

General Mechanisms of Hormone Actions

Endocrine Block

OBJECTIVES

By the end of this lecture, students should be able to:

- **Acquire the knowledge for general consequence of hormone-receptor interaction**
- **Understand different mechanisms of action of hormones**
- **Recognize the biomedical importance due to disturbance in the normal mechanisms of hormonal action**

Lecture Outlines

- **Background**
- **Factors determining the response of a target cell to a hormone**
- **Hormone-receptor interaction**
- **General features of hormone classes**
- **Classification of hormones by mechanism of action**
- **Biomedical importance**

Background

- **Multicellular organisms depend in their survival on their adaptation to a constantly changing environment**
- **Intercellular communication is necessary for this adaptation to take place**
- **Human body synthesizes many hormones that can act specifically on different cells of the body**

Background

- **More than one hormone can affect a given cell type**
- **Hormones can exert many different effects in one cell or in different cells**
- **A target is any cell in which the hormone (ligand) binds to its receptor**

Factors determining the response of a target cell to a hormone

- **The rate of synthesis & secretion of the hormones**
- **The conversion of inactive forms of the hormone into the fully active form**
- **The rate of hormone clearance from plasma (half-life & excretion)**
- **The number, relative activity, and state of occupancy of the specific receptors**
- **Post-receptor factors**

Stimulus

Group I hormones

Group II hormones

Hormone release

Hormone/receptor binding at the target cells

Recognition

Hormone-receptor complex

Second messengers

Signal generation

Gene transcription

Transporters, channels

Protein translocation

Protein Modification

Effects

Coordinated response to stimulus

General Features of Hormone Classes

| | Group I | Group II |
|--------------------|--|---|
| Types | Steroids Thyroid Hs (T ₃ & T ₄) Calcitriol, retinoids | Polypeptides Glycoproteins Catecholamines |
| Solubility | Lipophilic | Hydrophilic |
| Transport proteins | Yes | No |
| Plasma half-life | Long (hours – days) | Short (minutes) |
| Receptor | Intracellular | Plasma membrane |
| Mediator | Receptor-hormone complex | cAMP, cGMP, Ca ²⁺ , metabolites of complex phosphoinositols, tyrosine kinase cascades |

Classification of Hormones by Mechanism of Action

I. Hormones that bind to intracellular receptors (Steroid-Thyroid superfamily):

Steroid hormones

Thyroid Hormones (T_3 & T_4)

Calcitriol (active form of vitamin D, $1,25[\text{OH}]_2\text{-D}_3$)

Retinoic acid

Mechanism of Action of Steroid-Thyroid Hormones

Steroid Hormones:

Glucocorticoids

Mineralocorticoids

Sex hormones:

Male sex hormones: Androgens

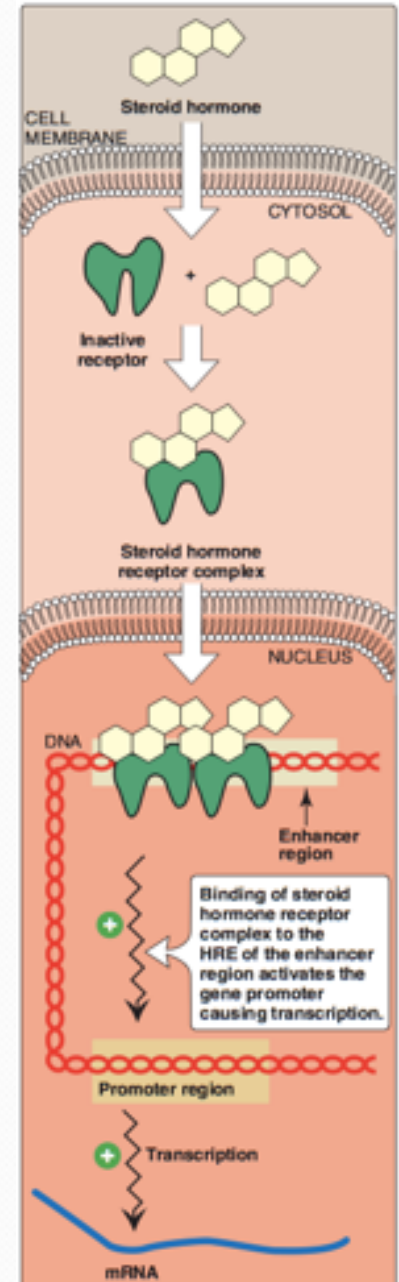
Female sex hormones: Estrogens &

Progestins

Thyroid Hormones (T_3 & T_4)

Calcitriol ($1,25[\text{OH}]_2\text{-D}_3$)

Retinoic acid



Classification of Hormones by Mechanism of Action

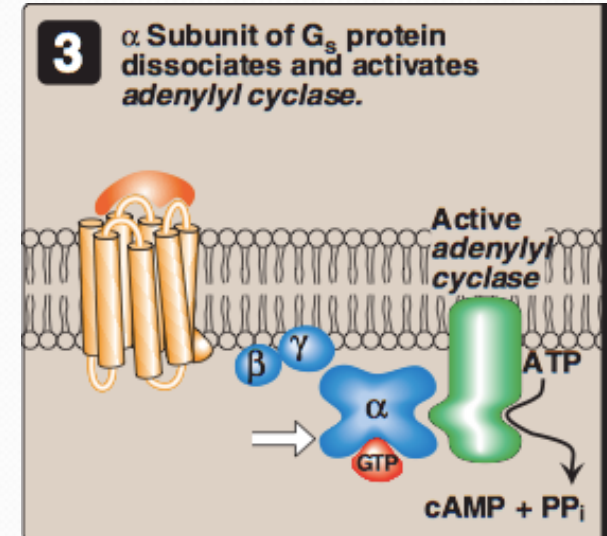
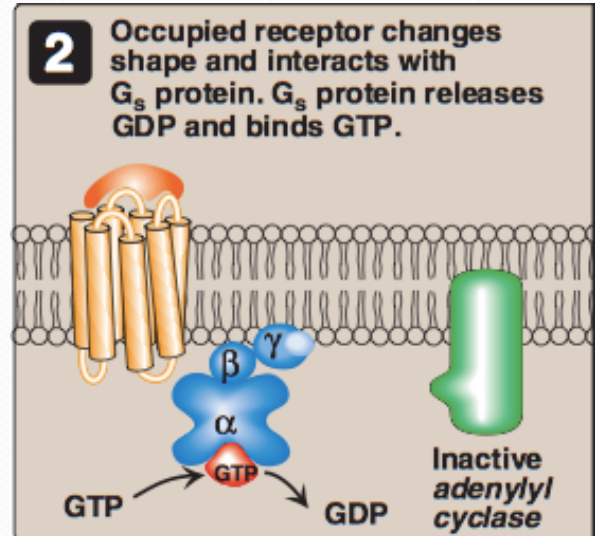
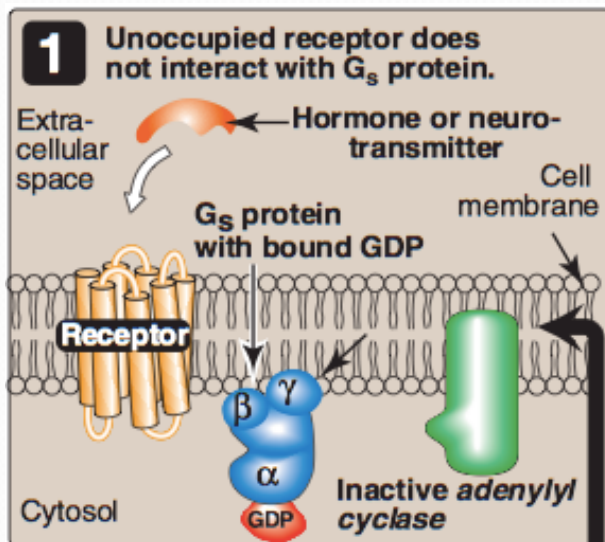
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II. Hormones that bind to cell surface receptors

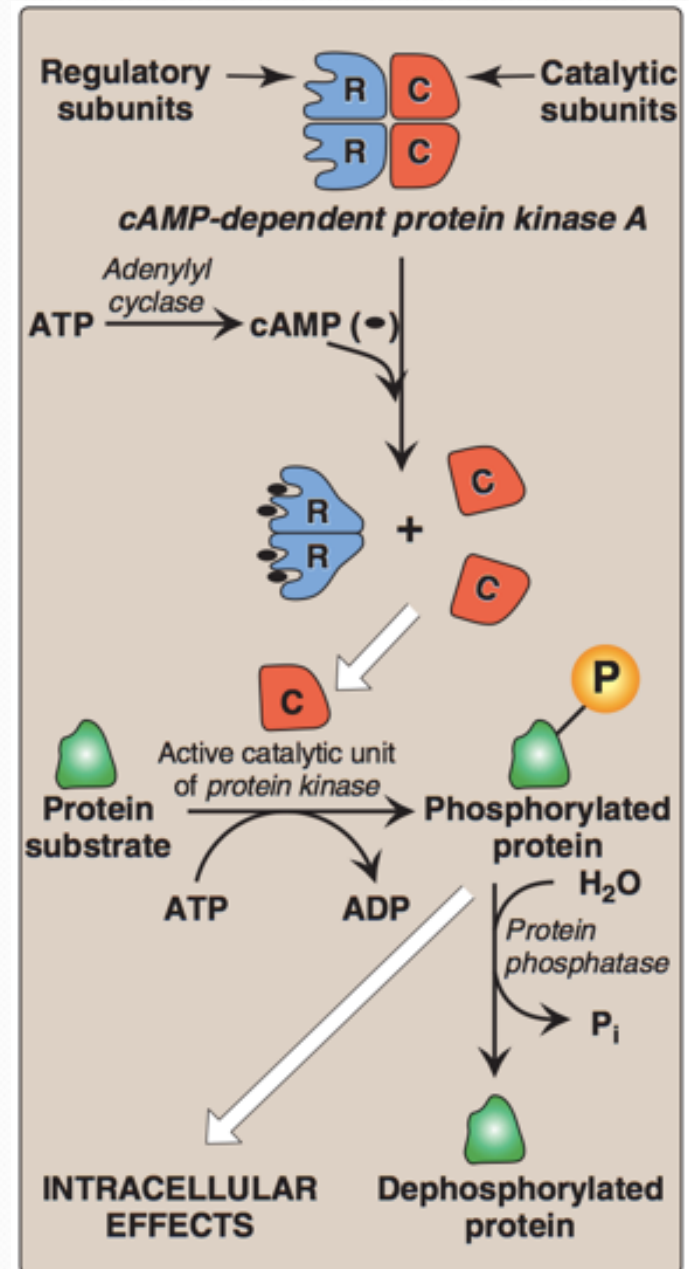
A. The second messenger is cAMP

- Catecholamines (α_2 - Adrenergic)
- Catecholamines (β - Adrenergic)
- Ant. Pituitary: ACTH, FSH, LH & TSH
- ADH (Renal V₂-receptor)
- Calcitonin & PTH
- Glucagon

Cascade for formation of cAMP by cell-surface hormones

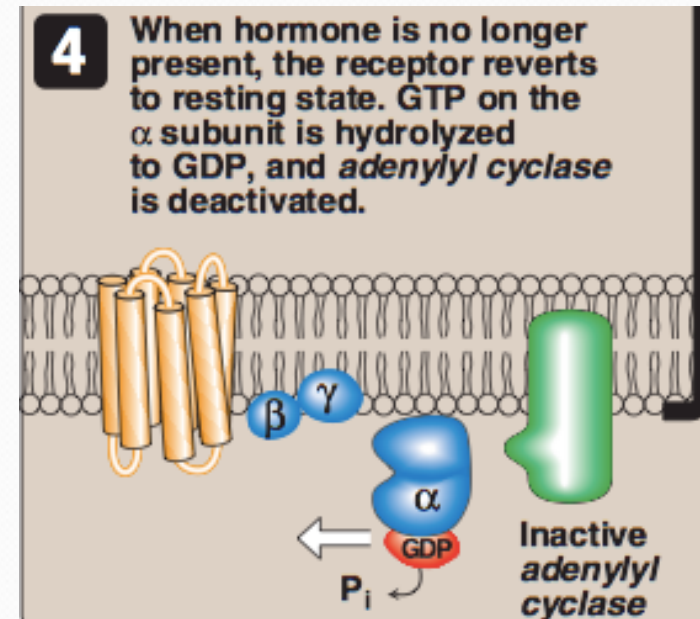
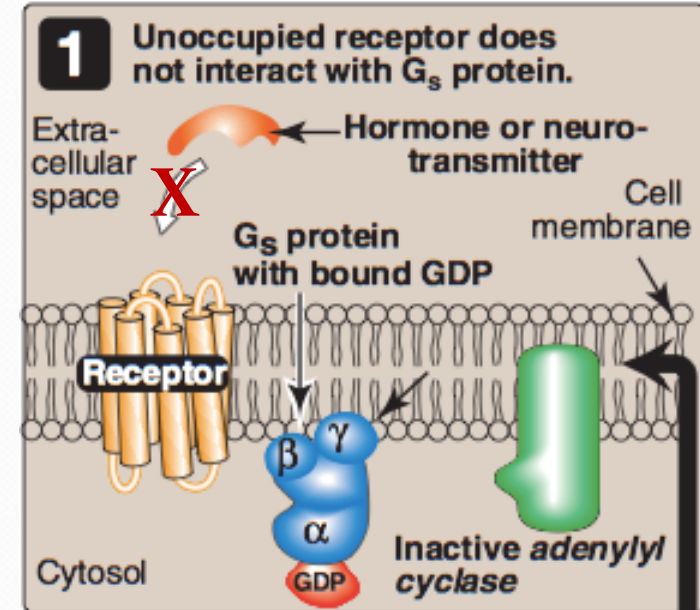


Actions of cAMP



Abortion of Hormonal Stimulus

1. Release of hormone from its receptor (unbound receptor)
2. Dephosphorylation of protein substrate by phosphatase
3. Degradation of cAMP into AMP by phosphodiesterase
4. Inactivation of protein kinase A by a decrease of cAMP
5. Hydrolysis of GTP into GDP
6. Binding of α -subunit to $\beta\gamma$ -subunits
7. Inactivation of adenylyl cyclase



Classification of Hormones by Mechanism of Action

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II. Hormones that bind to cell surface receptors B. The second messenger is cGMP

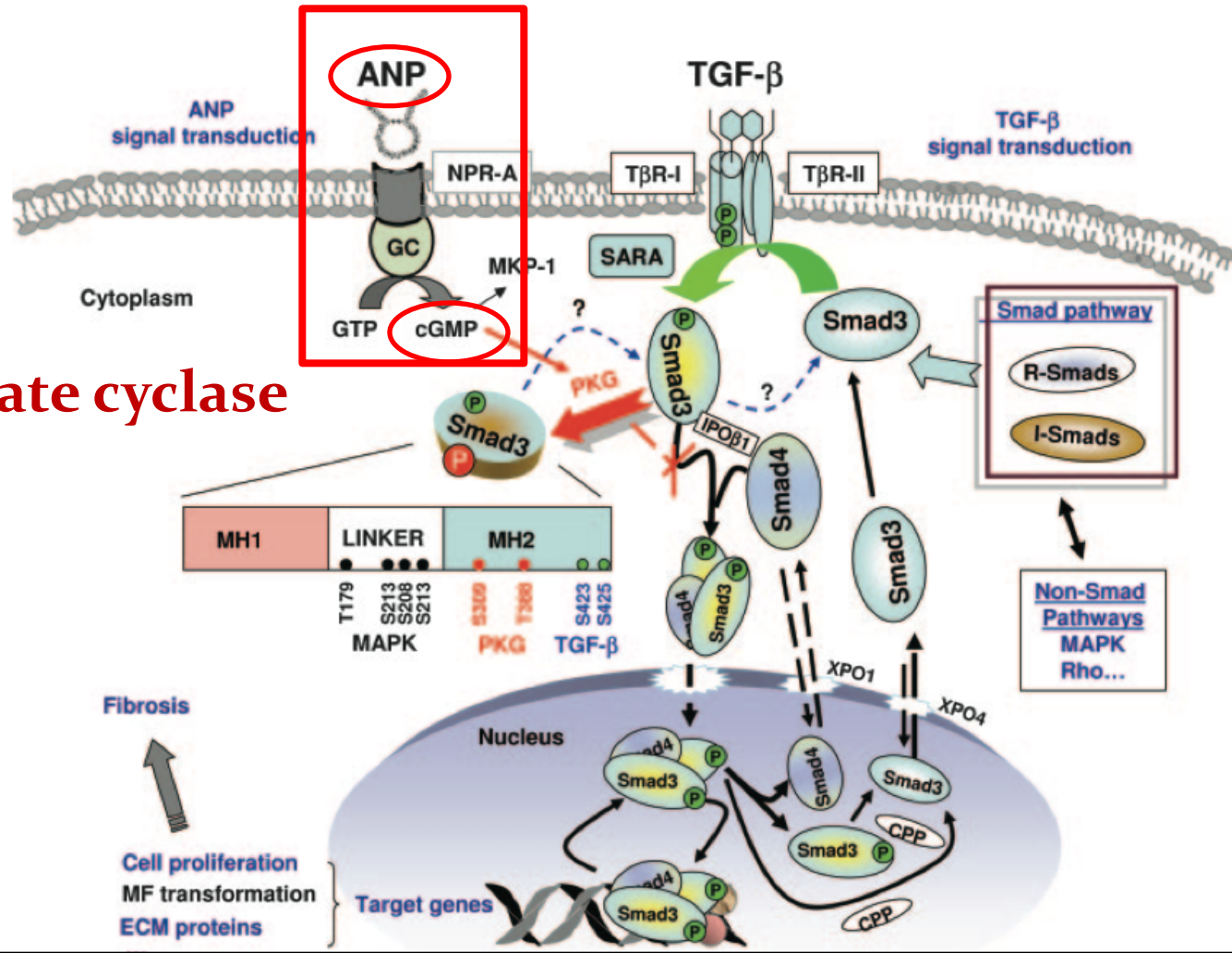
Atrial natriuretic peptide (ANP)

Nitric oxide

Atrial Natriuretic Peptide (ANP)

Circulation Research

February 1, 2008



GC: Guanylate cyclase

Classification of Hormones by Mechanism of Action

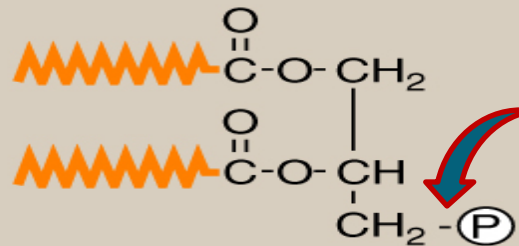
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II. Hormones that bind to cell surface receptors C. The second messenger is calcium or phosphatidylinositol (or both)

- Acetylcholine (muscarinic)
- Catecholamines (α_1 -Adrenergic)
- Angiotensin II
- ADH (vasopressin): Extra-renal V_1 -receptor

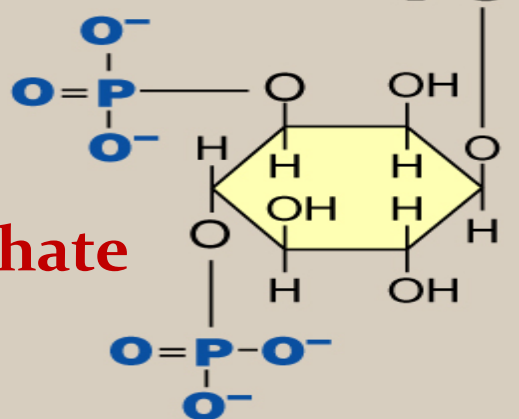
Calcium/Phosphatidylinositol System

Diacylglycerol (DAG)

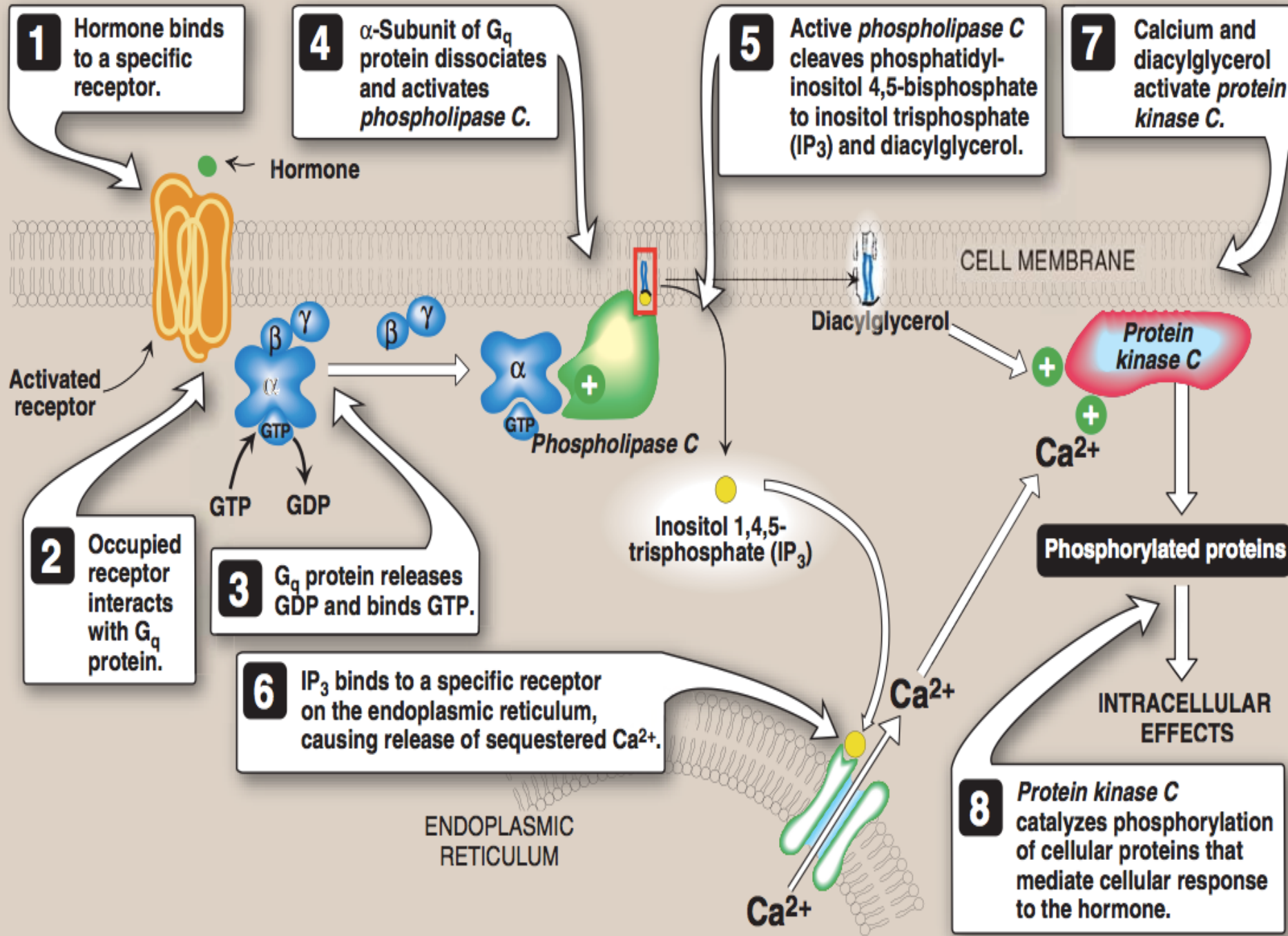


Phospholipase C

Inositol Trisphosphate (IP₃)



Phosphatidylinositol 4,5-bisphosphate



Classification of Hormones by Mechanism of Action

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II. Hormones that bind to cell surface receptors

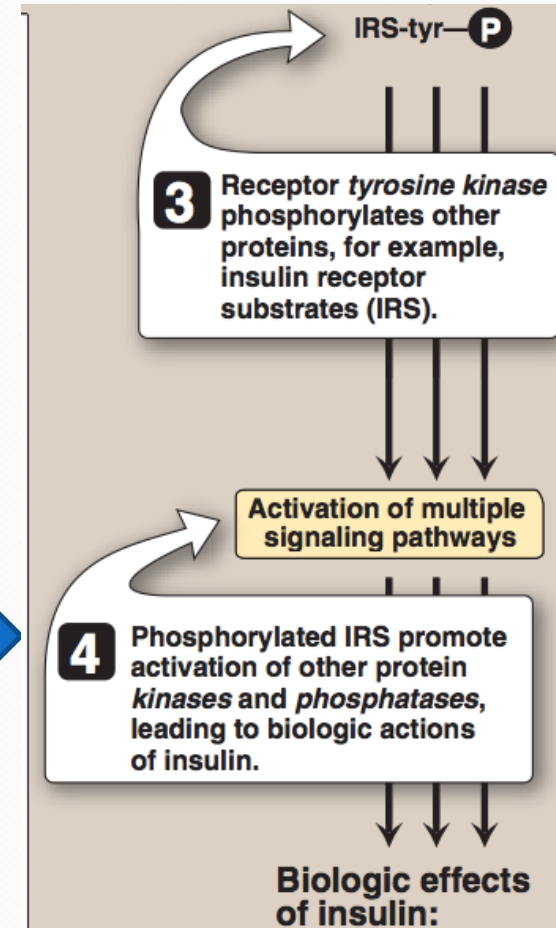
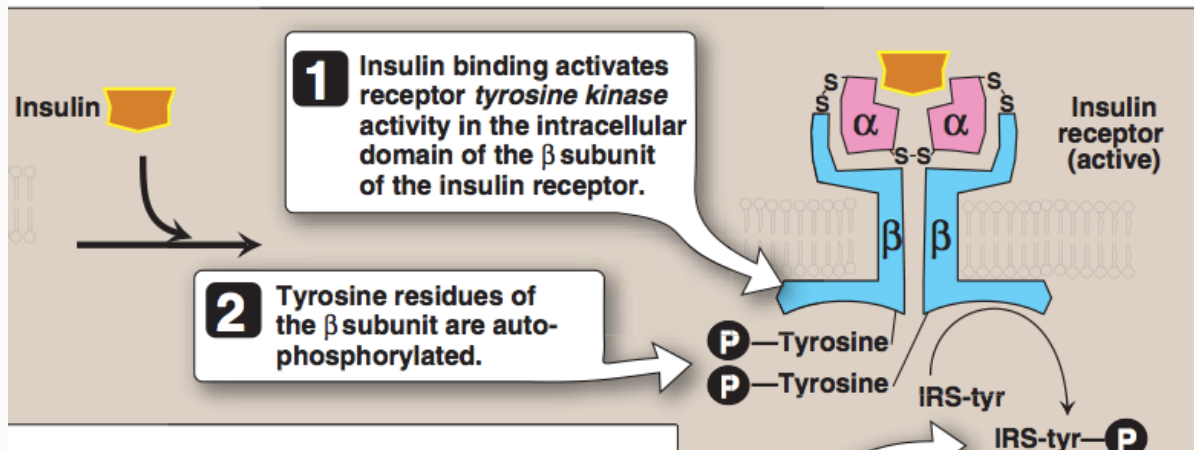
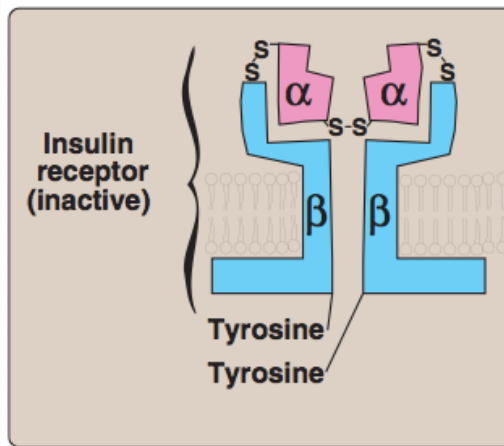
D. The second messenger is a tyrosine kinase cascade

GH & Prolactin

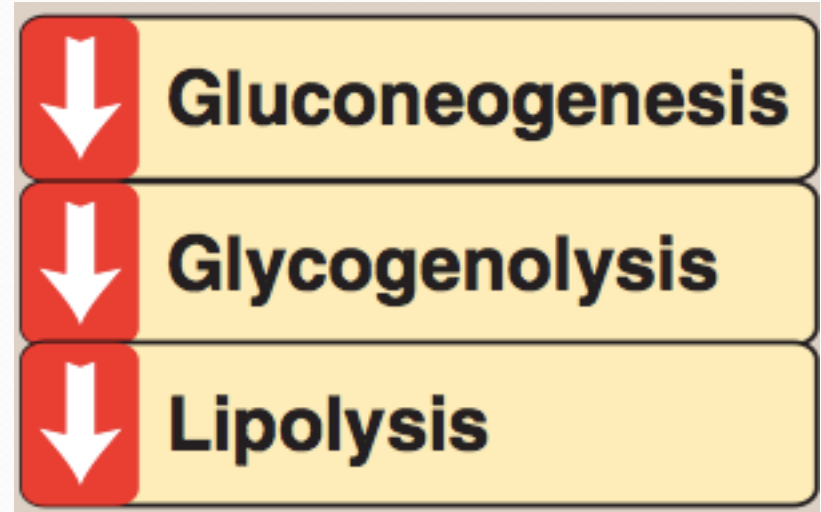
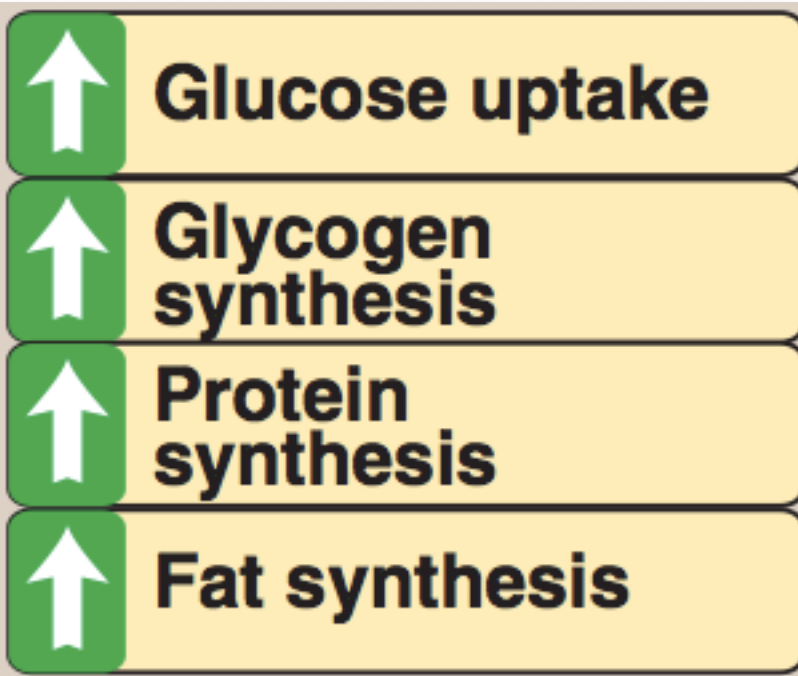
Insulin

Erythropoietin

Mechanism of Insulin action



Biologic Effects of Insulin



Altered gene expression

Biomedical Importance

- **Excessive** (e.g., hyperthyroidism, Cushing), **deficient** (e.g., hypothyroidism, Addison), or **inappropriate secretion** (e.g., syndrome of inappropriate secretion of ADH “SIADH”) of hormones are major causes of diseases
- Pharmacological treatment of these diseases depends on replacement of deficient hormone (*hypo-*) or use of drugs that interfere with the mechanism of action of the hormones (*hyper- or inappropriate*)

Take home message

- **Hormones are involved in responses to a stimulus, using a variety of signaling mechanisms to facilitate cellular adaptive responses.**
- **Group I hormones are lipophilic, while group II are hydrophilic. Other differences exist between both groups.**
- **Hormones can be classified according to their mechanism of action (*specific examples of each category were discussed*)**
- **Biomedically, studying hormones' actions in details helps to:**
 - **understand consequences of abnormal hormone release-related diseases (excessive, deficient or inappropriate)**
 - **design therapeutic approach for such diseases.**

References

- Lippincott's Illustrated Reviews Biochemistry: 6th edition, Chapters 8, 17 and 23.
- Buxton, Iain LO, and Dayue Duan. "Cyclic GMP/Protein Kinase G Phosphorylation of Smad3 Blocks Transforming Growth Factor- β -Induced Nuclear Smad Translocation." (2008): 151-153.†

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THANK YOU