VETS30015/ VETS 90121
Cells to Systems
Lecture 1: Introduction

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Intended Learning Outcomes

- Describe the relationship between cells, tissues, organs and body systems in terms of their anatomical structure and physiological functions
- Describe the basic structure of a cell and understand the function of the major cell components
- Explain the general concept of homeostasis and the principles of positive and negative feedback in physiological systems

Subject Overview

Cells to systems brings together the basic principles of histology, anatomy, cell biology, physiology, neurophysiology, pharmacology, haematology, developmental biology and pathology. It assumes a background in biological principles and aims to integrate that knowledge into an understanding of how cells, tissues and organs interact to maintain homeostasis

It is taught in 10 theme blocks and in an integrated fashion.

- Histology –Microscopic structure of tissues
- Anatomy –Study of body layout and how to describe it
- Physiology –How the body functions
    - Cellular Physiology - Biochemical and biophysical processes occurring within cells.
    - Organ & Body Systems- Regulation of physiological processes by homeostatic mechanisms
- Pharmacology –Biological effects of drugs and toxins on body systems
- Developmental Biology - Development of cells, tissues and organs from fertilization to death
- Pathology – Abnormal changes associated with disease and aging

Levels of structural organization

This lecture will describe the levels of structural organization in animals.

1. Cellular level

- Cells are the basic structural and functional unit of the body.
- Each cell is specially adapted to perform one or a number of specialist functions
- There are common basic cell functions that all cells undertake such as production of energy, protein synthesis and transport of substances through the cell membrane as well as specialist functions that only certain cells can undertake.For example, muscle cells have the ability to contract (e.g. smooth muscle in the walls of blood vessels) whereas others have the ability to secrete specific hormones (e.g. beta cells of the pancreas).
- Origin of cells in the body - during embryogenesis (early fetal development) three fetal layers are formed from embryonic stem cells: the ectoderm, mesoderm, and endoderm. These layers initiate the development of hundreds oftypes of cells that form tissues and organs of the body.

2. Tissues

Tissues are groups of cells from the same origin (and material surrounding them) that carry out a specific function.
There are four basic types:

- Nervous tissue - functions to transmit messages in form of nerve impulses.
- Connective tissue – functions to support, connect or separate tissues. Composed of cells, fibers and extracellular matrix made up from collagen, proteoglycans, and glycosaminoglycan.
- Muscle - contracts to move body parts and generate heat. Three types: Cardiac, smooth and skeletal.
- Epithelial tissue - Cells that cover organ surfaces, line hollow surfaces and form glands.

3. Organs

Organs consist of two or more different types of tissues that perform particular functions. Examples include heart, liverstomach, and kidneys.

4. Body systems

Associations of organs that have a common function.

- Musculo-skeletal system
  - Permit external voluntary movements. Protects and supports body organs. Bone stores minerals and producesstem cells and blood cells.
- Cardiovascular system
  - Heart and blood vessels. Heart pumps blood and blood vessels transport blood which carries O_2 CO_2 nutrients,hormones antibodies, white blood cells and waste products.

- Immune and lymphatic system
  - Lymphatic network and lymphoid organs such as lymph nodes, spleen, tonsils, Peyer's patches and thymus. Lymph returns fluid and cells from tissues to the blood, and also proteins that leak from the blood.White blood cells inactivate and kill pathogens.
- Endocrine system,
  - Control system. Endocrine glands and specialized cells in other organs secrete hormones that regulatemany body processes e.g. growth, metabolism and reproduction and maintain homeostasis
- Nervous system,
  - Control system
  - Conducts electrical impulses (action potentials) in response to external and internal stimuli
- Integumentary system
  - External covering with barrier function. Sweat glands and cutaneous blood vessels are important inthermoregulation.
- Respiratory system
  - Nasal cavity pharynx, larynx, trachea, lung, bronchus and bronchiole and alveoli. At alveoli (air sacs)gaseous exchange O_2 & CO_2 between the atmosphere and bloodstream
- Digestive system
  - The mouth, salivary glands, pharynx, oesophagus, stomach, small and large intestine, liver, gall bladder, and pancreas. Breaks down food into absorbable units and absorbs them into blood stream.
- Urinary system
  - Kidney, ureter urinary bladder and urethra. Eliminates nitrogenous wastes from the body and regulateswater electrolyte and acid base balance.
- Reproductive systems
  - Produce offspring.
  - Male. Testes produce sperm and male sex hormones. Ducts and glands aid in delivery of sperm
  - Ovaries produce eggs and female sex hormones. Remaining structures are sites for fertilization,implantation and development of foetus. Mammary glands produce milk.

Functional organization of a cell

- Cell nucleus
  - chromatin (DNA) & nucleolus (which synthesises ribosomes).
- Ribosomes
  - site of translation and protein assembly
- Endoplasmic reticulum
  - continuous membranous network involved in synthesis of proteins and lipids and as an intracellular Ca^{2+}store.
  - Rough endoplasmic reticulum has ribosomes attached. Involved in synthesis, folding & modification ofproteins. Continuous with nuclear membrane.
  - Smooth endoplasmic reticulum produces lipids and is involved in carbohydrate metabolism. No ribosomes.
- Golgi apparatus
  - post-translational modification e.g. glycosylation of proteins, phosphorylation of sugars of glycoproteins and'packaging' of proteins into secretory vesicles.
- Mitochondria
  - site of oxidation of carbohydrates and lipids. Use O_2 and generate ATP.
- Lysosome

    - vesicles involved in intracellular digestion of macromolecules.
- Peroxisomes
    - contain enzymes that detoxify certain toxins
- Cytoskeleton
    - allows cell via actin filaments and microtubules to maintain and change the shape of the cell and promote movement.
- Cell membrane
    - selective barrier function between exterior and interior of cell, involved in communication via receptors andin selective transport processes.

Cell functions

- Metabolism
    - Result of chemical processes that occur in the cell. Consists of both catabolism (breaking down) and anabolism (building up) of complex chemical substances. Glycolysis involves the making and breaking ofbonds between atoms within the organic molecules such as glucose and other intermediaries ultimately generating energy (ATP)
- Detect and respond
    - Cells are able to detect and respond to change in their environment. Muscle cells are able to contract, andendocrine cells are able to release hormones in certain conditions.
- Movement
    - Receptors and transport molecules can be mobilised to the cell surface. Cells are able to move along chemical gradients or can be transported with blood and enter tissues in a process called extravasation. In secretory organs, such as the gall bladder, smooth muscle cells contract to release bile. Muscles can contractor relax resulting in skeletal movement that allows the whole body or parts to move.
- Growth
    - Increase in size or number of cells. May also be due to deposition of material between cells as occurs inbone.
- Differentiation
    - cells can develop new functional characteristics. For example, immune cells can go from naive cells toimmune effectors via differentiation or haematopoietic stem cells can differentiate into erythrocytes or different types of white blood cells.
- Reproduction (hereditary transmission of genetic material)
    - Includes formation of sperm or eggs for sexual reproduction.

Homeostasis

Homeostasis is the ability of physiological systems to maintain conditions within the body in a **relatively** constant state ofequilibrium.

- Animals (and cells) are required to exist within limits or ranges.
- The composition of the internal environment must be kept in a state compatible with the survival of individual cellsand the entire animal. Body systems work together in an integrated fashion to maintain homeostasis. In this way, there is an interdependent relationship between cells, body systems and homeostasis.
- Homeostasis is a dynamic process, the body's equilibrium responds to changed conditions and keeps the internal environment within limits compatible with life.
    - There are thousands of control systems, such as:
        - pH
        - electrolytes (Na+, Ca2+, K+, Cl-)
        - nutrients (O2, glucose)
        - waste products
        - temperature
        - fluid volume and pressure
        - cell numbers

Homeostatic mechanisms involve a series of elements:

1. A stimulus, which produces a change in a variable. For example, the loss of body fluids and dehydration after exercise.
2. A receptor which detects the change – e.g. osmotic receptors detect fluid and salt balance.

3. A control centre –receives the input (via afferent pathways) and via nerve impulses or chemical signals (efferent pathways), it regulates effectors.
4. Effectors –bring about change, that reduces the effect of the stimulus to maintain homeostasis. For instance, hormones that regulate salt and water balance arereleased and homeostasis is maintained.

Feedback mechanisms

For homeostasis to occur, detection of an imbalance and an appropriate response is required. Communication between cells, organs and body systems is required to have useful cooperation and to permit functions to be altered to meet specific needs. Control is usually mediated by feedback mechanisms. **Negative feedback mechanisms** counteract changes that have occurred, sometimes by negating the original stimulus. They therefore contribute to homeostasis. For example, whenthe level of thyroxine (released by the thyroid gland) is high this has a negative feedback effect on both the anterior pituitary and the hypothalamus, which ultimately inhibits the release of further thyroxine, maintaining homeostasis. **Positive feedback systems** provide rapid amplification and therefore do not contribute to homeostasis. Found in dramatic events, like birth, where there is a defined endpoint. The hormone oxytocin stimulates and enhances labour contractions and isproduced in response to the stimulation of pressure receptors in the birth canal. Once the stimulation is removed (birth), oxytocin production stops.

Further reading

Hall JE: *Guyton and Hall Textbook of Medical Physiology*, Elsevier, 2021.Ebook. Chapters 1&2.
Klein BG: *Cunningham's textbook of veterinary physiology*. Elsevier, 2020. Available in BioMed and Werribee libraries.