Lecture 2
Discipline: Bioorganic Chemistry
Lecturer: Associate Professor, Dr. Gulnaz Seitimova

Title: The key role of hormones in the body, their classification, methods of isolation and identification. Amino acids and peptides related to hormones and used in hormone therapy.

Objective: The aim of this lecture is to explain the biochemical nature and physiological functions of hormones, describe their major classes, outline modern approaches to their isolation and identification, and discuss amino acids and peptides that exhibit hormonal activity or are used for hormone replacement therapy.

Main Questions: Definition and general characteristics of hormones. Physiological role of hormones in the human body. Classification of hormones (chemical and functional). Biosynthesis and regulation of hormonal activity. Methods for the isolation and purification of hormones from biological sources. Techniques for identification and quantitative determination of hormones. Amino acid–based and peptide hormones: structure and examples. Therapeutic peptides and amino acid derivatives used in hormone therapy.

Key Notes and Theses

Definition and General Characteristics of Hormones

Hormones are biologically active chemical messengers synthesized by endocrine glands and transported through blood to target organs, where they regulate metabolism, growth, differentiation, homeostasis, and reproduction.

Key features include high specificity, low effective concentration, and a broad spectrum of physiological effects.

Physiological Role of Hormones

Hormones regulate:

- Carbohydrate, lipid, and protein metabolism
- Water–salt balance
- Stress response
- Growth and development
- Reproductive functions
- Neural–endocrine integration

Even minimal changes in hormonal balance lead to significant physiological responses.

Classification of Hormones

By chemical structure:

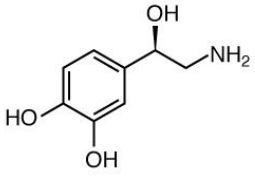
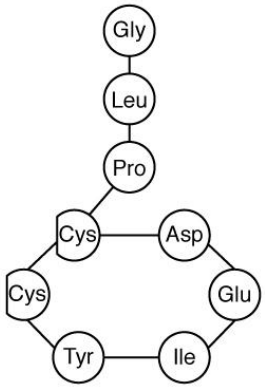
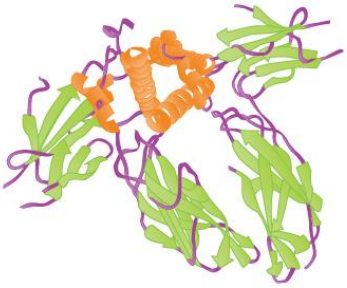
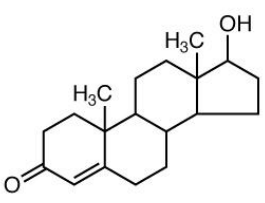
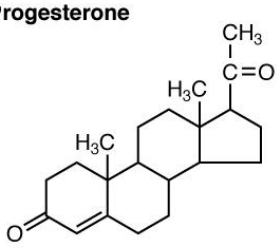
1. Peptide and protein hormones – insulin, glucagon, oxytocin, ACTH.
2. Amino acid derivatives – epinephrine, thyroxine, melatonin.
3. Steroid hormones – cortisol, aldosterone, testosterone, estradiol.
4. Fatty acid derivatives (eicosanoids) – prostaglandins, leukotrienes.

By mechanism of action:

- Hormones acting via membrane receptors (peptide hormones, catecholamines).
- Hormones acting via intracellular receptors (steroids, thyroid hormones).

Types of Hormones

The hormones of the human body can be divided into two major groups on the basis of their chemical structure. Hormones derived from amino acids include amines, peptides, and proteins. Those derived from lipids include steroids. These chemical groups affect a hormone's distribution, the type of receptors it binds to, and other aspects of its function.

Hormone Class	Components	Example(s)
Amine Hormone	Amino acids with modified groups (e.g. norepinephrine's carboxyl group is replaced with a benzene ring)	**Norepinephrine** 
Peptide Hormone	Short chains of linked amino acids	**Oxytocin** 
Protein Hormone	Long chains of linked amino acids	**Human Growth Hormone** 
Steroid Hormones	Derived from the lipid cholesterol	**Testosterone**  **Progesterone** 

Amine Hormones

Hormones derived from the modification of amino acids are referred to as amine hormones. Typically, the original structure of the amino acid is modified such that a −COOH, or carboxyl, group is removed, whereas the NH+3, or amine, group remains.

Amine hormones are synthesized from the amino acids tryptophan or tyrosine. An example of a hormone derived from tryptophan is melatonin, which is secreted by the pineal gland and helps regulate circadian rhythm. Tyrosine derivatives include the metabolism-regulating thyroid hormones, as well as the catecholamines, such as epinephrine, norepinephrine, and dopamine. Epinephrine and norepinephrine are secreted by the adrenal medulla and play a role in the fight-or-flight response, whereas dopamine is secreted by the hypothalamus and inhibits the release of certain anterior pituitary hormones.

Peptide and Protein Hormones

Whereas the amine hormones are derived from a single amino acid, peptide and protein hormones consist of multiple amino acids that link to form an amino acid chain. Peptide hormones consist of short chains of amino acids, whereas protein hormones are longer polypeptides. Both types are synthesized like other body proteins: DNA is transcribed into mRNA, which is translated into an amino acid chain.

Examples of peptide hormones include antidiuretic hormone (ADH), a pituitary hormone important in fluid balance, and atrial-natriuretic peptide, which is produced by the heart and helps to decrease blood pressure. Some examples of protein hormones include growth hormone, which is produced by the pituitary gland, and follicle-stimulating hormone (FSH), which has an attached carbohydrate group and is thus classified as a glycoprotein. FSH helps stimulate the maturation of eggs in the ovaries and sperm in the testes.

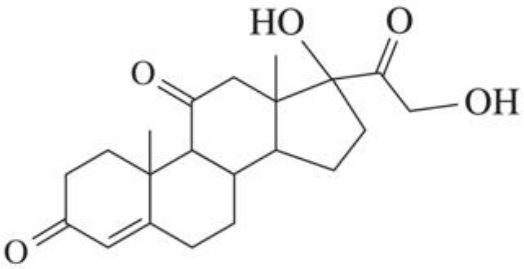
Steroid Hormones

The primary hormones derived from lipids are steroids. Steroid hormones are derived from the lipid cholesterol. For example, the reproductive hormones testosterone and the estrogens—which are produced by the gonads (testes and ovaries)—are steroid hormones. The adrenal glands produce the steroid hormone aldosterone, which is involved in osmoregulation, and cortisol, which plays a role in metabolism.

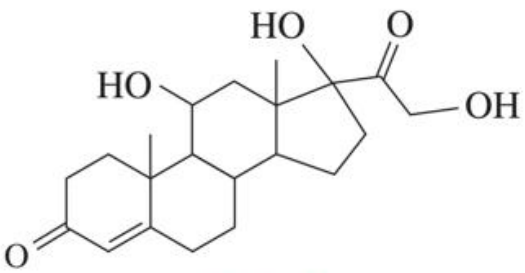
Like cholesterol, steroid hormones are not soluble in water (they are hydrophobic). Because blood is water-based, lipid-derived hormones must travel to their target cell bound to a transport protein. This more complex structure extends the half-life of steroid hormones much longer than that of hormones derived from amino acids. A hormone's half-life is the time required for half the concentration of the hormone to be degraded. For example, the lipid-derived hormone cortisol has a half-life of approximately 60 to 90 minutes. In contrast, the amino acid–derived hormone epinephrine has a half-life of approximately one minute.

Adrenal corticosteroids are steroid hormones produced by the adrenal glands located on the top of each kidney and include

- aldosterone, which regulates electrolytes and water balance by the kidneys;
- cortisol, released under stress to increase blood sugar and regulate carbohydrate, fat, and protein metabolism; and
- prednisone, a synthetic corticosteroid, derived from cortisone, used for reducing inflammation, treating asthma and rheumatoid arthritis.



Cortisone



Cortisol

Methods of Hormone Isolation

Isolation from tissues, blood plasma, or endocrine glands involves:

- Extraction (aqueous, organic solvents, acid–base extraction)
- Chromatography
  - ion-exchange chromatography
  - gel filtration
  - HPLC
  - affinity chromatography (for peptide hormones)
- Electrophoresis (for peptide hormones)

These methods ensure purification from proteins, lipids, and other biomolecules.

Identification and Quantitative Determination

Modern analytical techniques:

- UV–vis spectroscopy (for aromatic amino acid–containing peptides)
- Mass spectrometry (MS) – accurate molecular weight and structure
- NMR spectroscopy – structural analysis
- ELISA – immunochemical determination of hormones
- Radioimmunoassay (RIA) – highly sensitive quantification
- HPLC coupled with MS – gold standard for steroid profiling

Amino Acids and Peptides Related to Hormones

Many hormones are peptides composed of amino acids:

- Insulin – 51 amino acids
- Glucagon – 29 amino acids
- Oxytocin and vasopressin – cyclic nonapeptides
- Some amino acids serve as precursors for hormone biosynthesis:
- Tyrosine → catecholamines, thyroid hormones
- Tryptophan → serotonin, melatonin
- Histidine → histamine

Peptides in Hormone Therapy

Examples of peptide-based therapeutic agents:

- Insulin analogues – lispro, glargine
- Gonadotropin-releasing hormone analogues – leuprolide, triptorelin
- Somatostatin analogues – octreotide

- Synthetic oxytocin – Pitocin

These peptides are produced through biotechnological synthesis or recombinant DNA technologies.

Questions for Knowledge Assessment

1. What are the main physiological functions of hormones?
2. How are hormones classified according to their chemical structure?
3. What distinguishes peptide hormones from steroid hormones in terms of action?
4. Name modern chromatographic methods used for hormone purification.
5. What analytical techniques are applied for the identification of steroid hormones?
6. Which amino acids act as precursors for biologically active amines?
7. What is the structural difference between oxytocin and vasopressin?
8. Name at least three peptide-based drugs used in hormone therapy.
9. Why are immunochemical methods important for hormonal analysis?

Recommended Literature

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