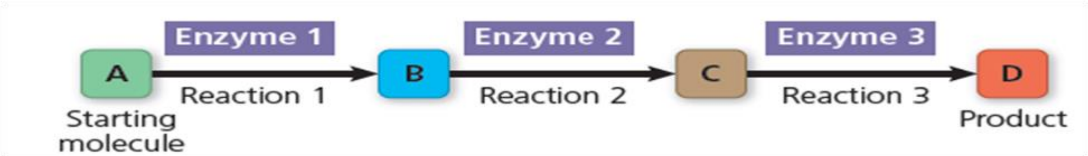
BB101
Molecular Cellular Biology

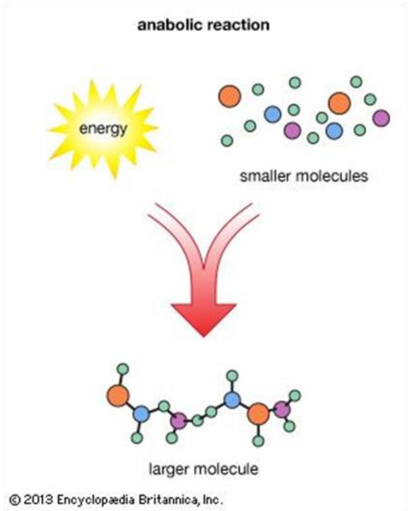
Tutorial 2

Metabolism



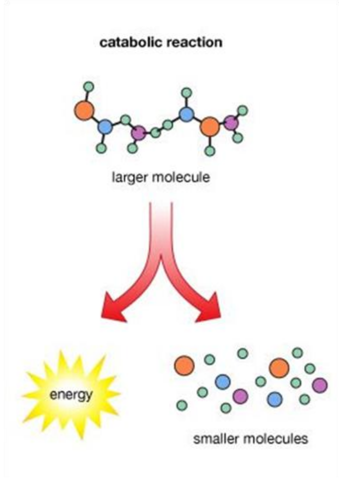
Metabolic Reactions

Anabolic reactions



- Absorption of Energy
- Building complex molecules from simpler ones.
- Biosynthetic

Catabolic reactions



- Release of Energy
- Breakdown of bigger compounds to form smaller ones.
- Degradative

Catabolic Pathways

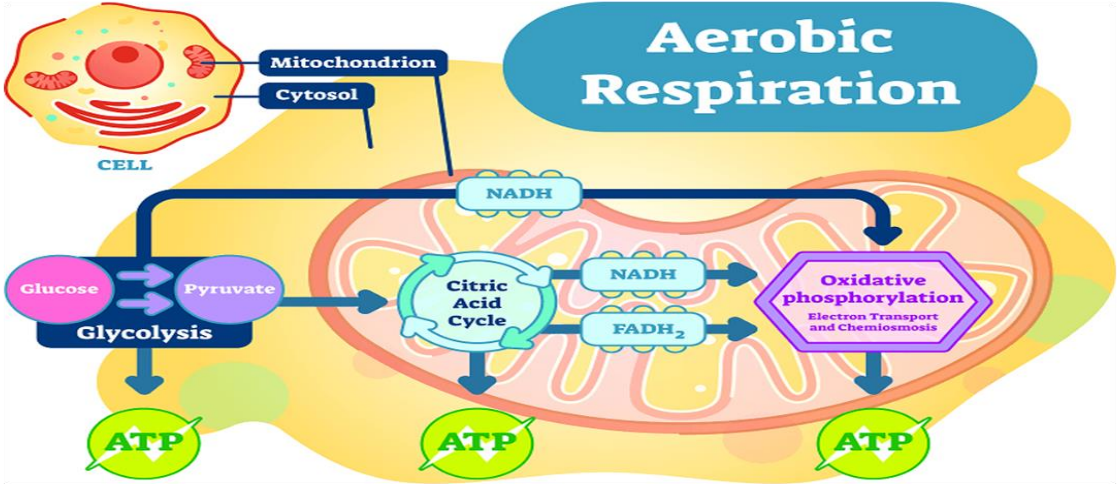
- Release of Energy

- Breakdown of bigger compounds to form smaller ones.

- Degradative

Food → Simpler Biomolecules, Energy

→ Work

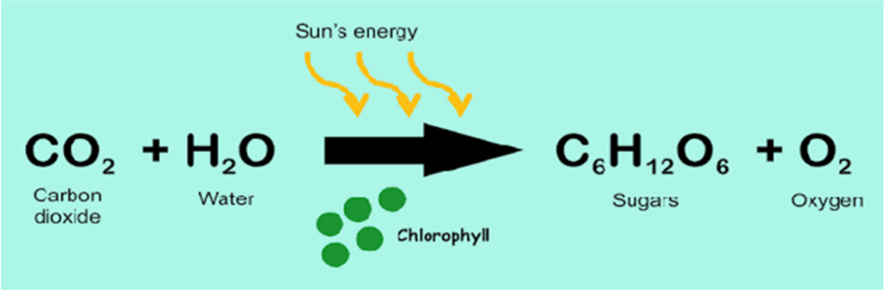


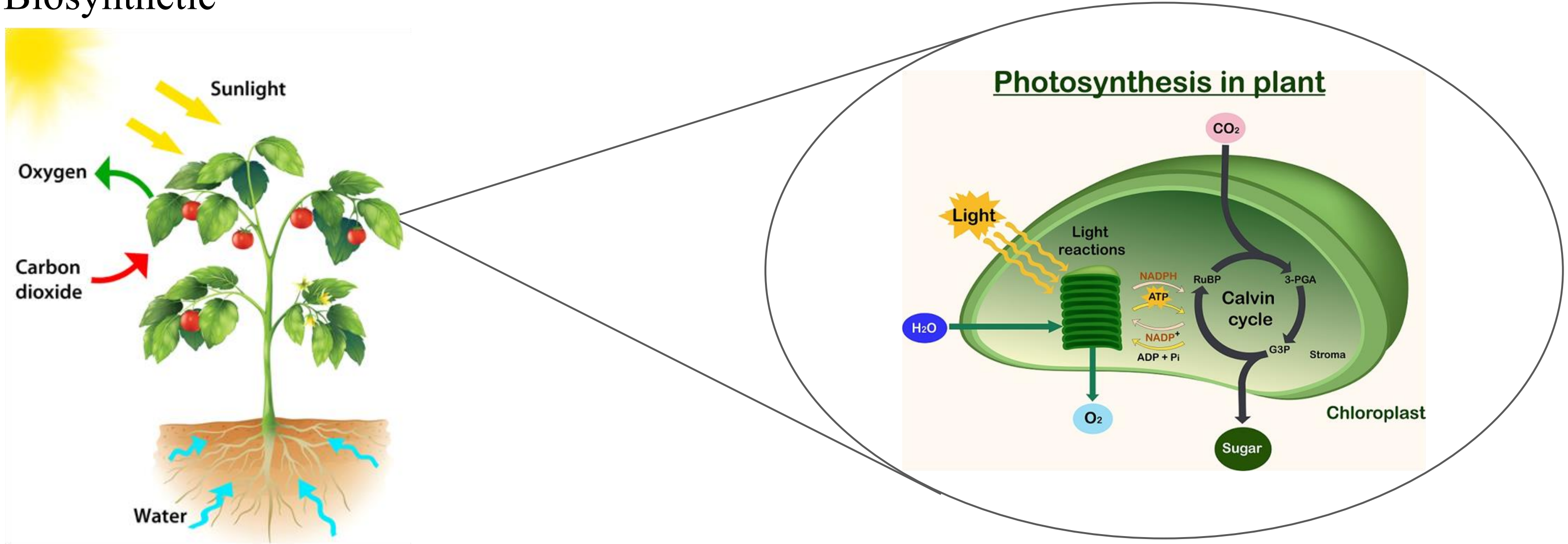
Anabolic Pathways

•Absorption of Energy

• Building complex molecules from simpler ones.

• Biosynthetic





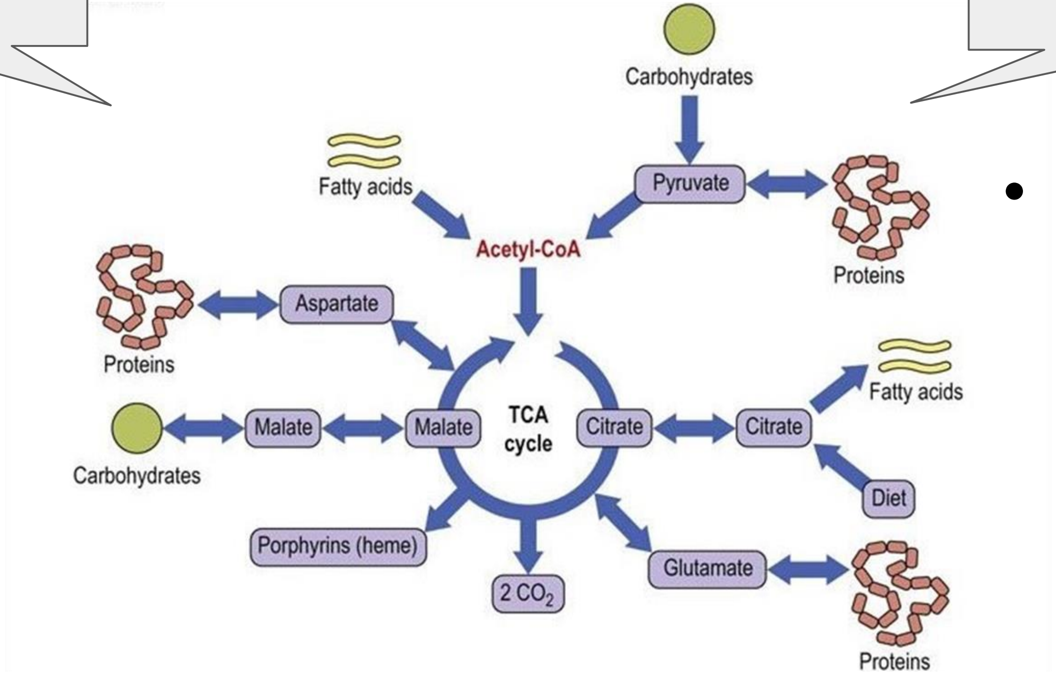
TCA Cycle: a special case

Catabolic Reaction

- Break down of Sugars
- Release energy via Oxidative phosphorylation

Anabolic Reaction

- Intermediates utilized for synthesizing macromolecules.

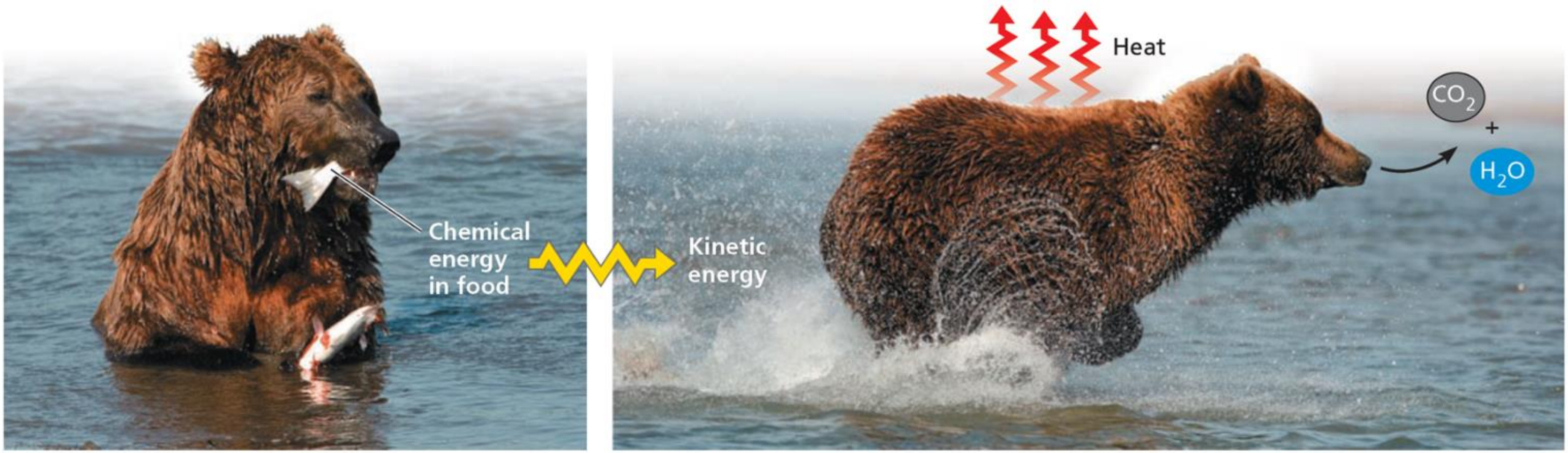


Amphibolic

Laws of thermodynamics

first law of thermodynamics, the energy of the universe is constant: *Energy can be transferred and transformed, but it cannot be created or destroyed.*

second law of thermodynamics: *Every energy transfer or transformation increases the entropy of the universe.*



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Free energy

Free energy is the portion of a system's energy that can perform work when temperature and pressure are uniform throughout the system, as in a living cell

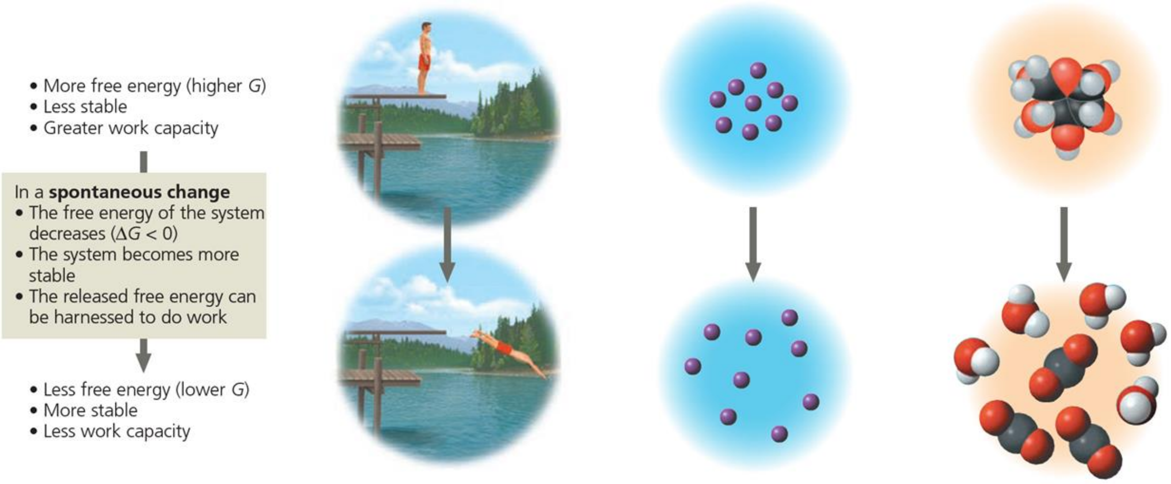
$\Delta G = \Delta H - T\Delta S$

G: free energy change

H: the change in the system's *enthalpy*

T: absolute temperature

S: change in entropy



(a) Gravitational motion. Objects move spontaneously from a higher altitude to a lower one.
(b) Diffusion. Molecules in a drop of dye diffuse until they are randomly dispersed.
(c) Chemical reaction. In a cell, a glucose molecule is broken down into simpler molecules.

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Exergonic and Endergonic Reactions

An **exergonic reaction** proceeds with a net release of free energy and occurs spontaneously

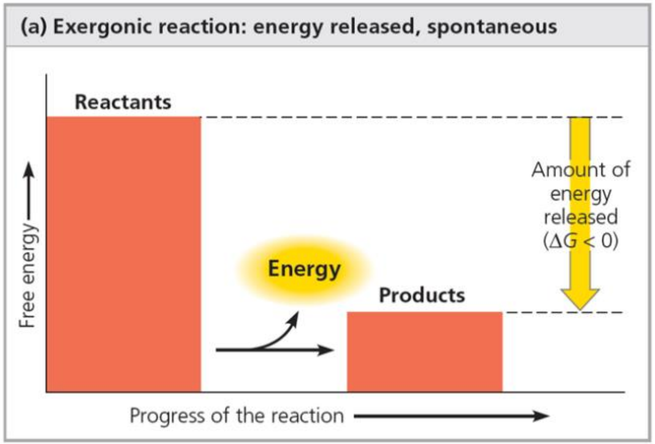
$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$$

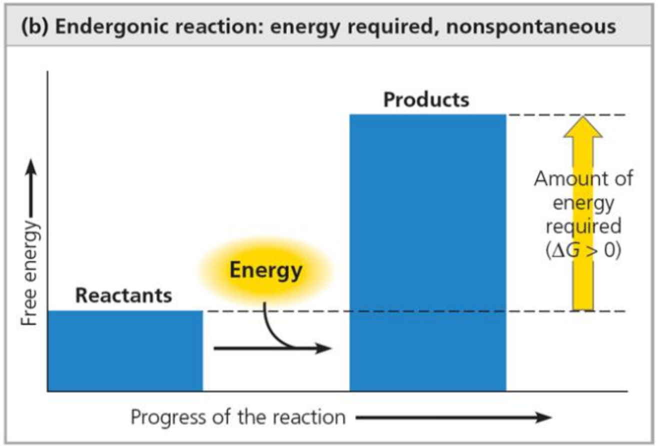
$$\Delta G = -686 \text{ kcal/mol } (-2{,}870 \text{ kJ/mol})$$

An **endergonic reaction** is one that absorbs free energy from its surroundings

$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

$$\Delta G = +686 \text{ kcal/mol}$$





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Difference between exo/endothermic and exer/enderogonic reactions

Exo/endothermic reactions represents the relative change in the enthalpy of the system. Energy released or absorbed is always in the form of heat

Examples of endothermic reaction: Melting ice, evaporation, cooking

Examples of exothermic reaction: rusting iron, nuclear fission

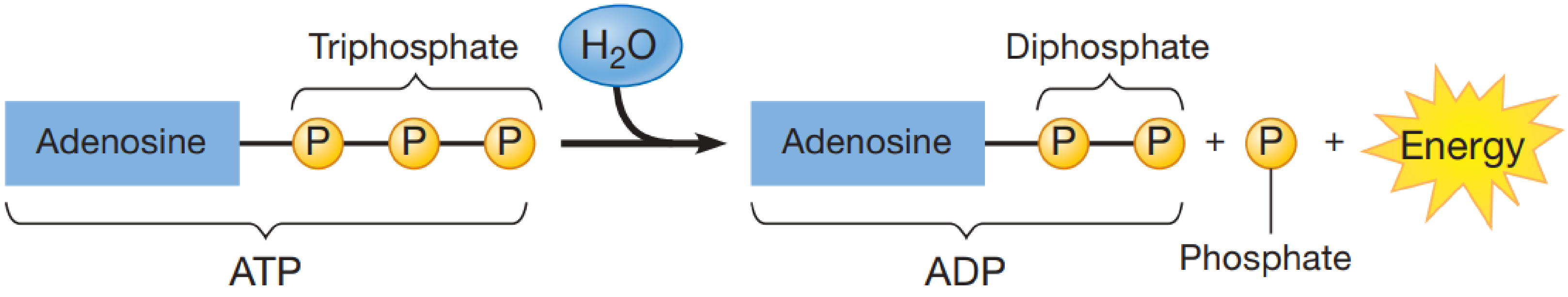
Exer/endergonic reactions represents the relative change in the free energy of the system. Energy released or absorbed can be in the form other than heat such as light or sound.

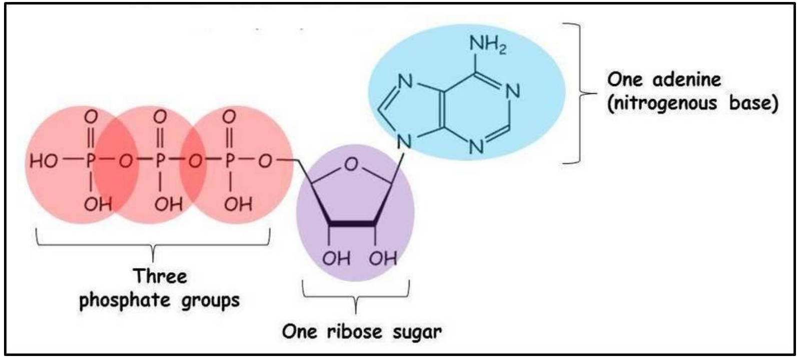
Examples of endergonic reaction: photosynthesis, protein synthesis, dissolving potassium chloride in water.

Examples of exergonic: cellular respiration, combustion, decomposition of H_2O_2

How ATP drives chemical work

ATP powers nearly all forms of cellular work.





- ATP - adenosine and a triphosphate tail of three phosphate groups
- All three phosphate groups are negatively charged
- The bonds connecting the phosphate groups are unstable and can readily be broken by hydrolysis
- The hydrolysis of ATP is exergonic—it releases energy

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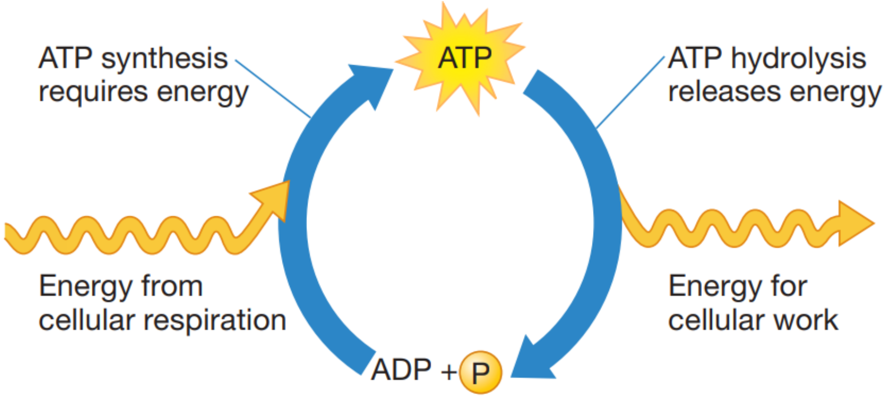
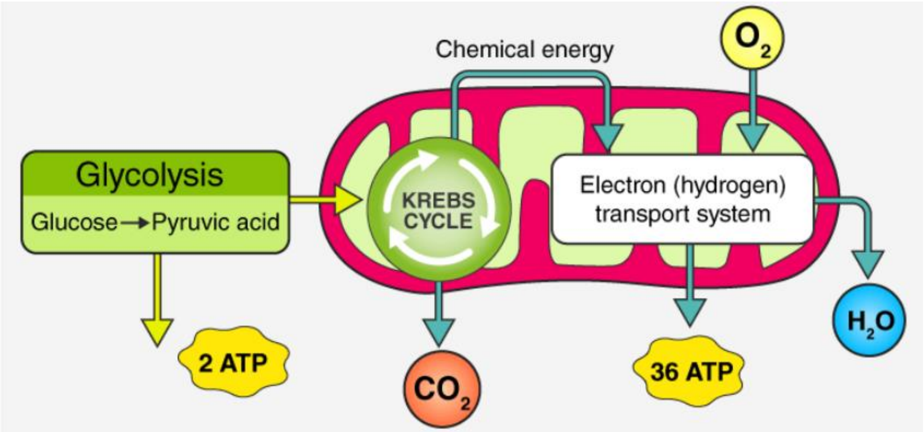
ATP powers nearly all forms of cellular work.





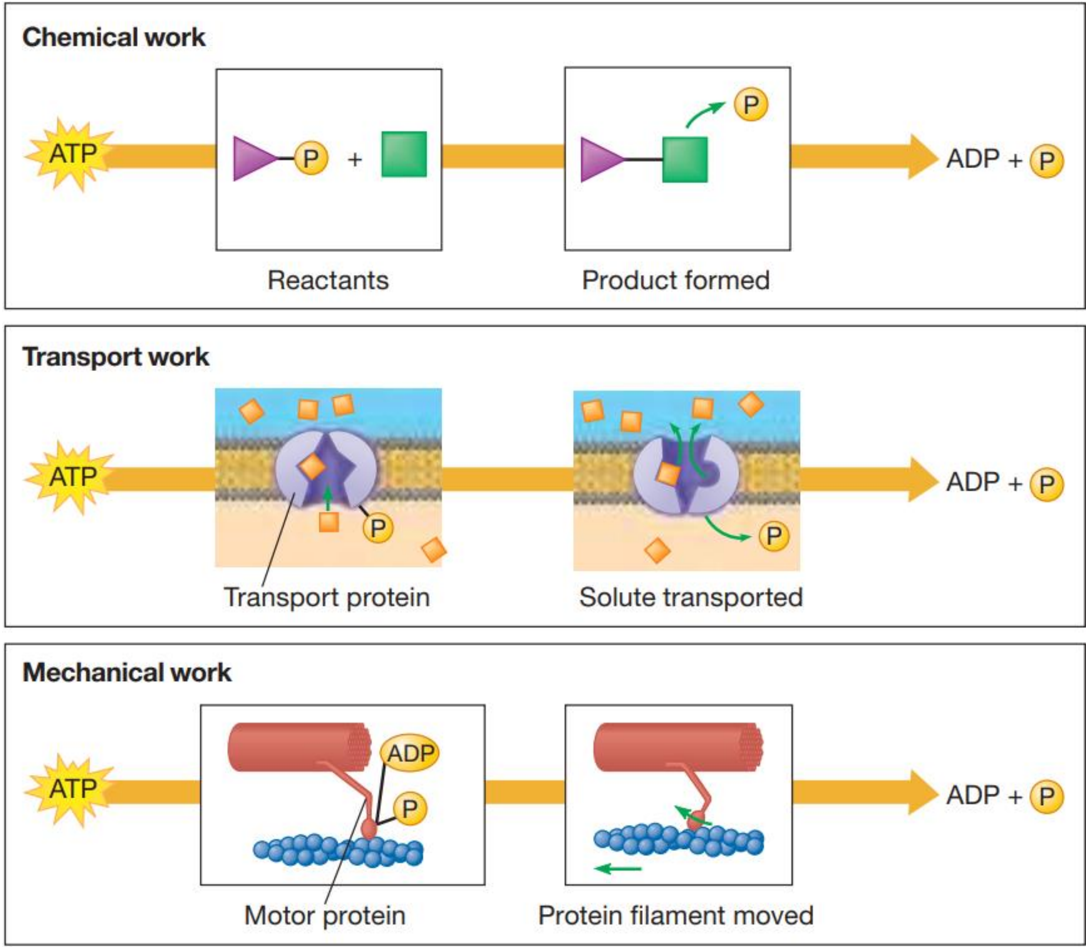
$$\mathbf{ATP} + H_2O \xrightarrow[\text{hydrolysis}]{\text{ATPase}} \mathbf{ADP} + \mathrm{Pi} \qquad \Delta G = -30.5 \text{ kJ/mol}$$

http://loretocollegebiology.weebly.com/atp-structure--function.html

How ATP drives chemical work

Cellular work often depends on ATP energizing molecules by phosphorylating them.

What types of work does a cell do?....

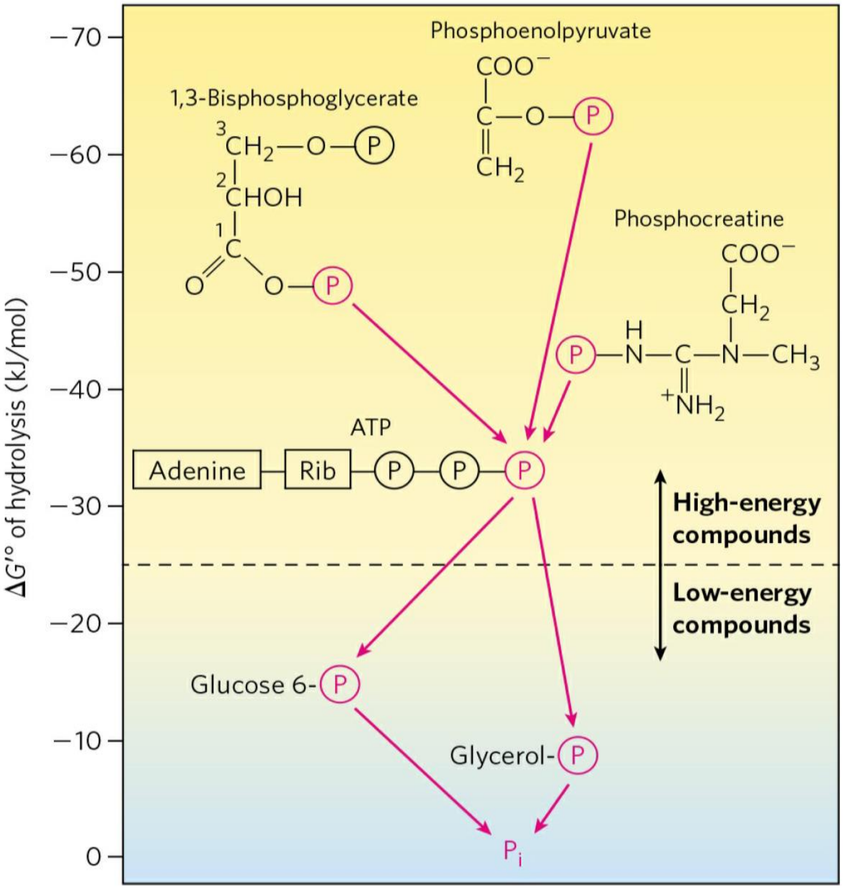


ATP as the energy currency of the cell

ATP can transfer its phosphoryl group from high energy compounds like 1-3-bisphosphoglycerate to lower energy compounds like glucose.

This flow of phosphoryl group in the system is driven by enzymes called kinases.

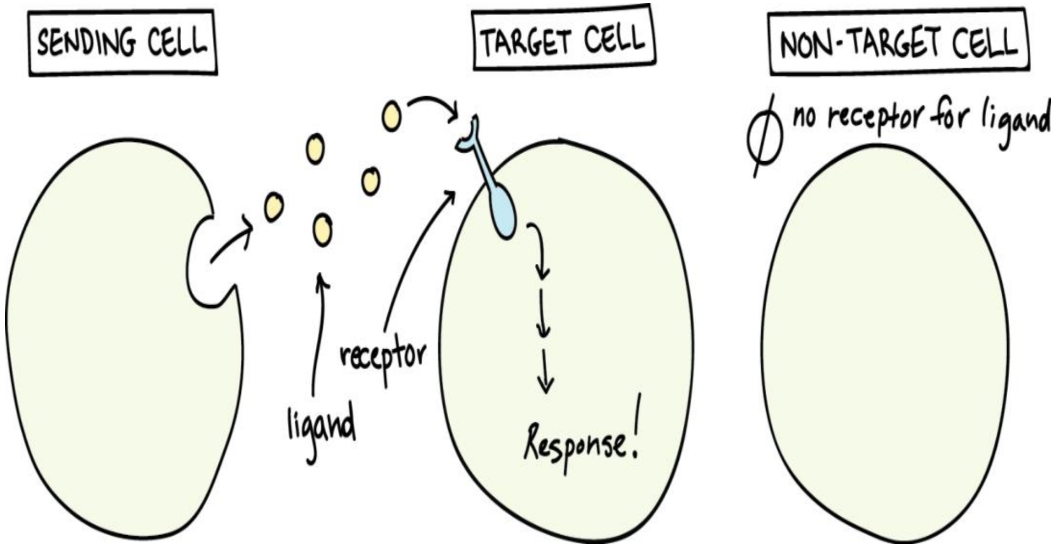
The reaction proceeds with a overall loss of free energy under extracellular conditions.



Cell communication

There several ways a cell communicate with other cells , some of them are

1) Autocrine signaling (self signalling)
2) Paracrine signalling (communication with adjacent cells)
3) Hormonal/ Endocrine signalling (Long Distance signalling)



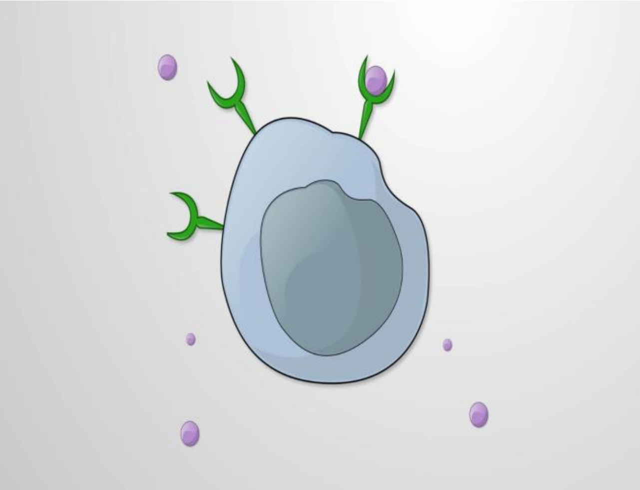
Ref :- https://www.khanacademy.org/science/ap-biology/cell-communication-and-cell-cycle/cell-communication/a/introduction-to-cell-signaling

Autocrine (self signalling)

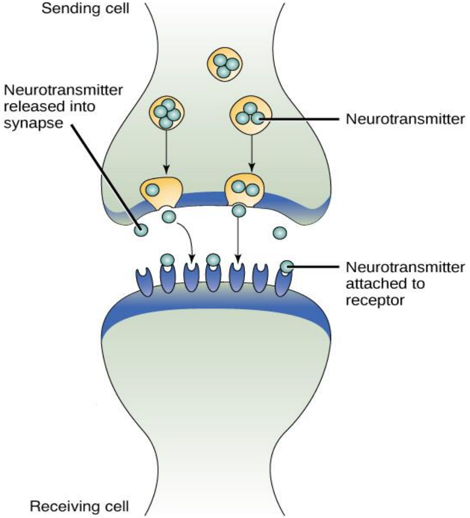
Paracrine (adjacent signalling)

Endocrine(Long signalling)

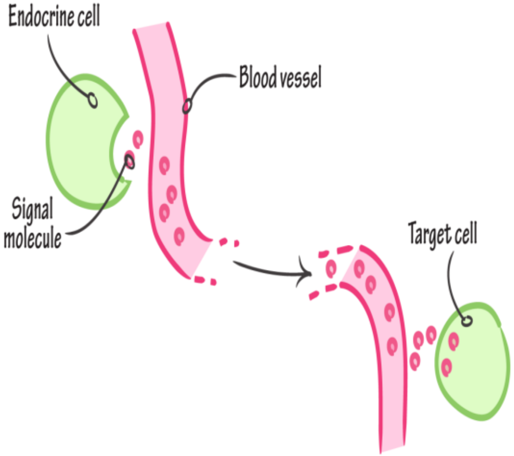
Many Immune cells , or cancer cells does this kind of signalling ..



Unique example of paracrine signalling is communication of nerve cells although it’s long but the signalling is happening within adjacent cell



Hormonal signalling carried through blood , eg - Insulin produced in pancreas controls glucose in every cell of body

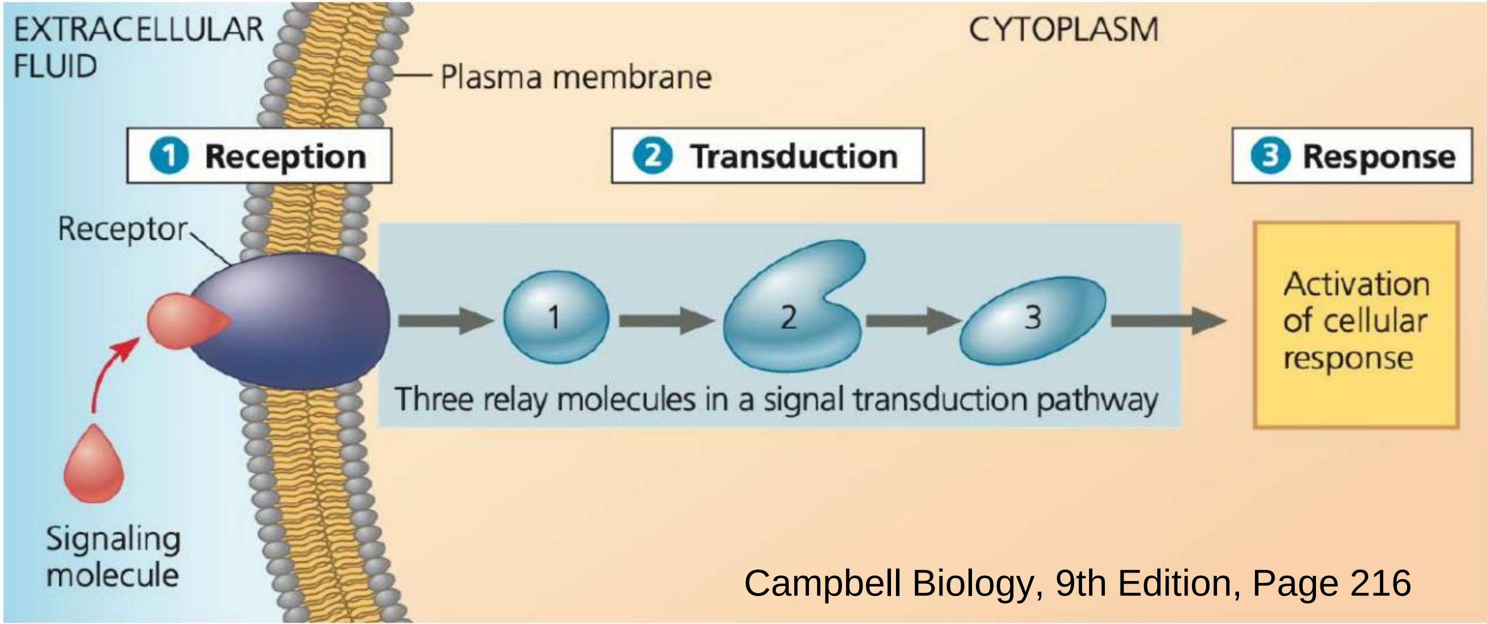


Ref :- https://www.khanacademy.org/science/ap-biology/cell-communication-and-cell-cycle/cell-communication/a/introduction-to-cell-signaling

Signal Transduction and cell communication

In a cell, signal transduction refers to a process when one form of stimuli/signal gets converted into another form that can generate a response.

This includes a chain of biochemical events that allows the cell to communicate information from external environment to the internal environment.



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Three main steps:

1) Reception
1) Transduction
1) Response

How signal transduction works in a cell?

Cell surface receptors help in sensing the ligand molecules in the external environment.

The receptor has two domains:

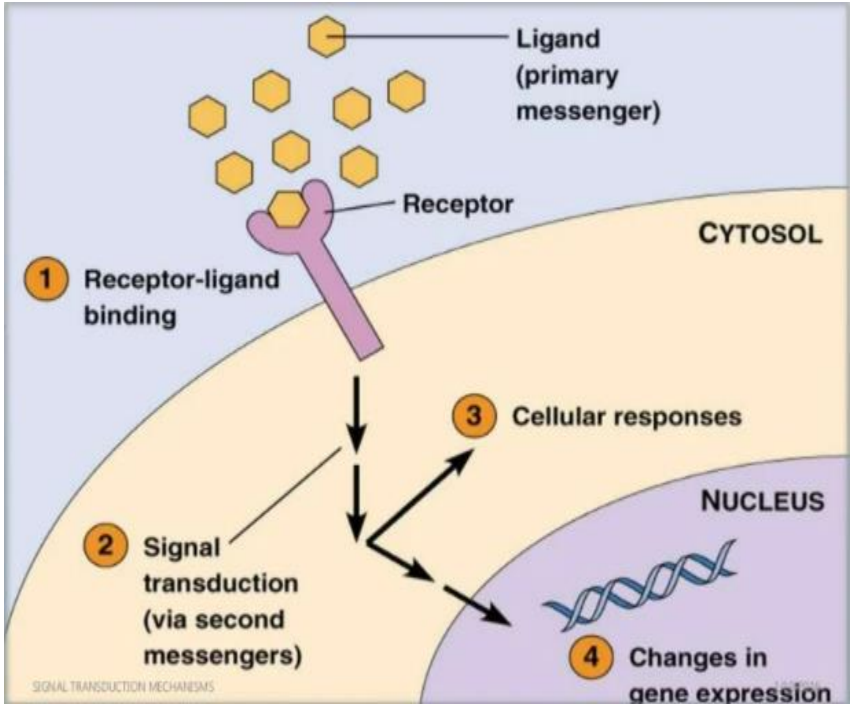
Extracellular domain

Intracellular domain

On binding of the ligand molecule, the intracellular domain changes its confirmation and subsequently activates secondary messengers which generates cellular response.

Primary messengers:steroid hormones, growth factors, chemoattractants and neurotransmitters.

Secondary messengers: cyclic nucleotides (e.g., cAMP and cGMP), inositol trisphosphate (IP3) , diacylglycerol (DAG), and calcium ions (Ca2+)



Types of receptors

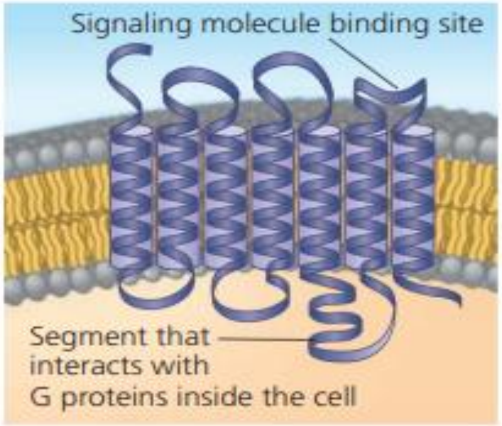
Two types: Extracellular and intracellular

Extracellular receptors: These are present on the plasma membrane of the cells.

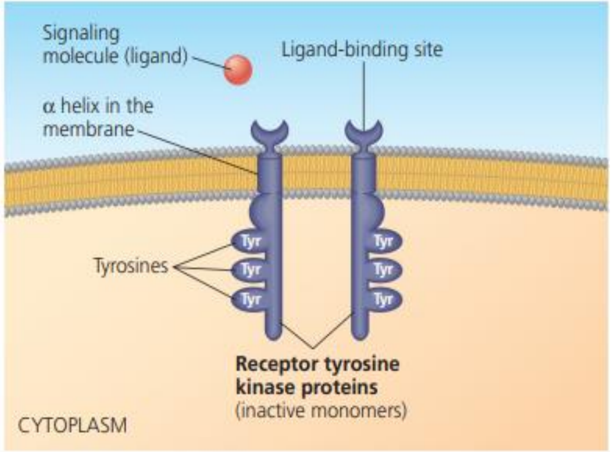
Example: G protein coupled receptors (GPCR)

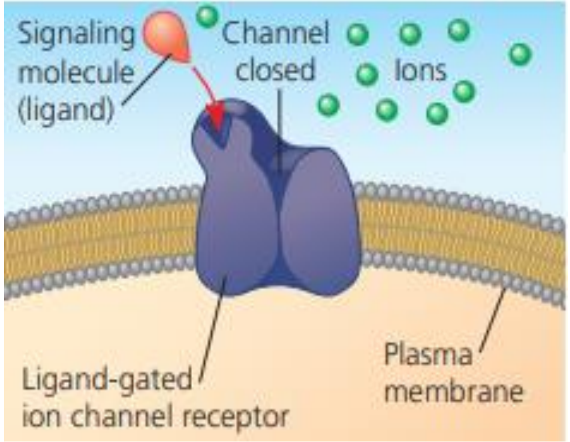
Ion channel receptors

Receptor tyrosine kinases (RTKs)



G protein-coupled receptor





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Intracellular receptors

Intracellular receptor proteins are found in either the cytoplasm or nucleus of target cells.

To reach such a receptor, a signaling molecule passes through the target cell's plasma membrane.

A number of important signaling molecules can do this because they are either hydrophobic enough or small enough to cross the hydrophobic interior of the membrane .

The hydrophobic signaling molecules include both steroid hormones and thyroid hormones of animals.

Once a hormone has entered a cell, its binding to an intracellular receptor changes the receptor into a hormone-receptor complex that is able to cause a response—in many cases, the turning on or off of particular genes.

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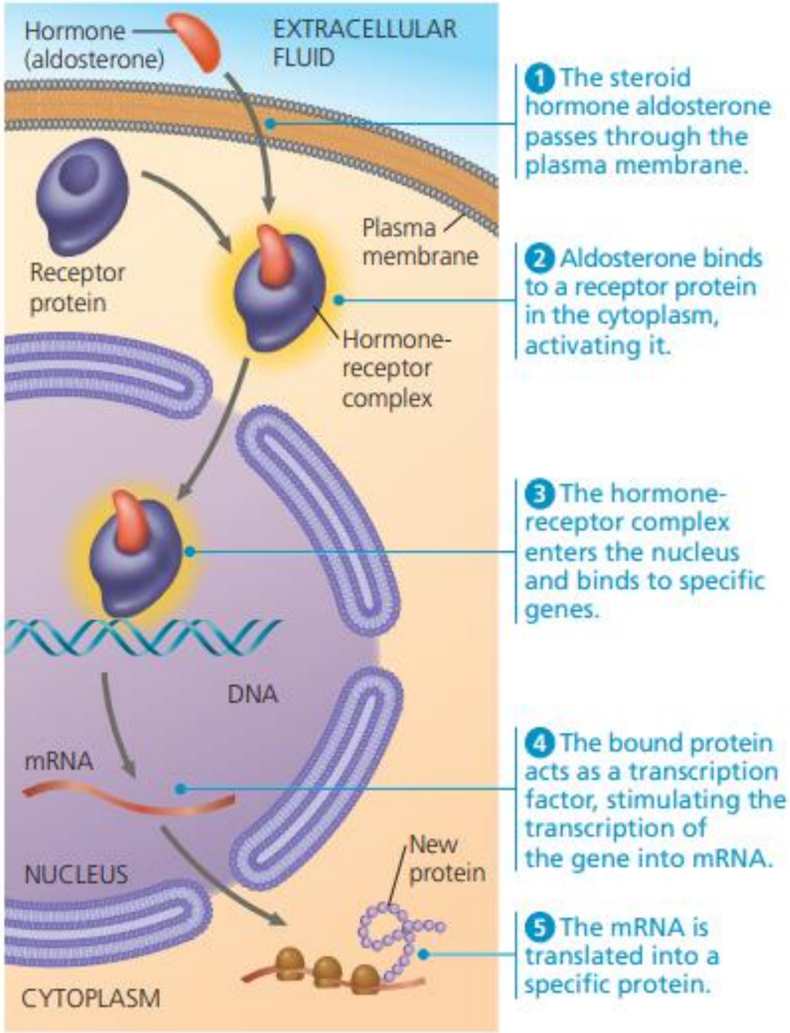
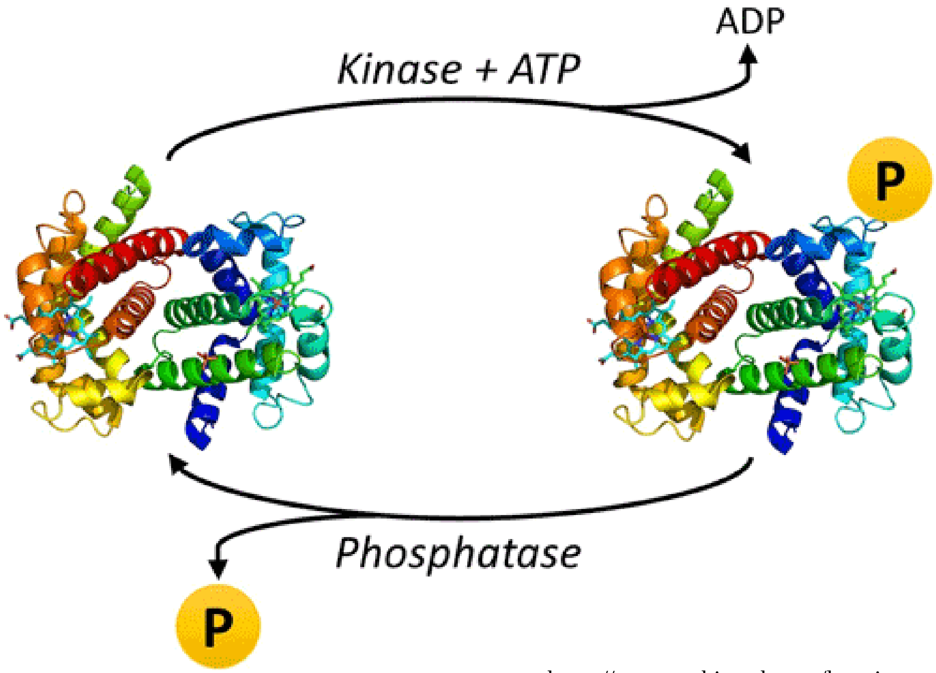


Protein activation and phosphates

Cells utilise the process of adding and removing phosphate groups to activate or inactivate a protein involved in the signaling cascade.

An enzyme that transfers phosphate groups from ATP to a protein is generally known as a **protein kinase**.

The enzymes that can rapidly remove phosphate groups from proteins are called **protein phosphatases**.



https://www.raybiotech.com/learning-center/7-ways-to-study-protein-phosphorylation/

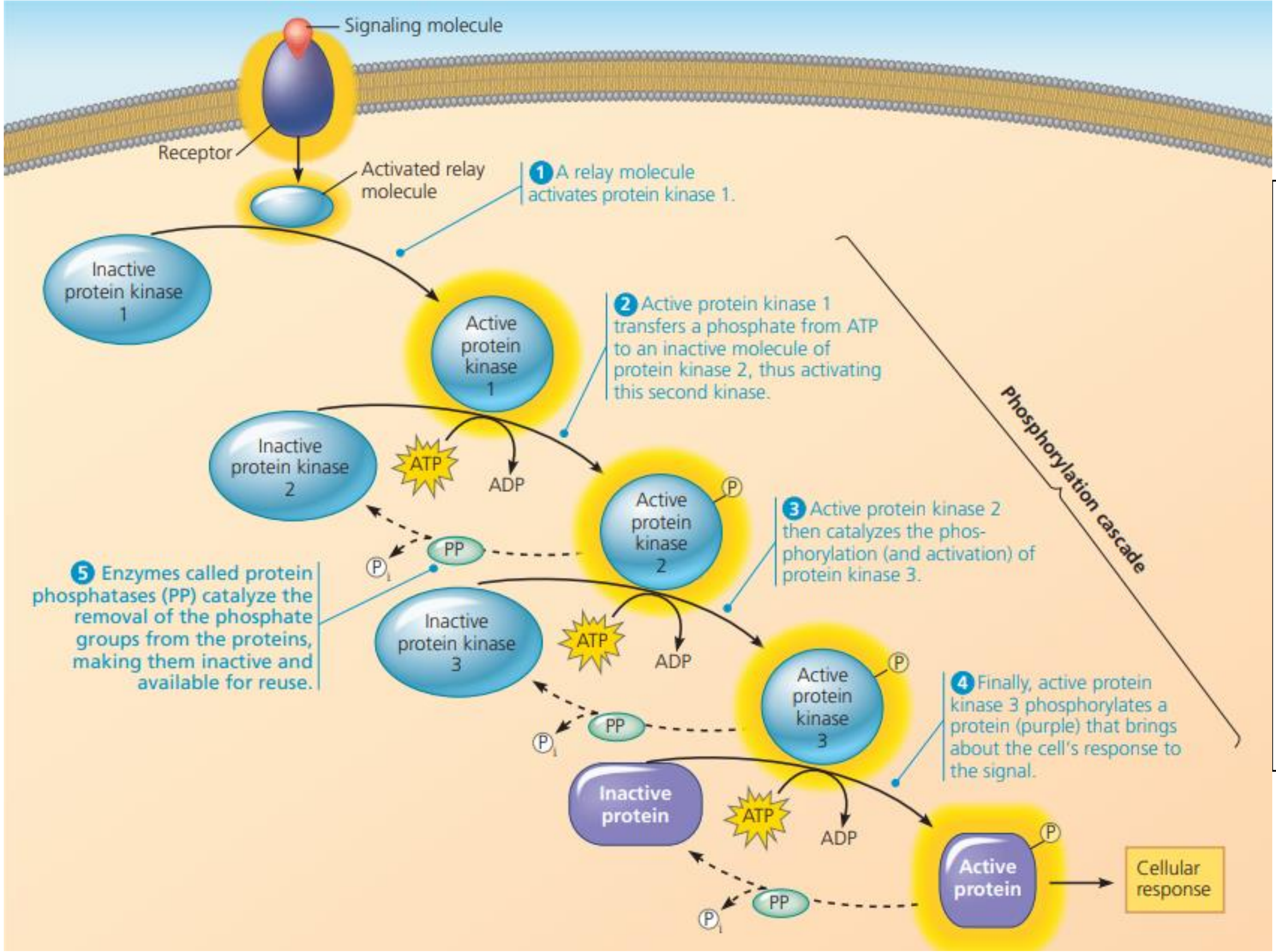


Figure: A **phosphorylation cascade** is organised from many signalling proteins controlled by kinases. A protein kinase is activated by phosphorylation which in turn phosphorylates the next protein kinase in a sequence and so on. As the signal is carried onwards it is amplified.

The delicate balance and signal activation

Phosphatases make the protein kinases available for reuse, enabling the cell to respond again to an extracellular signal.

At any given moment, the activity of a protein regulated by phosphorylation depends on the balance in the cell between active kinase molecules and active phosphatase molecules.