HUMAN PHYSIOLOGY (normal)

LECTURE 10. Hormonal regulation of Physiology Functions

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Regulation Mechanisms

All the **physiological activities** of the body are **regulated** by two major systems:

1. **Nervous** system
2. **Endocrine** system

Endocrine system functions by secreting some **chemical substances** called **hormones**

Function of the endocrine system is regulation of long-term processes:

- **Growth**, development, reproduction
- **Adaptation**
- **Homeostasis maintaining**

Endocrine Regulation Mechanisms

Chemical messengers

- are the substances involved in cell signaling
- carry the message (signal) from the **signaling cells** (controlling cells) to the **target cells**
- can be **classified** into two types:
  1. **Classical hormones** secreted by **endocrine glands**
  2. **Local hormones** secreted from **other tissues**

However, recently chemical messengers are classified into three types:

1. Endocrine messengers (hormones)
2. Paracrine messengers
3. Neurocrine messengers (mediators of CNS)

Chemical Messengers

Endocrine messengers are the classical hormones

- synthesized by endocrine glands
- transported by blood to the target organs or tissues (site of action)

Paracrine messengers are the chemical messengers

- diffuse from the control cells to the target cells through the interstitial fluid

Neurocrine or neural messengers are **neurotransmitters**

Hormones

Can be divided into three groups:

- **Proteins** and **polypeptides**, including hormones secreted by the anterior and posterior pituitary gland, the pancreas (insulin and glucagon), and many others
- **Derivatives** of the amino acid **tyrosine**, secreted by the thyroid (thyroxine and triiodothyronine) and the adrenal medullae (epinephrine and norepinephrine).
- **Steroids** secreted by the adrenal cortex (cortisol and aldosterone), the ovaries (estrogen and progesterone), and the testes (testosterone)

Mechanisms of Hormone Action

- Hormone can act on a target cell only if the target cell has the **receptor** for that particular hormone
- Hormone receptors are the **large proteins** present in the target cells
- The **locations** for the different types of hormone receptors:
  - On the surface of the cell membrane (mostly for the protein, peptide, and catecholamine hormones)
  - In the cell cytoplasm (primary receptors for the different steroid hormones)
  - In the cell nucleus (the receptors for the thyroid hormones)

Mechanisms of Hormone Action

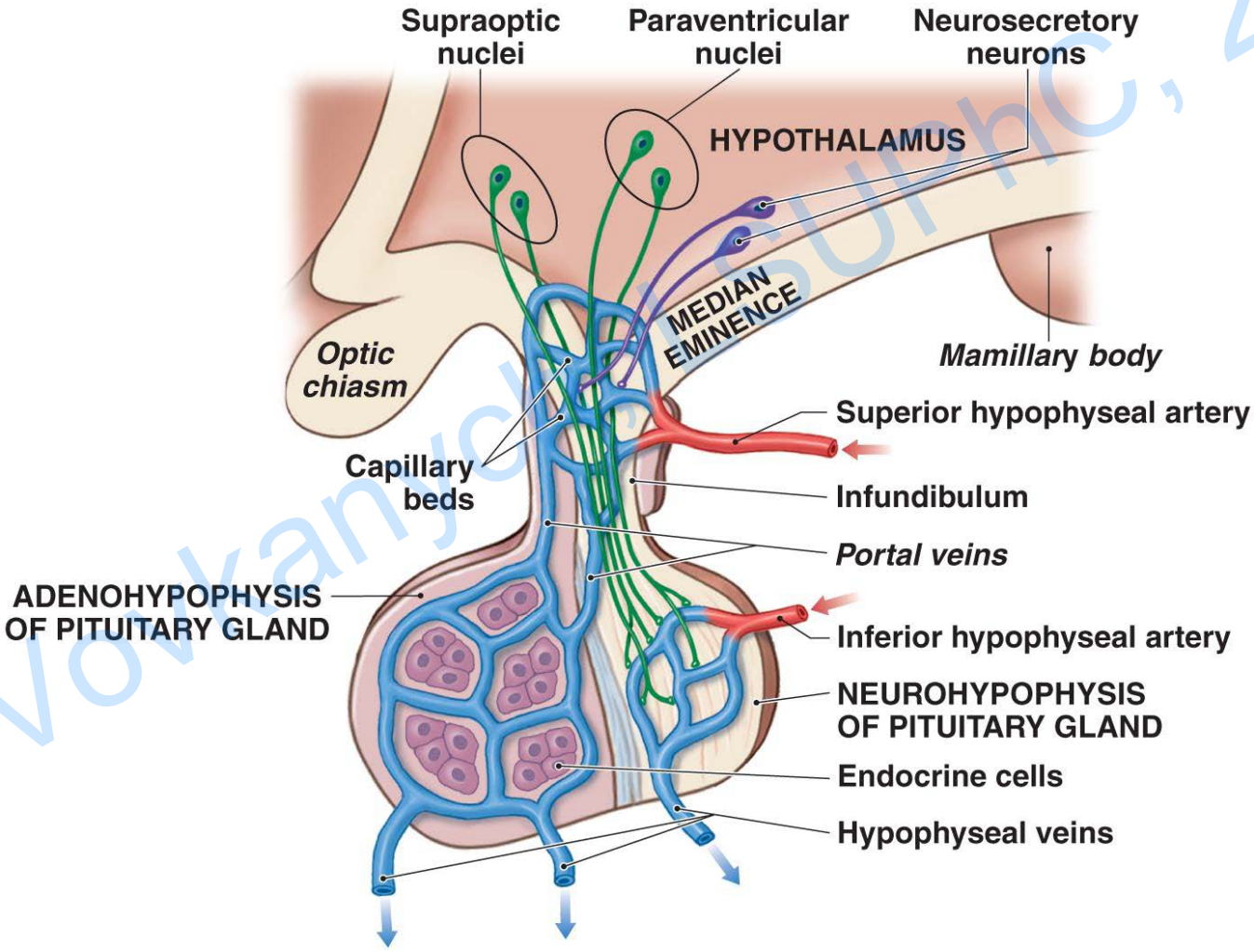
The **hormone-receptor complex** executes the hormonal action by any one of the following mechanisms:

- By altering **permeability** of cell membrane
- By activating intracellular enzyme, which causes the formation of **second messenger** or intracellular hormonal mediator:
  - Cyclic AMP (cAMP)
  - G proteins
  - Calcium ions and calmodulin
  - Inositol triphosphate (IP_3)
  - Diacylglycerol (DAG)
  - Cyclic guanosine monophosphate (cGMP)
- By **acting on genes** (thyroid and steroid hormones), binds with DNA, increases transcription of mRNA, activated ribosomes, proteins produce proteins for physiological responses

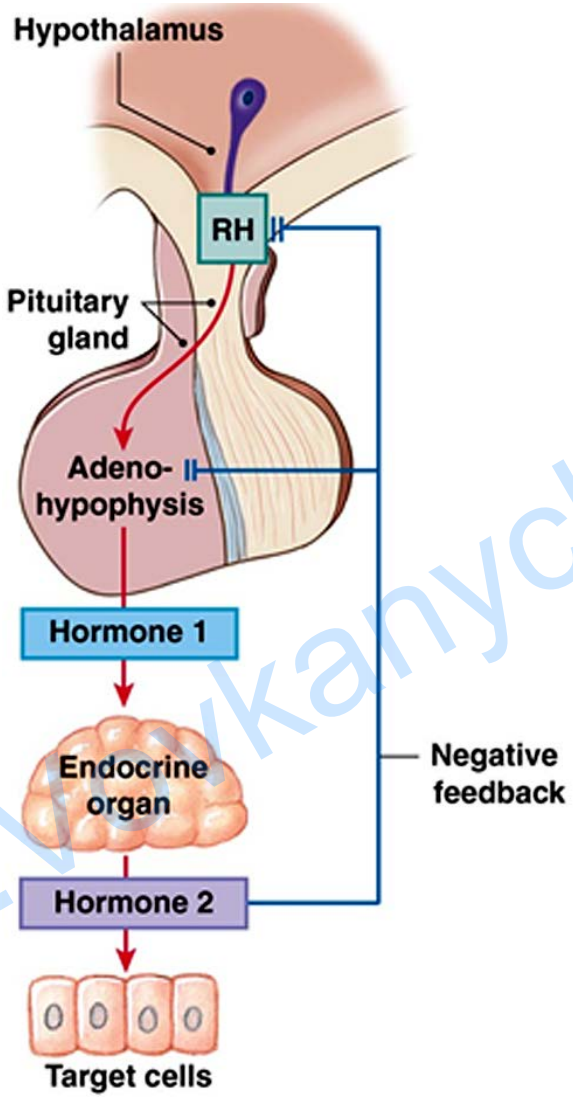
Hypothalamus Control of Pituitary Secretion

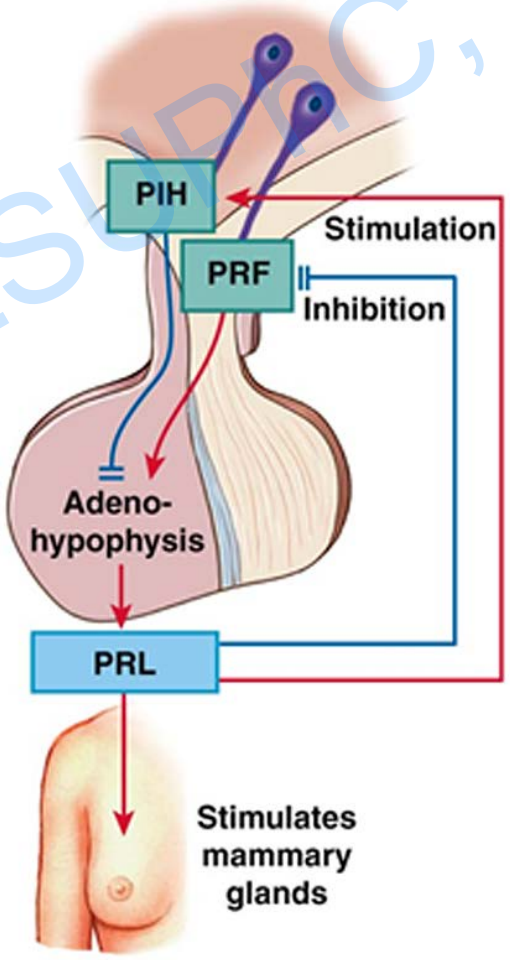
- Two Classes of Hypothalamic Regulatory Hormones
  - **Releasing hormones (RH) -** stimulate synthesis and secretion of one or more hormones at anterior lobe
  - **Inhibiting hormones (IH) –** decrease synthesis and secretion of hormones from the anterior lobe
- Rate of secretion is controlled by negative feedback

Hypothalamus Control of Pituitary Secretion



Feedback Control of Endocrine Secretion





The main Hypothalamic Releasing and Inhibitory Hormones

Hormone	Primary Action
Thyrotropin-releasing hormone (TRH)	Stimulates secretion of TSH
Gonadotropin-releasing hormone (GnRH)	Stimulates secretion of FSH and LH
Corticotropin-releasing hormone (CRH)	Stimulates secretion of ACTH
Growth hormone–releasing hormone (GHRH)	Stimulates secretion of growth hormone
Growth hormone inhibitory hormone	Inhibits secretion of growth hormone
Prolactin-inhibiting hormone (PIH)	Inhibits secretion of prolactin

Anterior Pituitary Hormones

Hormone	Target Tissue	Principal Actions
GH (growth hormone)	Most tissue	Promotes protein synthesis and growth; lipolysis and increased blood glucose
PRL (prolactin)	Mammary glands	Promotes milk production in lactating females; additional actions in other organs

Anterior Pituitary Hormones

Hormone	Target Tissue	Principal Actions
ACTH (adrenocorticotropic hormone)	Adrenal cortex	Stimulates secretion of glucocorticoids and androgens by the adrenal cortex
TSH (thyroid-stimulating hormone)	Thyroid gland	Stimulates secretion of thyroid hormones
FSH (follicle-stimulating hormone)	Gonads	Promotes gamete production and stimulates estrogen production in females, regulates spermatogenesis
LH (luteinizing hormone)	Gonads	Stimulates sex hormone secretion; ovulation and corpus luteum formation in females; stimulates testosterone secretion in males

Posterior Pituitary

Stores and releases two hormones, both of which are **produced in the hypothalamus**

Hormone	Target Tissue	Principal Actions
Antidiuretic hormone (ADH) or vasopressin (AVP)	Kidneys	Promotes the retention of water, causes vasoconstriction
Oxytocin	Uterus, mammary gland	Stimulates contractions of the smooth muscles of the uterus and mammary gland (milk-ejection)

Disorders of Pituitary Gland

Gigantism

- **hypersecretion** of GH in **childhood** or in pre-adult life before the fusion of epiphysis
- subjects look like the **giants** with average height of about 7 to 8 feet

Acromegaly

- hypersecretion of GH in **adults** after the fusion of epiphysis with shaft of the bone
- gorilla face, enlargement of hands and feet, overgrowth of body hair

Dwarfism

- **reduction** in GH secretion in **infancy** or early **childhood**
- stunted skeletal growth, the maximum height at the adult ageis only about 3 feet

The Thyroid Gland

Hormone	Target Tissue	Principal Actions
Thyroxine (T_4), Triiodothyronine (T_3)	Most cells	Increased energy utilization, oxygen consumption, growth and development (in children), increases the overall activity of cardiovascular system, essential for the normal activity of skeletal muscles, very essential for the development and maintenance of normal functioning of central nervous system (CNS)
Calcitonin (CT)	Bone, kidneys	Decreases Ca^{2+} concentration in body fluids

Disorders of Thyroid Gland

Hyperthyroidism (increased secretion of thyroid hormones)

- increased basal metabolic rate
- increased sweating
- decreased body weight
- muscular weakness because, extreme fatigue
- nervousness, inability to sleep
- tachycardia (increased heart rate)

Hypothyroidism (decreased secretion of thyroid hormones)

- **myxedema** is the hypothyroidism in adults (swelling of the face, fatigue and muscular sluggishness, decreased cardiovascular functions)
- **cretinism** is the hypothyroidism in children, characterized by stunted growth

Parathyroid Glands

Hormone	Target Tissue	Principal Actions
Parathyroid hormone (PTH)	Bone, kidneys	Increases Ca^{2+} concentration in body fluids

Pancreatic Islets (Islets of Langerhans)

Hormone	Target Tissue	Principal Actions
Glucagon (alpha cells)	Liver, adipose tissue	Elevates blood glucose concentration, promote glycogen breakdown and glucose synthesis in liver, mobilizes lipid reserves
Insulin (beta cells)	Most cells	Facilitates the glucose uptake by target cells, stimulates formation and storage of lipids and glycogen
Somatostatin (delta cells)	Other islet cells, digestive epithelium	Inhibits insulin and glucagon secretion, slows rate of absorption and secretion in digestive tract

Disorders of Pancreatic Islets

Diabetes Mellitus - hypofunction (a metabolic disorder characterized by high blood glucose level, associated with other manifestations). ‘Diabetes’ means ‘polyuria’ and ‘mellitus’ means ‘honey’

- **Type I diabetes** mellitus or **insulin-dependent** diabetes mellitus (IDDM) is due to deficiency of insulin because of destruction of β-cells in islets of Langerhans
- **Type II diabetes** mellitus or **noninsulindependent** diabetes mellitus (NIDDM) is due to insulin resistance (failure of insulin receptors to give response to insulin)

Signs and Symptoms of Diabetes Mellitus:

- Glucosuria, Polyuria
- Asthenia, Acidosis, Acetone breathing etc.

Suprarenal (Adrenal) Glands. Adrenal Cortex

Hormone	Target Tissue	Principal Actions
Zona glomerulosa		
Mineralocorticoids (primary **aldosterone**)	Kidneys	Increase the renal absorption of Na^+ and water, accelerate the loss of K^+. Helps to increase the blood volume and pressure, and to regulate blood electrolyte balance
Zona fasciculate		
Glucocorticoids (**cortisol** [hydrocortisone], **corticosterone**)	Most cells	Stimulate gluconeogenesis and inhibit glucose utilization, promote lipolysis and the release of free fatty acids, inhibit inflammation
Zona reticularis		
Sex steroids (weak **androgens, small quantity of estrogen**)	Most cells	Not important in adult men, encourage the bone and muscle growth in children and women

Suprarenal (Adrenal) Glands. Adrenal Medulla

Hormone	Target Tissue	Principal Actions
Epinephrine and norepinephrine (ratio 4 : 1)	Most cells	Increase the cardiac output and heart rate, dilate coronary blood vessels, increase mental alertness, increase the respiratory rate, elevate the metabolic rate, increase glycogen breakdown and blood glucose level, releases lipids by adipose tissue

Disorders of Suprarenal Glands

Addison disease or chronic adrenal insufficiency

- Pigmentation of skin
- Muscular weakness
- Hypotension
- Decreased cardiac output
- Hypoglycemia
- Inability to withstand any stress, resulting in Addisonian crisis

Cushing syndrome (hypersecretion of adrenocortical hormones)

- Obesity, Reddish purple stripes on Abdomen, Pigmentation of skin, Hyperglycemia etc.

Hormones of the Reproductive System

Hormone	Target Tissue	Principal Actions
Testes		
Androgens	Most cells	Support functional maturation of the sperm, protein synthesis in skeletal muscles, development of male secondary sex characteristics and associated behavior
Ovaries		
Estrogen	Most cells	Support follicle maturation, development of female secondary sex characteristics and associated behavior
Progestin	Uterus, mammary glands	Prepare uterus for implantation, prepare mammary glands for secretory activity

Hormones of Other Tissues

Pineal Gland (Epiphysis) synthesize hormone **Melatonin**

- inhibiting reproductive functions
- setting circadian rhythms (rhythms of physiological activity that follow a 24-hour pattern)
- secretion of melatonin begins to increase with darkness and peaks by the middle of the nigh

Thymus secretes two hormones: **Thymosin** and **Thymin** (thymopoietin)

- accelerates lymphopoiesis
- stimulates the proliferation of T lymphocytes

Hormones of Other Tissues

Kidneys secrete some hormonal substances, among them:

- **Erythropoietin** (stimulates erythropoiesis)
- **Thrombopoietin** (stimulates the production of platelets)
- **Renin** (starts the cascade of reactions for the fluids retention in the organism and blood pressure increase)

Heart

- **atrial natriuretic peptide** (decreases the blood pressure)

Adipose Tissue

- **Leptin** (inhibits the feeding center, resulting in stoppage of food intake)

General adaptation syndrome

Stress, according to Hans Selye, is the reaction of an organism to stimuli called **stressors**, which may produce damaging effects

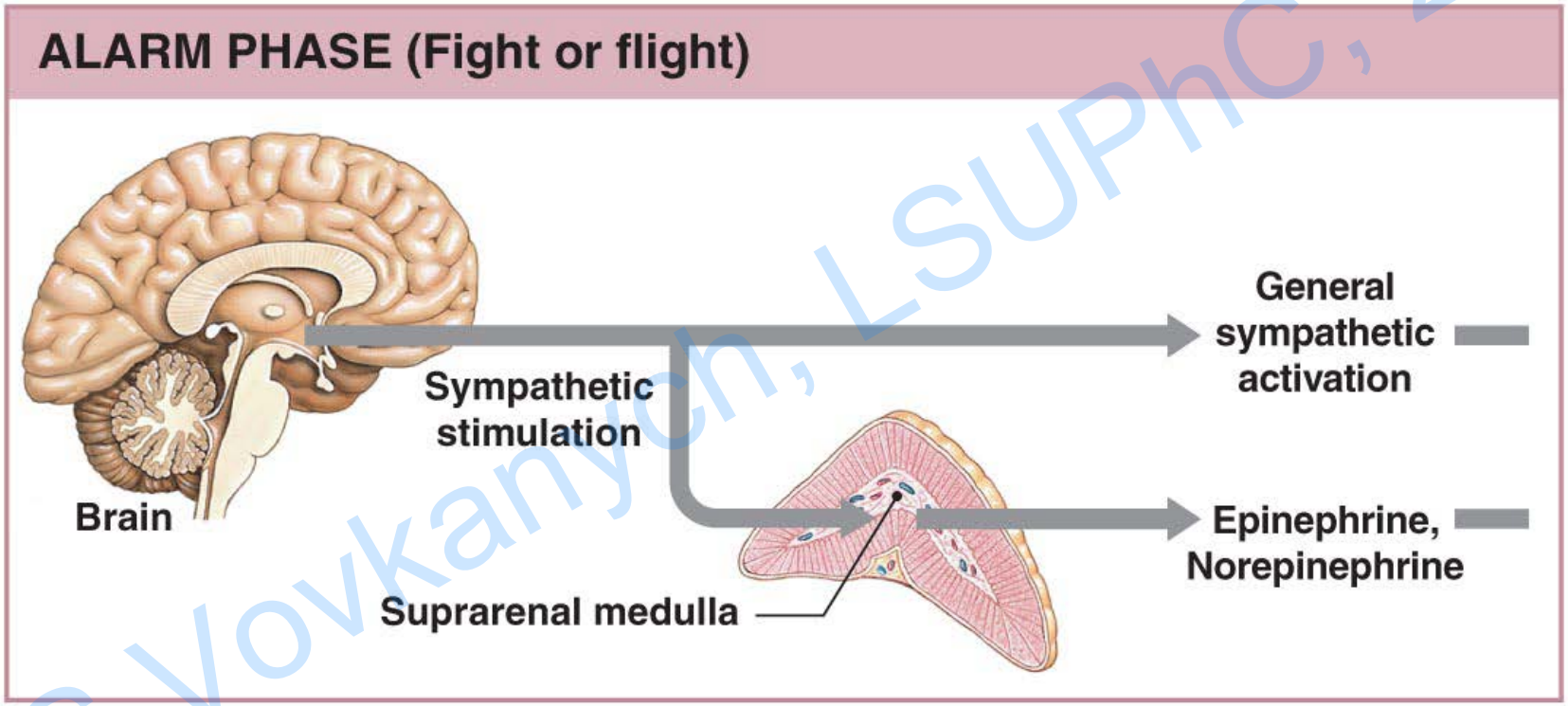
Stressors produce **specific** (adaptation to particular agents – high temperature, physical loadings etc.) **and unspecific responses** (by stimulation of the pituitary-adrenal axis and other mechanisms)

The **nonspecific response** to the stressors **is called general adaptation syndrome** (GAS)

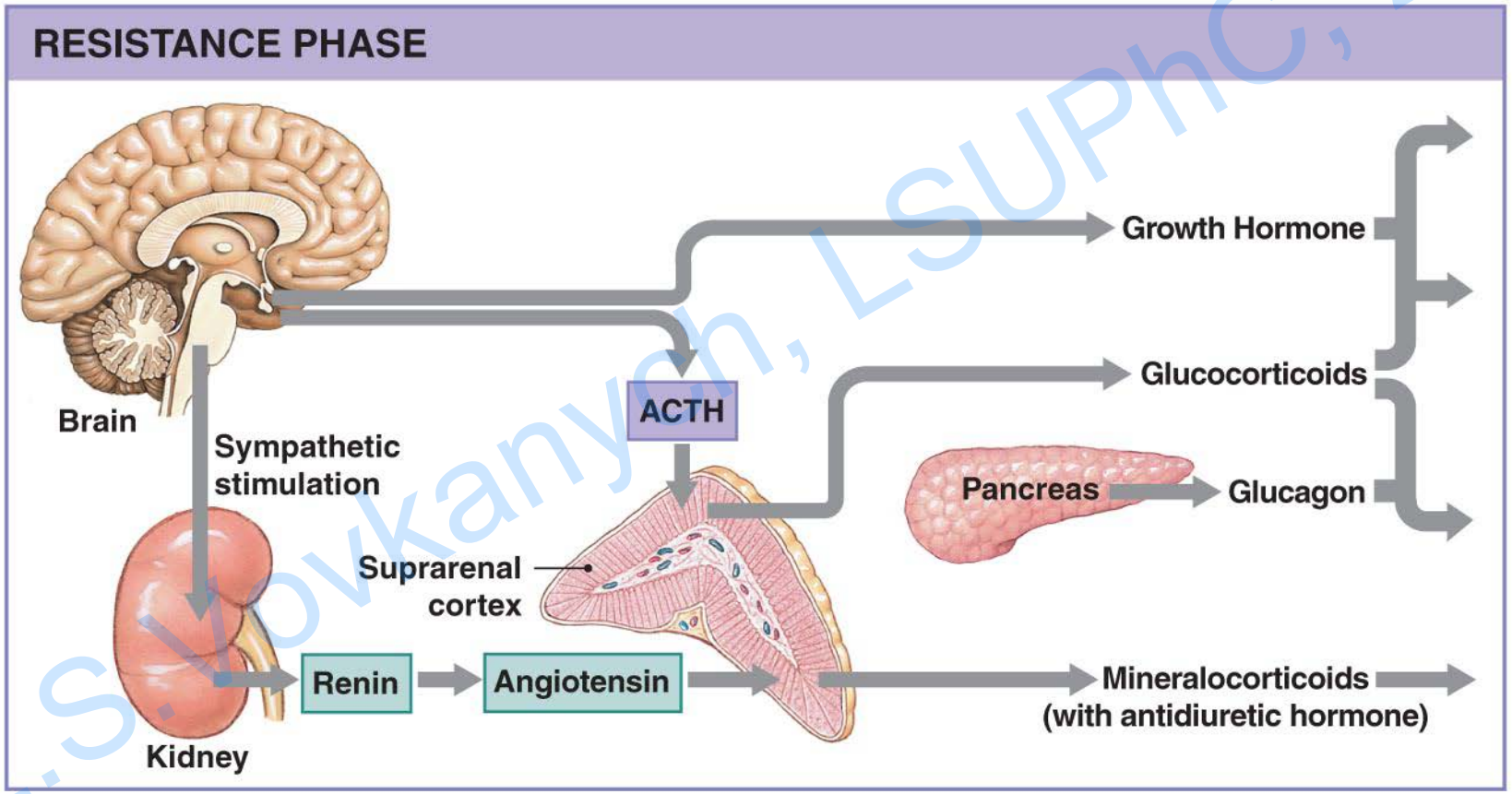
There **are three stages** in the response to stress:

- **alarm** reaction (the adrenal glands are activated)
- stage of **resistance** (readjustment occurs)
- stage of **exhaustion** (incomplete readjustment, which may lead to sickness and possibly death)

Alarm reaction



The stage of resistance



The stage of exhaustion

- Cumulative structural and functional damage of vital organs
- Decrease of glucocorticoids production
- Failure of electrolyte balance

- Signs:
  - stimulated growth of the adrenal cortex
  - atrophy of the lymphoid tissue
  - produced bleeding peptic ulcers

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