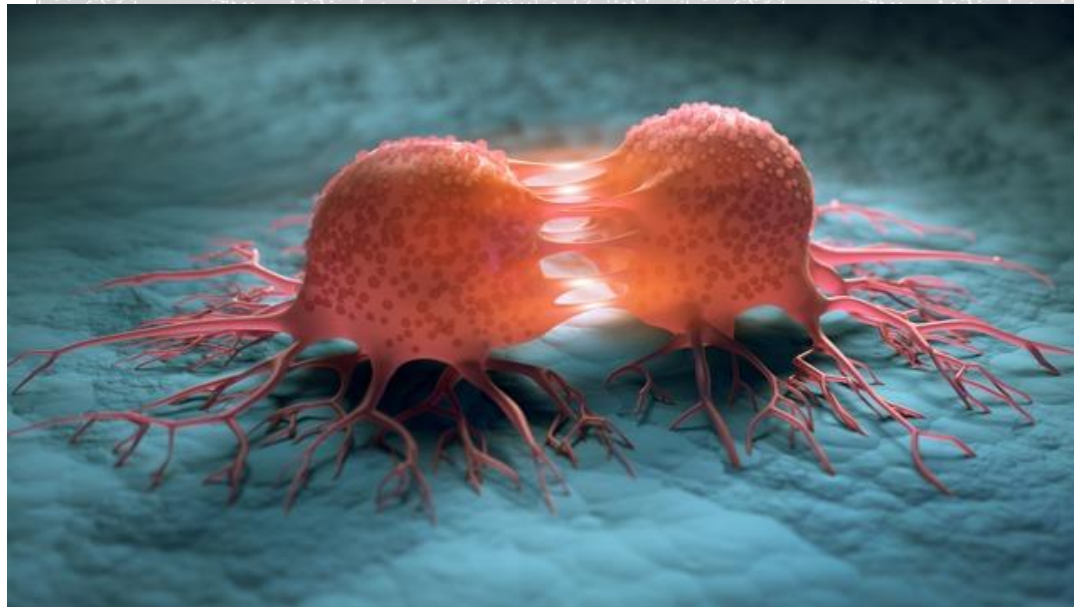


# METABOLISM & CELL COMMUNICATION

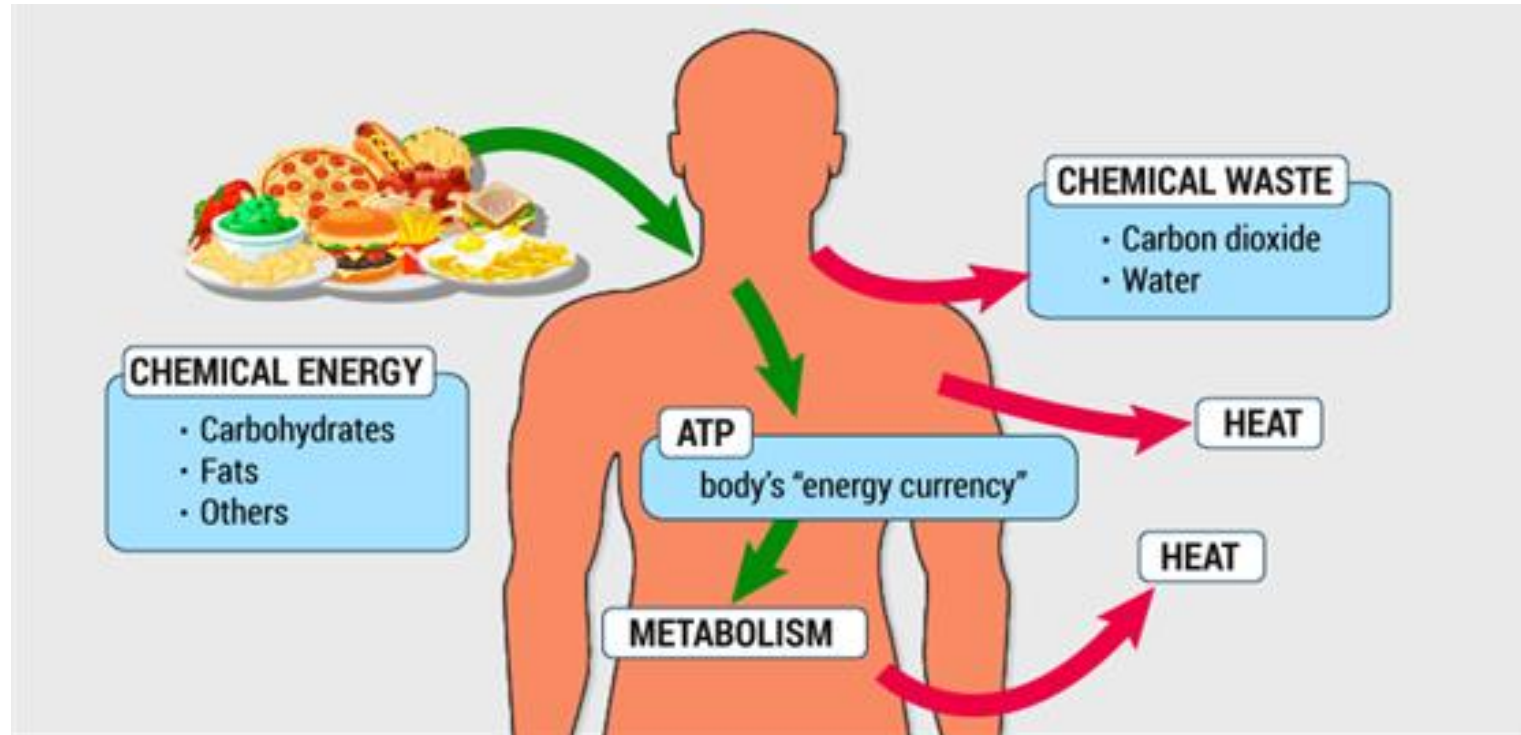


Dr. Manu Smriti Singh

Department of Biotechnology

Bennett University

# METABOLISM



All the chemical processes that take place in the body in order to sustain life- allowing you to breathe, pump blood, keep your brain functioning and extract energy from your food.

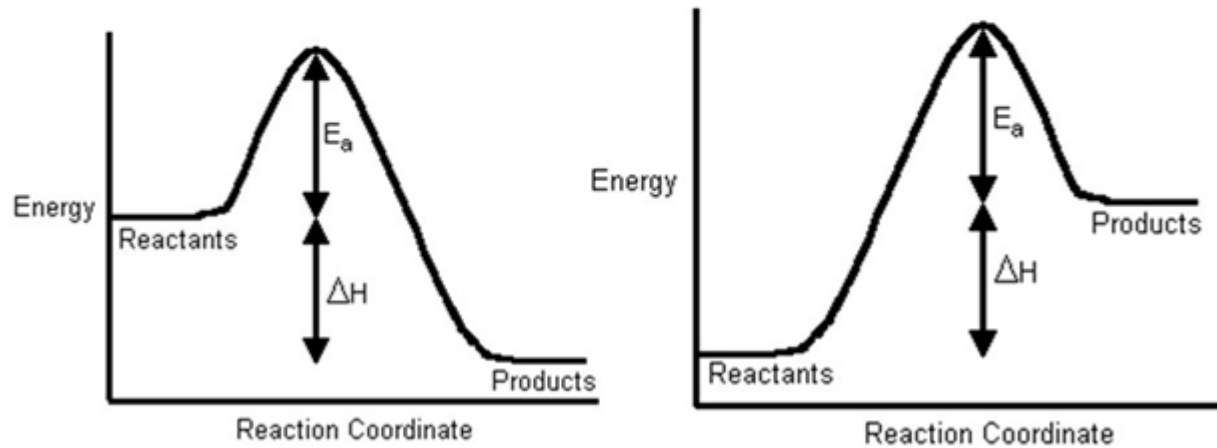
# LIVING ORGANISMS AS THERMODYNAMIC SYSTEMS

- The matter flowing into the living system contains a high energy potential.
- The matter flowing out of the system is at a low energy potential.
- The energy changes that occur between these two mass flow events are used to perform chemical and physical work processes.

- ❖ Enthalpy ( $\Delta H$ )
- ❖ Entropy ( $\Delta S$ )

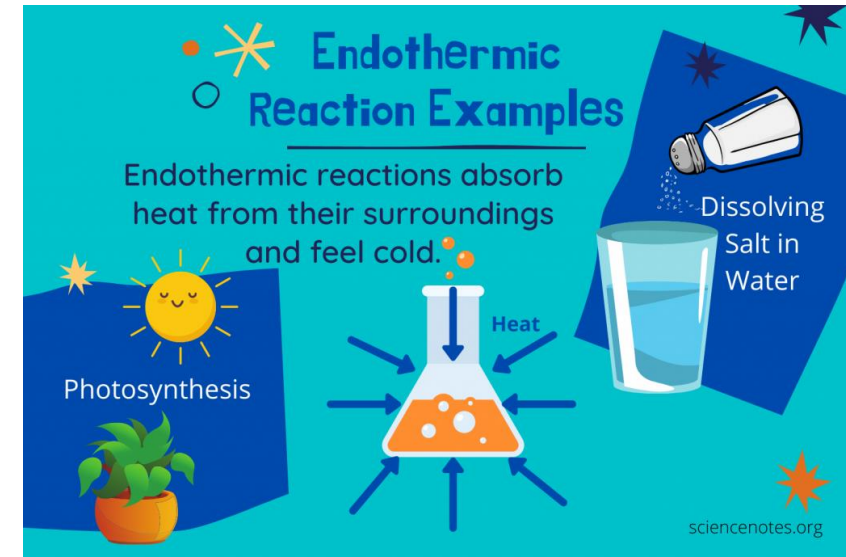
# What is Enthalpy?

- $\Delta H$ , heat energy
- ENDOthermic: heat is taken in by the reactants →
- EXOthermic: heat is released as a product

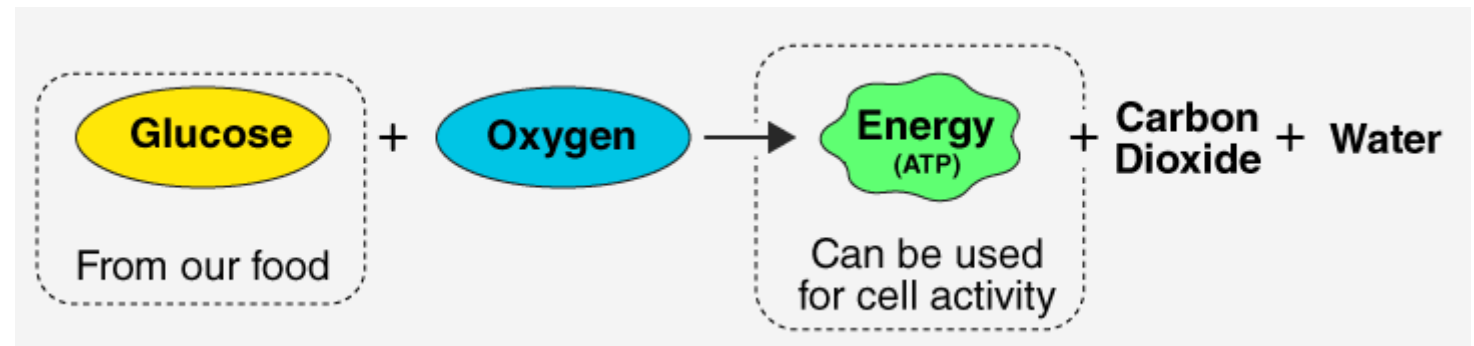


Exo ( $\Delta H$ )= -ve (heat given out)

Endo ( $\Delta H$ )= +ve (heat absorbed)



Exothermic Reaction →

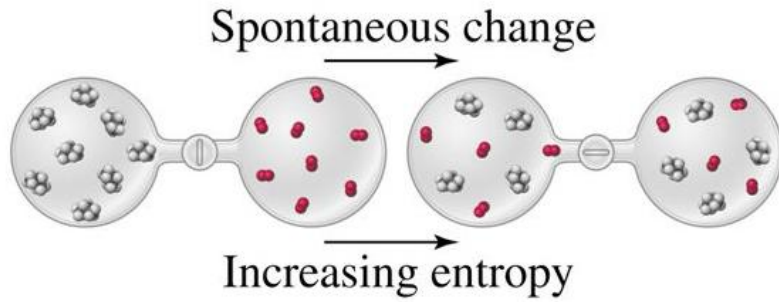




# ENTROPY

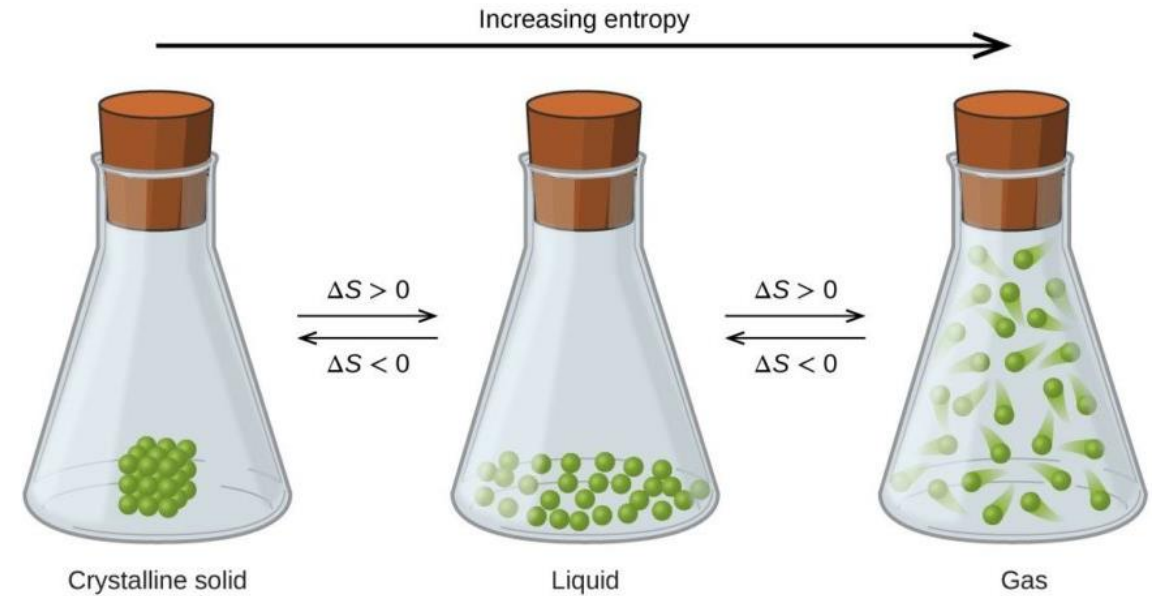
Consider mixing two gases: this occurs spontaneously, and the gases form a homogeneous mixture.

There is essentially no enthalpy change involved, so why is the process spontaneous?



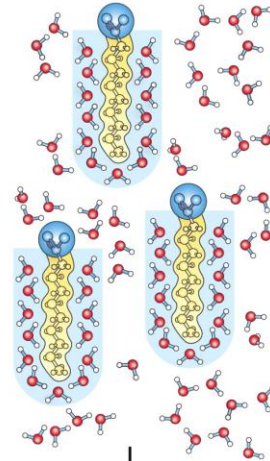
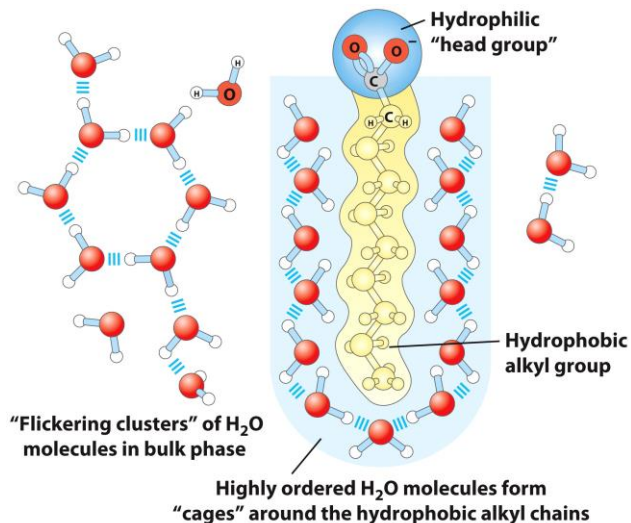
The driving force is a thermodynamic quantity called entropy, a mathematical concept that is difficult to portray visually

F.O.S



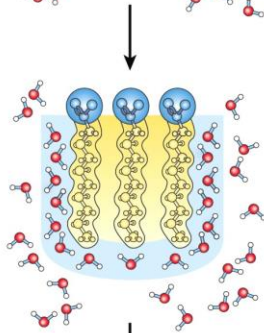
# HYDROPHOBIC EFFECT

Suspension of a hydrophobic substance in water is **thermodynamically unfavorable** due to the decreased entropy of water molecules in the cage-like shell.



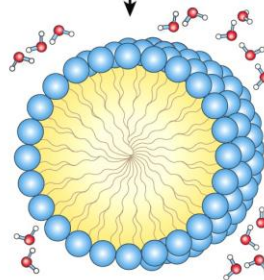
## Dispersion of lipids in H<sub>2</sub>O

Each lipid molecule forces surrounding H<sub>2</sub>O molecules to become highly ordered.



## Clusters of lipid molecules

Only lipid portions at the edge of the cluster force the ordering of water. Fewer H<sub>2</sub>O molecules are ordered, and entropy is increased.



## Micelles

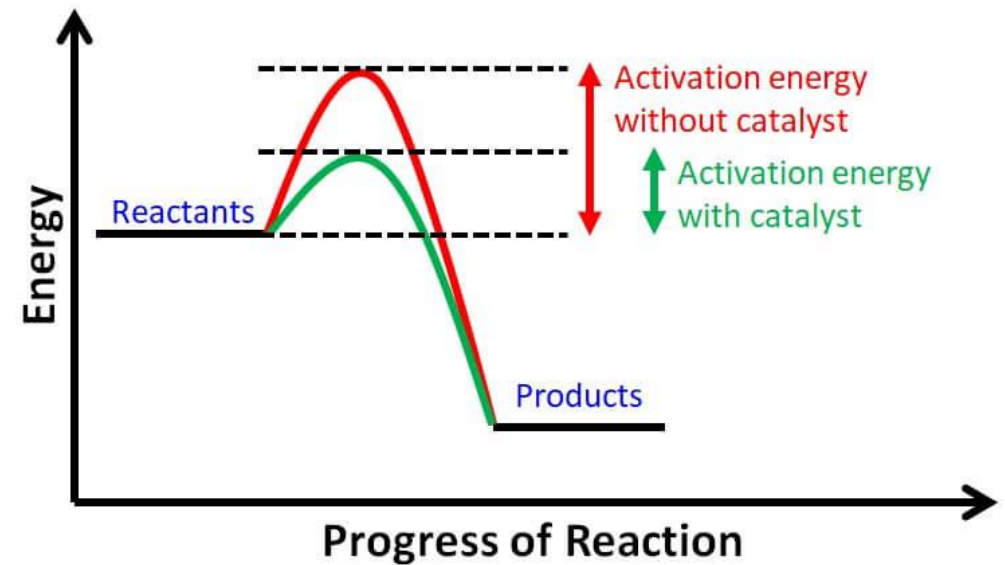
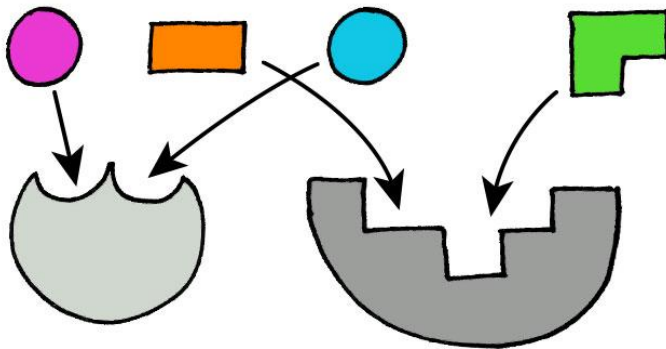
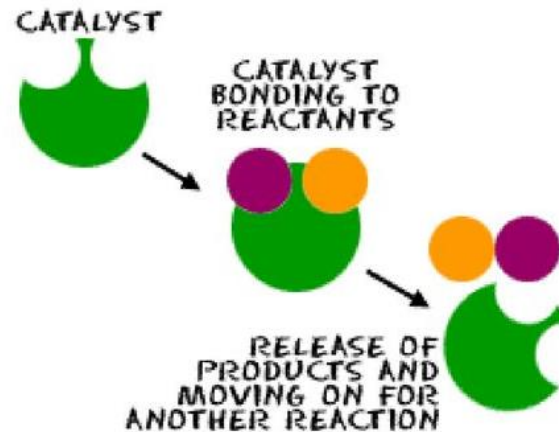
All hydrophobic groups are sequestered from water; ordered shell of H<sub>2</sub>O molecules is minimized, and entropy is further increased.

- The hydrophobic effect, and the term hydrophobic interactions, refers to the entropy-driven aggregation of nonpolar molecules in aqueous solution that occurs to minimize the ordering of water molecules with which they are in contact. This is not an attractive force, but rather a thermodynamically driven process.
- The hydrophobic effect drives the formation of membranes and contributes to the folding of proteins and the formation of double helical DNA.



# What is a **catalyst**?

- A compound that **speeds up the rate of a chemical reaction**, but is not used up in the reaction.
- Can be used over and over



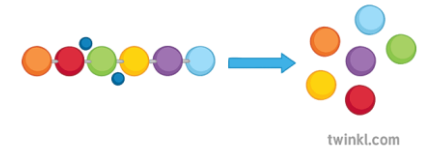
A. Without a catalyst. Note the higher activation energy required for the process to start. Reaction would take longer to form and products would gradually form.

B. With the help of a catalyst, the activation energy required for the reaction goes down significantly. This means the process would go faster and yield more of the products.



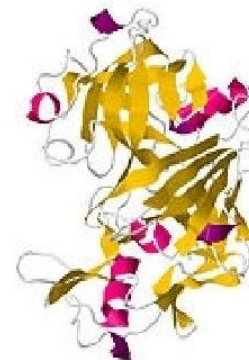
# Examples of Classification of Enzymes

- **Oxidoreductoases**  
oxidases - oxidize , reductases – reduce
- **Transferases**  
transaminases – transfer amino groups  
kinases – transfer phosphate groups
- **Hydrolases**  
proteases - hydrolyze peptide bonds  
lipases – hydrolyze lipid ester bonds
- **Lyases**  
carboxylases – add  $\text{CO}_2$   
hydrolases – add  $\text{H}_2\text{O}$



Enzyme	Reactant	Product
Pepsin	Protein	Short polypeptides
Rennin	Soluble casein (milk protein)	Insoluble casein (curdled milk)

## Rennin (Chymosin)



1. The main proteolytic enzyme found in rennet.
2. It is produced by Infants in the lining of the stomach.
3. It curdles milk, allowing a longer residence in the bowels and better absorption.



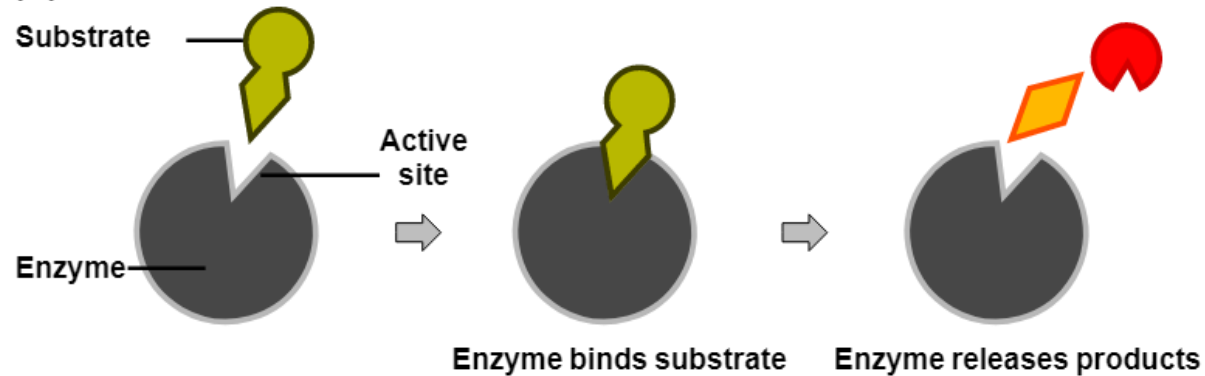
# Enzyme Locations

- Summary of enzymes involved with digestion, what reaction they catalyse and where they are produced: -

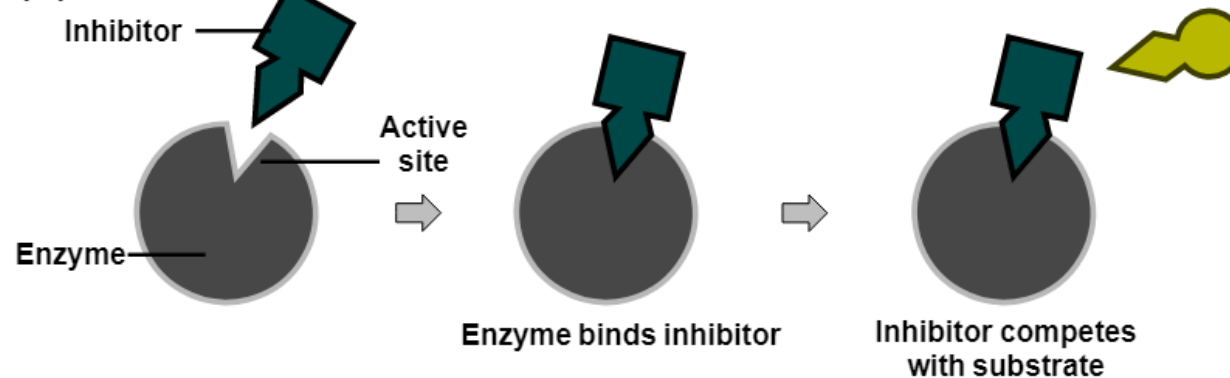
Enzyme	Reaction Catalysed	Location Produced
Amylase	Starch → Sugars	Salivary glands; pancreas; small intestines
Protease	Proteins → Amino Acids	Stomach; pancreas; small intestines
Lipase	Lipids → Fatty Acids + Glycerol	Pancreas; small intestines

# ENZYME INHIBITORS

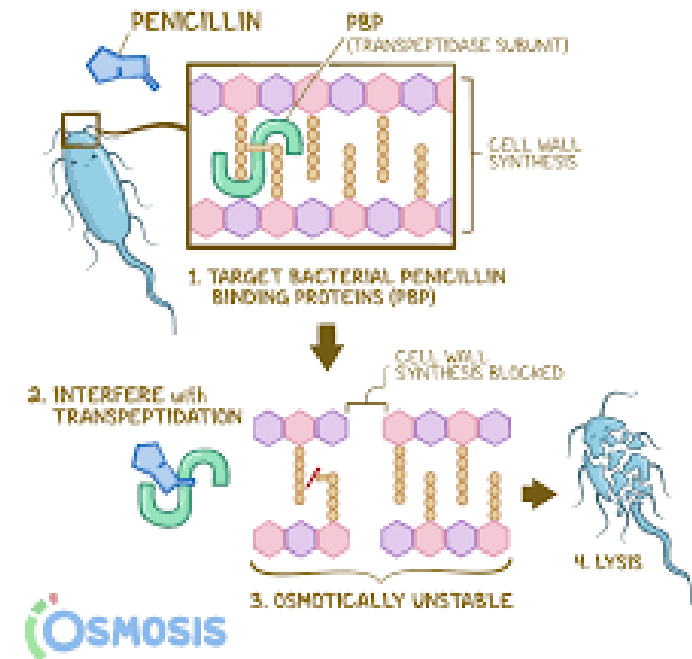
## (a) Reaction



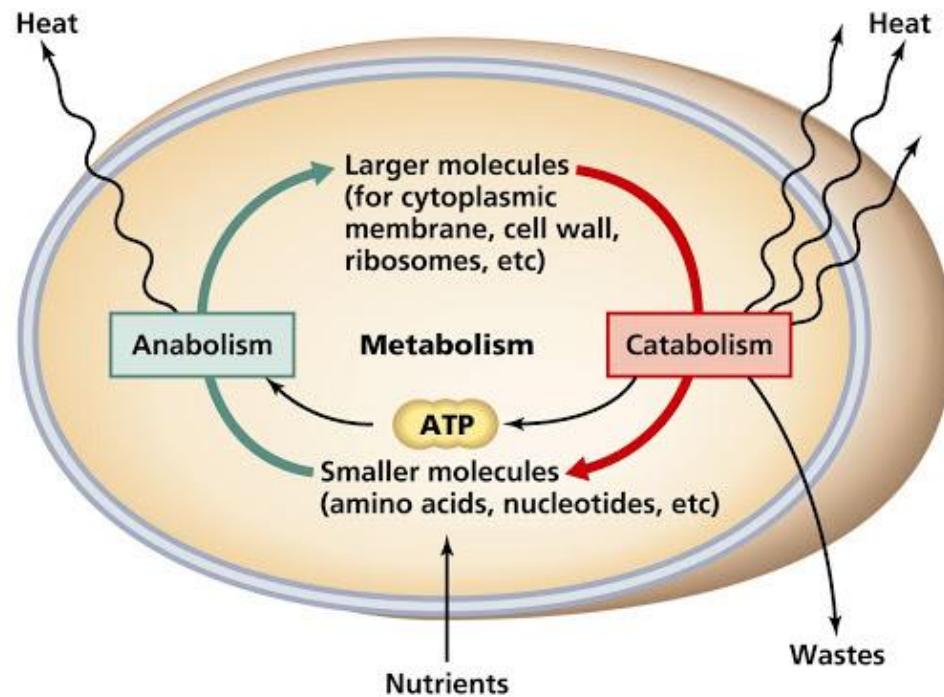
## (b) Inhibition



- Penicillins inhibit a bacterial enzyme called the transpeptidase enzyme which is involved in the synthesis of the bacterial cell wall
- The  $\beta$ -lactam ring is involved in the mechanism of inhibition
- Penicillin becomes covalently linked to the enzyme's active site leading to irreversible inhibition



# METABOLITES



## Primary Metabolites:

Enzymes, Vitamins, Lactic Acid, Proteins, Lipids, Carbohydrates

## Secondary Metabolites:

Steroids, Essential Oils, Pigments, Antibiotics, Flavonoids, Gums/ Latex/ Tannins

The reactants, intermediates and products of metabolic pathways are referred to as metabolites

# SECONDARY METABOLITES

- Also called specialized metabolites, toxins or natural products, are organic compounds produced by bacteria, fungi, or plants which are not directly involved in the normal growth, development, or reproduction of the organism.
- Mediate ecological interactions, which may produce a selective advantage for the organism by increasing its survivability or fecundity.
- Specific within a phylogenetic group.
- Secondary metabolites often play an important role in plant defense against herbivory and infections.
- Humans use secondary metabolites as medicines, flavorings, pigments, and recreational drugs





	Primary Metabolites	Secondary Metabolites
<b>DEFINITION</b>	Primary metabolites are compounds that are essential and directly involved in the growth, development and reproduction of an organism	Secondary metabolites are the end products that are not directly involved in the growth, development and reproduction of an organism
<b>AMONG ORGANISMS</b>	Most primary metabolites are identical among most organisms	Secondary metabolites are numerous and widespread
<b>ORIGIN</b>	Produced during the growth phase of the cell	Produced during the non-growth phase of the cell
<b>QUANTITY</b>	Produced in large quantities	Accumulated by plant cells in very small quantities than primary metabolites
<b>PHASE OF PRODUCTION</b>	The growth phase where primary metabolites are produced is sometimes called 'trophophase'	The phase during which secondary metabolites are made is called 'idiophase'
<b>INVOLVEMENT IN DEFENSE REACTIONS</b>	Do not participate in defense reactions	Most secondary metabolites participate in defense reactions
<b>EXAMPLE</b>	Proteins, carbohydrates, and lipids are the main primary metabolites	Alkaloids, phenolics, sterols, steroids, essential oils and lignins, are several secondary metabolites

# METABOLITES IN USE

## Secondary Metabolites:

Plant-Taxol/ Quinine/ Tannin/ Caffeine/ Nicotine

Bacteria- Botulin

Fungi- Penicillin

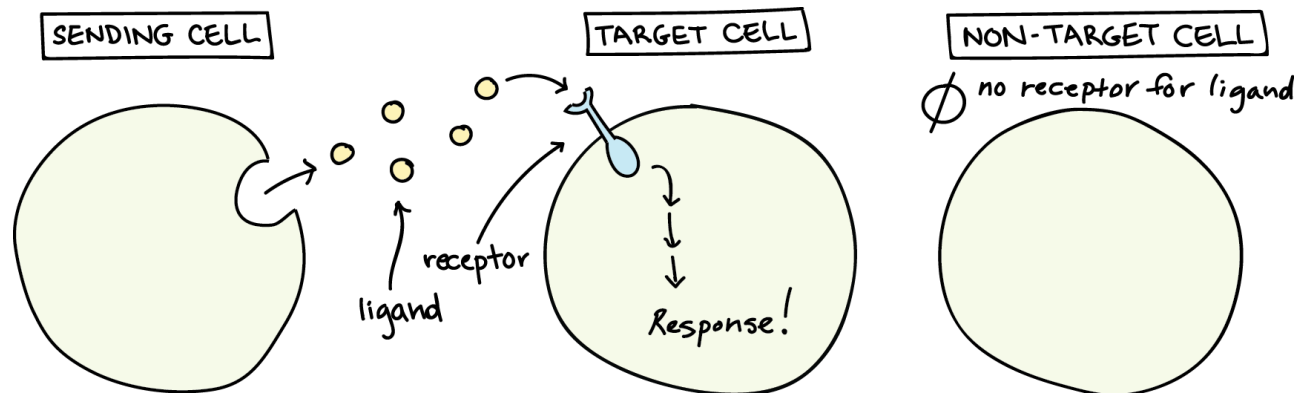
# CELLS TALK IN CODES

Some UNIVERSAL PRINCIPLES of cell communication are now well known

- cells may use many different signal molecules including gas (NO)
- but only a few mechanisms have survived throughout evolution.

In multi-cell organisms cell-to-cell contact is critical.

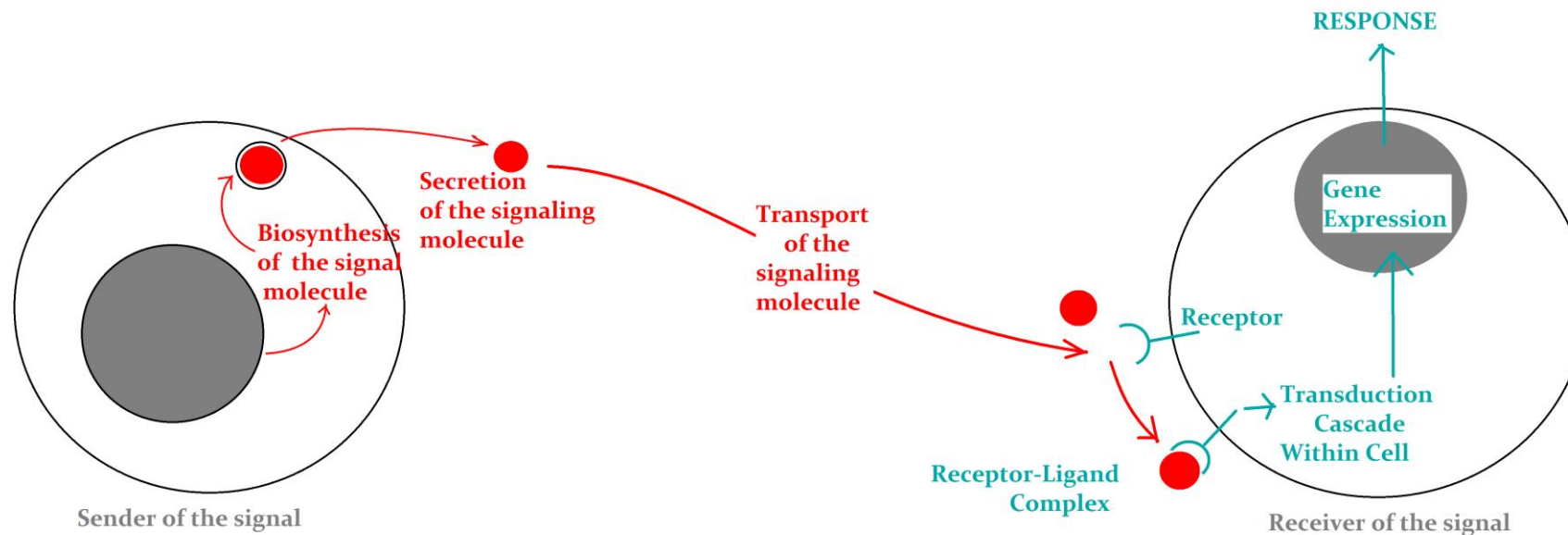
- cell membranes contain specific protein-receptors, which bind & transmit extra-cellular signal molecules converting signals into specific cellular responses.



**Specificity!**

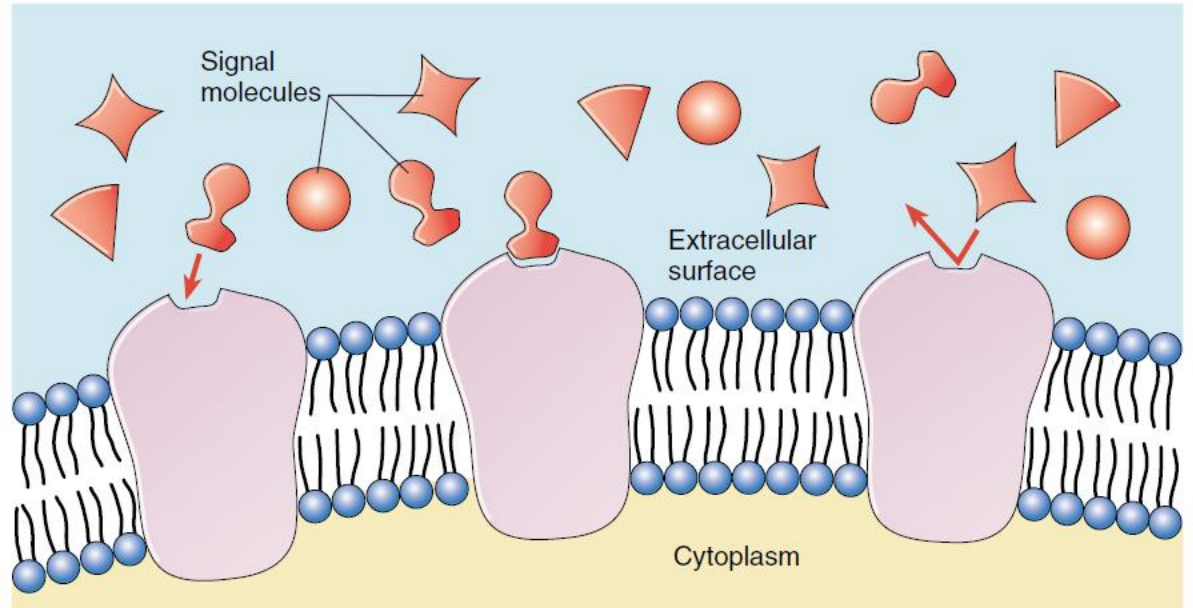
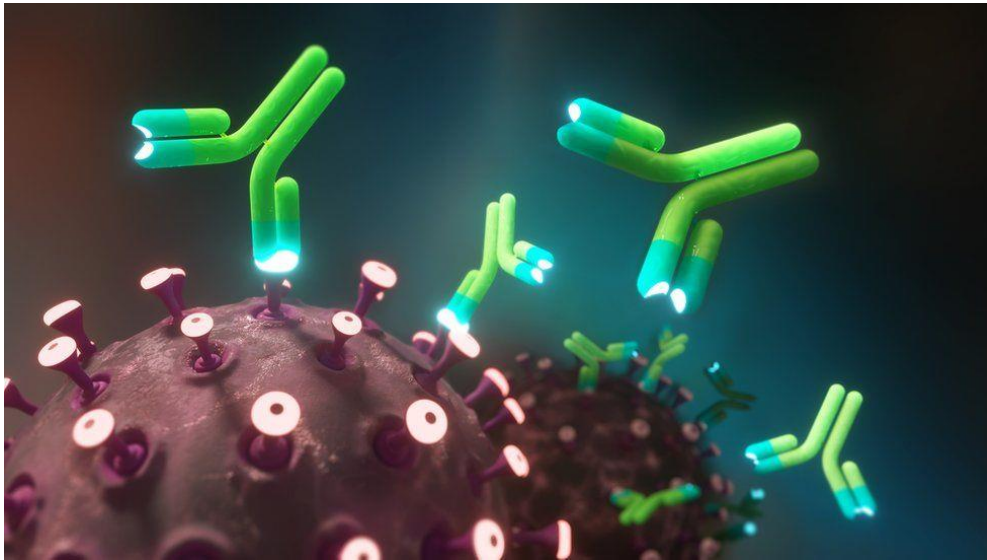
# WHY DO CELLS SIGNAL?

- Regulate gene expression- (Vitamin D, Thyroid)
- Warn of possible infection
- Regulate metabolism
- Allow enzyme secretion in stomach
- Relay messages to-and-from brain-to-body and vice versa
- Fight or flight reaction



# RECEPTORS

- 0.01% of the total mass of protein in a cell
- Search through:
  1. Gene analysis
  2. Monoclonal antibodies



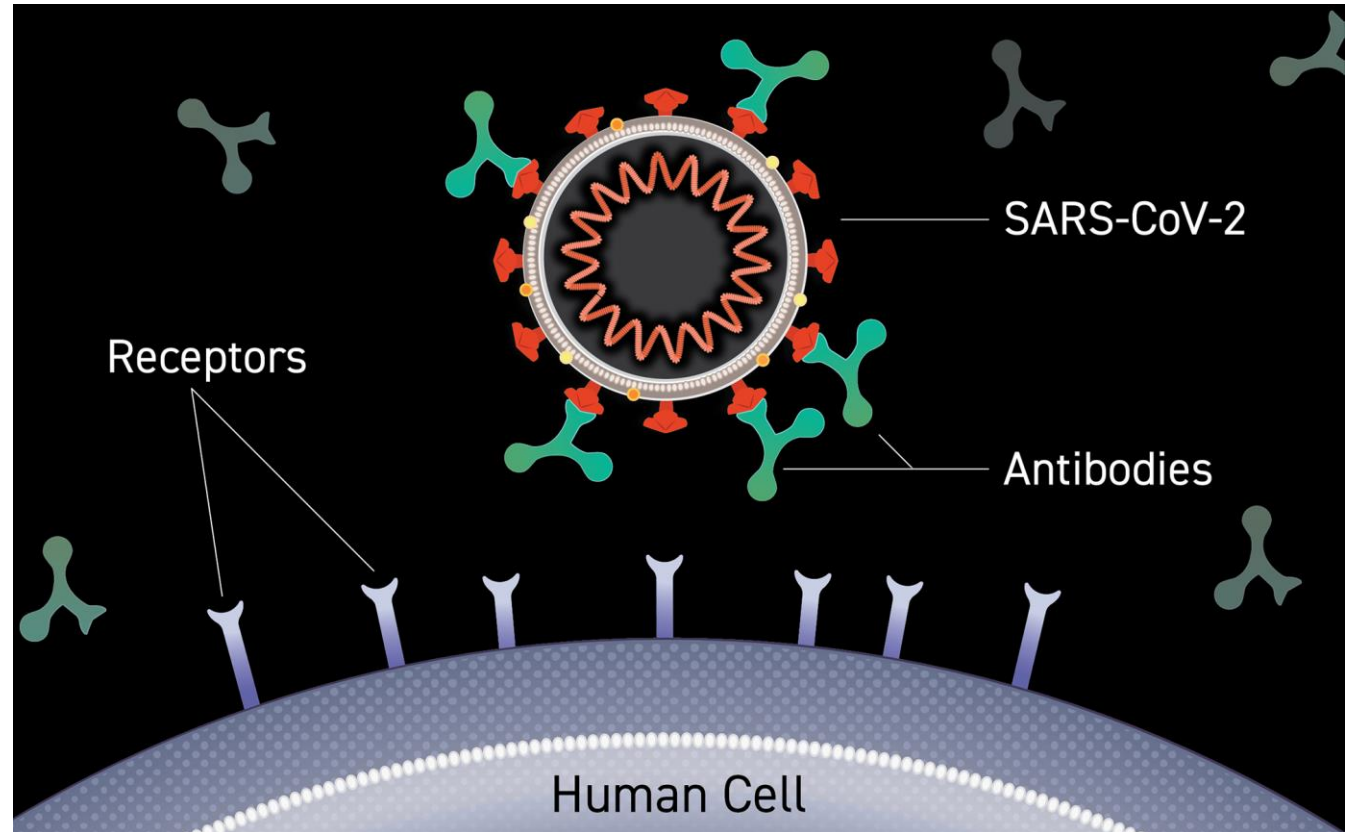
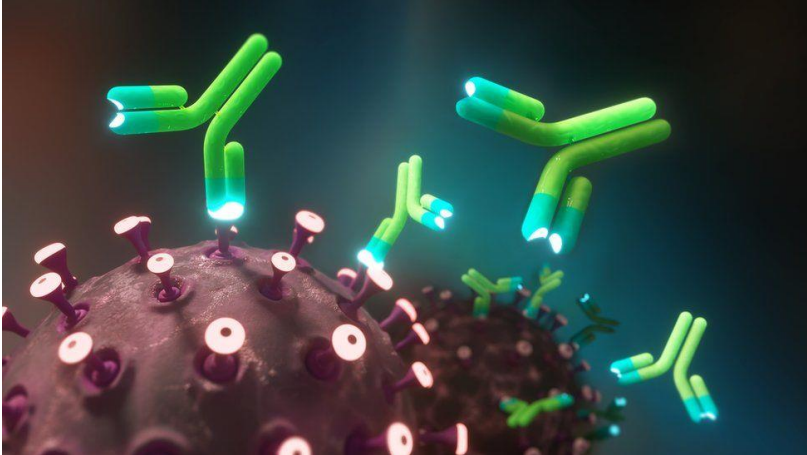
**FIGURE 7.2**

**Cell surface receptors recognize only specific molecules.** Signal molecules will bind only to those cells displaying receptor proteins with a shape into which they can fit snugly.



# RECEPTORS

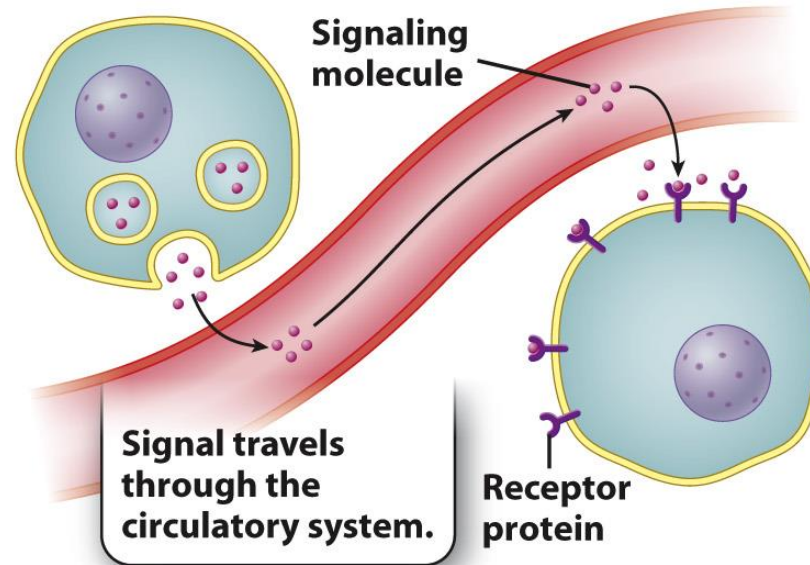
- 0.01% of the total mass of protein in a cell
- Search through:
  1. Gene analysis
  2. Monoclonal antibodies



# CELLS TALK IN CODES

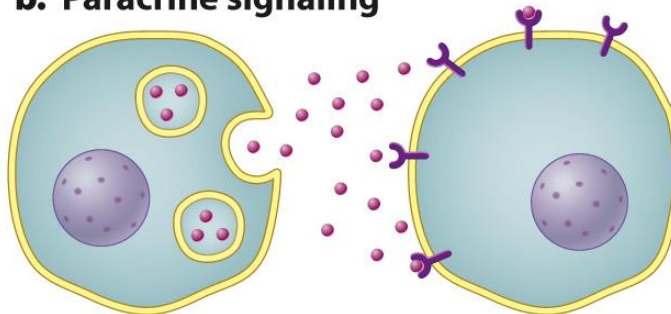
Hormones

a. Endocrine signaling

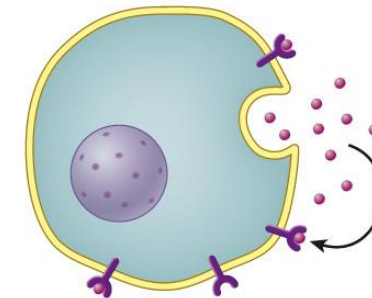


Growth factors/  
Neurotransmitters

b. Paracrine signaling

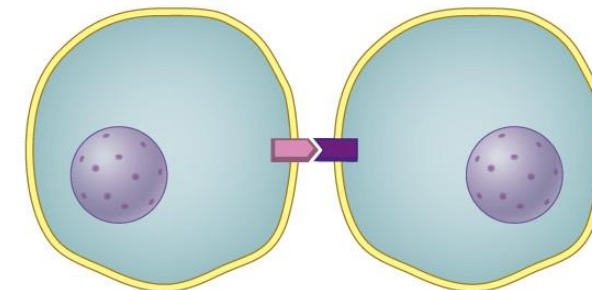


c. Autocrine signaling



Cancer

d. Contact-dependent signaling



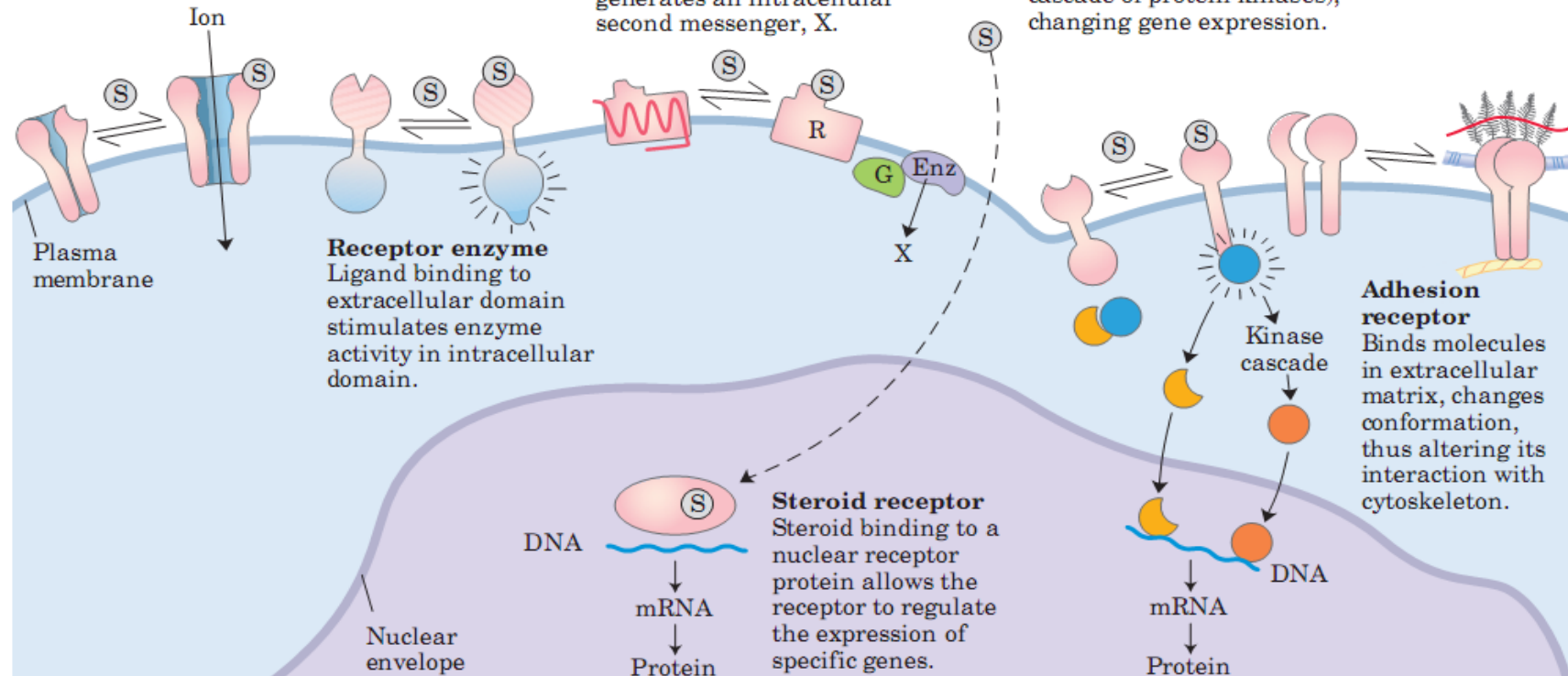
Immune cells  
(T-cell)

# CELL SIGNALLING

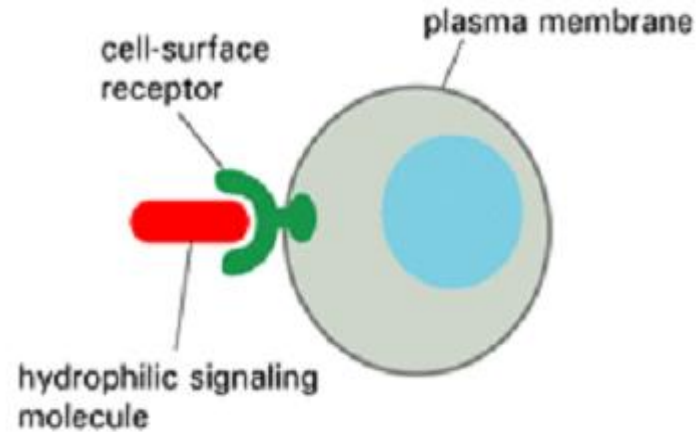
**Gated ion channel**  
Opens or closes in response to concentration of signal ligand (S) or membrane potential.

**Serpentine receptor**  
External ligand binding to receptor (R) activates an intracellular GTP-binding protein (G), which regulates an enzyme (Enz) that generates an intracellular second messenger, X.

**Receptor with no intrinsic enzyme activity**  
Interacts with cytosolic protein kinase, which activates a gene-regulating protein (directly or through a cascade of protein kinases), changing gene expression.



### CELL-SURFACE RECEPTORS



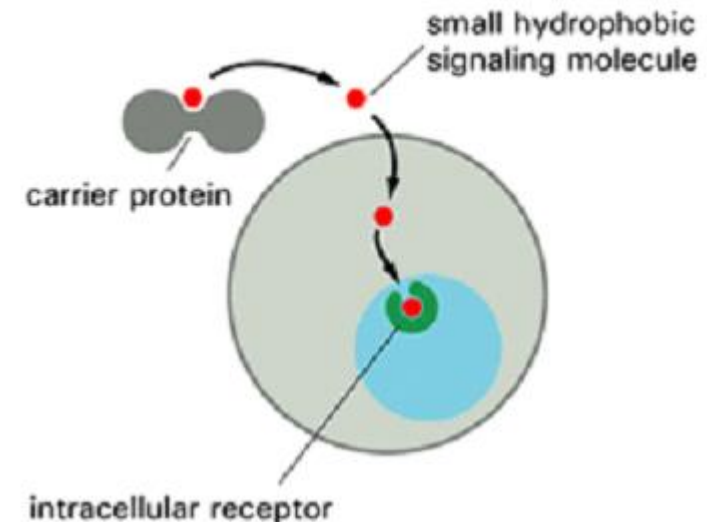
## Extra cellular Hormone

- a) Hydrophilic- Glucagon, Insulin, Epinephrine and Norepinephrine
- b) Lipophilic-
  - 1) Membrane Receptor-Prostaglandins
  - 2) Nuclear Receptor- sex hormones, thyroxine, Vitamin D, Retinoic Acid

## Intra cellular Hormone

- a) Proteinaceous- Kinase, Phosphatase, GTPase switch protein (ras, rab)
- b) Non-proteinaceous (sec. messenger)- cAMP, IP3, DAG, Ca<sup>2+</sup>, Phosphoinoside

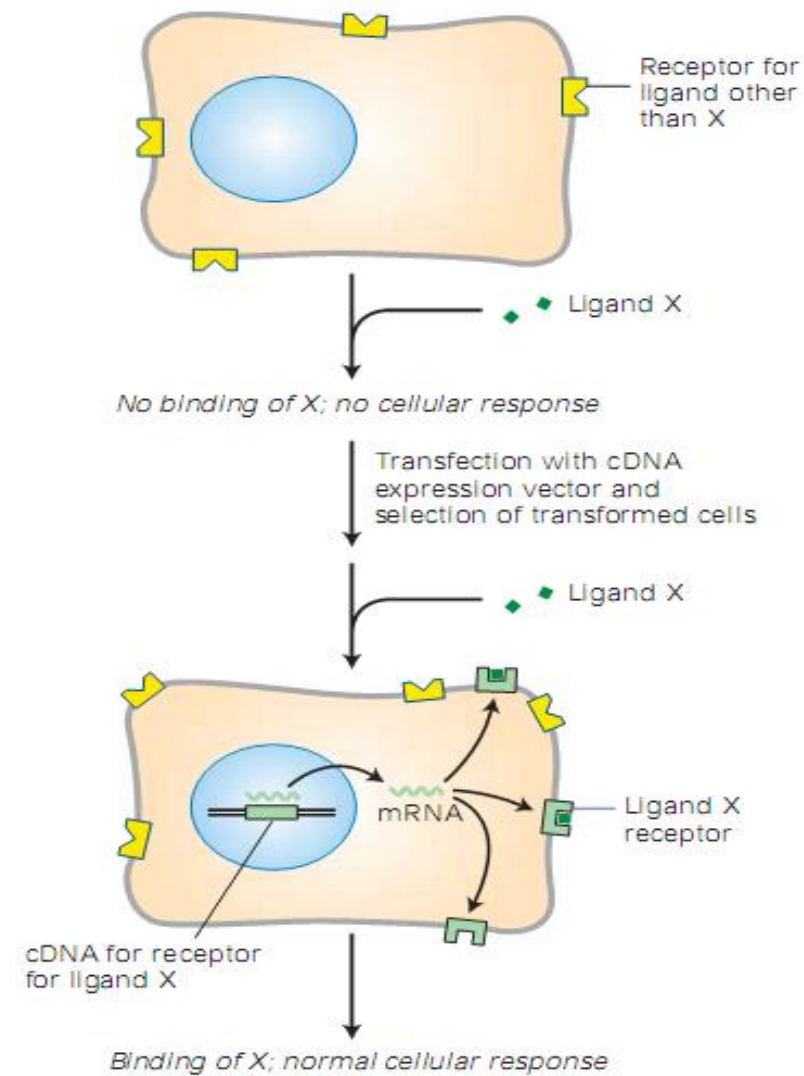
### INTRACELLULAR RECEPTORS



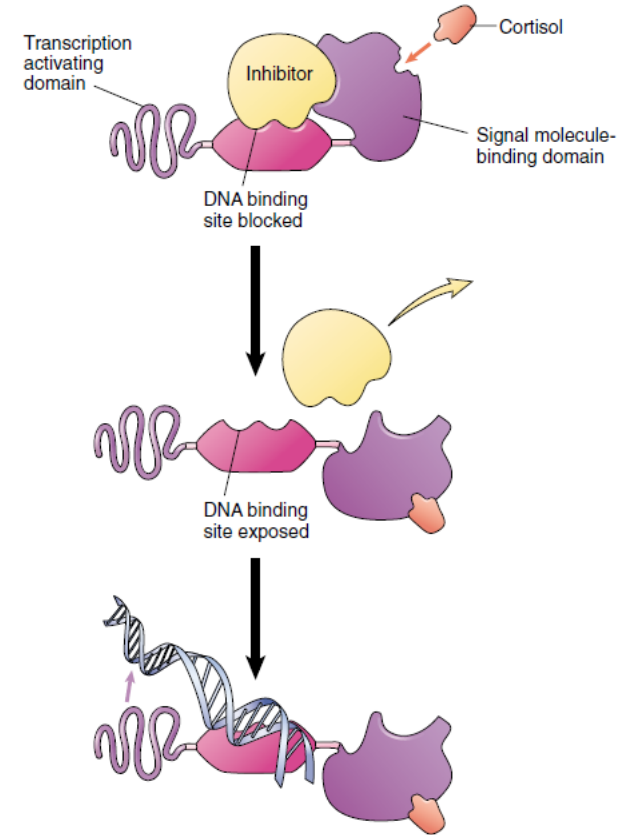


# CELL RECEIVING

- Modulation of the gene activity



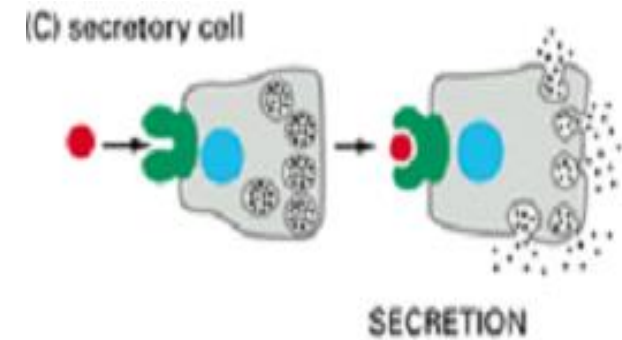
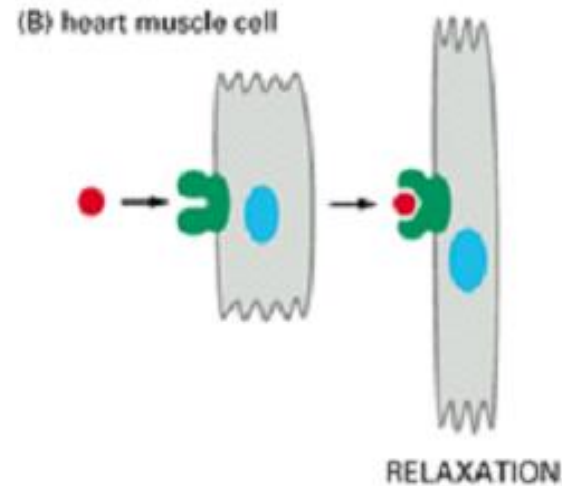
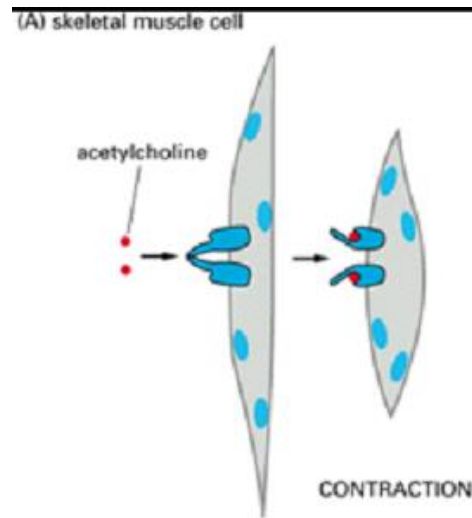
# RECEPTOR COMPLEX



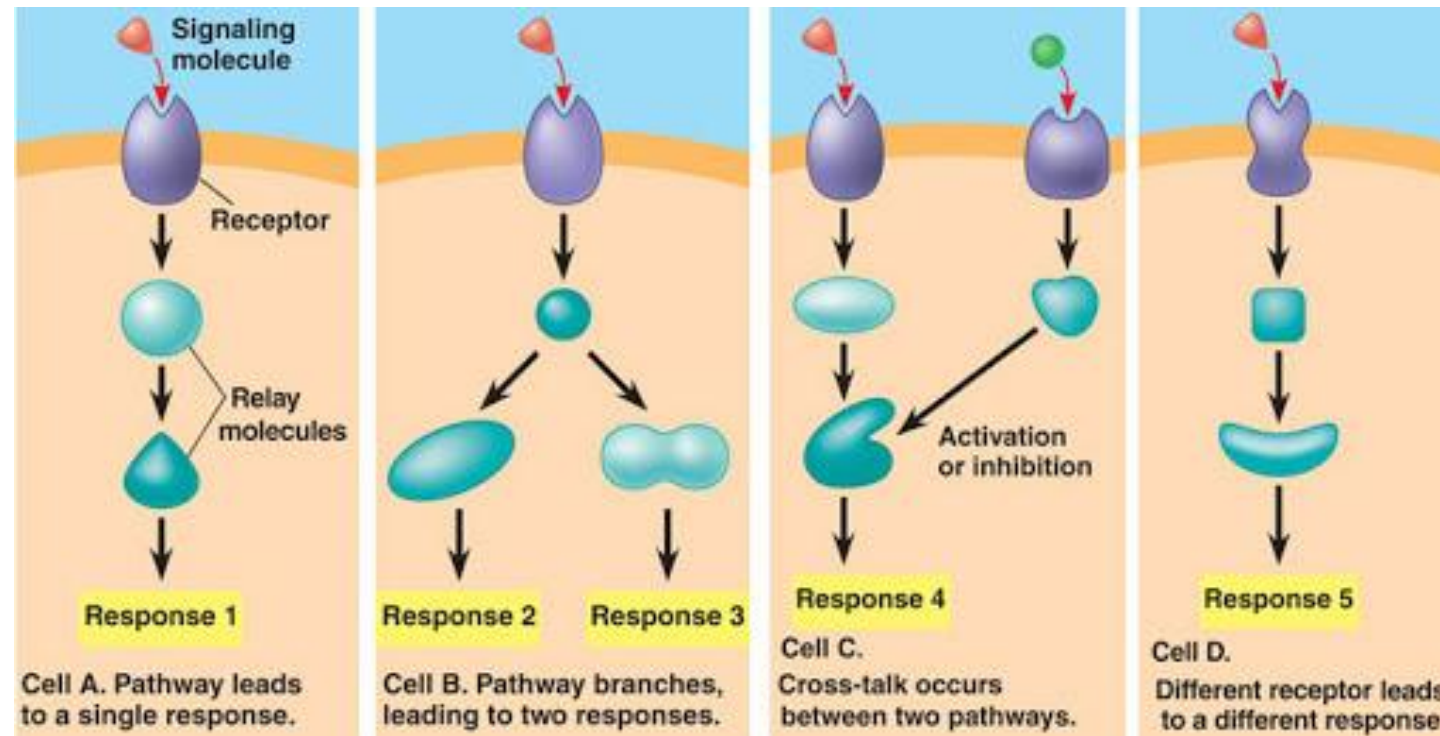
**FIGURE 7.5**

**How intracellular receptors regulate gene transcription.** In this model, the binding of the steroid hormone cortisol to a DNA regulatory protein causes it to alter its shape. The inhibitor is released, exposing the DNA binding site of the regulatory protein. The DNA binds to the site, positioning a specific nucleotide sequence over the transcription activating domain of the receptor and initiating transcription.

# ACETYLCHOLINE AS THE SIGNALING MOLECULE



# PERMUTATION-COMBINATIONS



Group I



# CELL-CELL JUNCTIONS

## Gap Junctions:

- Tube formed between cells
- Facilitates exchange
- Electrochemical signals in cardiac cells and neuron

## Tight Junctions

- Only cells sticking tightly
- Fluid passage
- Intestine and Kidneys

## Plasmodesmata

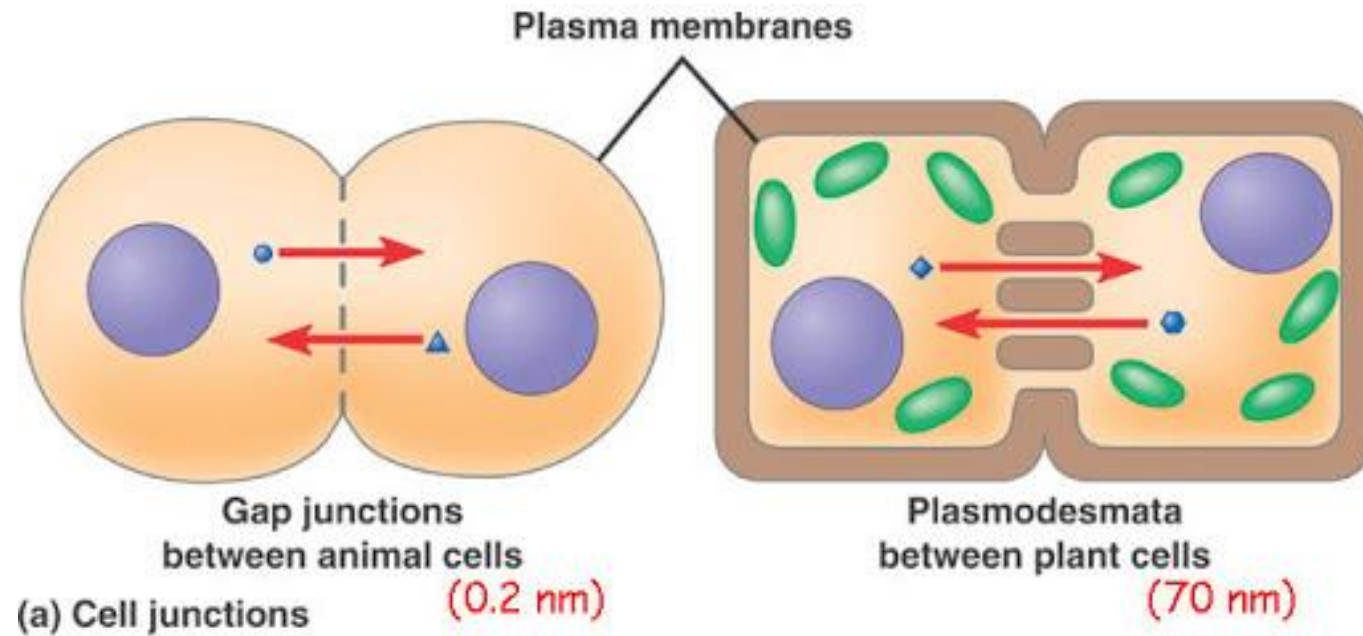
- Cell junction in plants

## TIGHT JUNCTION VERSUS GAP JUNCTION

TIGHT JUNCTION	GAP JUNCTION
A specialized connection of two adjacent animal cell membranes, such that, space usually lying between them is absent	A linkage of two adjacent cells consisting of a system of channels extending across a gap from one cell to the other, allowing the passage
Also known as occluding junctions and zonulae occludentes	Also known as nexus and macula communicans
Occur in the epithelia of vertebrates	Occur in all types of tissues, except in fully-developed skeletal muscles and mobile cells types
Contain plasma membranes, which are very tightly pressed against each other due to bound proteins	Consist of cytoplasmic channels from one to the other cytoplasm, surrounding with membrane proteins
Contain proteins called claudins	Contain proteins called connexins
Regulate the movement of water and solutes between epithelial layers	Allows the direct chemical communication between adjacent cytoplasm
Prevent the leakage of extracellular fluid across the epithelial cell layer	Allow the movement of ions, sugars, amino acids, and other small molecules between cells

Visit [www.PEDIAA.com](http://www.PEDIAA.com)

# CELL-CELL JUNCTIONS



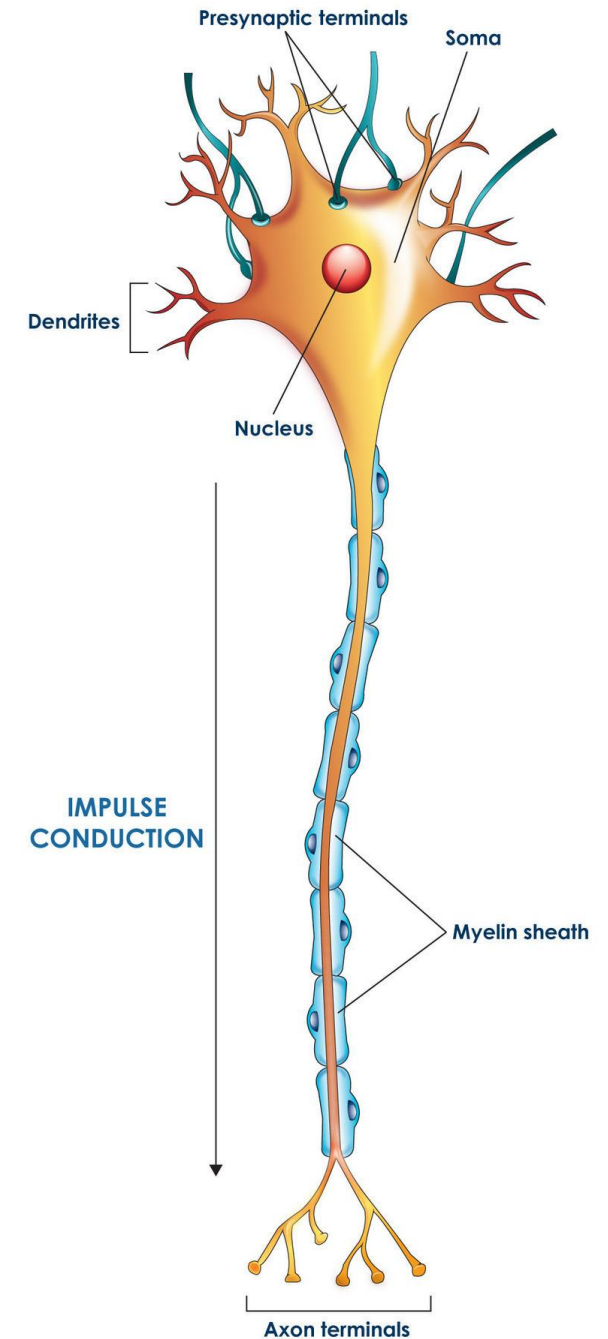
# COMMUNICATION LOSS LEADS TO:

## Multiple Sclerosis

Myelin sheath that protects nerve cells disappears

Brain and spinal cord

Signal do not pass



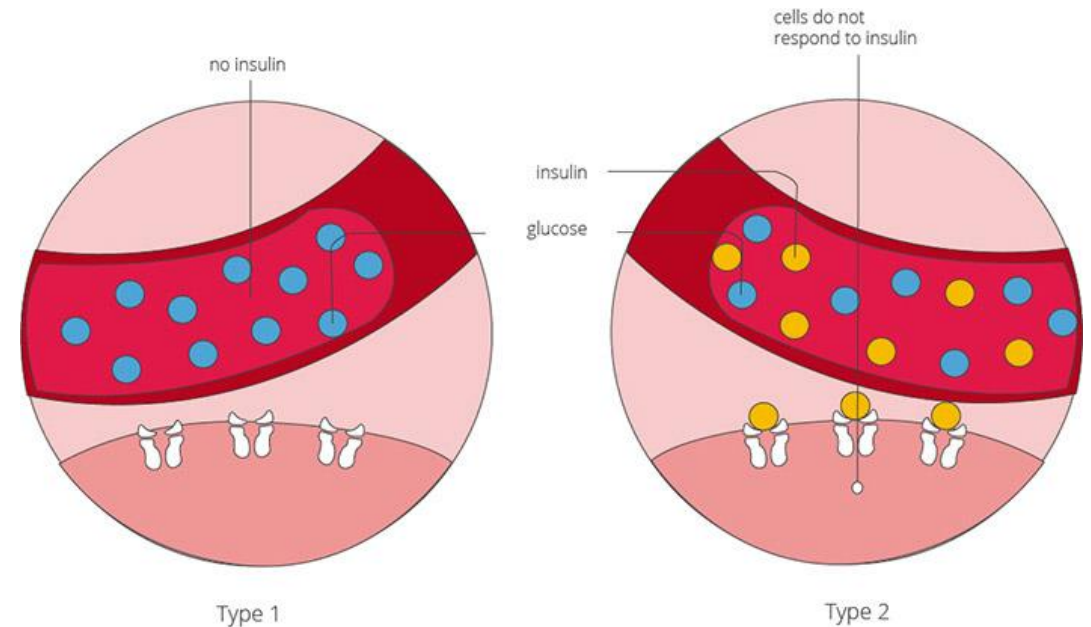
# COMMUNICATION LOSS LEADS TO:

## Diabetes

Target cell receptor not responding to Insulin signal

Diabetes 1- insulin signal is unable to be produced

Diabetes 2- cells have lost the ability to respond to the signals, resulting in abnormally high and dangerous sugar levels in the blood





# COMMUNICATION LOSS LEADS TO:

## **Brain Stroke**

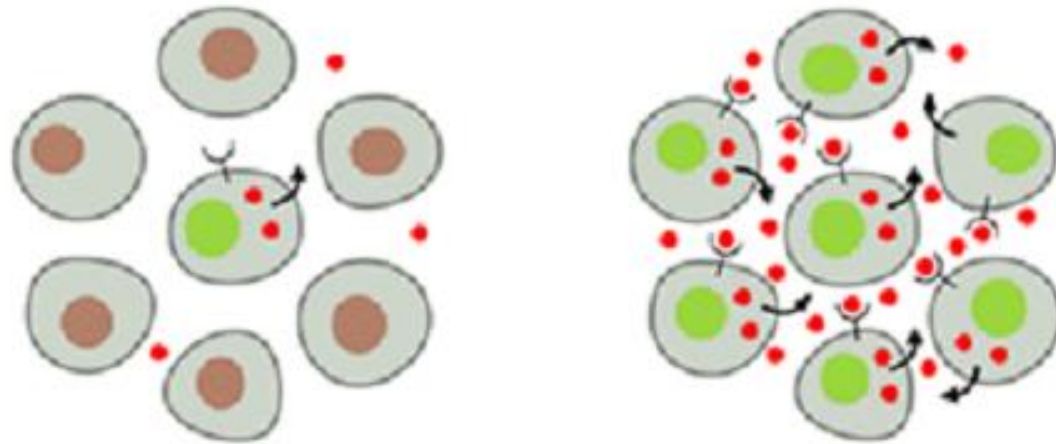
- Abnormally high amount of glutamate secreted by dying brain cells
- Kills healthy brain cells (excitotoxicity)
- Extensive brain damage



# COMMUNICATION LOSS LEADS TO:

## Cancer

Breakdown of multiple signaling pathways  
Uncontrolled proliferation of cells- cancer





The background features a repeating pattern of various business and financial icons. These include calculators, pie charts, dollar bills, coins, lightbulbs, hourglasses, and documents. The icons are drawn in a simple, line-art style with some color accents like yellow, blue, and red.

# Questions?

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