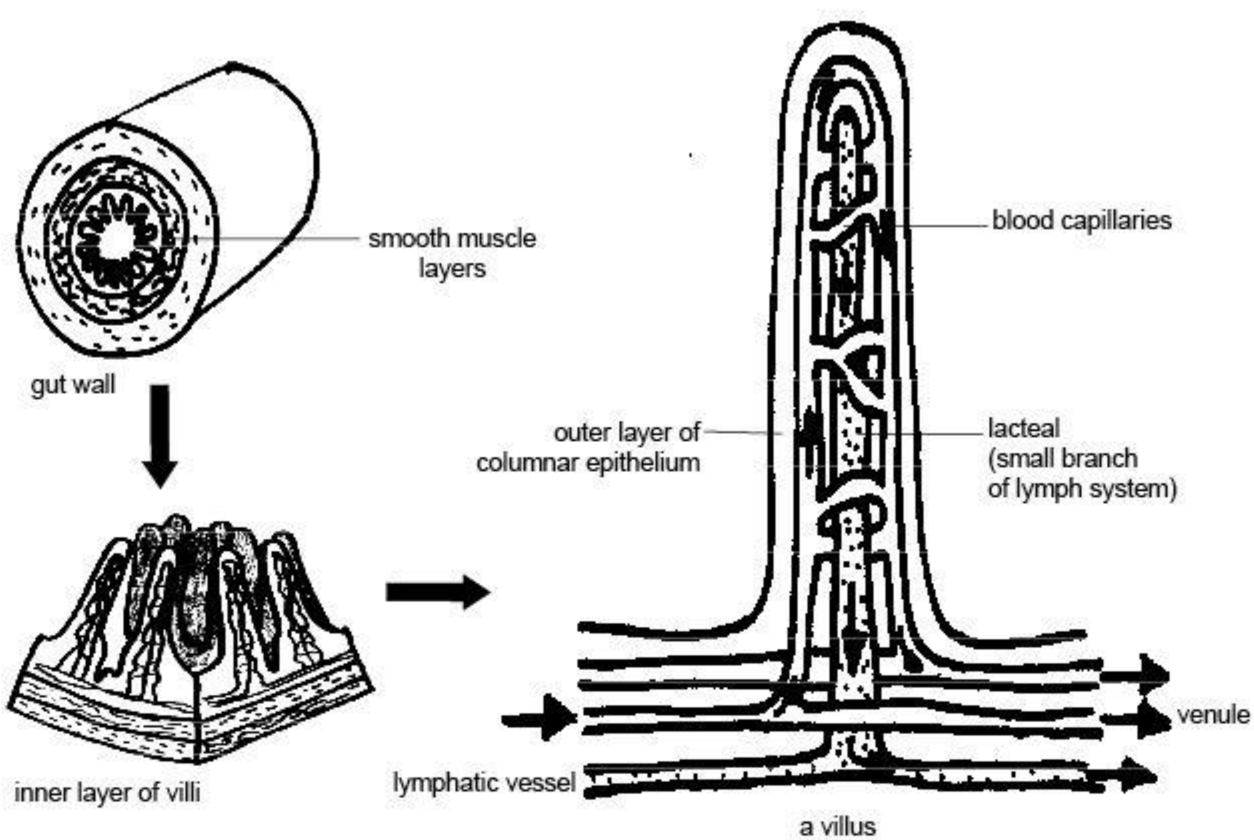


Diagram 11.10 - The wall of the small intestine showing villi

The Rumen

In ruminant herbivores like cows, sheep and antelopes the stomach is highly modified to act as a "fermentation vat". It is divided into four parts. The largest part is called the **rumen**. In the cow it occupies the entire left half of the abdominal cavity and can hold up to 270 litres. The **reticulum** is much smaller and has a honeycomb of raised folds on its inner surface. In the camel the reticulum is further modified to store water. The next part is called the **omasum** with a folded inner surface. Camels have no omasum. The final compartment is called the **abomasum**. This is the 'true' stomach where muscular walls churn the food and gastric juice is secreted (see diagram 11.11).

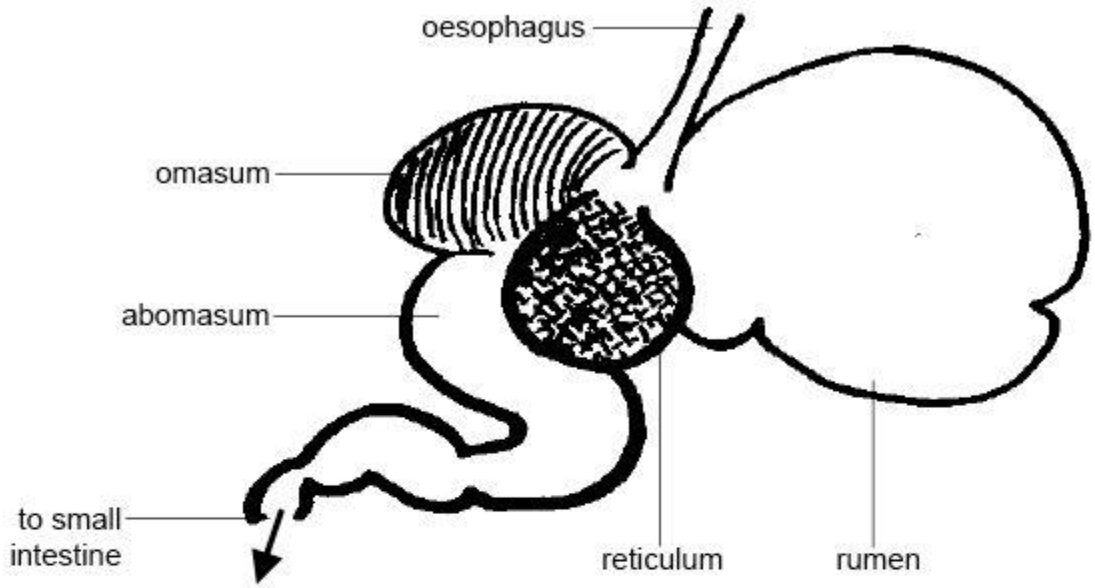


Diagram 11.11 - The rumen

Ruminants swallow the grass they graze almost without chewing and it passes down the oesophagus to the rumen and reticulum. Here liquid is added and the muscular walls churn the food. These chambers provide the main fermentation vat of the ruminant stomach. Here bacteria and single-celled animals start to act on the cellulose plant cell walls. These organisms break down the cellulose to smaller molecules that are absorbed to provide the cow or sheep with energy. In the process, the gases methane and carbon dioxide are produced. These causes the "burps" you may hear cows and sheep making.

Not only do the micro-organisms break down the cellulose but they also produce the **vitamins E, B and K** for use by the animal. Their digested bodies provide the ruminant with the majority of its protein requirements.

In the wild grazing is a dangerous activity as it exposes the herbivore to predators. They crop the grass as quickly as possible and then when the animal is in a safer place the food in the rumen can be regurgitated to be chewed at the animal's leisure. This is 'chewing the cud' or **rumination**. The finely ground food may be returned to the rumen for further work by the microorganisms or, if the particles are small enough, it will pass down a special groove in the wall of the oesophagus straight into the omasum. Here the contents are kneaded and water is absorbed before they pass to the abomasum. The abomasum acts as a "proper" stomach and gastric juice is secreted to digest the protein.

Large Intestine

The **large intestine** consists of the **caecum**, **colon** and **rectum**. The chyme from the small intestine that enters the colon consists mainly of water and undigested material such as cellulose (fibre or roughage). In omnivores like the pig and humans the main function of the colon is absorption of water to give solid faeces. Bacteria in this part of the gut produce vitamins B and K.

The caecum, which forms a dead-end pouch where the small intestine joins the large intestine, is small in pigs and humans and helps water absorption. However, in rabbits, rodents and horses, the caecum is very large and called the **functional caecum**. It is here that cellulose is digested by micro-organisms. The **appendix**, a narrow dead end tube at the end of the caecum, is particularly large in primates but seems to have no digestive function.

Functional Caecum

The caecum in the rabbit, rat and guinea pig is greatly enlarged to provide a “fermentation vat” for micro-organisms to break down the cellulose plant cell walls. This is called a **functional caecum** (see diagram 11.12). In the horse both the caecum and the colon are enlarged. As in the rumen, the large cellulose molecules are broken down to smaller molecules that can be absorbed. However, the position of the functional caecum after the main areas of digestion and absorption, means it is potentially less effective than the rumen. This means that the small molecules that are produced there can not be absorbed by the gut but pass out in the faeces. The rabbit and rodents (and foals) solve this problem by eating their own faeces so that they pass through the gut a second time and the products of cellulose digestion can be absorbed in the small intestine. Rabbits produce two kinds of faeces. Softer night-time faeces are eaten directly from the anus and the harder pellets you are probably familiar with, that have passed through the gut twice.

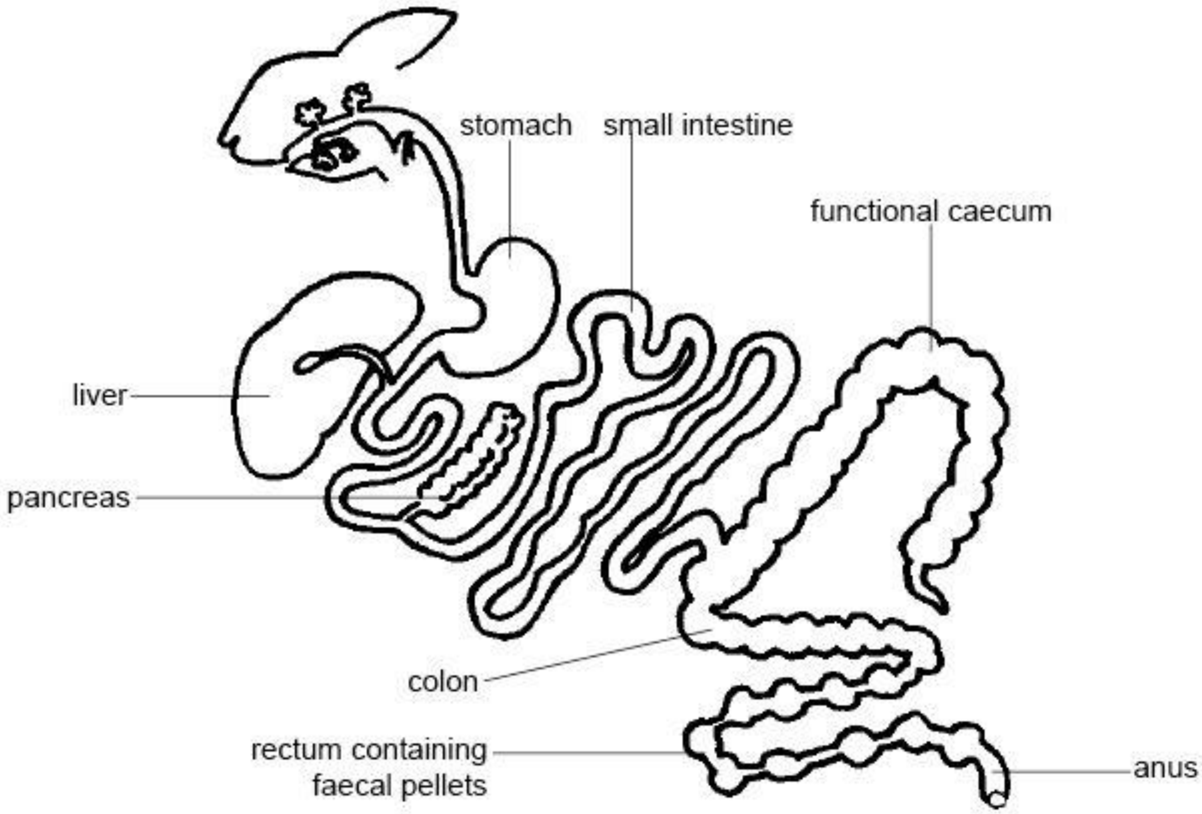


Diagram 11.12 - The gut of a rabbit

The Gut of Birds

Birds' guts have important differences from mammals' guts. Most obviously, birds have a **beak** instead of teeth. Beaks are much lighter than teeth and are an adaptation for flight. Imagine a bird trying to take off and fly with a whole set of teeth in its head! At the base of the oesophagus birds have a bag-like structure called a **crop**. In many birds the crop stores food before it enters the stomach, while in pigeons and doves glands in the crop secretes a special fluid called **crop-milk** which parent birds regurgitate to feed their young. The stomach is also modified and consists of two compartments. The first is the true stomach with muscular walls and enzyme secreting glands. The second compartment is the **gizzard**. In seed eating birds this has very muscular walls and contains pebbles swallowed by the bird to help grind the food. This is the reason why you must always supply a caged bird with grit. In birds of prey like the falcon the walls of the gizzard are much thinner and expand to accommodate large meals (see diagram 11.13).

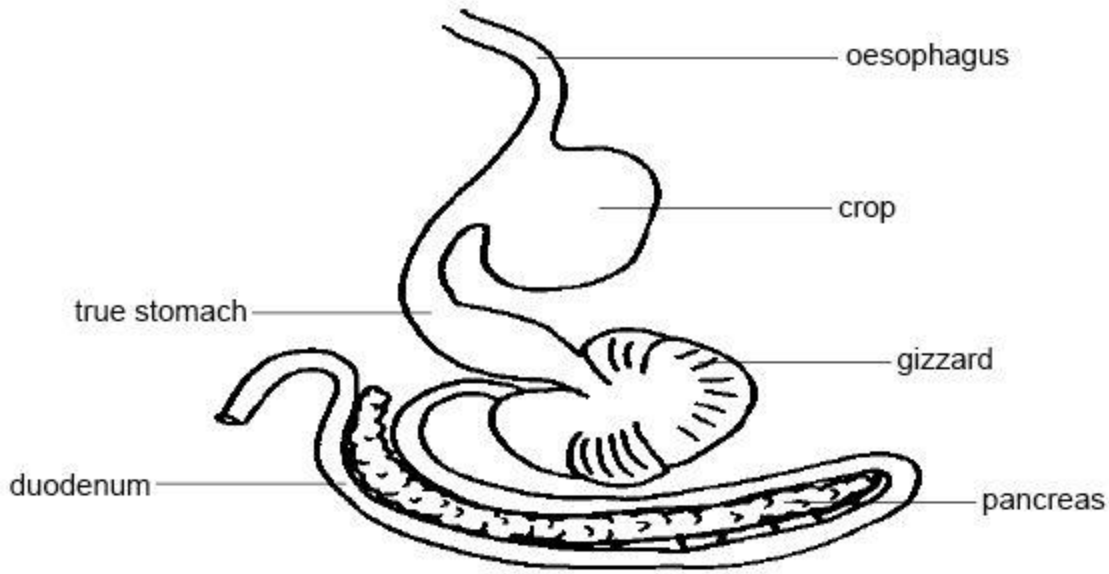


Diagram 11.13 - The stomach and small intestine of a hen

Digestion

During digestion the large food molecules are broken down into smaller molecules by **enzymes**. The three most important groups of enzymes secreted into the gut are:

1. **Amylases** that split carbohydrates like starch and glycogen into monosaccharides like glucose.
2. **Proteases** that split proteins into amino acids.
3. **Lipases** that split lipids or fats into fatty acids and glycerol.

Glands produce various secretions which mix with the food as it passes along the gut.

These secretions include:

1. **Saliva** secreted into the mouth from several pairs of **salivary glands** (see diagram 11.3). Saliva consists mainly of water but contains salts, mucous and salivary amylase. The function of saliva is to lubricate food as it is chewed and swallowed and salivary amylase begins the digestion of starch.
2. **Gastric juice** secreted into the stomach from glands in its walls. Gastric juice contains **pepsin** that breaks down protein and hydrochloric acid to produce the acidic conditions

under which this enzyme works best. In baby animals rennin to digest milk is also produced in the stomach.

3. **Bile** produced by the liver. It is stored in the **gall bladder** and secreted into the duodenum via the **bile duct** (see diagram 11.14). (Note that the horse, deer, parrot and rat have no gall bladder). Bile is not a digestive enzyme. Its function is to break up large globules of fat into smaller ones so the fat splitting enzymes can gain access the fat molecules.

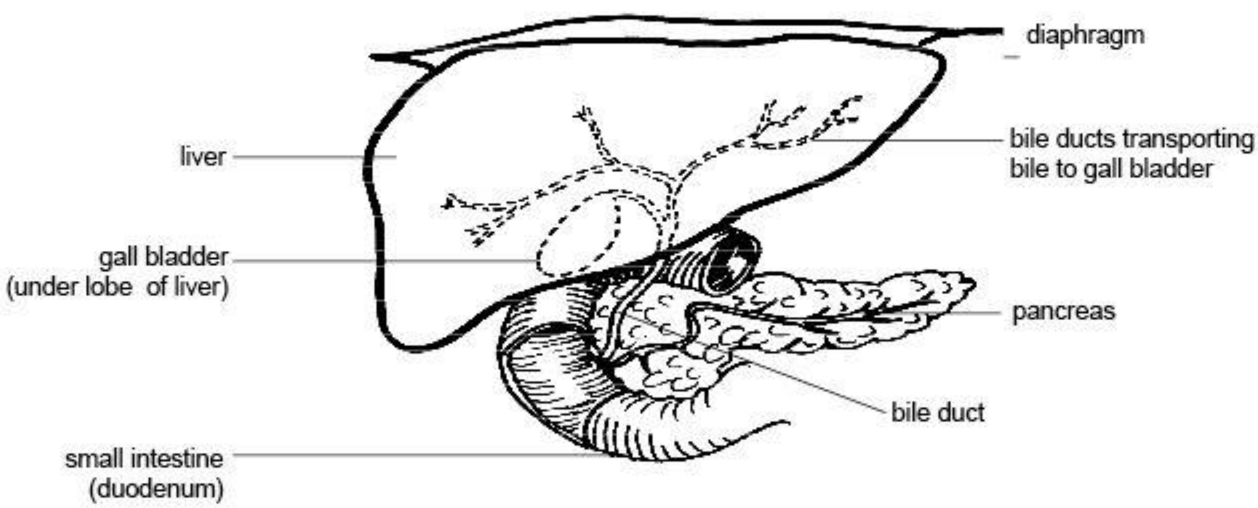


Diagram 11.14 - The liver, gall bladder and pancreas

Pancreatic juice

The **pancreas** is a gland located near the beginning of the duodenum (see diagram 11.14). In most animals it is large and easily seen but in rodents and rabbits it lies within the membrane linking the loops of the intestine (the **mesentery**) and is quite difficult to find. **Pancreatic juice** is produced in the pancreas. It flows into the duodenum and contains **amylase** for digesting starch, **lipase** for digesting fats and **protease** for digesting proteins.

Intestinal juice

Intestinal juice is produced by glands in the lining of the small intestine. It contains enzymes for digesting disaccharides and proteins as well as mucus and salts to make the contents of the small intestine more alkaline so the enzymes can work.

Absorption

The small molecules produced by digestion are absorbed into the **villi** of the wall of the **small intestine**. The tiny finger-like projections of the villi increase the surface area for absorption. Glucose and amino acids pass directly through the wall into the blood stream by diffusion or active transport. Fatty acids and glycerol enter vessels of the lymphatic system (**lacteals**) that run up the centre of each villus.

The Liver

The liver is situated in the abdominal cavity adjacent to the diaphragm (see diagrams 2 and 14). It is the largest single organ of the body and has over 100 known functions. Its most important digestive functions are:

1. the production of **bile** to help the digestion of fats (described above) and
2. the control of **blood sugar** levels

Glucose is absorbed into the capillaries of the villi of the intestine. The blood stream takes it directly to the liver via a blood vessel known as the **hepatic portal vessel** or **vein** (see diagram 11.15).

The liver converts this glucose into glycogen which it stores. When glucose levels are low the liver can convert the glycogen back into glucose. It releases this back into the blood to keep the level of glucose constant. The hormone **insulin**, produced by special cells in the **pancreas**, controls this process.

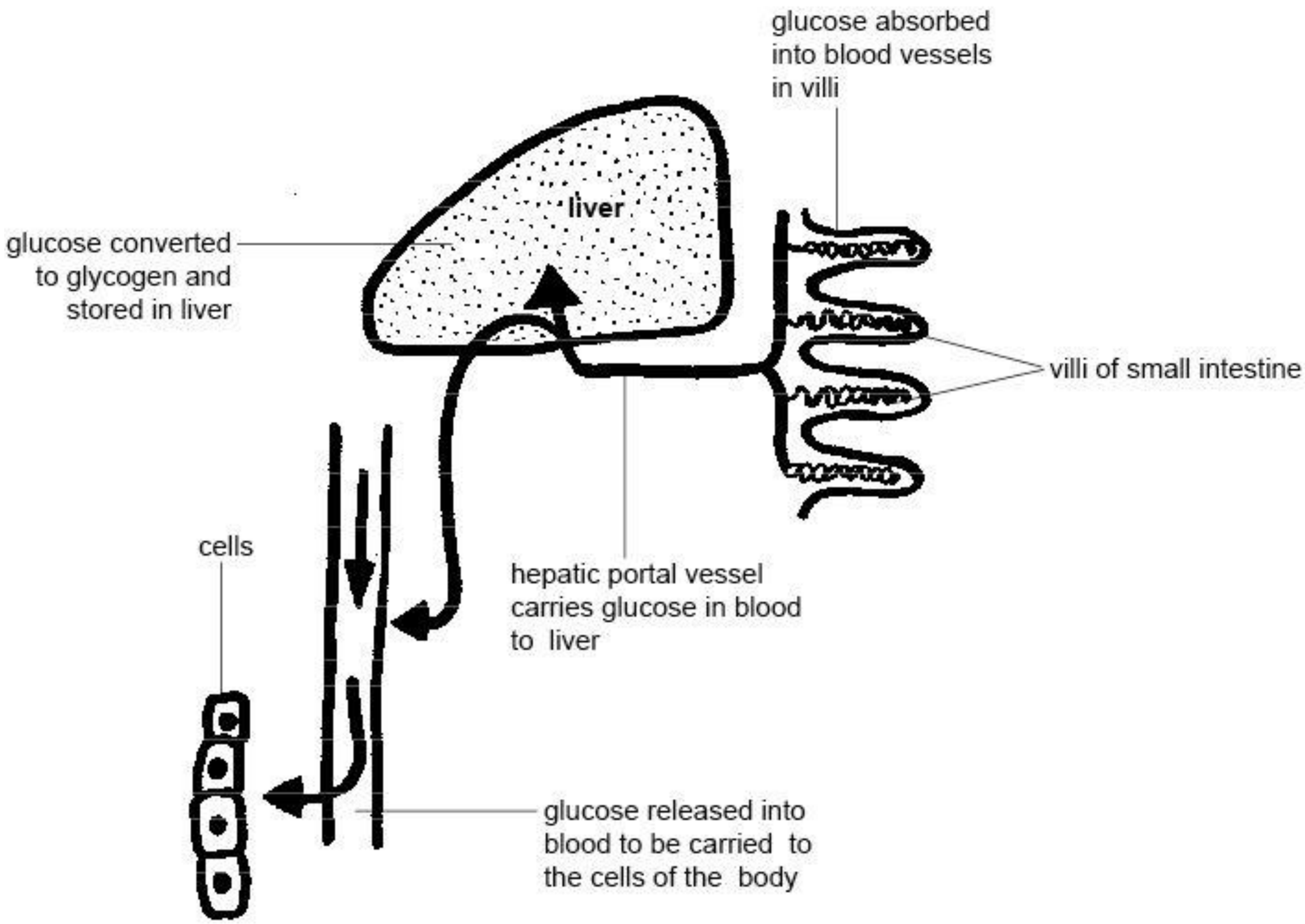


Diagram 11.15 - The control of blood glucose by the liver

Other functions of the liver include:

3. making **vitamin A**,
4. making the **proteins** that are found in the **blood plasma** (**albumin, globulin** and **fibrinogen**),
5. storing **iron**,
6. removing **toxic substances** like alcohol and poisons from the blood and converting them to safer substances,
7. producing **heat** to help maintain the temperature of the body.

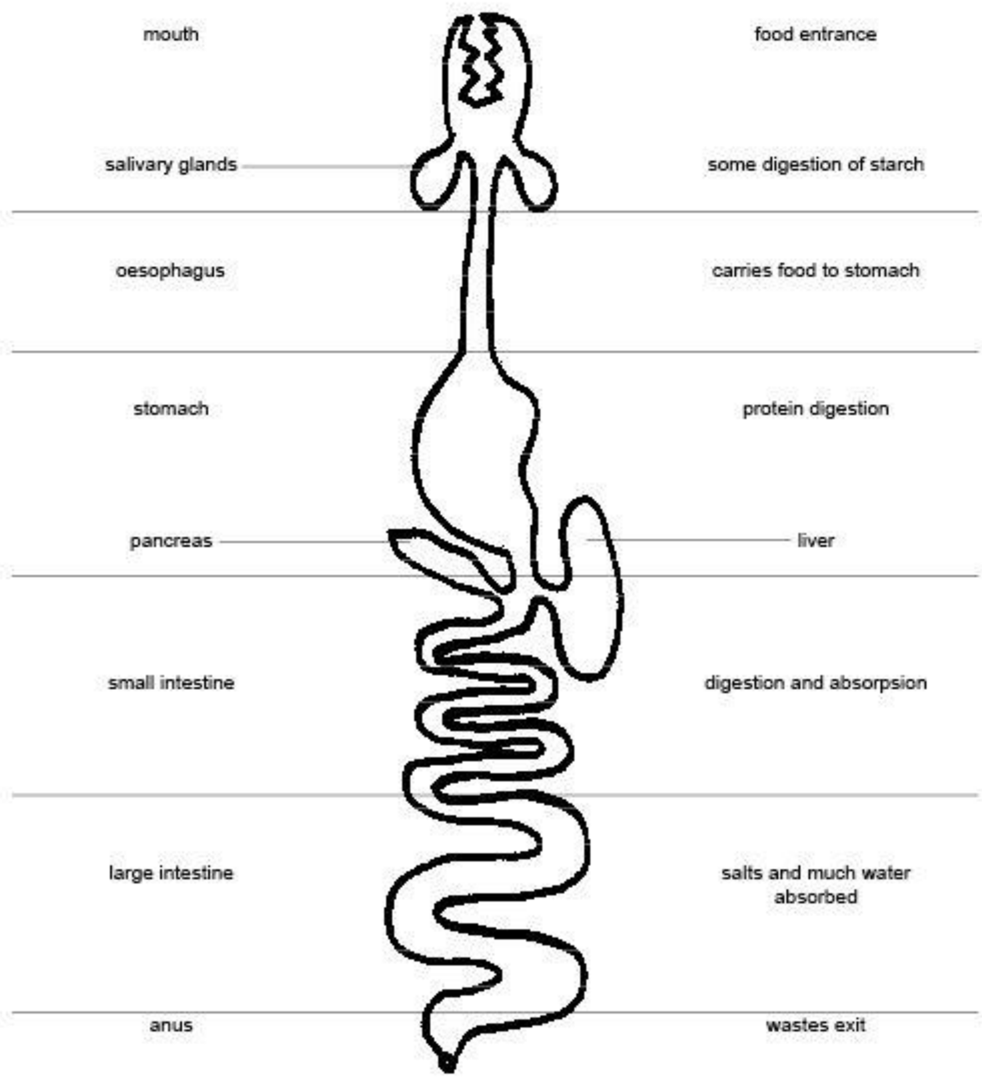


Diagram 11.16 - Summary of the main functions of the different regions of the gut

Summary

- The **gut** breaks down plant and animal materials into nutrients that can be used by animals' bodies.
- Plant material is more difficult to break down than animal tissue. The gut of **herbivores** is therefore longer and more complex than that of **carnivores**. Herbivores usually have a compartment (the **rumen** or **functional caecum**) housing micro-organisms to break down the **cellulose** wall of plants.

- Chewing by the teeth begins the food processing. There are 4 main types of teeth: **incisors, canines, premolars** and **molars**. In dogs and cats the premolars and molars are adapted to slice against each other and are called **carnassial** teeth.
- **Saliva** is secreted in the mouth. It lubricates the food for swallowing and contains an enzyme to break down starch.
- Chewed food is swallowed and passes down the **oesophagus** by waves of contraction of the wall called **peristalsis.** The food passes to the stomach where it is churned and mixed with acidic **gastric juice** that begins the digestion of protein.
- The resulting **chyme** passes down the small intestine where enzymes that digest fats, proteins and carbohydrates are secreted. **Bile** produced by the liver is also secreted here. It helps in the breakdown of fats. **Villi** provide the large surface area necessary for the absorption of the products of digestion.
- In the **colon** and **caecum** water is absorbed and micro organisms produce some **vitamin B and K**. In rabbits, horses and rodents the caecum is enlarged as a **functional caecum** and micro-organisms break down cellulose cell walls to simpler carbohydrates. Waste products exit the body via the **rectum** and **anus**.
- The **pancreas** produces **pancreatic juice** that contains many of the enzymes secreted into the small intestine.
- In addition to producing bile the liver regulates blood sugar levels by converting glucose absorbed by the villi into glycogen and storing it. The liver also removes toxic substances from the blood, stores iron, makes vitamin A and produces heat.

Worksheet

Use the Digestive System Worksheet to help you learn the different parts of the digestive system and their functions.

Test Yourself

Then work through the Test Yourself below to see if you have understood and remembered what you learned.

1. Name the four different kinds of teeth

2. Give 2 facts about how the teeth of cats and dogs are adapted for a carnivorous diet:

1.
2.

3. What does saliva do to the food?

4. What is peristalsis?

5. What happens to the food in the stomach?

6. What is chyme?

7. Where does the chyme go after leaving the stomach?

8. What are villi and what do they do?

9. What happens in the small intestine?

10. Where is the pancreas and what does it do?

11. How does the caecum of rabbits differ from that of cats?

12. How does the liver help control the glucose levels in the blood?

13. Give 2 other functions of the liver:

1.
2.

Test Yourself Answers

Websites

- http://www.second-opinions.co.uk/carn_herb_comparison.html Second opinion. A good comparison of the guts of carnivores and herbivores
- http://www.chu.cam.ac.uk/~ALRF/giintro.htm The gastrointestinal system. A good comparison of the guts of carnivores and herbivores with more advanced information than in the previous site.
- http://www.westga.edu/~lkral/peristalsis/index.html Peristalsis animation.

- http://en.wikipedia.org/wiki/Digestion Wikipedia on digestion with links to further information on most aspects. Like most websites this is mainly about human digestion but much is applicable to animals.

MODULE 4: Physiological functions of farm animals

CONTENTS

Physiological functions of animals

1.0 INTRODUCTION

There are many types of physiological functions that help in the wellbeing of farm animals among are,homeostatic, nutrition and digestion, respiration. Temperature regulation, excretion and reproduction, endocrinology, the blood and circulation, lactation, milk let down and egg production, water balance which are essential and also important in all activities of the body.

2.0 OBJECTIVES

By the end of this unit, you should be able to:

- Know the different physiological functions
- Identify the different type of digestion
- Know the different types of excretion and reproductions

3.0 MAIN CONTENT

3.1: Homeostasis**.** This is a physiological process of a body to maintain constant internal environment in response to fluctuations in outer external environment. Internal environment refers the interstitial fluids surrounding individual cells while external environment refers to the environment in which organisms live. Maintaining a dynamic equilibrium between body's internal environment and changing external environment requires constant monitoring and adjustments. This adjusting of physiological systems within the body is called homeostatic regulation. The liver, the kidneys and the brain (hypothalamus, the autonomic nervous system and the endocrine system help maintain homeostasis. An inability to maintain homeostasis may lead to death or a disease, a condition known as **homeostatic imbalance.** Other diseases which result from a homeostatic imbalance include **diabetes, dehydration, hypoglycemia, hyperglycemia, gout, hypothermia etc**. Medical intervention can help restore homeostasis and possibly prevent permanent damage to the organs.

3.1b: The control system for regulation of homeostasis is an open system, which involves stimulus as input and response as output.

Control system or homeostasis regulation involves five basic components:

1. **Stimulus:** any physical, chemical or environmental factors or disturbance that causes deviation of normal body's environment
2. **Receptor or detector**: The receptor receives the stimulus and forward to the control center. Eg. neurons
3. **Control center or regulator**: The control center or coordinator center receives and processes information from the receptor. It set the normal reference point or setup point for any physiological processes. Eg. Hypothalamus or brain

4. **Effector:** The control center commands the effector to respond to the stimulus. Eg. Glands, muscles
5. **Response:** It is the reaction to the stimulus. It is a corrective measure toward the disturbance. It can oppose or enhance the stimulus. All the physiological process have their own reference point or setup point. Any deviation from reference point activates the control system. The control system after optimizing the physiological process to its reference point is always feed backed. The control system is known as **feed-back mechanism.** There are two form of feed-back mechanism
    1. Negative feed-back mechanism
    2. Positive feed-back mechanism

The Internal Environment | Back to Top There are two types of extracellular fluids in animals: the extracellular fluid that surrounds and bathes cellsplasma, the liquid component of the blood. Internal components of homeostasis:

1. Concentration of oxygen and carbon dioxide
2. pH of the internal environment
3. Concentration of nutrients and waste products
4. Concentration of salt and other electrolytes
5. Volume and pressure of extracellular fluid Control Systems

. Closed Systems has two components: a sensor and an effect or, such as a thermostat (sensor) and furnace (effect or). Most physiological systems in the body use feedback to maintain the body's internal environment. Extrinsic Most homeostatic systems are extrinsic: they are controlled from outside the body. Endocrine and nervous systems are the major control systems in higher animals.

The nervous system depends on sensors in the skin or sensory organs to receive stimuli and transmit a message to the spinal cord or brain. Sensory input is processed and a signal is sent to an effector system, such as muscles or glands, whichaffects the response to the stimulus. The endocrine system is the second type of extrinsic control, and involves a chemical component to the reflex. Sensors detect a change within the body and send a message to anendocrine effector (parathyroid), which makes PTH. PTH is released into the blood when blood calcium levels are low. PTH causes bone to release calcium into the bloodstream, raising the blood calcium levels and shutting down the production of PTH. Some reflexes have a combination of nervous and endocrine response. The thyroid gland secretes thyroxin (which controls the metabolic rate) into the bloodstream. Falling levels of thyroxin stimulate receptors in the brain to signal the hypothalamus to release a hormone that acts on the pituitary gland to release thyroid-stimulating hormone (TSH) into the blood. TSH acts on the thyroid, causing it to increase production of thyroxin. Intrinsic Local, or intrinsic, controls usually involve only one organ or tissue. When muscles use more oxygen, and also produce more carbon dioxide, intrinsic controls cause dilation of the blood vessels allowing more blood into those active areas of the muscles. Eventually the vessels will return to "normal".Feedback Systems in Homeostasis | Negative feedback control mechanisms (used by most of the body's systems) are called negative because the information caused by the feedback causes a reverse of the response.TSH is an example: blood levels of TSH serve as feedback for production of TSH.

Positive feedback control is used in some cases. Input increases or accelerates the response. During uterine contractions, oxytocin is produced. Oxytocin causes an increase infrequency and strength of uterine contractions. This in turn causes further production of oxytocin, etc. Homeostasis depends on the action and interaction of a number of body systems to maintain a range of conditions within which the body can best operate. Body Systems and Homeostasis | Eleven major organ systems are present within animals, although some animals lack one or more of them. The vertebrate body has two cavities: the thoracic, which contains the heart and lungs; and the abdominal, which contains digestive organs. The head, or cephalic region, contains four of the five senses as well as a brain encased in the bony skull. These organ systems can be grouped according to their functions.

The integumentary, skeletal, and muscular systems. Image from Purves et al., Life:

The Science of Biology, 4th Edition, by Sinauer Associates (www.sinauer.com) andWH Freeman (www.whfreeman.com), used with permission.

Muscular System facilitates movement and locomotion. The muscular system produces body movements, body heat, maintains posture, and supports the body. Muscle fibers are the main cell type. Action of this system is closely tied to that of the skeletal system. Skeletal System provides support and protection, and attachment points for muscles. The skeletal system provides rigid framework for movement. It supports and protects the body and body parts, produces blood cells, and stores minerals. Skin or Integument is the outermost protective layer. It prevents water loss from and invasion of foreign microorganisms and viruses into the body. There are three layers of the skin. The epidermis is the outer, thinner layer of skin. Basal cells continually undergo mitosis. Skin is waterproof because keratin, a protein is produced. The next layer is the dermis a layer of fibrous connective tissue. Within the dermis many structures are located, such as sweat glands, hair follicles and oil glands. The subcutaneous layer is composed of loose connective tissue. Adipose tissue occurs here, serving primarily for insulation. Nerve cells run through this region, as doarteries and veins.

3.1.2:Animal Nutrition and Digestion

Animal Nutrition and Digestion in today's society, one can't turn on the TV or read a newspaper without seeing or reading information about health issues. What is the major factor discussed in these issues? Nutrition. Along with nutrition, genetics and environment are all factors that influence your health. Just like in humans, agricultural animals are influenced by these same factors. If animals don't have proper nutrition, their growth rate, reproduction rate, immunity, and well-being are all affected. Just as proper nutrition is vital for your good health and proper function, it is just as vital for the health and function of agricultural animals.

3.1.2a: Importance of Nutrition and Digestion

Nutrition is important for a variety of reasons. Animals need the proper nutrition for growth and maintenance, and to provide energy for work and vital functions. Maintenance is the nutrition required for an animal to maintain its current weight. Energy is the ability of the body to perform functions. Proper nutrition is also needed to maintain body temperature, produce milk, reproduce, and develop proper bone structures. Without proper nutrition, animals can develop health problems, which could result in treatment costs or even fatality. Good nutrition is essential for all of the systems of an animal to function and work together properly. Animals that do not receive the proper nutrition are more likely to develop health and reproductive problems, and be less productive and marketable. Nutrition is important to have healthy animals, and, in turn, healthy animals help ensure profitability in agricultural operations. Producers must understand not only what nutrition an animal needs but also how to supply that needed nutrition. Producers must know what ration is appropriate for a specific animal and how to provide a balanced ration. A ration is the feed an animal receives over a 24-hour period. A variety of feedstuffs, or basic ingredients, are used in rations, and producers must choose those that best suit their needs. A ration with all the nutrients an animal needs is a balanced ration. Digestion is the process of breaking down feeds into simple substances that can be absorbed into the bloodstream and used by the body's cells. It is important for producers to understand the digestive process because it helps in selecting the proper feed for the animal's type of digestive system. The digestive system is the system in which food is acted upon through physical (chewing) and chemical (stomach acids) means. It includes all parts from the mouth to the anus. Understanding the digestive system can help the producer become more efficient in feeding, resulting in a more cost-effective livestock enterprise. It also helps the producer have a better understanding of animal health and problems that may occur. Understanding the chemical and physical changes that take place after an animal eats is important in noticing health problems related to digestion. Jupiter Images Some animals need just enough nutrients to maintain current body weight.

3.1.2c: Animal Nutrition and Digestion

- Discuss the importance of nutrition and digestion for animal growth.
- Explore the basics of animal physiology.
- Determine how nutrients are used by various livestock species.
- Identify classes and sources of nutrients.
- Identify symptoms of nutrient deficiencies.
- Explain the role of feed additives in livestock nutrition.
- Formulate a feed ration using the Pearson square.
- Compare and contrast animal digestive systems.

3.1.3: The digestive and respiratory systems. Respiratory System moves oxygen from the external environment into the internal environment; also removes carbon dioxide. The respiratory system exchanges gas between lungs(gills in fish) and the outside environment. It also maintains pH of the blood and facilitates exchange of carbon dioxide and oxygen. Digestive System digests and absorbs food into nutrient molecules by chemical and mechanical breakdown; eliminates solid wastes into the environment. Digestion isaccomplished by mechanical and chemical means,breaking food into particles small enough to pass into bloodstream. Absorption of food molecules occurs in the smallintestine and sends them into circulatory system. The digestive system also recycles water and reclaims vitamins from food in the large intestine. transports oxygen, carbon dioxide, nutrients, waste products, immune components, and hormones. Major organs include the heart, capillaries,arteries, and veins. The lymphatic system also transports excess fluids to and from circulatory system and transports fat to the heart.Immune System (Lymphatic system, Figure 3) defends the internal environment from invading microorganisms and viruses, as well as cancerous cell growth. The immunesystem provides cells that aid in protection of the body from disease via the antigen/antibody response. A variety of general responses are also part of this system.

3.1.3.2: Respiratory system and thermoregulation

Respiratory system and thermoregulation Air sacs and lungs the respiratory system is one of the major systems of the body. It has a number of very important functions including the provision of oxygen, the removal of carbon dioxide, the removal of excess heat (thermoregulation) and vocal communication. The respiratory system is a complex one and while there are some similarities with that of mammals, there are a number of quite significance differences

Nasal cavity the openings to the nasal cavity, the nares, lie at the point of the base of the comb on the top beak or mandible. The nasal cavity occupies a triangular shaped space between the nares and the margin of the eye and within the beak. Between the integument and the nasal cavity lie the lacrimal sinuses that empty into the cavity through the lateral wall. The lateral wall of the cavity has three conchae, or projections, into the cavity:

i. Anterior – of squamous epithelium – a single layer of attended cells
ii. ii. Medial – ciliated columnar epithelium – special cube shaped cells with cilia or hairs that trap foreign material

iii. Posterior – olfactory membrane – that gives the sense of smell

Smell, protection and reduction of electrolyte the odour or smell of any material or object is a result of minute quantities of special chemicals that are detected by the olfactory membrane that in turn sends a signal via the olfactory nerve to the brain where it will be recognized for what it is. The epithelium of the nasal cavity is well endowed with mucosal a gland which produce mucous that helps to keep foreign material from gaining entry to the body through the respiratory system. The nasal glands are small and located on either side. Their action is to supplement the action of the kidneys by reducing the electrolyte content of body ids, especially when the level is higher than the kidneys can handle (electrolyte – common chemical salts e.g. sodium chloride).

Oropharynx (mouth and pharynx)The oropharynx consists of the mouth and the pharynx that is located immediately behind it.The palate is part hard and part soft. The choanal opening (from the nasal cavity) is the cleft in the palate. The pharynx begins between the choanal opening and the common opening for the auditory tubes and extends to the rear to include that section of the oral cavity carrying the base of the tongue, the tip of which is located in the mouth. Behind the base of the tongue is found the rima glottidis or opening into the larynx, which is sometimes called the cranial larynx. This opening is located in a conspicuous mound called the laryngeal prominence. The opening into the larynx is a median slit that is supported one ach side by the arytenoid cartilages. These are special cartilages with a shape resembling the mouth of a jug or pitcher. It varies in length from approximately 8.5 mm in the female to 11mm in the male. During gasping while the bird is in a state of respiratory distress it can open to a width of 7 to 9 mm. There are no vocal cords, epiglottis and thyroid cartilages that are normally found in mammals.

Trachea:This organ is a long tube with the function of moving the respiratory gases from the upper respiratory system to the organs of respiration – the lungs and air sacs or from the air sacs and lungs to the upper respiratory organs. The trachea in medium sized adults measures between15 and 18 centimetres. It is held open permanently by 108 to 125 cartilaginous rings each one complete and lapping its neighbour. This arrangement prevents the trachea from collapsing or compressing but allows elongation and The syrinx is the vocal organ of the fowl. It is located at the caudal end of the trachea and issus pended within the clavicular air sac. At rest, it is compressed laterally (at the sides). It consists of the pessulus, a wedge shaped cartilage located where the trachea divides into two to form the two bronchi plus the last four specialised cartilaginous rings at the bottom of the trachea. Below this section there are 4-7 thin,

On entering the lungs, the primary bronchi divide to form four series of secondary bronchi and these, in turn, divide again to form numerous anastomising tertiary bronchi orpara bronchi. The secondary and tertiary bronchi are lined with squamous epithelium and not the ciliated epithelium of the primary bronchi. The tertiary bronchi are arranged in layers. Theyare not blind ending, but join others that in turn lead back to the secondary and primarybronchi. Ultimately, the bronchial system is continuous.

Gas exchange Leading off from the bronchi in the lungs are a large number of extremely small air capillaries(ducts) that are interlocked with the capillaries of the lung circulatory system. These interlocked capillaries are the lungs' gas exchange system and are very thin which accommodates gaseous exchange. The blood/gas barrier in this area consists of whatever cell layers separate the two systems – the blood circulatory system and the air supply system of the lungs. These layers are:

. Single cell epithelial wall of the air capillary

ii. Base membrane one cell thickiii. Single cell epithelial wall of the blood capillary

Lungs

3.3: Respiration is the movement of oxygen from the outside environment to the cells within tissues, and the transport of carbon dioxidein the opposite direction.

The physiological definition of respiration differs from the biochemical definition, which refers to a metabolic process by which an organism obtains energy (in the form of ATP) by oxidizing nutrients and releasing waste products. Although physiologic respiration is necessary to sustain cellular respiration and thus life in animals, the processes are distinct: cellular respiration takes place in individual cells of the organism, while physiologic respiration concerns the diffusion and transport of metabolites between the organism and the external environment.

In animals with lungs, physiological respiration involves respiratory cycles of inhaled and exhaledbreaths. Inhalation (breathing in) is usually an active movement. The contractions of the diaphragm muscle cause a pressure variation, which is equal to the pressures caused by elastic, resistive and inertial components of the respiratory system. In contrast, exhalation (breathing out) is usually a passive process. Breathing in, brings air into the lungs where the process of gas exchange takes place between the air in thealveoliand thebloodin the pulmonarycapillaries

The process of breathing does not fill the alveoli with atmospheric air during each inhalation (about 350 ml per breath), but the inhaled air is carefully diluted and thoroughly mixed with a large volume of gas (about 2.5 liters in adult humans) known as the functional residual capacity which remains in the lungs after each exhalation, and whosegaseous composition differs markedly from that of the ambient air. Physiological respiration involves the mechanisms that ensure that the composition of the functional residual capacity iskept constant, and equilibrates with the gases dissolved in the pulmonary capillary blood, and thus throughout the body. Thus, in preciseusage, the words *breathing* and *ventilation* are hyponyms, not synonyms, of *respiration*; but this prescription is not consistently followed, even by most health care providers, because the term *respiratory rate*(RR) is a well-established term in health care, even though it would need to be consistently replaced with *ventilation rate* if the precise usage were to be followed.

3.1.4: Physiology, Temperature Regulation

(Introduction)

Thermoregulation, by definition, is a mechanism by which mammals maintain body temperature by tightly controlled self-regulation, no matter the temperature of their surroundings. Temperature regulation is a type of homeostasis, which is a process that biological systems use to preserve a stable internal state to survive. Ectotherms are animals that depend on their external environment for their body heat, and endotherms are animals that use thermoregulation to maintain a somewhat consistent internal body temperature to survive, even when their external environment changes. Humans and other mammals and birds are endotherms. Human beings have a normal core, or internal, temperature of around 37 degrees Celsius, which is equivalent to around 98.6 degrees Fahrenheit. Core temperature is most accurately measured via rectal probe thermometer. This is the temperature at which the human body's systems work together at their optimum, which is the reason the body has such tightly regulated mechanisms. Thermoregulation is crucial to human life. Without thermoregulation, the human body would not be able to adequately function and, inevitably, will expire.

Issues of Concern

When the body's ability to thermoregulation becomes hindered and is left untreated, organ failure is imminent. Blood flow will be reduced, leading to ischemia, and, ultimately, multiple organ failures.

Cellular

Viral illness or another infectious disease can cause a person to develop a fever, and the body no longer has that same core temperature of 37 degrees Celsius. This is because when the body experiences an infection from invading pathogens, it tries to fight back by releasing pyrogens such as cytokines, prostaglandins, and thromboxane—all of which increase the body’s temperature. By releasing these pyrogens, the foreign pathogens are not able to breed. This allows for antibodies to develop and enzymes to be activated to fight the infection further.

Development

The brain, or more specifically the hypothalamus, controls thermoregulation. If the hypothalamus senses external temperatures growing too hot or too cold, it will automatically send signals to the skin, glands, muscles, and organs. For example, when the body is in a very hot external environment, or simply undergoing high activity levels such as exercise, it’s temperature will rise, causing the hypothalamus to send signals to the cells of the skin that produce sweat. Sweating is the body's approach to cooling itself down. As the body’s temperature rises, sweat is expelled, the muscles relax, and body hair lies flat against the skin. These are all ways to release heat and therefore lower the temperature of the body. In contrast, when the body experiences a cold environment, the skeletal muscles tense up leading to the shivering reflex, and the arrector pili muscles, a type of smooth muscle, raise the bodily hair follicles where they are attached. These processes, in turn, create warmth and trap heat, respectively.

Organ Systems Involved

Multiple organs and body systems are affected when thermoregulation is not working correctly. During heat illness as a result of improper thermoregulation, the following organs and systems are impaired. Notice that many of these issues cause or are influenced by the other issues.

- The heart experiences an increased burden due to elevations in heart rate and increased cardiac output.
- The circulatory system sustains intravascular dehydration.
- The brain suffers from cerebral ischemia and/or cerebral edema.
- The gastrointestinal tract is vulnerable to hemorrhage and also sepsis because the mucosa of the intestines increases its permeability.
- The lungs suffer when ARDS results from the increase of hyperventilation, hyperpnea, and pulmonary vasodilation.

- Acute renal failure can commence because of the dehydration and impairment in circulation.
- Liver cells suffer because of the fever, ischemia, and cytokines increase in the intestinal tract.
- Various organs can result in DIC and microthrombi.
- Electrolyte abnormalities are likely as well as hypoglycemia, metabolic acidosis, and respiratory alkalosis.

When body temperatures severely decrease in hypothermia, the body’s systems are negatively affected. The cardiovascular system experiences dysrhythmias such as the Osborn, or J, wave on EKG. The central nervous system's (CNS) electrical activity is noticeably diminished, noncardiogenic pulmonary edema will occur, as well as cold diuresis, and decreases in glomerular filtration rate (GFR) and renal blood flow (RBF). Basically, hypothermia causes pre-glomerular vasoconstriction, which leads to decreased GFR and RBF.

Function

Slight changes in core body temperature occur every day, depending upon variables such as circadian rhythm and menses; but otherwise, the temperature is tightly controlled. When a person is unable to regulate his or her body temperature, various pathologies may occur. The human body has four different methods for keeping itself at its core temperature: vaporization, radiation, convection, and conduction. To keep the body functioning, it must be at its ideal temperature, and for this to happen, physical factors must be sufficient. This includes having enough intravascular volume and cardiovascular function; the body must be able to transport the rising internal heat to its surface for release. The reason that elderly people are at higher risk for disorders of thermoregulation is that they, as a whole, have less intravascular volume and decreased cardiac function.

Mechanism

Thermoregulation has three mechanisms: afferent sensing, central control, and efferent responses. There are receptors for both heat and cold throughout the human body. Afferent sensing works through these receptors to determine if the body is experiencing either too hot or too cold of a stimulus. Next, the hypothalamus is the central controller of thermoregulation. Lastly, efferent responses are carried out primarily by the body's behavioral reactions to fluctuations in body temperature. For example, if a person is feeling too warm, the normal response is to remove an outer article of clothing. If a person is feeling too cold, they choose to wear more layers of clothing. Efferent responses also consist of automatic responses by the body to protect itself from extreme changes in temperature, such as sweating, vasodilation, vasoconstriction, and shivering.

Related Testing

The thermoregulatory sweat test (TST) is a specific clinical test that is used to diagnose certain conditions that cause abnormal temperature regulation and defects in sweat production in the body. It measures a patient's ability to produce sweat in a controlled, heated and humidified environment and assesses the patient's central and autonomic nervous systems to determine if the thermoregulatory centers are working correctly.To perform the thermoregulatory sweat test, the patient is placed in a chamber that slowly rises in temperature. Before the chamber is heated, the patient is coated with a special kind of indicator powder that will change in color when sweat is produced. This powder, when changing color, will be useful in visualizing which skin is sweating versus not sweating. Results of the patient's sweat pattern will be documented by digital photography, and abnormal TST patterns can indicate if there is dysfunction in the autonomic nervous system. Certain differentials can be made depending on the type of sweat pattern found from the TST (along with history and clinical presentation) including hyperhidrosis, small fiber and autonomic neuropathies, multiple system atrophy, Parkinson disease with autonomic dysfunction, and pure autonomic failure.

Pathophysiology

When external environments are exceedingly warm, or a person is engaging in an excessive amount of physical activity, the heat is produced inside his or her body is typically transported to the blood. The blood then carries the heat through numerous capillaries that are located directly under the skin. Because the blood is near the surface, it can cool the person down. This cooled blood can then be transported back through the body to prevent the body temperature from becoming too high. Sweat is also a means by which the body cools itself down; it is created by glands to carry out evaporation at the topmost skin layer, the epidermis, to release heat. This describes vaporization, one of the four mechanisms used to maintain core body temperature. Radiation is when the heat that is released from the body's surface is moved into the surrounding air; convection occurs when cooler air surrounds the body's surface, and conduction comes into play when a person is either immersed in cold water or uses an ice pack—their internally generated heat is transferred to the cold water or the ice pack. This is another reason why it is very important to stay hydrated in the heat or during physical activity—not only to maintain adequate intravascular fluid volume, but also to aid in conduction processes that cool the body down. When cold fluids are ingested, the heat is released into the fluid and excreted out of the body as sweat or urine.While infection can cause the body's temperature to rise internally, a number of mechanisms can cause body temperature to rise externally. As previously discussed, a number of diseases with dysfunctional thermoregulatory mechanisms prove to be clinically significant, including small fiber and autonomic neuropathies, radiculopathies, and central autonomic disorders such as multiple system atrophy, Parkinson disease with autonomic dysfunction, and pure autonomic failure. Decreased cardiac function is also a notable risk factor for abnormal thermoregulatory function. Patients who are in externally hot environments do not have the ability to use their heart as efficiently to pump blood to their bodies' surface. With the loss of contractility, the blood is unable to be cooled, and therefore they are at risk of having heat-related illnesses. Even patients with the diagnosis of hypertension have an increased risk of these types of illnesses because some medications used to treat hypertension decrease the pumping ability of the heart, thereby decreasing the heated blood's means of getting cool at the body surface.

When patients are dehydrated, they contain a decreased amount of intravascular volume. This in itself is another risk factor for dysfunctional thermoregulation. If there are not enough fluids in the body, there is not enough blood. When there is not enough blood, the body cannot transport the internally made heat to the body's surface to be cooled. Heat will remain retained, blood will become thicker, and the heart becomes strained.In contrast, hypothermia is defined as low internal body temperature, or a temperature less than 35 degrees Celsius (95 degrees Fahrenheit). It is usually caused by too much heat loss from cold weather exposure or cold water immersion.

During cold water immersion, there is a reflex known as the diving reflex, which causes vasoconstriction in the visceral muscles. The body does this as a protective mechanism to keep a person's essential organs, like their heart and brain, supplied with blood. The body also does this to prevent the brain from hypoxia, since metabolic demand will have decreased.There are two different types of hypothermia: primary and secondary. Primary hypothermia is when the cold environment is the direct pathology, and secondary hypothermia is when a patient's illness is what causes his hypothermia. Conduction, convection, and radiation also come into play with hypothermia; this is how the rate of heat loss is determined. Hypothermia decelerates all physiologic roles include metabolic rate, mental awareness, nerve conduction, neuromuscular reaction times, and both the cardiovascular and respiratory systems. As previously mentioned, the vasoconstriction caused by hypothermia induces renal dysfunction and, eventually, cold diuresis due to the decreased levels of ADH. These decreased levels of antidiuretic hormone mean that the patient's urine will be very dilute, the definition of cold diuresis and another outcome of hypothermia. Because of the vasoconstriction, the patient may not know he is hypovolemic, which may lead to cardiac arrest or abrupt shock as the patient's vasculature is dilated while being rewarmed, a condition referred to as the rewarming collapse.

Clinical Significance

When a person who cannot sustain his or her core body temperature presents with heat illness, multiple organ support is indicated. It is imperative to be comprehensive in their care and utilize any and every cooling method available to sustain their body. Support must be provided to their respiratory, hepatic, renal, and circulatory systems. Giving fresh frozen plasma and blood platelets as needed is also recommended. Previous animal studies have also shown that administration of thrombomodulin can be helpful because it demonstrates anti-DIC and anti-inflammatory mechanisms.

Malignant hyperthermia is a rare type of event, but one that is life-threatening. It can occur when a susceptible patient is given certain anesthetic agents, notably halogenated ones or ones that are agents that depolarize neuromuscularly. Predisposed patients who are given such anesthetics either have abnormal ryanodine receptors (RYR-1) or have other myopathies such as Duchenne muscular dystrophy, central core disease, neuroleptic malignant syndrome, and King-

Denborough syndrome. Ryanodine receptors are located in skeletal muscles, which typically contain calcium channels and sarcoplasmic reticulum; these are what control the release of calcium. However, in malignant hyperthermia, calcium release is not regulated, and this leads to a continued release, which leads to an increased frequency of muscle metabolism. The clinical features first would present as muscle rigidity and an overwhelmingly high heart rate and end-tidal carbon dioxide. The person's temperature will increasingly elevate, and soon after, muscle tightening and shortening will occur as well as metabolic acidosis.

The rapid treatment of malignant hyperthermia is of the utmost importance to prevent fatality. Once malignant hyperthermia is suspected, dantrolene must be given intravenously. This will prevent that uncontrolled release of calcium as described above. It is also important to rapidly cool the patient, give 100% oxygen, and regulate metabolic acidosis.Serotonin syndrome and neuroleptic malignant syndrome are other disorders of temperature regulation. They both are due to adverse drug reactions, and they both present with clinical hyperthermia. It is important to distinguish them from one another. Neuroleptic malignant syndrome (NMS) continues over many days and is depicted by slow movements or the complete loss of voluntary movements. Serotonin syndrome is much more rapid, happening over a timespan of hours and presenting with fast movements such as tremor, muscular spasms, and hyperactive reflexes. These two reactions must be managed rapidly to avoid organ failure, especially if the patient's temperature goes past 40.5 degrees Celsius. There are both physical and pharmaceutical ways to cool the affected patients. Physical methods include providing cool towels, ice packs, cooling blanket systems, and intravenous infusion of fluids. Pharmaceuticals include sedatives and antipyretics such as paracetamol and NSAIDs. (Note that in critically ill patients, it is important to consider individual patient's renal function and gastric function before administering NSAIDs.)

Hyperthyroidism is another disorder of thermoregulation. In this endocrinological disease, the core temperature is raised in the body because the basal metabolic rate is raised. Essentially, with this disorder, all of the body's metabolic pathways are accelerated. Heat production is increased as a result, and both oxygen consumption and ATP turnover are increased. The thyroid is overactive and causes a person to feel too warm.Certain patients who have endured traumatic brain injuries (TBI) or suffered from cardiac arrests may do well with therapeutic hypothermia. In these patients with TBI and post-cardiac arrest, it is very dangerous for them to have an elevation of their core temperatures. High temperatures in these patients are associated with higher mortality rates and slower recovery, especially neurologically. Thus, hypothermia in post-cardiac arrest patients and perinatal hypoxic patients is used to prevent neuronal injury. This is because therapeutic hypothermia (TH) lowers the body's demand for metabolic oxygen. With this mechanism, neurons can be protected before they are injured.

When TH is recommended, it should proceed very rapidly. Ice packs and intravenous administration of cold fluids are imperative to keep the patient cool. Cooling blanket systems or cooling suits may be utilized as well as cooling helmets and caps. For post-cardiac arrest patients, intranasal cooling using nasal probes also may be utilized.

In contrast, some diseases that can cause decreased heat production, or hypothermia include endocrinological diseases such as diabetes, hypothyroidism, hypoadrenalism, and hypopituitarism. Those who are most at risk for hypothermia are elderly patients, trauma patients, those who are mentally ill, those who are abusing alcohol, drugs, or on other types of medication, and, lastly, those with low socio-economic status. Ordinarily, people who get hypothermia have an underlying issue—either from a disease or surgery.

When a patient with one of these diseases presents with hypothermia, it is imperative to treat the underlying disease to effectively treat the hypothermia. This includes treatments with pharmaceuticals including triiodothyronine and steroids. Other causes of hypothermia from decreased metabolic rates are people who are very malnourished, those who suffer from burns, and also those with hypoglycemia.

Hypothermia, like hyperthermia, affects all of the human body's systems. When the core temperature drops below 30 degrees Celsius, the heart responds with arrhythmias. The body may be hypovolemic, hypokalemic, and hypomagnesemic as a result of their hypothermia; therefore, it is important to keep the patient hydrated and to manage their electrolyte disturbances.

The reason that patients with traumatic brain injury are likely to have impaired thermoregulation is that the hypothalamus regulates the core body temperature. When this essential body part is injured, the body is unable to control how it regulates the body's heat. Other problems in the

CNS that affect thermoregulation by the same mechanism can include tumors in the CNS, spinal cord injuries, intracranial hemorrhage, and diseases such as Parkinson, Wernicke encephalopathy, and multiple sclerosis.

Patients who are on the extreme spectrums of age (such as infants and elderly persons) are at higher risk for disorders of thermoregulation and exhibit these features more readily when sick. The very young and the very old cannot increase their metabolic rates, and this can provoke them into hypothermia since they do not have the shivering reflux or much muscle mass. Changes that occur as one ages include those affecting vasomotor sweating function, skeletal muscle response, and temperature perception. Elderly persons have lower than normal internal body temperatures and decreased immunity, so when they have an infection, they may not get the normal pyretic response. Instead, they may present with hypothermia caused by a septic infection. In fact, studies have shown that the core temperatures of elderly patients with sepsis within their first 24 hours of presentation are a huge predictor of their mortality. This is the reason that elderly patients who are septic have a higher mortality rate than younger patients who are septic.

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3.1. 5: Excretion and Reproduction

Excretory System regulates volume of internal body fluids as well as eliminates metabolic wastes from the internal environment. The excretory system removes organic wastes from the blood, accumulating wastes as urea in the kidneys. These wastes are then removed as urine. This system is also responsible for maintaining fluid levels. The nervous and endocrine system coordinates and controls actions of internal organs and body systems. Memory, learning, and conscious thought are a few aspects of the functions of the nervous system. Maintaining autonomic functions such as heartbeat, breathing, control of involuntary muscle actions are performed by some of the parts of this system. Reproductive System, is mostly controlled by the endocrine system, and is responsible for survival and perpetuation of the species. Elements of the reproductive system produce hormones (from endocrine control) that control and aid in sexual development. Organs of this system produce gametes that combine in the female system to produce the next generation

3.1.5.1: Excretory and Reproductive Systems

Excretory and reproductive systems each have important but different functions in animals. The excretory system maintains water, ion, and nitrogen balance within the body and eliminates wastes. The reproductive system creates new individuals of a species. Both the excretory and reproductive systems are under endocrine control but are also influenced by the external environment.

3.1.5.2: The Excretory System

Vertebrates have a closedcirculatory system, which means that they have arteries and veins that transport blood. Cellular metabolism produces waste and uses nutrients and water. The circulatory system carries water and nutrients to cells and carries waste products away from cells. Water and nutrients come from ingestion and digestion. Waste removal is critical to maintaining internal homeostasis.

Nitrogen is the most toxic byproduct of cellular metabolism. The body must excrete nitrogen. Nitrogen is commonly produced as ammonia from cells. Many animals will convert ammonia, which is extremely toxic, into a less toxic form of nitrogenous waste. These include urea and uric acid.

The habitat of an animal determines which kind of nitrogenous waste it produces. Most aquatic animals, both invertebrates and freshwater fish, excrete ammonia. Ammonia dissolves in water and is easy to transport outside of the body by diffusion when an animal is surrounded by water. This happens primarily through the skin in invertebrates and through the gills of fishes. Ammonia must be diluted by a great deal of water to be nontoxic. There is not enough water in land animals to dilute ammonia enough, so ammonia is turned into either urea oruric acid.

Which of these an animal produces is linked to where the offspring develop. Animals characterized by internal development of offspring such as mammals make urea. So do animals that have eggs which develop in water, such as amphibians, sharks, and some fish that live in saltwater.

Urea is not very toxic and can be concentrated by the kidney to conserve water. Urea is dissolved in water, so transport of waste out of a developing egg that is sitting in freshwater is done by diffusion. Uric acid is not water soluble and is excreted in a paste. Birds, reptiles, and insects all produce uric acid. These animals develop in an egg on land, and waste must accumulate in the egg as the individual grows and develops. Because uric acid is not water soluble, it can sit in the egg and not be reabsorbed by the developing zygote.

Water balance in the body is maintained through a process called osmoregulation. The vertebrate kidney is a specialized organ that both concentrates urea or uric acid and maintains water balance, mostly by filtering the blood. When blood passes through the kidney, water is reabsorbed and reused by the body. Additionally, almost all sugar, salts, and other nutrients are reabsorbed by the body from the kidney. Waste products are taken out and eliminated, the main waste product being nitrogenous waste. The kidney contains about 20 percent of the blood volume at any one time.

In invertebrates, a variety of specialized structures exist for waste removal. Flame bulb protonephridia in planaria are the most primitive specialized osmoregulation structure in invertebrates. Annelids have an excretory system called the metanephridium, and it functions for both osmoregulation and nitrogenous waste removal. Insects use Malpighian tubules for both osmoregulation and filtering the hemolymph.

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3.1.5.3. The Reproductive System

The reproductive system functions to produce more individuals of a species. The reproductive system is regulated by the endocrine system and is affected by environmental conditions outside of the animal and internal conditions inside the animal. Reproductive cycles are influenced by the time of year, amount of daylight and rainfall, and temperature, in addition to nutrition and general health of the animal.

The main organs in the reproductive system are the gonads, which include the ovary and testis. The ovaries produce eggs and the testes produce sperm. The egg and the sperm are gametes that combine to form a zygote in a process called fertilization. The zygote will grow and develop into a new individual of the species.

The egg and sperm both carry DNA, the material that contains the genetic instructions for the growth and development of a new individual. Ga-metes are produced through meiosis and contain only one-half of the genetic information of the parent. When the gametes come together and form a zygote, the zygote will have half of its genetic information from the egg and half from the sperm.

In vertebrates such as humans, egg and sperm come separately from different individuals. Humans and most other animals (both vertebrates and invertebrates) have different sexes commonly called males and females. In the case of animals without separate sexes, one individual produces both eggs and sperm and is called a hermaphrodite. Most hermaphrodites, including many annelids, pair with another individual and exchange eggs and sperm rather than fertilizing themselves. Some platyhelminthes self fertilize. Other animals switch between being male and female, a condition called sequential hermaphroditism.

In addition to sexual reproduction, the fusion of the egg and sperm, some animals can reproduce asexually. In asexual reproduction, genetic material is not combined. Therefore, it produces an offspring that is genetically identical to the parent. Types of asexual reproduction include budding, fission, and parthenogenesis. Parthenogenesis occurs in rotifers, some bees, wasps, ants, and several species of fish, lizards, and amphibians. Some animals switch between sexual and asexual reproduction, and some reproduce only asexually.

Fertilization can happen internally or externally. External fertilization occurs in most sea-living creatures as well as freshwater fish and amphibians. In external fertilization both eggs and sperm are shed into water and fertilization, development, and growth of the zygote all take place outside the body. Internal fertilization occurs when egg and sperm are joined inside of the body. The zygote can develop inside of the reproductive tract, as in mammals. Birds and reptiles have internal fertilization but lay eggs. The zygote develops inside the egg but outside of the body. Invertebrates that have internal fertilization also lay eggs.

3.1. 6: Endocrinology

Endocrine System, function as to control the activity internal organs as well as coordinating long-range response to external stimuli. The endocrine system secretes hormones that regulate body metabolism, growth, and reproduction. These organs are not in contact with each other, although they communicate by chemical messages dumped into the circulatory system.

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Endocrinology

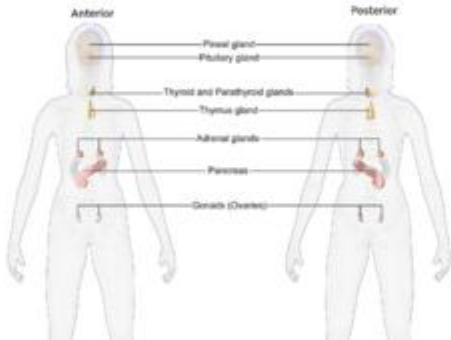


Illustration depicting the primary endocrine organs of a female

System	**Endocrine**
Significant diseases	Diabetes, Thyroid disease, Androgen excess
Significant tests	Thyroid function tests, Blood sugar levels
Specialist	Endocrinologist

Endocrinology (from*endocrine* + *-ology*) is a branch of biology and medicine dealing with the endocrine system, its diseases, and its specific secretions known as hormones. It is also concerned with the integration of developmental events proliferation, growth, and differentiation, and the psychological or behavioral activities of metabolism, growth and development, tissue function, sleep, digestion, respiration, excretion, mood, stress, lactation, movement, reproduction, and sensory perception caused by hormones. Specializations include behavioral endocrinology and comparative endocrinology.

The endocrine system consists of several glands, all in different parts of the body that secrete hormones directly into the blood rather than into a duct system. Therefore, endocrine glands are regarded as ductless glands. Hormones have many different functions and modes of action; one hormone may have several effects on different target organs, and, conversely, one target organ may be affected by more than one hormone.

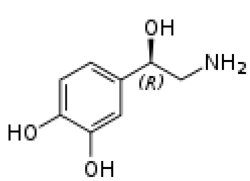
Endocrinology is the study of the endocrine system in the human body. This is a system of glands which secrete hormones. Hormones are chemicals which affect the actions of different organ systems in the body. Examples include thyroid hormone, growth hormone, and insulin. The endocrine system involves a number of feedback mechanisms, so that often one hormone (such as thyroid stimulating hormone) will control the action or release of another secondary hormone (such as thyroid hormone). If there is too much of the secondary hormone, it may provide negative feedback to the primary hormone, maintaining homeostasis.

In the original 1902 definition by Bayliss and Starling (see below), they specified that, to be classified as a hormone, a chemical must be produced by an organ, be released (in small amounts) into the blood, and be transported by the blood to a distant organ to exert its specific function. This definition holds for most "classical" hormones, but there are also paracrine mechanisms (chemical communication between cells within a tissue or organ), autocrine signals (a chemical that acts on the same cell), and intracrine signals (a chemical that acts within the same cell).[4] A neuroendocrine signal is a "classical" hormone that is released into the blood by a neurosecretory neuron (see article on neuroendocrinology).

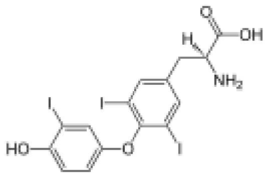
Hormones

Griffin and Ojeda identify three different classes of hormones based on their chemical composition:[5]

Amines



Norepinephrine



Triiodothyronine

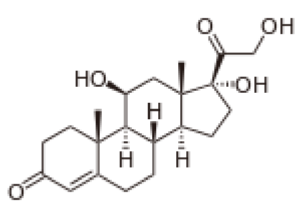
Examples of **amine hormones**

Amines, such as norepinephrine, epinephrine, and dopamine (catecholamines), are derived from single amino acids, in this case tyrosine. Thyroid hormones such as 3,5,3’-triiodothyronine (T3) and 3,5,3’,5’-tetraiodothyronine (thyroxine, T4) make up a subset of this class because they derive from the combination of two iodinated tyrosine amino acid residues.

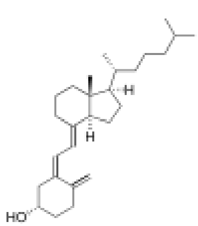
Peptide and protein

Peptide hormones and protein hormones consist of three (in the case of thyrotropin-releasing hormone) to more than 200 (in the case of follicle-stimulating hormone) amino acid residues and can have a molecular mass as large as 31,000 grams per mole. All hormones secreted by the pituitary gland are peptide hormones, as are leptin from adipocytes, ghrelin from the stomach, and insulin from the pancreas.

Steroid



Cortisol



Vitamin D_3

Examples of **steroid hormones**

Steroid hormones are converted from their parent compound, cholesterol. Mammalian steroid hormones can be grouped into five groups by the receptors to which they bind: glucocorticoids, mineralocorticoids, androgens, estrogens, and progestogens. Some forms of vitamin D, such as calcitriol, are steroid-like and bind to homologous receptors, but lack the characteristic fused ring structure of true steroids.

Work

The medical specialty of endocrinology involves the diagnostic evaluation of a wide variety of symptoms and variations and the long-term management of disorders of deficiency or excess of one or more hormones.

The diagnosis and treatment of endocrine diseases are guided by laboratory tests to a greater extent than for most specialties. Many diseases are investigated through *excitation/stimulation* or *inhibition/suppression* testing. This might involve injection with a stimulating agent to test the function of an endocrine organ. Blood is then sampled to assess the changes of the relevant hormones or metabolites. An endocrinologist needs extensive knowledge of clinical chemistry and biochemistry to understand the uses and limitations of the investigations.

A second important aspect of the practice of endocrinology is distinguishing human variation from disease. Atypical patterns of physical development and abnormal test results must be assessed as indicative of disease or not. Diagnostic imaging of endocrine organs may reveal incidental findings called incidentalomas, which may or may not represent disease.

Endocrinology involves caring for the person as well as the disease. Most endocrine disorders are chronic diseases that need lifelong care. Some of the most common endocrine diseases include diabetes mellitus, hypothyroidism and the metabolic syndrome. Care of diabetes, obesity and other chronic diseases necessitates understanding the patient at the personal and social level as well as the molecular, and the physician–patient relationship can be an important therapeutic process.

Apart from treating patients, many endocrinologists are involved in clinical science and medical research, teaching, and hospital management.

Training

Endocrinologists are specialists of internal medicine or pediatrics. Reproductive endocrinologists deal primarily with problems of fertility and menstrual function—often training first in obstetrics. Most qualify as an internist, pediatrician, or gynecologist for a few years before specializing, depending on the local training system. In the U.S. and Canada, training for board certification in internal medicine, pediatrics, or gynecology after medical school is called residency. Further formal training to subspecialize in adult, pediatric, or reproductive endocrinology is called a fellowship. Typical training for a North American endocrinologist involves 4 years of college, 4 years of medical school, 3 years of residency, and 2 years of fellowship. In the US, adult endocrinologists are board certified by the American Board of Internal Medicine (ABIM) or the American Osteopathic Board of Internal Medicine (AOBIM) in Endocrinology, Diabetes and Metabolism.

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Unit 7: Blood and circulation

2.0. Objectives | Blood Circulation

After completing this section, you should know:

- that the circulatory system is double consisting of pulmonary and systemic circuits with the blood passing through the heart twice;
- the differences in the structure and function of arteries, capillaries and veins;
- how the pulse is produced and where it can be felt;
- what tissue fluid and lymph are and how they are formed;
- the names of the main arteries and veins.

3.1.7: Blood Circulation

The circulatory system is the continuous system of tubes through which the blood is pumped around the body. It supplies the tissues with their requirements and removes waste products. In mammals and birds the blood circulates through two separate systems - the first from the heart to the lungs and back to the heart again (the pulmonary circulation) and the second from the heart to the head and body and back again (the systemic circulation) (see diagram 8.12).

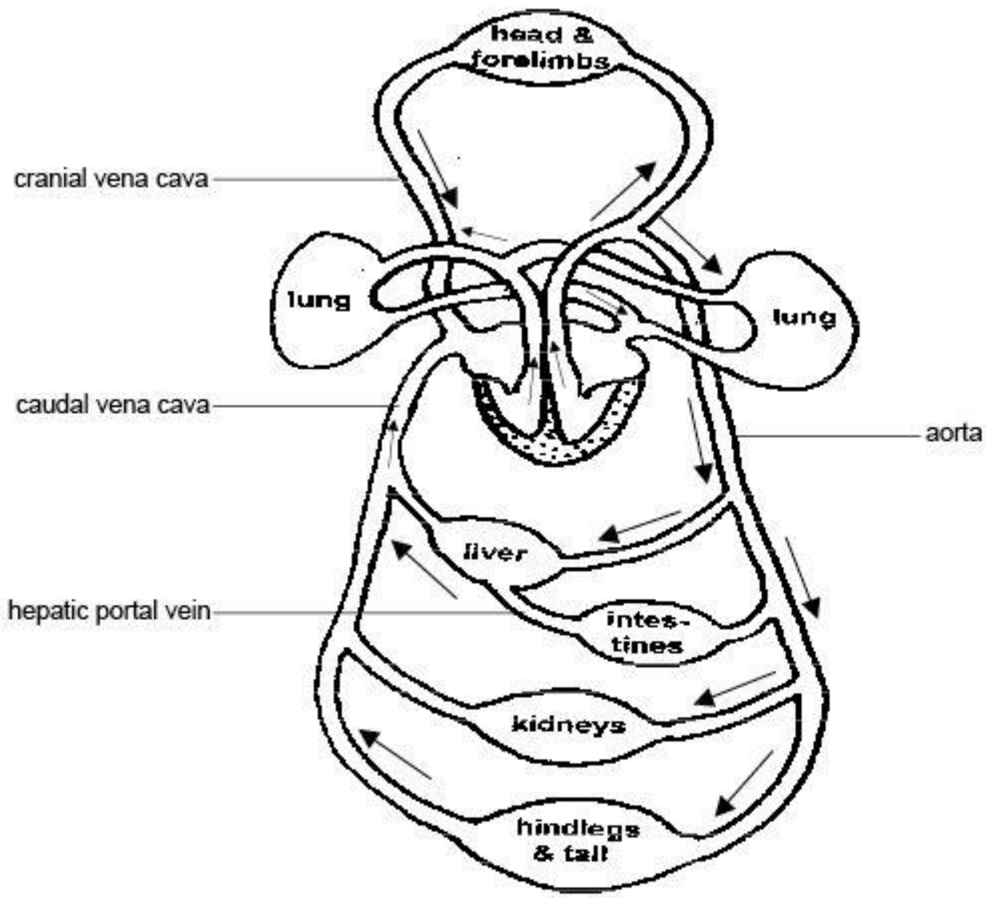


Diagram 8.12 - The mammalian circulatory system

The tubes through which the blood flows are the **arteries, capillaries** and **veins**. The heart pumps blood into arteries that carry it away from the heart. The arteries divide into very thin vessels called capillaries that form a network between the cells of the body. The capillaries then join up again to make veins that return the blood to the heart.

Arteries

Arteries carry blood away from the heart. They have thick elastic walls that stretch and can withstand the surges of high pressure blood caused by the heartbeat (the pulse, see later). The arteries divide into smaller vessels called **arterioles**. The hole down the centre of the artery is called the **lumen**. There are three layers of tissue in the walls of an artery. It is lined with squamous epithelial cells. The middle layer is the thickest layer. It made of elastic fibres and smooth muscle to make it stretchy. The outer fibrous layer protects the artery (see diagram 8.13). The **pulse** is only felt in arteries.

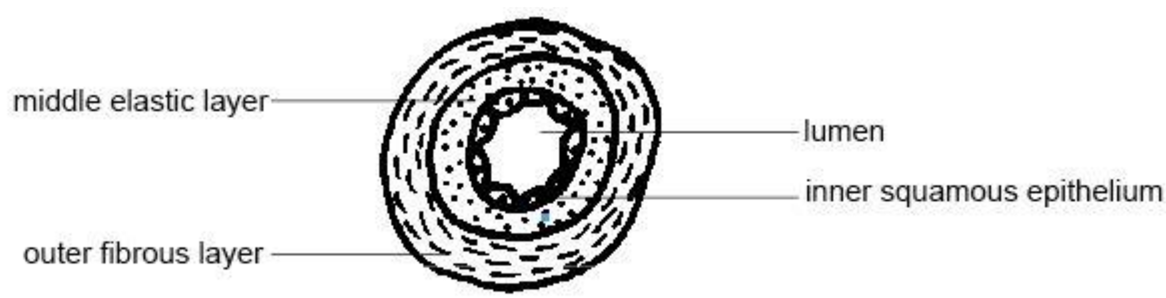


Diagram 8.13 - Cross section of an artery

The Pulse

The pulse is the spurt of high pressure blood that passes along the aorta and arteries when the left ventricle contracts. As the pulse of blood passes along an artery the elastic walls stretch. When the pulse has passed the walls contract and this helps push the blood along. The pulse is easily felt at certain places where an artery passes near the surface of the body. It is strongest near the heart and becomes weaker as it travels away from the heart. The pulse disappears altogether in the capillaries.

Capillaries

Arterioles divide repeatedly to form a network penetrating between the cells of all tissues of the body. These small vessels are called capillaries. The walls are only one cell thick and some capillaries are so narrow that red blood cells have to fold up to pass through them. Capillaries form networks in tissues called capillary beds. The capillary networks in capillary beds are so dense that no living cell is far from its supply of oxygen and food (see diagram 8.14).

Note: All arteries carry oxygenated blood except for the pulmonary artery that carries deoxygenated blood to the lungs.

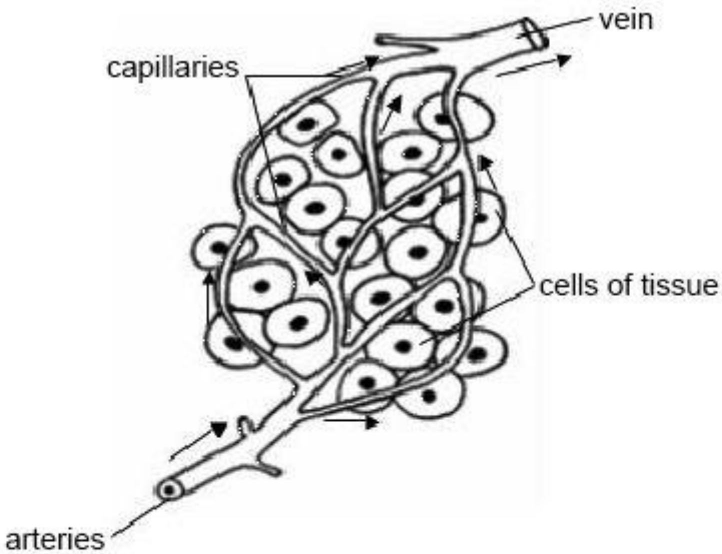


Diagram 8.14 - A capillary bed

The Formation Of Tissue Fluid And Lymph

The thin walls of capillaries allow water, some white blood cells and many dissolved substances to diffuse through them. These form a clear fluid called **tissue fluid** (or **extracellular fluid** or **interstitial fluid**) that surrounds the cells of the tissues. The tissue fluid allows oxygen and nutrients to pass from the blood to the cells and carbon dioxide and other waste products to be removed from the tissues (see diagram 8.15).

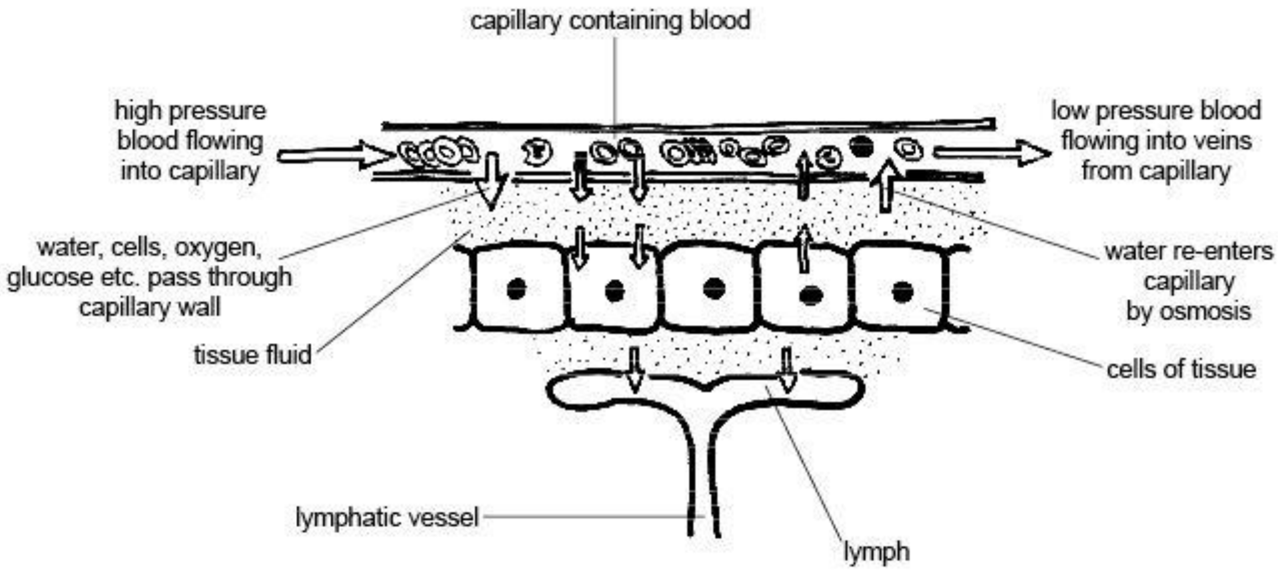


Diagram 8.15 - The formation of tissue fluid and lymph from blood

Some tissue fluid finds its way back into the capillaries and some of it flows into the blind-ended lymphatic vessels that form a network in the tissues. Once the tissue fluid has entered the lymphatics it is called **lymph** although its composition remains the same. The lymph vessels have walls that are even thinner than the capillaries. This means that molecules and particles that are larger than those that can pass into the blood stream e.g. cancer cells and bacteria can enter the lymphatic system. These are then filtered out as the lymph passes through lymph nodes. (See chapter 10 for more information on the lymphatic system).

Veins

Capillaries unite to form larger vessels called **venules** that join to form veins. Veins return blood to the heart and since blood that flows in veins has already passed through the fine capillaries, it flows slowly with no pulse and at low pressure. For this reason veins have thinner walls than arteries although there have the same three layers in them as arteries (see diagram 8.16). As there is no pulse in veins, the blood is squeezed along them by the contraction of the skeletal muscles that lay alongside them.

Veins also have **valves** in them that prevent blood flowing backwards (see diagram 8.17a and b).

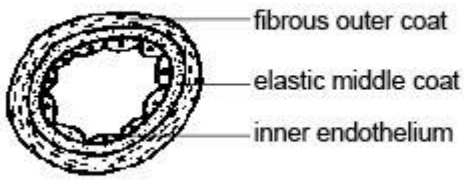


Diagram 8.16 - Cross section of a vein

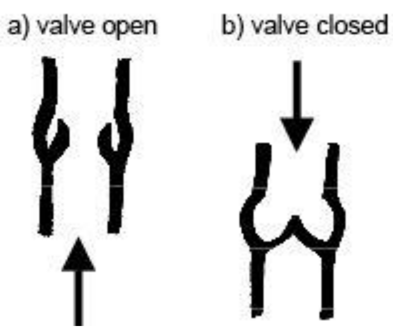


Diagram 8.17 a) and b) Valves in a vein

Note: Most veins carry deoxygenated blood. The pulmonary vein that carries oxygenated blood from the lungs to the left atrium of the heart is an exception.

Regulation Of Blood Flow

The flow of blood along arteries, arterioles and capillaries is not constant but can be controlled depending upon the requirements of the body. For example more blood is directed to the skeletal muscles, brain or digestive system when they are active. Regulation of the blood flow to the arterioles of the skin is also important in controlling body temperature. The size of the vessels is adjusted by the contraction or relaxation of smooth muscle fibres in their walls.

Oedema And Fluid Loss

Oedema is the swelling of the tissues due to the accumulation of tissue fluid. This may occur because the tissue fluid is prevented from returning to the bloodstream and accumulates in the tissues. This may be caused by physical inactivity (e.g. long car or plane trips in humans) or because of imbalances in the proteins in the blood. This is what causes the “pot-belly” of the malnourished child or worm-infested puppy.

Loss of body fluid can be caused not only by drinking insufficient liquid but also through diarrhea and vomiting or sudden loss of blood due to **haemorrhage.** The effect is to reduce the volume of the blood which decreases the blood pressure. This could be dangerous because the supply of adequate blood to the brain depends upon maintaining the blood pressure at a constant level.

To compensate for the loss of fluid various mechanisms come into play. First of all the blood vessels contract in order to try and maintain the pressure. Then, since the loss of fluid tends to make the blood more concentrated and increases its osmotic pressure, fluid is drawn into the blood from the tissues by osmosis.

The Spleen

The spleen is situated near the stomach. It has a rich blood supply and acts as a reservoir of red blood cells. When there is a sudden loss of blood, as happens when a haemorrhage occurs, the spleen contracts to release large numbers of red blood cells into the circulation. The spleen also destroys old red cells and makes new lymphocytes but it is not an essential organ because its removal in adult life seems to cause few problems.

3.1.7:.2 Important Blood Vessels Of The Systemic (Body) Circulation

Blood is pumped out into the body via the main artery, the **aorta**. This takes the blood to the head, the limbs and all the body organs. After passing through a network of fine capillaries, the blood is returned to the heart in the largest vein, the **vena cava** (see diagrams 8.8, 8.12, 8.18 and 8.19).

Arteries and veins to and from many organs often run alongside each other and have the same name e.g. the **renal artery and vein** serve the kidney, the **femoral artery and vein** serve the hind limbs and the **subclavian artery and vein** serve the forelimbs. However, blood to the head passes along the **carotid artery** and returns to the cranial vena cava via the **jugular vein**.

One variation on this arrangement is found in the blood vessels that serve the digestive tract. A variety of arteries take blood from the aorta to the intestines but blood from the intestines is carried by the **hepatic portal vein** to the liver where the digested food can be processed (see diagram 8.12). This vessel is unlike others in that it transports blood from one organ to another rather precious Betine Diagram 8.18 - The main arteries and veins of the horse

3.1.7.3.Blood Pressure

The blood pressure is the pressure of the blood against the walls of the main arteries. The pressure is highest as the pulse produced by the contraction of the left ventricle passes along the artery. This is known as the **systolic pressure**. Pressure is much lower between pulses. This is known as the **diastolic pressure**. Blood pressure is measured in millimetres of mercury. A blood pressure that is higher than expected is known as **hypertension** while a pressure lower than expected is known as **hypotension.**

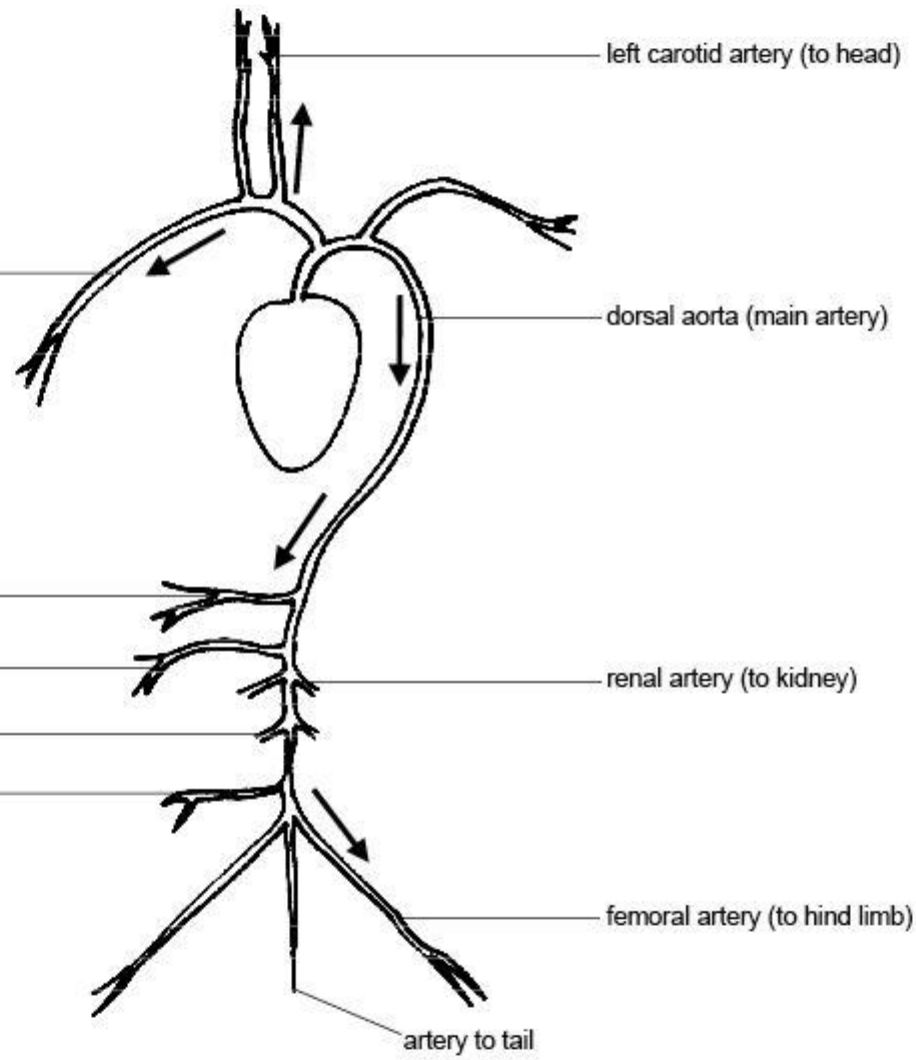


Diagram 8.19 - The main arteries of the body

Summary

- The circulatory system is double with the blood passing through the heart twice.
- **Arteries** carry blood away from the heart. They have thick elastic walls that stretch and can withstand the high pressure of the pulse.
- **Capillaries** are small, thin walled vessels that form a network between the cells of the tissues.
- **Veins** return low pressure blood to the heart. They have thinner walls than arteries.

- The **pulse** is the spurt of high pressure blood that passes along the arteries when the left ventricle contracts. It can be felt where arteries pass close to the body surface.
- **Tissue fluid** is the clear fluid that leaks from the capillaries and surrounds the cells of the tissues. **Lymph** forms when tissue fluid enters lymphatics.
- Important blood vessels include the vena cava, aorta, pulmonary artery, carotid artery, jugular vein, renal artery and vein and hepatic portal vessel.

Test Yourself

1. Give 2 differences between arteries and veins

2. What is systole?

3. Blood flows by this route through the blood vessels of the body?.

4. Name the vessel that carries bloodfrom the heart to the main organs of the body:

Importance of peripubertal mammary development as a foundation for subsequent mammary growth and milk production was discussed. Morphological differences in peripubertal mammary growth in rodents and ruminants were described. The relevance of tissue interactions and association with hormones and growth factors in mammary development were delineated. Data from specific studies with ruminant mammary parenchyma were outlined for comparison with rodent studies. It is concluded that the wholesale extrapolation of data from rodent studies to explain udder development is inappropriate. Lastly, recent data from experiments with culture of mammary explants from bulls is described. Pragmatically, these data suggest that responses of mammary tissue from bulls might provide a means for early selection of superior sires or provide a unique model to study tissue interactions in udder development.

2.0 Learning Objectives

By the end of this section, you will be able to:

- Describe the structure of the lactating breast
- Summarize the process of lactation

- Explain how the composition of breast milk changes during the first days of lactation and in the course of a single feeding

3.1.8: Lactation

Lactation is the process by which milk is synthesized and secreted from the mammary glands of the postpartum female breast in response to an infant sucking at the nipple. Breast milk provides ideal nutrition and passive immunity for the infant, encourages mild uterine contractions to return the uterus to its pre-pregnancy size (i.e., involution), and induces a substantial metabolic increase in the mother, consuming the fat reserves stored during pregnancy.

3.1.8.1: Structure of the Lactating Breast

Mammary glands are modified sweat glands. The non-pregnant and non-lactating female breast is composed primarily of adipose and collagenous tissue, with mammary glands making up a very minor proportion of breast volume. The mammary gland is composed of milk-transporting lactiferous ducts, which expand and branch extensively during pregnancy in response to estrogen, growth hormone, cortisol, and prolactin. Moreover, in response to progesterone, clusters of breast alveoli bud from the ducts and expand outward toward the chest wall. Breast alveoli are balloon-like structures lined with milk-secreting cuboidal cells, or lactocytes, that are surrounded by a net of contractile myoepithelial cells. Milk is secreted from the lactocytes, fills the alveoli, and is squeezed into the ducts. Clusters of alveoli that drain to a common duct are called lobules; the lactating female has 12–20 lobules organized radially around the nipple. Milk drains from lactiferous ducts into lactiferous sinuses that meet at 4 to 18 perforations in the nipple, called nipple pores. The small bumps of the areola (the darkened skin around the nipple) are called Montgomery glands. They secrete oil to cleanse the nipple opening and prevent chapping and cracking of the nipple during breastfeeding.

3.1. 8.2: The Process of Lactation

The pituitary hormone **prolactin** is instrumental in the establishment and maintenance of breast milk supply. It also is important for the mobilization of maternal micronutrients for breast milk.

Near the fifth week of pregnancy, the level of circulating prolactin begins to increase, eventually rising to approximately 10–20 times the pre-pregnancy concentration. We noted earlier that, during pregnancy, prolactin and other hormones prepare the breasts anatomically for the secretion of milk. The level of prolactin plateaus in late pregnancy, at a level high enough to initiate milk production. However, estrogen, progesterone, and other placental hormones inhibit prolactin-mediated milk synthesis during pregnancy. It is not until the placenta is expelled that this inhibition is lifted and milk production commences.

After childbirth, the baseline prolactin level drops sharply, but it is restored for a 1-hour spike during each feeding to stimulate the production of milk for the next feeding. With each prolactin spike, estrogen and progesterone also increase slightly.

When the infant suckles, sensory nerve fibers in the areola trigger a neuroendocrine reflex that results in milk secretion from lactocytes into the alveoli. The posterior pituitary releases oxytocin, which stimulates myoepithelial cells to squeeze milk from the alveoli so it can drain into the lactiferous ducts, collect in the lactiferous sinuses, and discharge through the nipple pores. It takes less than 1 minute from the time when an infant begins suckling (the latent period) until milk is secreted (the let-down).

Figure 1. Let-Down Reflex. A positive feedback loop ensures continued milk production as long as the infant continues to breastfeed.

The prolactin-mediated synthesis of milk changes with time. Frequent milk removal by breastfeeding (or pumping) will maintain high circulating prolactin levels for several months. However, even with continued breastfeeding, baseline prolactin will decrease over time to its pre-pregnancy level. In addition to prolactin and oxytocin, growth hormone, cortisol, parathyroid hormone, and insulin contribute to lactation, in part by facilitating the transport of maternal amino acids, fatty acids, glucose, and calcium to breast milk.

3.1: 8.3.Changes in the Composition of Breast Milk

In the final weeks of pregnancy, the alveoli swell with **colostrum**, a thick, yellowish substance that is high in protein but contains less fat and glucose than mature breast milk. Before childbirth, some women experience leakage of colostrum from the nipples. In contrast, mature breast milk does not leak during pregnancy and is not secreted until several days after childbirth.

*Cow's milk should never be given to an infant. Its composition is not suitable and its proteins are difficult for the infant to digest.

Compositions of Human Colostrum, Mature Breast Milk, and Cow's Milk (g/L) (Table 3)

	Human colostrums	**Human breast milk**	**Cow's milk***
Total protein	23	11	31
Immunoglobulins	19	0.1	1
Fat	30	45	38
Lactose	57	71	47
Calcium	0.5	0.3	1.4
Phosphorus	0.16	0.14	0.90
Sodium	0.50	0.15	0.41

Colostrum is secreted during the first 48–72 hours postpartum. Only a small volume of colostrum is produced—approximately 3 ounces in a 24-hour period—but it is sufficient for the newborn in the first few days of life. Colostrum is rich with immunoglobulins, which confer gastrointestinal, and also likely systemic, immunity as the newborn adjusts to a nonsterile environment.

After about the third postpartum day, the mother secretes transitional milk that represents an intermediate between mature milk and colostrum. This is followed by mature milk from approximately postpartum day 10. As you can see in the accompanying table, cow's milk is not a substitute for breast milk. It contains less lactose, less fat, and more protein and minerals.

Moreover, the proteins in cow's milk are difficult for an infant's immature digestive system to metabolize and absorb.

The first few weeks of breastfeeding may involve leakage, soreness, and periods of milk engorgement as the relationship between milk supply and infant demand becomes established. Once this period is complete, the mother will produce approximately 1.5 liters of milk per day for a single infant, and more if she has twins or triplets. As the infant goes through growth spurts, the milk supply constantly adjusts to accommodate changes in demand. A woman can continue to lactate for years, but once breastfeeding is stopped for approximately 1 week, any remaining milk will be reabsorbed; in most cases, no more will be produced, even if suckling or pumping is resumed.

Mature milk changes from the beginning to the end of a feeding. The early milk, called **foremilk**, is watery, translucent, and rich in lactose and protein. Its purpose is to quench the infant's thirst. **Hindmilk** is delivered toward the end of a feeding. It is opaque, creamy, and rich in fat, and serves to satisfy the infant's appetite.

During the first days of a newborn's life, it is important for meconium to be cleared from the intestines and for bilirubin to be kept low in the circulation. Recall that bilirubin, a product of erythrocyte breakdown, is processed by the liver and secreted in bile. It enters the gastrointestinal tract and exits the body in the stool. Breast milk has laxative properties that help expel meconium from the intestines and clear bilirubin through the excretion of bile. A high concentration of bilirubin in the blood causes jaundice. Some degree of jaundice is normal in newborns, but a high level of bilirubin—which is neurotoxic—can cause brain damage. Newborns, who do not yet have a fully functional blood–brain barrier, are highly vulnerable to the bilirubin circulating in the blood. Indeed, hyperbilirubinemia, a high level of circulating bilirubin, is the most common condition requiring medical attention in newborns. Newborns with hyperbilirubinemia are treated with phototherapy because UV light helps to break down the bilirubin quickly.

Chapter Review

The lactating mother supplies all the hydration and nutrients that a growing infant needs for the first 4–6 months of life. During pregnancy, the body prepares for lactation by stimulating the growth and development of branching lactiferous ducts and alveoli lined with milk-secreting lactocytes, and by creating colostrum. These functions are attributable to the actions of several hormones, including prolactin. Following childbirth, suckling triggers oxytocin release, which stimulates myoepithelial cells to squeeze milk from alveoli. Breast milk then drains toward the nipple pores to be consumed by the infant. Colostrum, the milk produced in the first postpartum days, provides immunoglobulins that increase the newborn's immune defenses. Colostrum, transitional milk, and mature breast milk are ideally suited to each stage of the newborn's development, and breastfeeding helps the newborn's digestive system expel meconium and clear bilirubin. Mature milk changes from the beginning to the end of a feeding. Foremilk quenches the infant's thirst, whereas hindmilk satisfies the infant's appetite.

Review Questions

1. Alveoli are connected to the lactiferous sinuses by ________.

2. How is colostrum most important to a newborn?

3. Mature breast milk ________.

Critical Thinking Questions

1. Describe the transit of breast milk from lactocytes to nipple pores.

2. A woman who stopped breastfeeding suddenly is experiencing breast engorgement and leakage, just like she did in the first few weeks of breastfeeding. Why?

Glossary

colostrum

thick, yellowish substance secreted from a mother's breasts in the first postpartum days; rich in immunoglobulins

foremilk

watery, translucent breast milk that is secreted first during a feeding and is rich in lactose and protein; quenches the infant's thirst

hindmilk

opaque, creamy breast milk delivered toward the end of a feeding; rich in fat; satisfies the infant's appetite

lactation

process by which milk is synthesized and secreted from the mammary glands of the postpartum female breast in response to sucking at the nipple

let-down reflex

release of milk from the alveoli triggered by infant suckling

prolactin

pituitary hormone that establishes and maintains the supply of breast milk; also important for the mobilization of maternal micronutrients for breast milk

3.1.9: Milk letdown and Egg Production

Answers for Critical Thinking Questions

1. Milk is secreted by lactocytes into alveoli. Suckling stimulates the contraction of myoepithelial cells that squeeze milk into lactiferous ducts. It then collects in lactiferous sinuses and is secreted through the nipple pores.
2. It takes time to establish a balance between milk supply and milk demand. When breastfeeding stops abruptly, it takes time for the supply to fall. Excessive milk supply creates breast engorgement and leakage.

Milk Let-down - an efficient routine

3.1.:9.2.Milk let-down and 'lag time'

The process of milk 'let-down' in the cow is of particular interest as the timing of let-down can be used to form an efficient routine to milk cows as quickly and efficiently as possible while minimising any teat damage that can be caused by 'overmilking' - when there is a high vacuum but little milk flow - and also by acknowledging that the time immediately following milking is crucial to controlling bacterial entry into the teat as the teat sphincter takes time to close post-milking.

Milk let-down is controlled by unconditioned factors, most notably the response to tactile stimuli provided by a calf rubbing the udder or teat when suckling, or a similar stimulus provided by the milker when foremilking the quarter or otherwise preparing it for being milked. Other, conditioned factors, such as the psychological stimuli provided by the sounds, smells and routine the cow experiences at or around milking time also contribute to milk let-down.

These stimuli result in the release of the hormone **oxytocin** from the cow's pituitary gland in the brain into the bloodstream, where it travels to the udder and causes several important processes to occur.

Oxytocin release causes the mass of interconnecting blood vessels at the base of theteatto fill with blood, making the teat more erect and allowing milk to enter it from higher in the udder and pass through the teat. Oxytocin also encourages muscles throughout the udder to act to release milk. Most importantly, the muscle cells around the milk-producing alveoli deep in the udder contract and force the milk into the various ducts in theudder, down into the udder cistern and then into the teat cistern, ready for the milk to be removed by the suckling calf or the milking equipment.

This is why during milking, for efficient let-down cows should be subjected to minimal stress, as this can cause the release of the hormone **adrenalin** (as a response to stress) which can counter the effect of oxytocin.

The average time between beginning to prepare the cow for milking and the resultant let-down of milk is in the order of 60 to 90 seconds. During the period between milkings, an amount of milk will have already collected in the udder and teat cisterns, and will be released almost immediately upon attachment of the milking equipment. There then follows a period known as *lag time*, whereupon the oxytocin released into the bloodstream causes the release of milk deep in the udder. If the time between the first stimulus of the udder by foremilking or wiping the teats occurs approximately 60 seconds after beginning the process, the release of milk from higher in the udder will be practically continuous with the first release of milk stored in the teat and udder cisterns.

Where a longer or shorter lag time occurs, the milk flow can become **bimodal**; there is effectively a gap where overmilking can occur, even at this early stage of the milking process. Here, the high vacuum from the milking machine combined with a low or nonexistent flow of milk can cause significant damage to the teat end, making the cow more susceptible to mastitis, and likely also to lengthen the milking time significantly.

During milking, the teat lengthens while the teat canal opens up and becomes shorter, to allow faster removal of the milk from the cistern structures above it. Following milking, the overall teat length shortens, the teat canal lengthens and the teat sphincter begins to close, as the folds of skin around the opening close around one another, creating a tight seal, and the lipidised film around the sphincter stops a column of milk forming through which bacterial entry could occur. A waxy keratin seal begins to form in the teat canal to protect against bacterial entry after milking.

However, the sphincter muscle can take in the order of 20 to 30 minutes to close, and it is during this time that the risk of bacterial entry is greatly increased. This is why post-dip treatments play an important role, and also why cows should not be permitted to lie down for a 30 minute period

Post milking

3.1. 10: Reproduction in Birds (Physiology of Egg Production)

It is apparent even to the casual observer that there are dramatic reproductive differences between mammals and birds. Chickens (Gallus domesticus) are familiar as domesticated birds in the poultry industry. These birds are believed to be domesticated from Red Jungle fowl found in south-eastern Asia. Humans take advantage of the prodigious egg production of these animals to provide breakfast staple around the world and meat for our tables. Before World War II, most egg production came from flocks of only a few hundred hens. Beginning in the 1960s, changing technology and creation specialized equipments shifted production from these small farm flocks to larger, vertically integrated (direct association between growers and producers) larger enterprises including several thousands of birds.

Avian reproduction is best understood in domestic chicken and turkeys. In fact, the modern poultry industry depends on a well-developed understanding of the reproductive cycle and how best to manipulate and control it for maximum egg production. Birds lay eggs in groups or clutches of one or more eggs. This is followed by a rest period and then another cycle. Clutch size, as well as the numbers of clutches laid in a breeding season, varies with species, but the principle is the same. Domestic hens usually lay five or more eggs in a clutch, with a day's break between clutches.

Hence ovulate in the morning and almost never after 3.00 p.m. under a normal photoperiod. The final stages to prepare the terminal egg for laying takes from 25 to 26h. This period includes approximately 3.5 h to add the layers of albumen (egg white) around the yolk, 1,5 h for shell membranes, and 20 h needed for shell formation. Ovulation of the next egg in sequence (part of the clutch) begins within an hour of laying the previous egg. This means that the hen starts to slowly get behind as each day presses. After several day she gets so far behind that she would have to ovulate after 3:00 p.m. Since this does not happen, the next ovulation is delayed and the clutch cycle is broken. After a couple of days the sequence begins again with a new clutch of eggs.

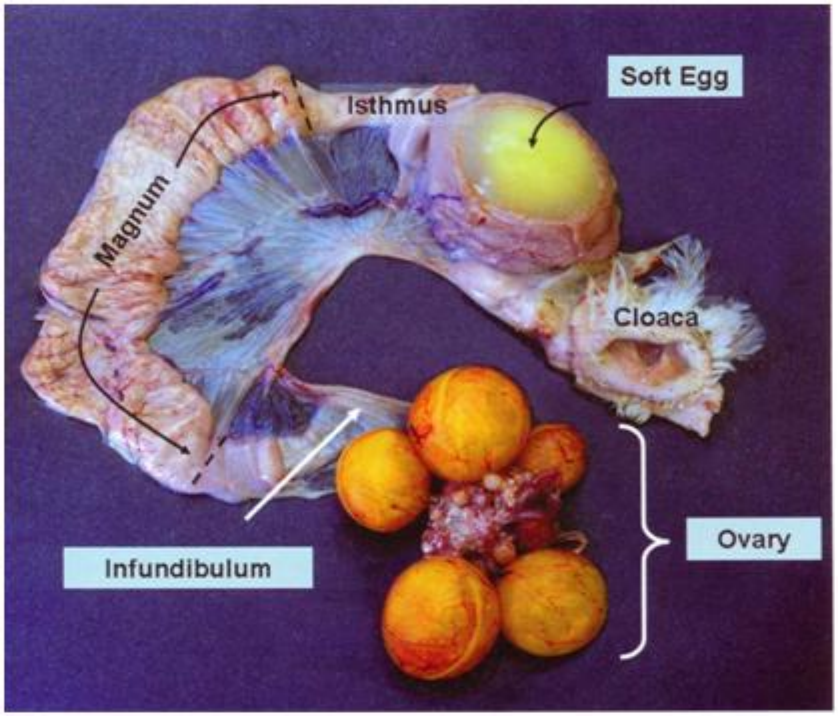
Sometimes a hen will stop laying additional eggs and begin to focus on the incubation of eggs. This is called "broodiness" or "going broody, A broody chicken will doggedly sit on her nest and protest or peck if distributed. While brooding, the hen maintains constant temperature and humidity, and also turns the eggs regularly. At the end of the21-day incubation period, if the eggs are fertilized they will hatch and the broody hen will take care of her chicks. Since individual eggs do not all hatched at the same time (the hen lays only one egg approximately every 25 h), the hen will usually stay on the nest for about 2 days after the first egg hatches. During this time, newly hatched chicks live off the egg yolk they absorb just before hatching. The hen can sense the chicks peeping inside the eggs and will gently cluck to stimulate them to break out of their shells. If the eggs are not fertilized and do not hatch, the hen will eventually lose interest and leave the nest.

3.1. 10.2 Female reproductive systems

Among female birds, both right and left ovaries are present embryologically, but chickens, turkey, and domestic geese the right organs regress early in development and only the left side develops (both sides persist and develop in ducks). The ovaries are located cranioventrally to the corresponding kidney, and the size varies with the reproductive status of the bird. Prior to the onset of the first laying period, the small ovary is smooth; as puberty is approached, it begins to develop a granular, then cobblestone appearance as follicles enlarge in preparation for ovulation. Just prior to "coming into lay", the ovary will resemble a bunches of grapes.

The mature ovum is more-or-less equivalent to the yolk of the egg; it will be released at ovulation and received into the expanded terminus of the oviduct, the infundibulum (Fig. 13. 1.).

Figure 1.1.: Structures of female chicken reproductive tract (Akers and Denbow, 2008). The ovary with multiple oocytes in various stages of development is apparent. After ovulation, the egg progresses through segments of the oviduct, infundibulum, magnum, and isthmus. In this illustration, a mature egg after albumin deposition (soft egg), but before shell formation, is shown. The mature egg is subsequently laid after passage into the cloaca



It is in the infundibulum that fertilization will take place if the bird is allowed to breed. The oviduct is variable in size, being maximally expanded and lengthened during the lay (60-70 cm long in the hen) and regress in size during broodiness and the moult. It possesses grossly identifiable sections (the magnum, isthmus, uterus, and vagina) that correlate with the important tasks of production the albumen and the laying down of the egg shell. The oviduct terminates in a slit-like aperture in the urodeum, next to the opening of the ureter.

3.1.11: Water Balance

2.0 Learning Objectives

By the end of this section, you will be able to:

- Explain how water levels in the body influence the thirst cycle
- Identify the main route by which water leaves the body
- Describe the role of ADH and its effect on body water levels
- Define dehydration and identify common causes of dehydration

On a typical day, the average adult will take in about 2500 mL (almost 3 quarts) of aqueous fluids. Although most of the intake comes through the digestive tract, about 230 mL (8 ounces) per day is generated metabolically, in the last steps of aerobic respiration. Additionally, each day about the same volume (2500 mL) of water leaves the body by different routes; most of this lost water is removed as urine. The kidneys also can adjust blood volume though mechanisms that draw water out of the filtrate and urine. The kidneys can regulate water levels in the body; they conserve water if you are dehydrated, and they can make urine more dilute to expel excess water if necessary. Water is lost through the skin through evaporation from the skin surface without overt sweating and from air expelled from the lungs. This type of water loss is called insensible water loss because a person is usually unaware of it.

3.1. 11.2.Regulation of Water Intake

Osmolality is the ratio of solutes in a solution to a volume of solvent in a solution. **Plasma osmolality** is thus the ratio of solutes to water in blood plasma. A person's plasma osmolality value reflects his or her state of hydration. A healthy body maintains plasma osmolality within a narrow range, by employing several mechanisms that regulate both water intake and output.

Drinking water is considered voluntary. So how is water intake regulated by the body? Consider someone who is experiencing **dehydration**, a net loss of water that results in insufficient water in blood and other tissues. The water that leaves the body, as exhaled air, sweat, or urine, is ultimately extracted from blood plasma. As the blood becomes more concentrated, the thirst response—a sequence of physiological processes—is triggered. Osmoreceptors are sensory receptors in the thirst center in the hypothalamus that monitor the concentration of solutes (osmolality) of the blood. If blood osmolality increases above its ideal value, the hypothalamus transmits signals that result in a conscious awareness of thirst. The person should (and normally does) respond by drinking water. The hypothalamus of a dehydrated person also releases antidiuretic hormone (ADH) through the posterior pituitary gland. ADH signals the kidneys to recover water from urine, effectively diluting the blood plasma. To conserve water, the hypothalamus of a dehydrated person also sends signals via the sympathetic nervous system to the salivary glands in the mouth. The signals result in a decrease in watery, serous output (and an increase in stickier, thicker mucus output). These changes in secretions result in a “dry mouth” and the sensation of thirst.

Thirst Response. The thirst response begins when osmoreceptors detect a decrease in water levels in the blood.

Decreased blood volume resulting from water loss has two additional effects. First, baroreceptors, blood-pressure receptors in the arch of the aorta and the carotid arteries in the neck, detect a decrease in blood pressure that results from decreased blood volume. The heart is ultimately signaled to increase its rate and/or strength of contractions to compensate for the lowered blood pressure.

Second, the kidneys have a renin-angiotensin hormonal system that increases the production of the active form of the hormone angiotensin II, which helps stimulate thirst, but also stimulates the release of the hormone aldosterone from the adrenal glands. Aldosterone increases the reabsorption of sodium in the distal tubules of the nephrons in the kidneys, and water follows this reabsorbed sodium back into the blood.

If adequate fluids are not consumed, dehydration results and a person’s body contains too little water to function correctly. A person who repeatedly vomits or who has diarrhea may become dehydrated, and infants, because their body mass is so low, can become dangerously dehydrated very quickly. Endurance athletes such as distance runners often become dehydrated during long races. Dehydration can be a medical emergency, and a dehydrated person may lose consciousness, become comatose, or die, if his or her body is not rehydrated quickly.

3.1: 11.2.Regulation of Water Output

Water loss from the body occurs predominantly through the renal system. A person produces an average of 1.5 liters (1.6 quarts) of urine per day. Although the volume of urine varies in response to hydration levels, there is a minimum volume of urine production required for proper bodily functions. The kidney excretes 100 to 1200 milliosmoles of solutes per day to rid the body of a variety of excess salts and other water-soluble chemical wastes, most notably creatinine, urea, and uric acid. Failure to produce the minimum volume of urine means that metabolic wastes cannot be effectively removed from the body, a situation that can impair organ function. The minimum level of urine production necessary to maintain normal function is about 0.47 liters (0.5 quarts) per day.

The kidneys also must make adjustments in the event of ingestion of too much fluid. **Diuresis**, which is the production of urine in excess of normal levels, begins about 30 minutes after drinking a large quantity of fluid. Diuresis reaches a peak after about 1 hour, and normal urine production is reestablished after about 3 hours.

Role of ADH

Antidiuretic hormone (ADH), also known as vasopressin, controls the amount of water reabsorbed from the collecting ducts and tubules in the kidney. This hormone is produced in the hypothalamus and is delivered to the posterior pituitary for storage and release. When the osmoreceptors in the hypothalamus detect an increase in the concentration of blood plasma, the hypothalamus signals the release of ADH from the posterior pituitary into the blood.

Antidiuretic Hormone (ADH). ADH is produced in the hypothalamus and released by the posterior pituitary gland. It causes the kidneys to retain water, constricts arterioles in the peripheral circulation, and affects some social behaviors in mammals.

ADH has two major effects. It constricts the arterioles in the peripheral circulation, which reduces the flow of blood to the extremities and thereby increases the blood supply to the core of the body. ADH also causes the epithelial cells that line the renal collecting tubules to move water channel proteins, called aquaporins, from the interior of the cells to the apical surface, where these proteins are inserted into the cell membrane. The result is an increase in the water permeability of these cells and, thus, a large increase in water passage from the urine through the walls of the collecting tubules, leading to more reabsorption of water into the bloodstream. When the blood plasma becomes less concentrated and the level of ADH decreases, aquaporins are removed from collecting tubule cell membranes, and the passage of water out of urine and into Aquaporins. The binding of ADH to receptors on the cells of the collecting tubule results in aquaporins being inserted into the plasma membrane, shown in the lower cell. This dramatically increases the flow of water out of the tubule and into the bloodstream.

A diuretic is a compound that increases urine output and therefore decreases water conservation by the body. Diuretics are used to treat hypertension, congestive heart failure, and fluid retention associated with menstruation. Alcohol acts as a diuretic by inhibiting the release of ADH. Additionally, caffeine, when consumed in high concentrations, acts as a diuretic.

Chapter Review

Homeostasis requires that water intake and output be balanced. Most water intake comes through the digestive tract via liquids and food, but roughly 10 percent of water available to the body is generated at the end of aerobic respiration during cellular metabolism. Urine produced by the kidneys accounts for the largest amount of water leaving the body. The kidneys can adjust the concentration of the urine to reflect the body's water needs, conserving water if the body is dehydrated or making urine more dilute to expel excess water when necessary. ADH is a hormone that helps the body to retain water by increasing water reabsorption by the kidneys.

Review Questions

1. The largest amount of water comes into the body via ________.

2. The largest amount of water leaves the body via ________.

3. Insensible water loss is water lost via ________.

4. How soon after drinking a large glass of water will a person start increasing their urine output?

Critical Thinking Questions

1. Describe the effect of ADH on renal collecting tubules.

2. Why is it important for the amount of water intake to equal the amount of water output?

Glossary

antidiuretic hormone (ADH)also known as vasopressin, a hormone that increases the volume of water reabsorbed from the collecting tubules of the kidney

dehydrationstate of containing insufficient water in blood and other tissues

diuresisexcess production of urine

plasma osmolalityratio of solutes to a volume of solvent in the plasma; plasma osmolality reflects a person’s state of hydration

Answers for Critical Thinking Questions

1. ADH constricts the arterioles in the peripheral circulation, limiting blood to the extremities and increasing the blood supply to the core of the body. ADH also causes the epithelial cells lining the renal collecting tubules to move water channel proteins called aquaporins from the sides of the cells to the apical surface. This greatly increases the passage of water from the renal filtrate through the wall of the collecting tubule as well as the reabsorption of water into the bloodstream.
2. Any imbalance of water entering or leaving the body will create an osmotic imbalance that will adversely affect cell and tissue function.

Unit 11: Water balance

Introduction

It is best that the fluid surrounding the cells remains fairly constant. If volume is varied dramatically then it has major knock on effects on the blood pressure and perfusion of the organs and tissue.

The Importance of Maintaining Adequate Levels of Water

Too Little Water

- Inadequate perfusion due to low blood volume
- A build up of waste products due to insufficient urine volume

- Increased solute concentrations affect cell function
- Inability to sweat and control body temperature
- Death

Too Much Water

- Oedema
- Increased blood volume and therefore pressure could damage the CVS
- A decrease in solute concentrations disrupt normal cell function

Inter-Animal Differences

There are differences in water content between the many tissues which make up the body. Tissues which have low metabolic activity such as adipose tissue and bone have relatively lower water content. This leads to a variation in water between individuals for example a very fat cow may only have a 40% body water content compared to 70% in a lean cow. There is also an age difference. Young animals tend to have a high body water content where as older well nourished animal have a lower.

Due to the differences in relative tissue distribution there is a sex related difference also. Males which tend to have more muscle have a higher water content where as female which tend to have more adipose tissue have a lower.

Water Locations

Although 65% of water is found intracellulary there is a significant quantity in the digestive and urinary tracts. In ruminants this could equal the volume of the interstial fluid. This water is not easy to mobilise but can be if it is required to stabilise blood volume.

Water Gain and Loss

Water volume varies very little from day to day suggesting intake is equal to loss. Water is gained from three sources - drinking, food and metabolic water. In the periods between water intake ADH is secreted because the osmolarity of the plasma increases. Once the osmolarity reaches a certain threshold the thirst centre makes the animal drink. However intake is not under precise control. Metabolic water is derived from the oxidation of hydrogen within cells and represents about 8-12% of an animal’s water supply. However this can be quite extreme. For example the kangaroo rat survives almost fully on this metabolic water.

If water gain and loss is to be balanced then the loss needs to be adjusted to match the variable intake. Water is lost from, 4/5 main areas - the body surface, the airways, faeces, urine and lactation (if applicable).

Insensible Water Loss

Insensible water loss is water loss which cannot be sensed by the individual and tends to be a response to thermoregulation rather than being a regulated process of water homeostasis. It includes evaporation from the skin and epithelial surfaces of the airways and varies with environmental temperature and humidity as well as air movement. The main losses being from sweating and increased respiration.

Water Loss Through the Faeces

This is minimal in omnivores and carnivores but of major importance to herbivorous species. It is not really under physiological control with regards to water balance and as such is not a viable means of adjusting the output to match the intake.

Renal Regulation of Water Loss

Only the kidneys are capable of precise adjustment of water loss to compensate for the variation in water intake. However a minimum amount must always be excreted to remove the waste. For example a **70kg human** produces **600mosmol** of solutes every 24 hours even without food. This is mainly Urea, Uric acid, phosphate, creatine, creatinine other waste products and ions. In humans the maximum urine osmolarity is **1200mosmol/l** therefore there is a minimum water loss of **500ml** even when no food or water is available. When this is added to another **500ml in the exhaled air** and **400ml evaporated** from the body surfaces a person loses 1400ml of water per

24 hours. This is the **inevitable water loss.300ml of metabolic water** is produced per 24 hours in this person leaving an **1100ml** deficit to be compensated for by drinking.

Water Intake and Lactation

Water intake during lactation increases significantly even over and above the requirement for milk. To produce 31l of milk and cow needs to take in an extra 57l of water. This is thought to be because of an increased loss from the airways, skin and faeces.

5.5 Summary

- Importance of water

Too **Little Water**

- Inadequate perfusion due to low blood volume
- A build up of waste products due to insufficient urine volume
- Increased solute concentrations affect cell function
- Inability to sweat and control body temperature
- Death

Too Much Water

- Oedema
- Increased blood volume and therefore pressure could damage the CVS
- A decrease in solute concentrations disrupt normal cell function

- Water loss
- Water balance
- **5.6 Tutor marked assignment**
- What do you understand by water balance?
- Using specific examples, differentiate between water gain and water loss
- Why is it necessary to water?

5.7 References/ Further Reading

FAO. (2015). the Second Report on the State of the World's Animal Genetic Resources for Food and Agriculture. Section A, p 5. Rome

Osinowo, O.A (2006).Introduction to Animal Reproduction. Sophie Academic ISBN 978-37674-0-2