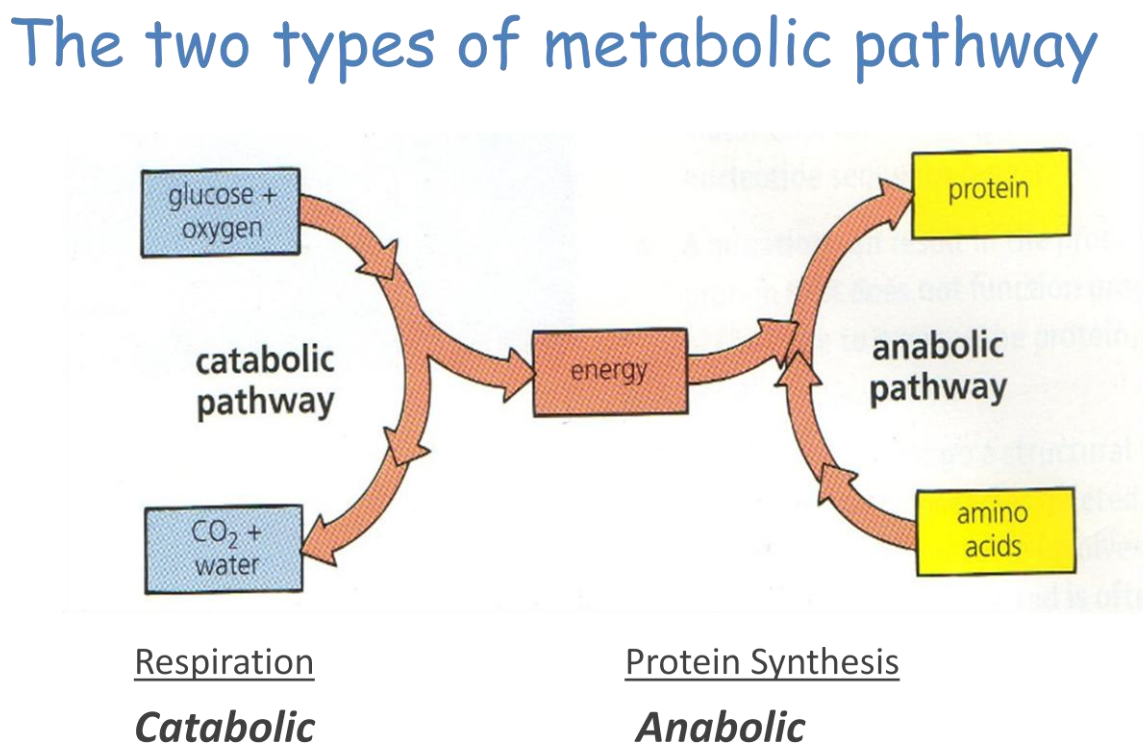
Metabolism and Enzymes

Metabolism – collective term for the Biochemical reactions within a living cell

2 types of metabolic pathways

Catabolic Pathways – breakdown of complex molecules to simpler ones, usually releasing energy (respiration)

Anabolic Pathways – synthesis of complex molecules from simpler ones, usually requiring energy



Metabolic pathways are regulated by enzymes - a pathway often contains both reversible and irreversible steps

In this summary of glycolysis, the reaction involving enzyme B is reversible

Glucose – enzyme A → intermediate 1 – enzyme B → intermediate 2 – enzyme C → intermediate 3 → pyruvate

If more intermediate 2 is made than the cell requires for the next step then some can be converted into back to intermediate 1 and used to build glycogen or starch

Conversion of int. 2 to int. 3 is irreversible and is a key regulatory point, no going back!

Example of reversible/ irreversible pathways

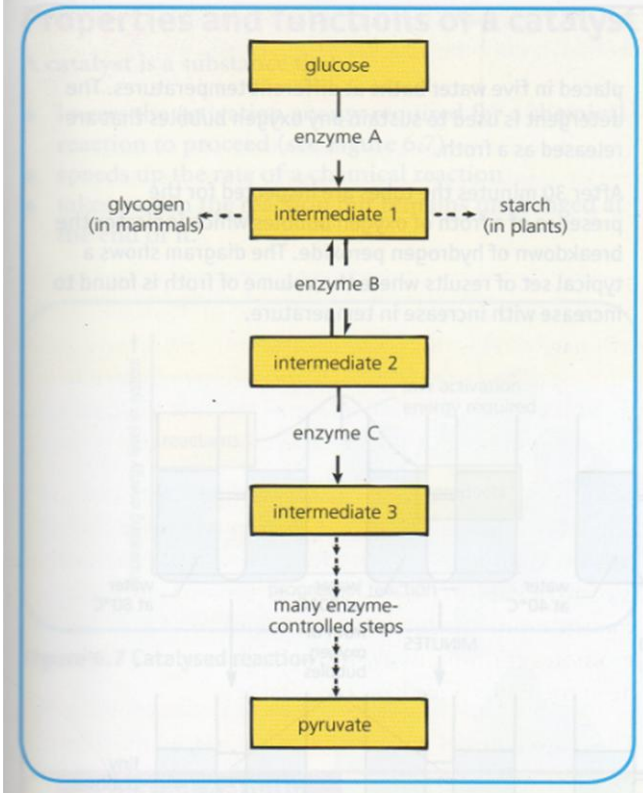


Figure 6.2 Example of a metabolic pathway

Example of alternative routes in metabolism, this allows steps to be by passed

A by pass is used, here, when cell has plentiful supply of glucose

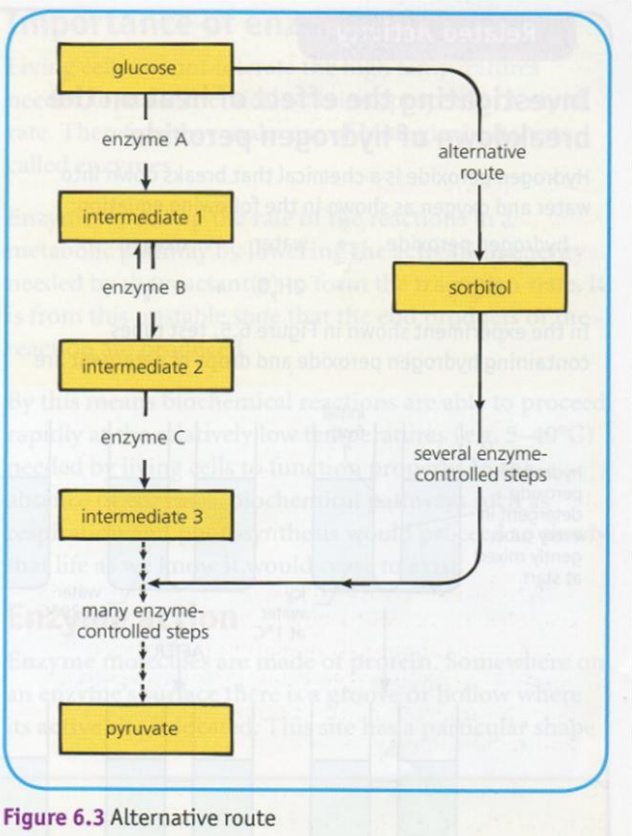


Figure 6.3 Alternative route

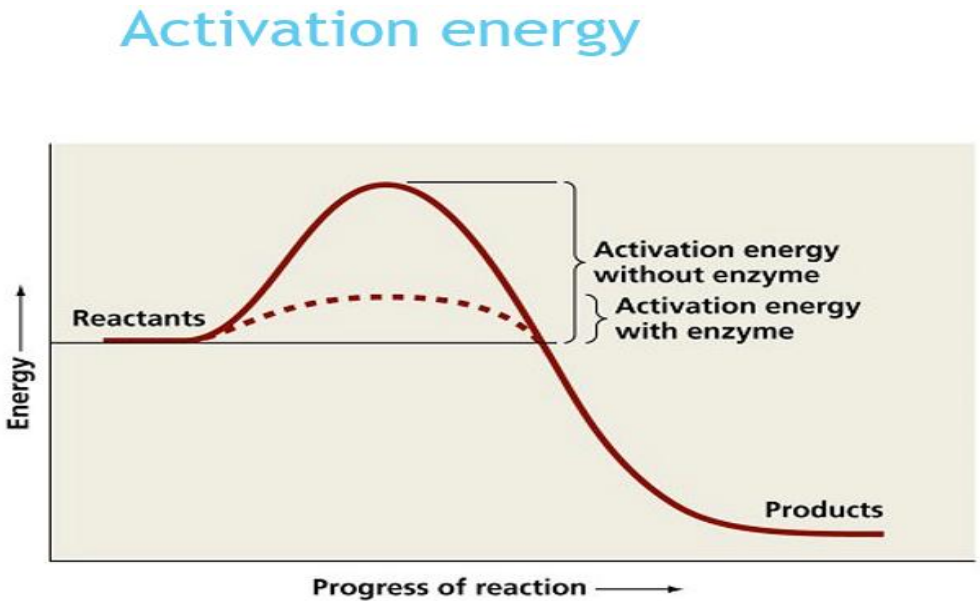
Properties and functions of a Catalyst

Catalyst

- Lowers activation energy (energy needed to break chemical bonds in reactant chemicals)
- Speeds up the rate of a chemical reaction
- Remains unchanged at the end of a reaction

Enzymes

- Are biological catalysts
- Speed up the rate of reaction by lowering the activation energy
- As a result, reactions are able to proceed rapidly at relatively low temperatures (5-40 C)



- Enzymes are made of protein
- The active site is located on the enzyme surface, it has a particular shape
- Enzymes are substrate specific
- Substrate molecules exactly fit the enzyme's active site
- Molecules of substrate are complementary to the enzyme active site

Induced fit

Active site is flexible, not a rigid structure

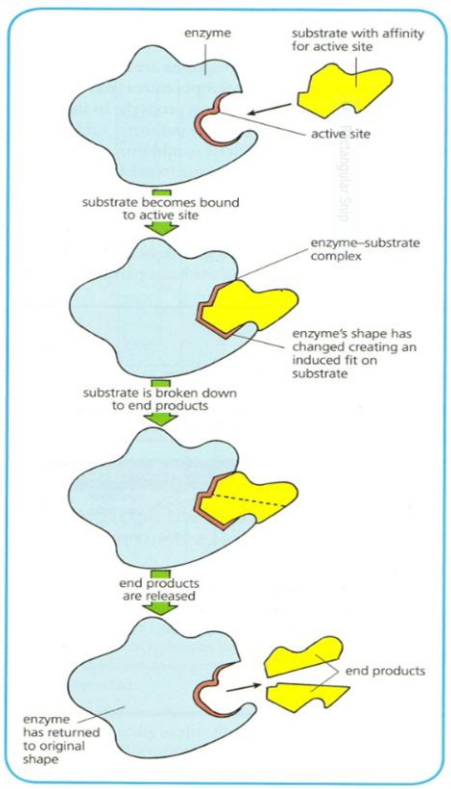


Figure 6.9 Induced fit during an enzyme-catalysed reaction

This induced fit increases the chance of a reaction taking place by . . . .

When a substrate molecule enters the active site, the shape of both changes slightly

This makes the active site fit very closely round the substrate – this is called 'induced fit'

Induced fit ensures active site comes into very close contact with substrate and this increases the chance of a reaction taking place

<u>Orientation</u>
When reaction involves two or more substrates the shape of the active site determines the orientation of the reactants so that the reaction between them can take place

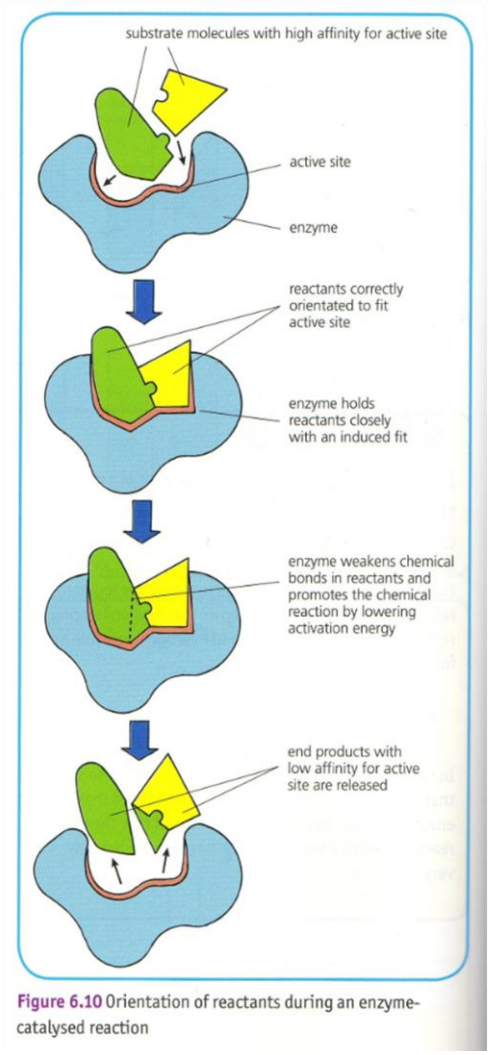


Figure 6.10 Orientation of reactants during an enzyme-catalysed reaction

. . . . . orientating the substrates into the best position to react.

Factors affecting enzyme action

1. Suitable temperature
2. Appropriate pH
3. Adequate supply of substrate
4. Inhibitors may slow down rate of reaction

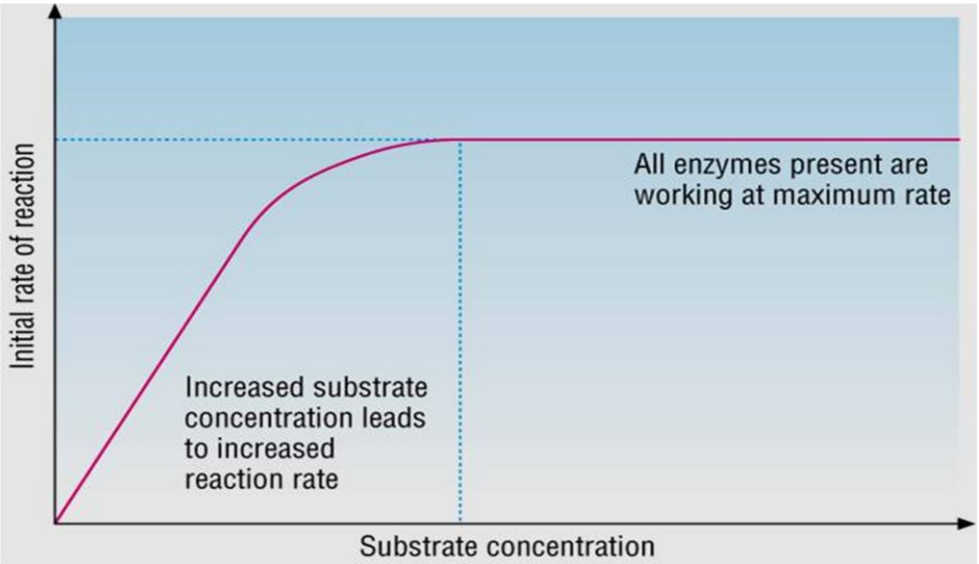
<u>Low concentration of substrate</u>

- Reaction rate low
- Too few substrate molecules to make use of all the active sites

<u>Increase in substrate concentration</u> – See graph on next page

- More active sites become involved
- Increase in reaction rate
- Further increase in substrate concentration fails to make reaction go faster
- At this point <u>all</u> active sites are occupied
- Graph levels off, more substrate molecules than free active sites

The effect of increasing substrate concentration.



Inhibitors

An inhibitor is a substance that decreases the rate of an enzyme – controlled reaction

2 types of inhibitor :-

- Competitive inhibitor
- Non-competitive inhibitor

Competitive inhibitors

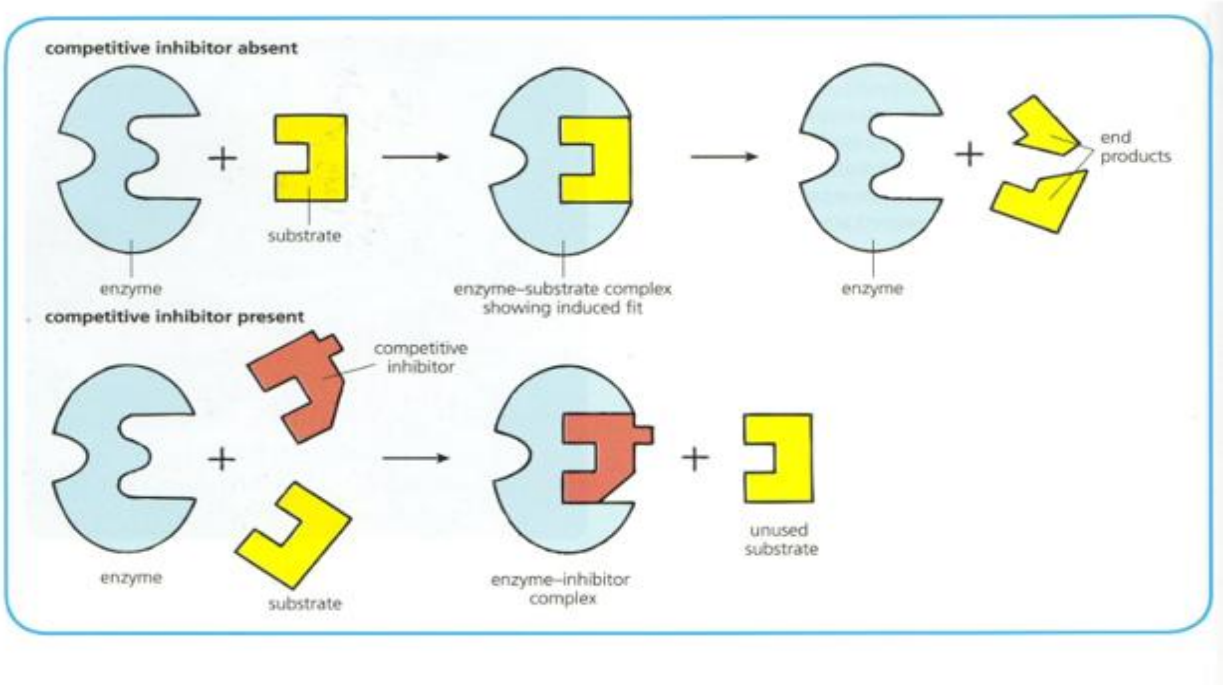
Compete with molecules of the substrate for active sites on the enzyme

The molecule structure of the inhibitor is similar to the substrate

Since active sites are blocked by the competitive inhibitor they cannot be occupied by substrate molecules

As a result, the rate of reaction is reduced

Competitive inhibitors



Non-competitive inhibitor

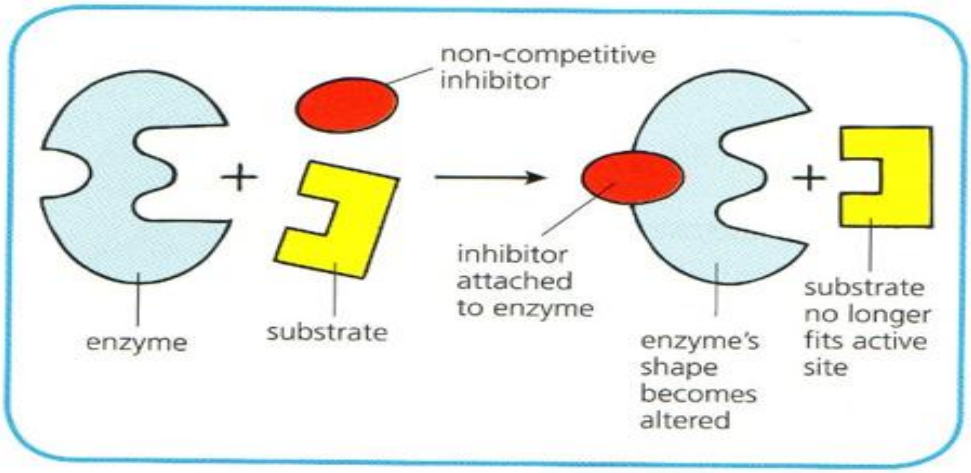
Does not combine directly with an enzymes active site

Instead, it becomes attached to a non-active, allosteric, site and changes the shape of the molecule

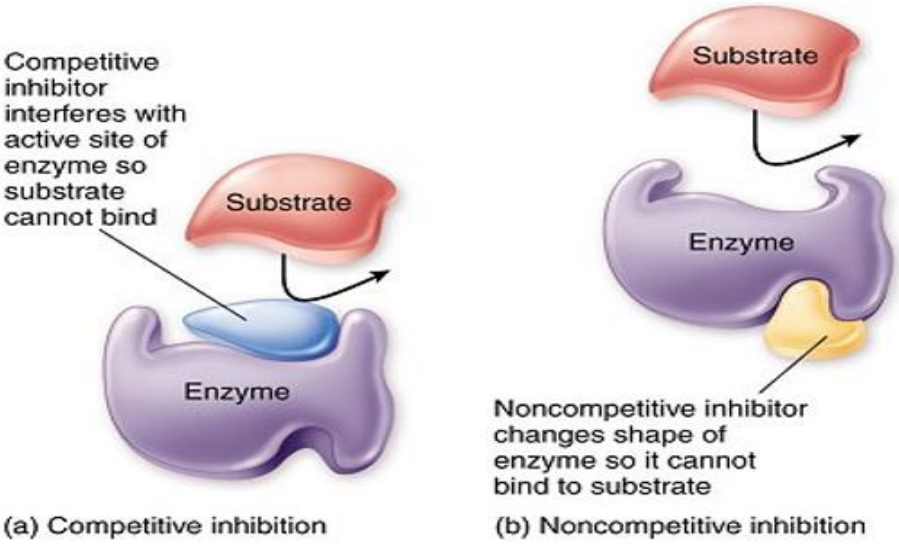
This results in active sites being altered indirectly

The larger the number of enzyme molecules affected the slower the reaction – therefore, the non competitive inhibitor acts as a type of regulator

Non - competitive inhibitors



Competitive and non-competitive inhibitors summary



Allosteric Enzymes and Regulatory Molecules

Some enzyme molecules are composed of several polypeptide subunits and each subunit has its own active site

The enzymes also has several allosteric, non-active sites

The enzyme may exist as an ‘active’ form or an ‘inactive’ form

The enzyme molecule changes shape if a ‘regulatory molecule’ binds to one of its allosteric sites

Regulatory molecules

A regulatory molecule can be an ‘activator’ (an allosteric activator) or a ‘non-competitive inhibitor’ (an allosteric inhibitor)

If the regulatory molecule is an ‘activator’ then the enzyme adopts its active form

If the regulatory molecule is an ‘inhibitor’ the enzyme changes to its inactive state and enzyme action is inhibited

End Product Inhibition

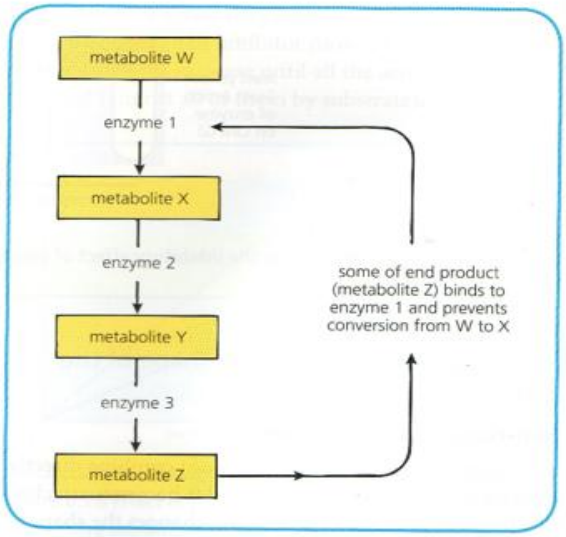
End product inhibition is a final way that enzyme reaction can be ‘fine tuned

Look at the diagram below and you will see :-

- As the concentration of the end product, metabolite Z, builds up some of it binds to molecules of enzyme 1
- This slows down the conversion of W to X and in turn regulates the whole pathway
- As the concentration of Z drops, fewer molecules of enzyme 1 are affected and more of W is converted to X and so on
- The pathway is kept under finely tuned control - negative feedback

Feedback (end product) inhibition

A third type of inhibition occurs when an end product binds to an enzyme that catalyses a reaction early in the pathway.



Controlling Metabolic Pathways through Gene Action

Gene action in Escherichia coli

Each step in a metabolic pathway is driven by a specific enzyme, and each enzyme is coded for by a gene

To prevent resources being wasted, genes that code for enzymes controlling each stage in a metabolic pathway are 'switched on' or 'switched off' when required

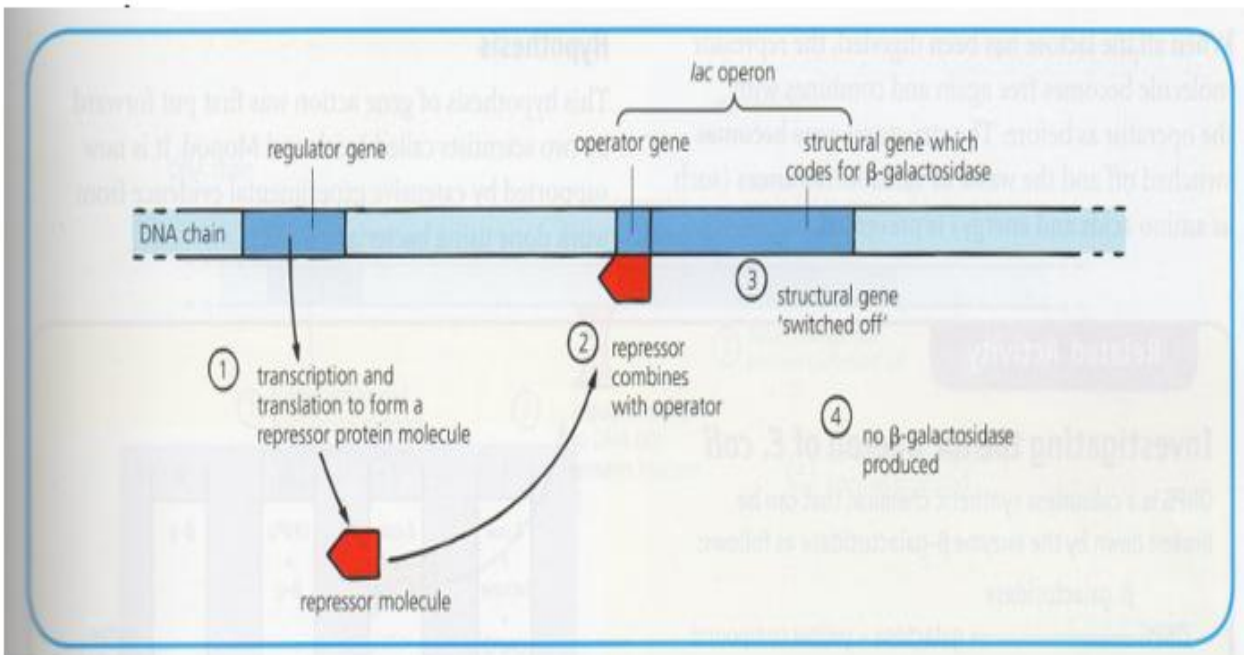
Background to gene action in E. Coli

- Lactose is composed of glucose + galactose
- E. coli uses glucose for energy
- Lactose is broken down to glucose + galactose by the enzyme B-galactosidase
- E. coli's chromosome has a gene that codes for the enzyme
- Gene 'switched on' in the presence of lactose

Process of switching on a gene only when the enzyme is needed is called 'enzyme induction'

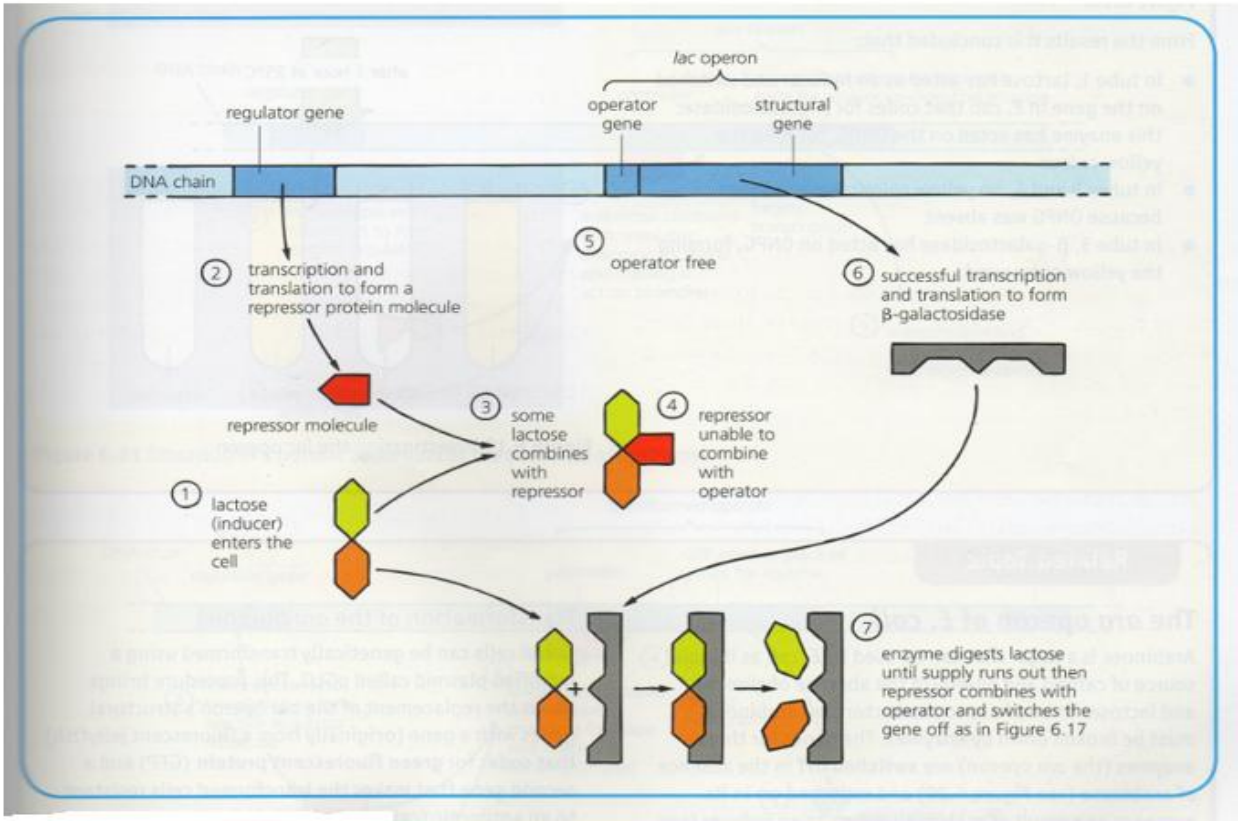
Absence of lactose

1. Regulator gene brings about the transcription and translation of a repressor molecule
2. Repressor combines with the operator gene
3. Operator gene is not free to switch on the structural gene
4. Structural gene is 'off' so no enzyme is made



Effect of inducer, lactose

1. Some lactose combines with the repressor molecule
2. Repressor cannot combine with the operator gene
3. System is no longer blocked
4. Structural gene is able to make the enzyme B-galactosidase
5. The enzyme breaks down lactose



Some metabolic pathways , glycolysis, are required to operate continuously

Genes that code for the enzymes are always switched on

Signal molecules

The activation of some enzymes is controlled by signal molecules.

In the Lac operon system the signal molecule is lactose sugar

It combines with the repressor molecule, allowing the structural gene for B – galactosidase to be expressed

Signal molecules that effect a cell's metabolism and originate from outwith the cell (e.g. lactose) are called **'extracellular** signal molecules'

Hormones such as adrenaline are also examples of extracellular signal molecules

It triggers a series of events in the liver to activate an enzyme that converts glycogen to glucose when energy is needed urgently

Molecules that effect a cell's metabolism and originate from inside the cell itself are called **'intracellular** signal molecules'