# HL IB Biology

Your notes

## Chemical Signalling

### Contents

# Cell Signalling (HL)

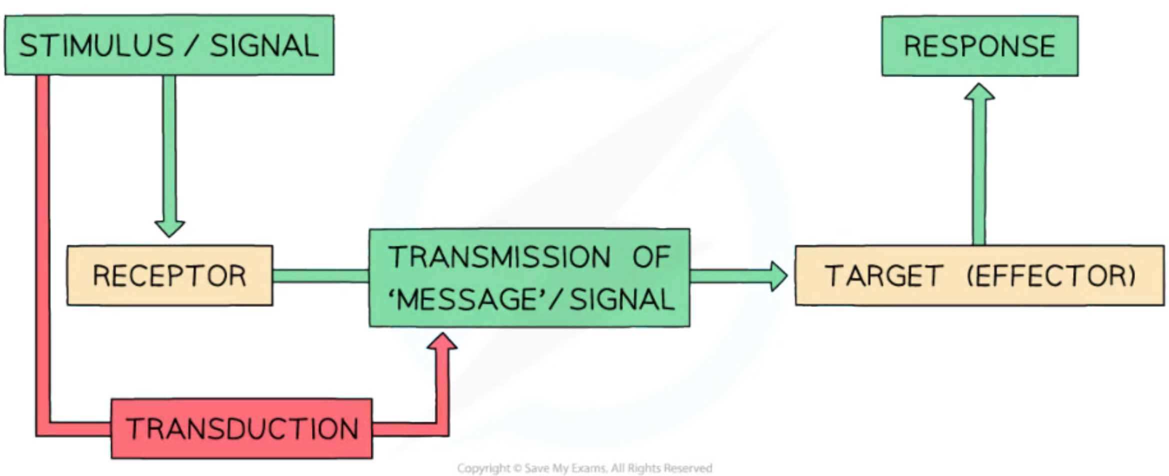
Your notes

## Receptors & Ligands

### Cell signalling

- Cell signalling is the process by which messages are sent to cells
- Cell signalling is very important as it **allows multicellular organisms to control and coordinate their bodies** and **respond to their environments**
- Cell signalling pathways coordinate the activities of cells, even if they are far apart within the organism
- The basic stages of a cell signalling pathway are:
  - A stimulus or signal is received by a receptor
  - The signal is converted to a signal that can be passed on – this process is known as **transduction**
  - The signal is transmitted to a target (effector)
  - An appropriate response is made

**Cell signalling diagram**




***Cells signalling involves the detection of a stimulus by a receptor, the transmission of a signal, and the response of an effector***

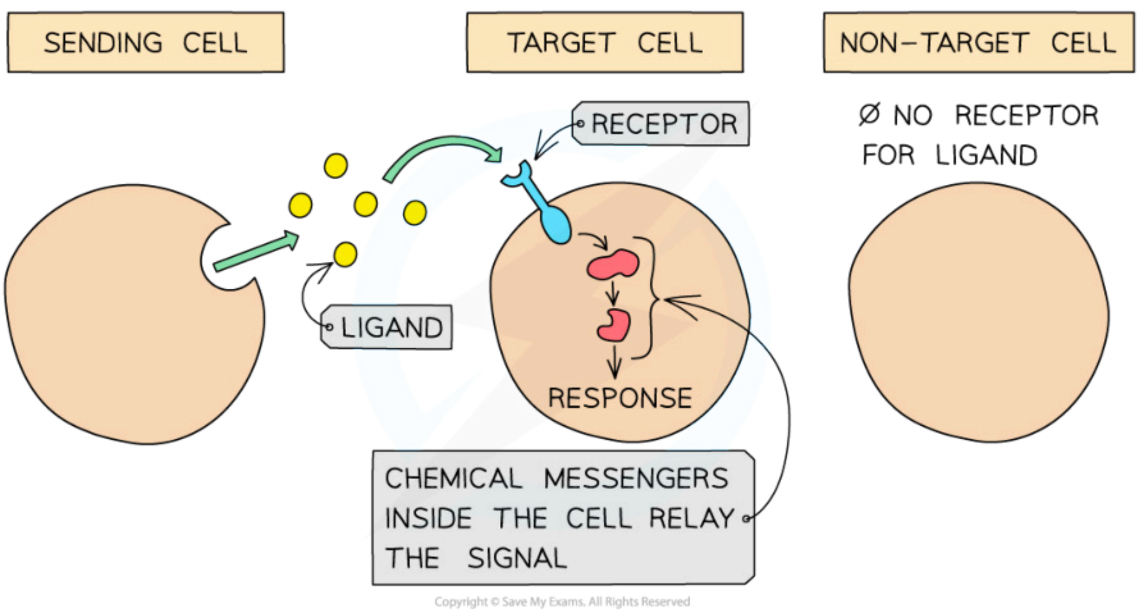
### Ligands

- Signalling molecules are often called ligands
- Examples of ligands include:
  - Proteins and amino acids
  - Nucleotides
  - Steroids
  - Amines
- Ligands are involved in the following stages of a cell signalling pathway:
  - Ligands are **secreted** from a cell (the sending cell) into the extracellular space

- The ligands are then **transported** through the extracellular space to a **target cell**
- The ligands **bind to surface receptors** (specific to that ligand) on the target cell
  - These receptors may be proteins with binding sites, e.g. a glycoprotein
- The message carried by the ligand is relayed through a **chain of chemical messengers inside the cell**, triggering a **response**

Your notes

**Ligand binding diagram**




***Ligands bind to specific binding sites, initiating a response inside the cell***

Your notes

## Cell Signalling: Quorum Sensing in Bacteria

- Bacteria communicate with each other using ligands
- This allows a bacterial colony to respond to changes in population size by altering **gene expression**
- The term **quorum sensing** has been applied to this concept as it suggests that a bacterial colony will monitor its size to assess when a threshold has been reached
  - The term quorum is used to describe the minimum number of individuals who much be present for a process to take place
- It works through the following mechanism:
  - **Ligands** released by bacteria bind to **receptors** on the surface of other bacteria
  - The **more bacteria** are present in a population, the **more ligands** are released
  - When a **threshold** number of receptors are occupied, a **change in gene expression** is triggered
  - A change in gene expression leads to a **change in activity** which signals that a quorum has been met in the bacterial colony

### *Vibrio fischeri*

- ***Vibrio fischeri*** is a species of bacterium found in marine environments, where they form mutualistic associations with some species of squid, e.g. the bobtail squid
  - The benefit to the squid is increased **camouflage**
    - The bacteria emit light by bioluminescence, lighting up the underside of the squid and making it less visible against the bright sky from underneath
  - The benefit to the bacterial colony is the provision of **amino acids** and **sugar** from the squid's metabolic processes
- Vibrio fischeri enable the squid to **produce light by bioluminescence** as follows:
  - *Vibrio fischeri* colonise a structure inside the squid called the light organ and release a **ligand** called an **autoinducer** into the extracellular environment
    - The more bacteria are present, the more autoinducer is released
  - The autoinducer enters other bacterial cells and binds to a receptor called **LuxR** in the cytoplasm
  - When enough **autoinducer-LuxR complexes** have formed, a **threshold** is reached, resulting in **transcription of DNA** that leads to the synthesis of the **enzyme luciferase**
  - Luciferase catalyses an **oxidation** reaction which **releases energy** as **bioluminescence**
- Production of bioluminescence only occurs in bacteria **when the colony is large enough** to switch on the synthesis of luciferase

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*Vibrio fischeri allow bobtail squid to emit bioluminescence, helping the squid to avoid predation*

# Signalling Molecules (HL)

Your notes

## Categories of Signalling Molecules

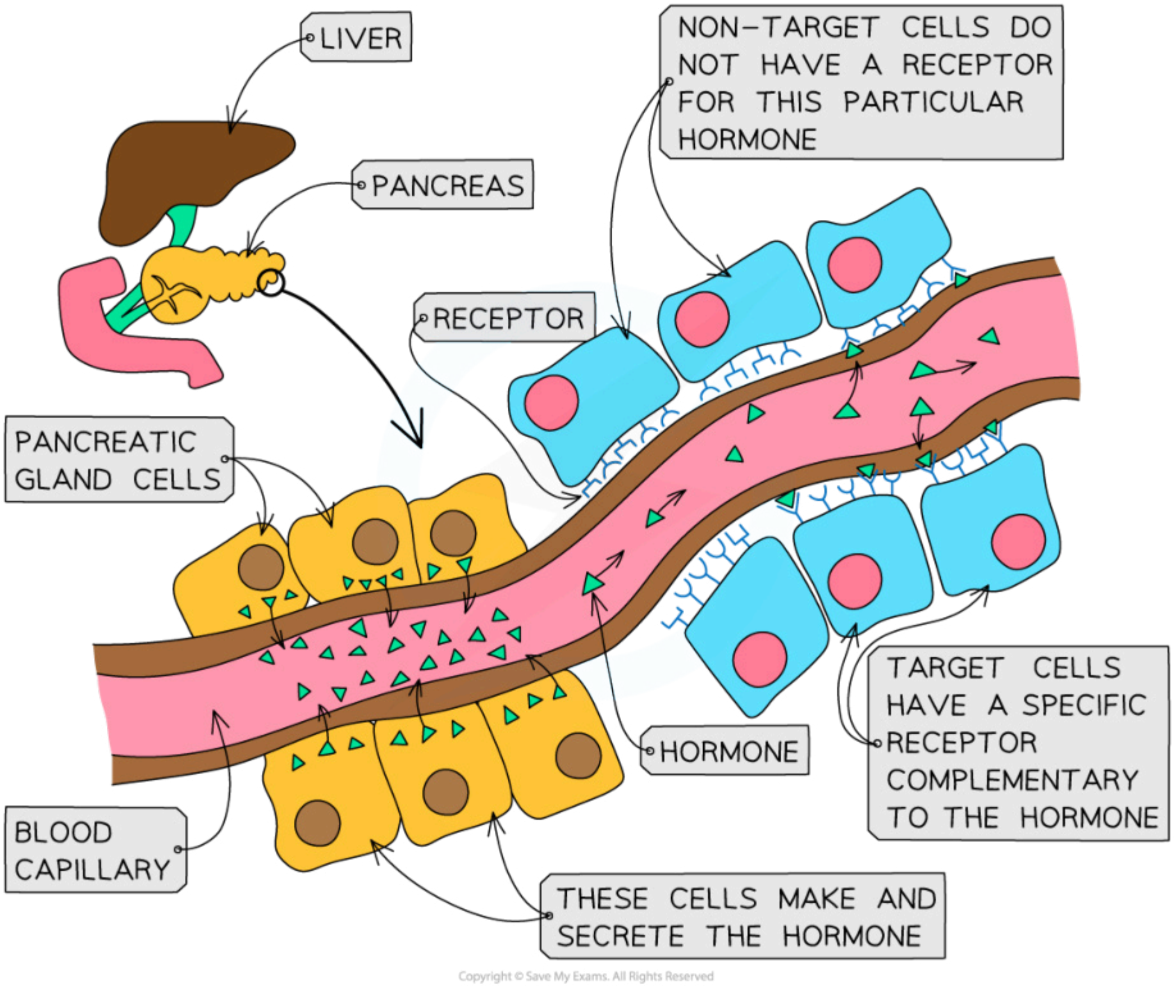
- There are many different types of chemical signalling molecules in animals

### Hormones

- A **hormone** is a chemical substance produced by a gland and carried by the blood, which alters the activity of one or more specific target organs, i.e. they are chemicals which transmit information from one part of the organism to another and bring about a change
- **Endocrine glands** produce hormones and secrete them **into capillaries** in the gland tissue
  - Collectively these glands are known as the **endocrine system**
- Hormones are transported in the **blood** to **target cells**
- Hormones only affect cells with **target receptors** to which the hormones can bind
  - These are either found on the cell surface membrane or inside cells
  - Receptors have to be **complementary** to hormones for binding to occur, so they are **specific** to a particular hormone

**Hormone action diagram**

Your notes




***Hormones are release by endocrine glands, e.g. the pancreas, and the bind to receptors on target cells***

- Examples of hormones might include
  - Insulin
  - Glucagon
  - Thyroxine
  - Testosterone

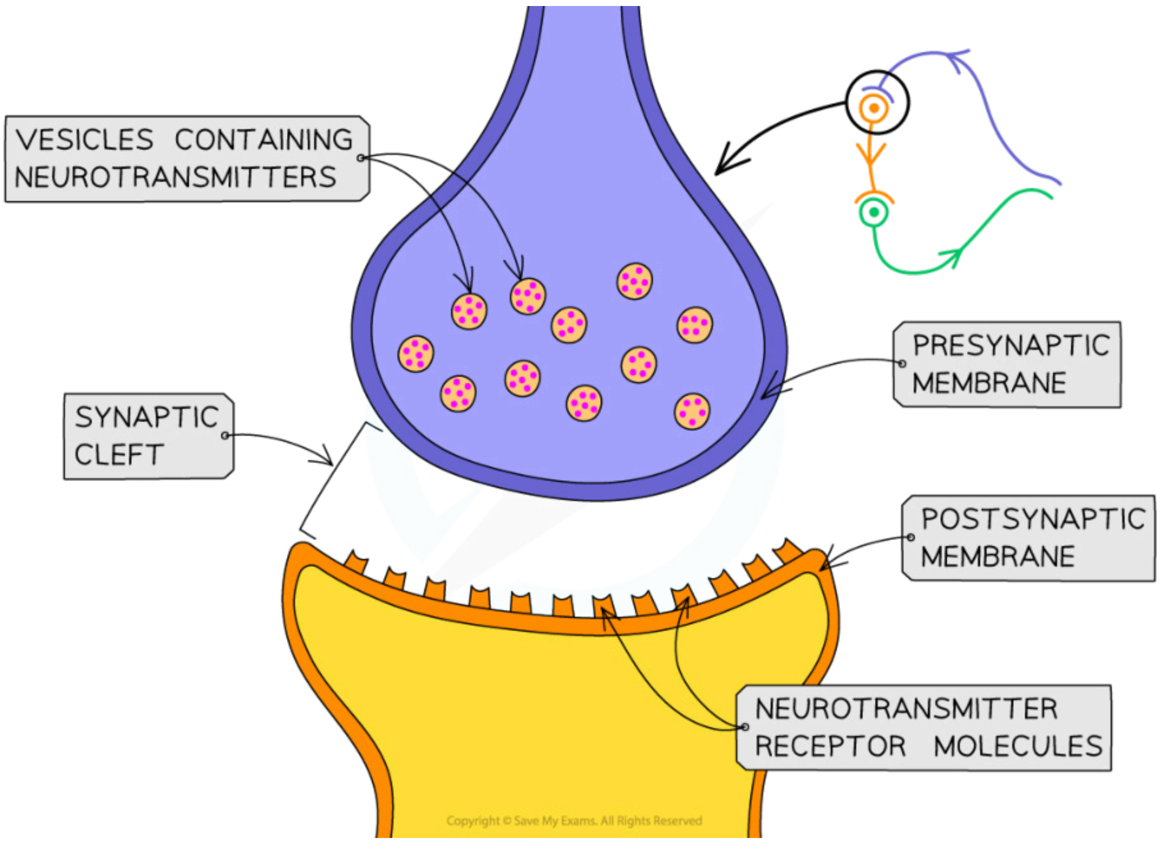
## Neurotransmitters

- **Neurotransmitters** are chemicals that transmit signals across the synaptic cleft from the presynaptic neurone to the post-synaptic neurone
- The neurotransmitters **diffuse** across the cleft and **bind with receptor molecules** on the postsynaptic **membrane**; this causes associated **sodium ion channels** on the postsynaptic membrane to open, allowing **sodium ions** to diffuse into the postsynaptic cell

Your notes

- If enough neurotransmitter molecules bind with receptors on the postsynaptic membrane, then a nerve impulse is generated, which then travels along the **postsynaptic neurone**
- The neurotransmitters are then **broken down** to prevent continued stimulation of the postsynaptic neurone

**Neurotransmitter diagram**




***Neurotransmitters are released from the presynaptic knob and bind to receptors on the postsynaptic membrane***

- Signals from neurotransmitters are **short-lived** and **localised** compared to hormones
- Examples of neurotransmitters include:
  - Acetylcholine
  - Norepinephrine
  - Dopamine

## Cytokines

- Cytokines are **proteins** released by **nearly all cells** in the human body
- There are **several different types** of cytokines and each one plays a role in determining **activity** of another cell

Your notes

- Cytokines interact with cells by binding to **receptors** on the **cell surface membrane**; they cannot enter the cytoplasm
- Binding of cytokines leads to a **cascade** of events inside the cell which impacts **gene expression** and, therefore, cell activity
- Cytokines are involved in signalling between white blood cells during an **immune response**, as well as regulating the cell cycle for **cell growth** and **proliferation** during embryonic development
- Examples of cytokines include
  - Interleukin
  - Erythropoietin
  - Interferon

## Calcium ions

- Calcium ions ($Ca^{2+}$) are involved in many of the signalling pathways of the human body, for example:
  - During **muscle contraction** an influx of $Ca^{2+}$ initiates a change in shape of specific proteins which allow contraction of fibres within muscle tissue
    - Calcium ions are pumped back out of the muscle fibres, meaning that the response is **rapid** and **short-lived**
  - At a **synapse** the arrival of a nerve impulse stimulates the movement of $Ca^{2+}$ into the presynaptic knob from the synaptic cleft, which then triggers vesicles to release neurotransmitters into the synapse
    - Calcium ions are pumped back into the synaptic cleft, meaning that the response is **rapid** and **short-lived**
  - Calcium ions sometimes act as **second messengers**, meaning that they are part of the **cascade of reactions** that occurs inside a cell after another signalling molecule binds to an external membrane receptor

## Chemical Diversity: Hormones & Neurotransmitters

Your notes

- Within the categories of hormones and neurotransmitters, there are several different **chemical configurations**
- Each configuration is fundamental in ensuring the efficacy of the molecule as a signalling molecule
- Chemicals must be:
  - Able to **bind to receptors**; this is dependent on the **shape** and **chemical properties** of the molecule
  - **Small** and **soluble** so that they can move around the body

### Hormones

- Hormones fit into **three** categories: **amines, peptides** or **steroids**
- Different categories of hormones have **different properties** which influence **how they interact with their target cells**, e.g.
  - Amines and proteins are **hydrophilic**, which makes it difficult to cross phospholipid bilayers, so they function by **binding to external membrane receptors**
  - Steroid hormones are **hydrophobic** so can cross cell membranes and **bind to receptors inside cells**

**Hormone category examples table**

| Amines | Proteins | Steroids |
|---|---|---|
| Melatonin | Insulin | Oestradiol |
| Thyroxin | Glucagon | Progesterone |
| Epinephrine | ADH | Testosterone |

### Neurotransmitters

- Neurotransmitters categories include: **amines, gases, amino acids** and **peptides**
- Most neurotransmitters are **hydrophilic**, so they function by **binding to receptors** on cell surface membranes
- Some neurotransmitters **also act as hormones**, e.g. epinephrine, also known as adrenaline
- Some neurones only produce one type of neurotransmitter, others produce **multiple** which can be released simultaneously
  - If multiple neurotransmitters are released at once they can stimulate **several different outcomes** at the same time

**Neurotransmitter categories examples table**

| Amines | Gases | Amino acids | Peptides |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Dopamine | Nitrous oxide | Glutamate | Endorphins |
| Epinephrine | | Glycine | |

Your notes

## Effects of Signalling Molecules

### Comparing the effects of hormones and neurotransmitters

- Neurotransmitters have a **localised** effect
  - There is a **very short distance** for them to diffuse **from the presynaptic to the post synaptic membrane**
  - This is an average distance of 20 nanometres
- Hormones may have a more **distant** effect
  - They travel **much longer distances** as they travel **in the blood** to cells which have the correct receptors
  - These cells could be located very close to the gland or could require transport to the furthest point of the body

Your notes

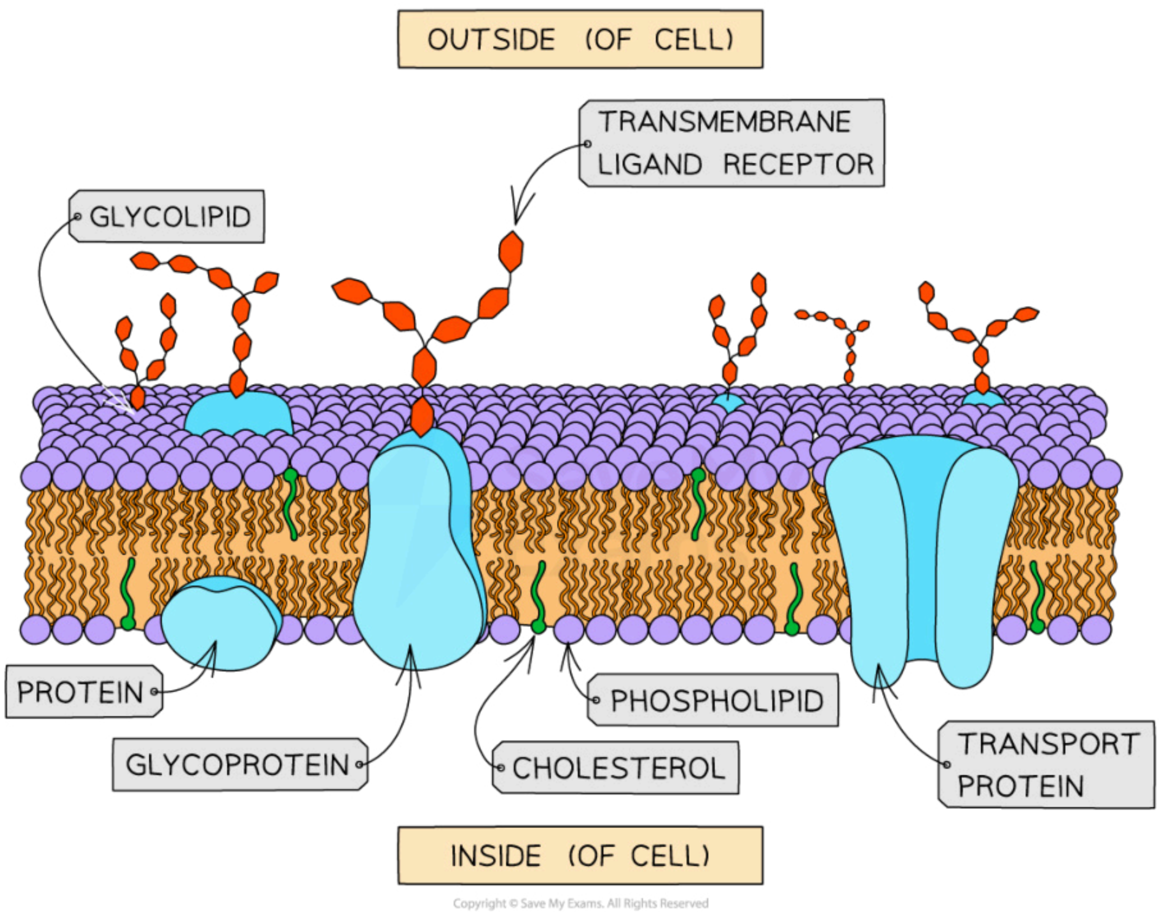
# Receiving the Signal (HL)

## Differences Between Transmembrane & Intracellular Receptors

### Transmembrane receptor proteins

- Receptors that are located in the **cell membrane** have an **external binding site** and an **internal region** which extends into the cytoplasm
  - These are **transmembrane proteins** as they extend across the width of the membrane
- Transmembrane receptors are characterised by:
  - **Hydrophilic** amino acid regions at either end of the protein that are contact with the **aqueous solution** inside and outside the cell
  - A **hydrophobic** amino acid region within the membrane that is in contact with the **hydrophobic tails** of the phospholipids inside the cell membrane
- Some ligands bind to these receptors instead of entering the cell cytoplasm

**Transmembrane receptor diagram**



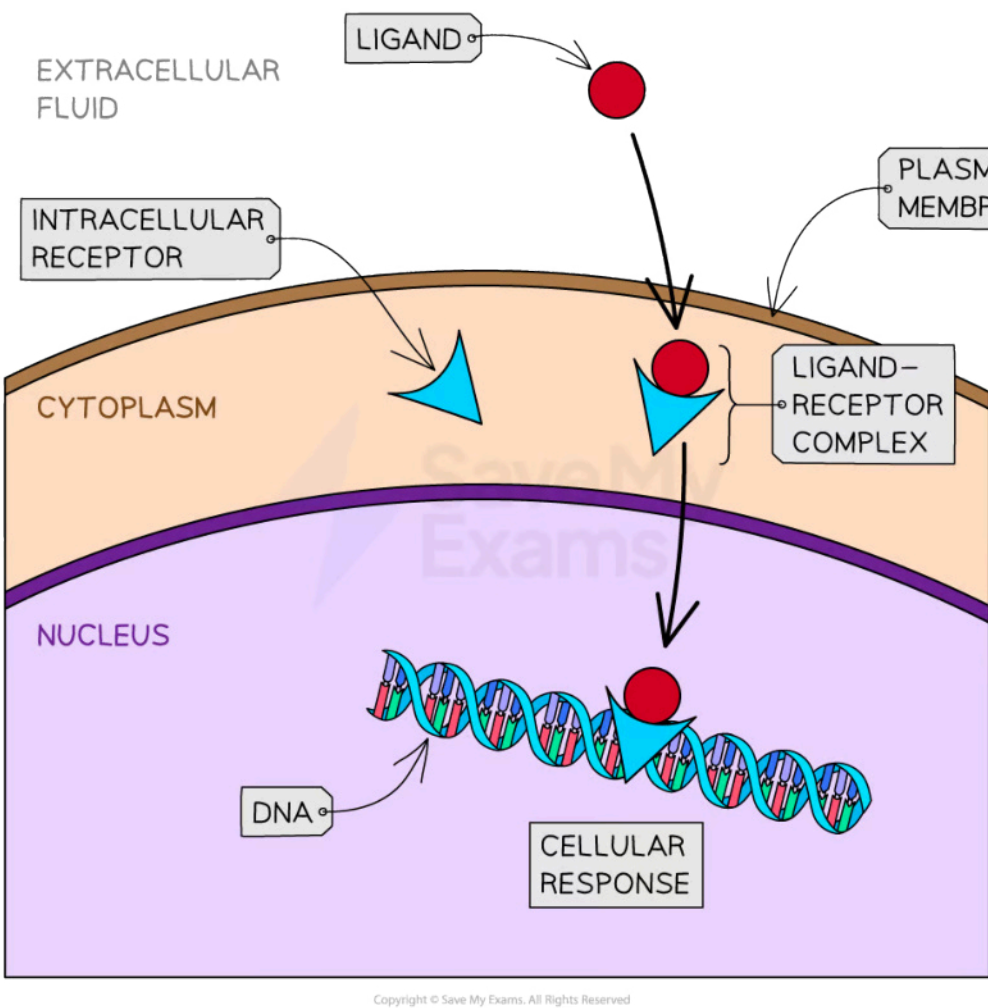
Your notes

***The cell surface membrane has many different components, including transmembrane proteins, e.g. glycoproteins, that function as receptors***

## Intracellular receptors

- Non polar, hydrophobic, ligands, e.g. steroid hormones, can diffuse through the phospholipid bilayer
- These ligands bind to receptors in the cytoplasm or on the DNA in the nucleus of the cell
  - Steroid hormones such as oestradiol will bind to the receptor molecule and activate it so that protein synthesis is initiated

**Intracellular receptor diagram**




***Oestradiol is a steroid hormone that diffuses across the cell membrane and binds to an intracellular receptor in the cytoplasm of target cells***

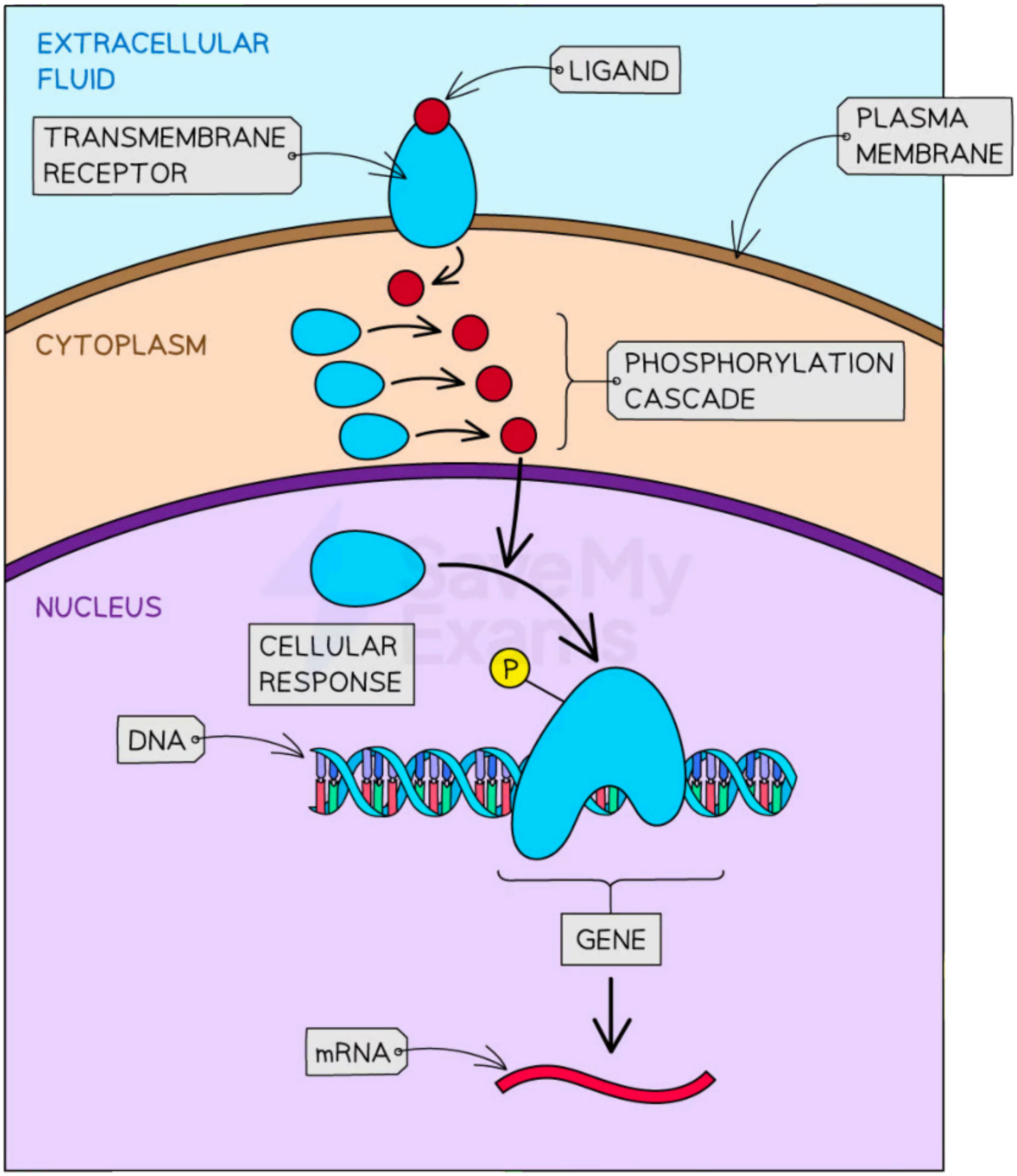
## Initiation of Signal Transduction Pathways



- When a ligand binds to either the **transmembrane receptor** or the **intracellular receptor**, a **cascade** of events follows which leads to a resulting change in **cell activity**
- The sequence of events is called the **signal transduction pathway**
  - Different ligands and different receptors trigger **different** signal transduction pathways
- All signal transduction pathways follow the same basic process
  - **Binding** with the **receptor**
    - For a transmembrane receptor:
      - A ligand binds to the extracellular region of the transmembrane receptor protein, causing a **change in shape** of the internal region of the protein
    - For an intracellular receptor:
      - A ligand binds to an intracellular receptor, forming a **ligand-receptor complex**
  - **Signal transduction** through a multistep pathway of events
    - For a transmembrane receptor:
      - Transmembrane proteins initiate a signal transduction pathway which involves phosphorylation events and a second messenger
    - For an intracellular receptor:
      - Intracellular ligand-receptor complexes are **activated** to follow a signal transduction pathway
  - **Cellular responses** which may include:
    - Regulation of **gene expression** through control of transcription or translation
    - Change in **metabolic activity**
    - Regulation of **enzyme** activity
    - Cell death
    - Rearrangement of the cytoplasm of the cell
    - Regulation of proteins, e.g. channels in the plasma membrane

**Signal transduction diagram**

Your notes






***Ligands can bind to transmembrane receptors, resulting in signal transduction and a cellular response***

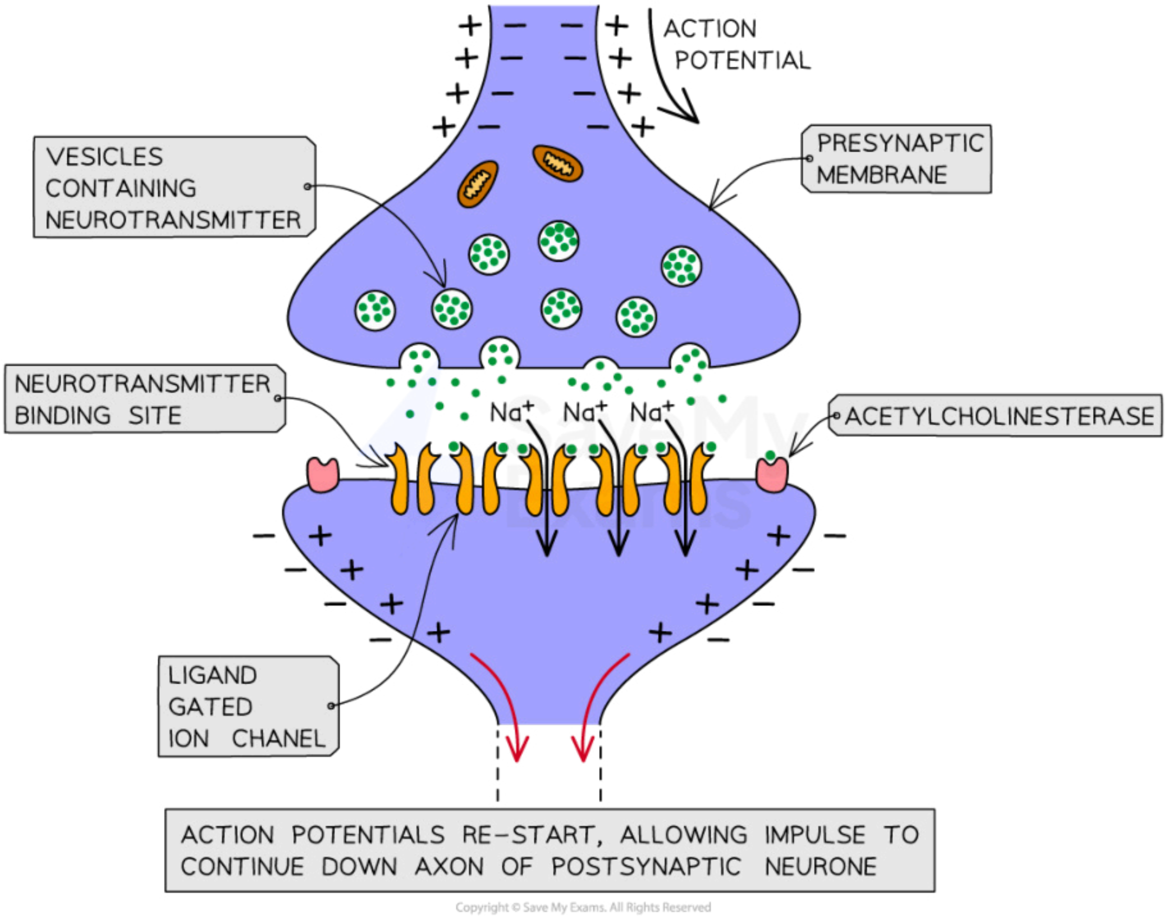
# Transmembrane Receptors (HL)

Your notes

## Neurotransmitters & Membrane Potential

- A key neurotransmitters used throughout the nervous system is **acetylcholine (ACh)**
- Synapses that use the neurotransmitter ACh are known as **cholinergic synapses**
- Acetylecholine can bring about a change in **membrane potential**, meaning that it can reverse the charge across a nerve cell membrane
  - Membrane potential is also referred to as the **voltage** across a membrane
- The mechanism by which ACh changes membrane potential in neurones is as follows:
  - The arrival of a nerve impulse, or action potential, at the **presynaptic** membrane stimulates release of **ACh** into the synaptic cleft
  - The ACh molecules **diffuse** across the synaptic cleft and temporarily bind to **ligand-gated sodium ion channels** in the postsynaptic membrane
    - These channels are specialised **transmembrane receptors**
  - This causes a **shape change** in the sodium ion channel, which then **opens**, allowing **positively charged sodium ions ($Na^+$) to diffuse** down a gradient **into the cytoplasm** of the postsynaptic neurone
  - The sodium ions **reverse the charge** across the postsynaptic membrane, initiating a new nerve impulse in the postsynaptic cell
  - ACh molecules are then **broken down**, using enzyme **acetylcholinesterase,** to **prevent continued stimulation**
  - **The products** are **absorbed** back into the presynaptic membrane**,** recycled and packaged into vesicles ready to be used when another action potential arrives

**Acetylcholine receptor diagram**




***Acetylcholine binds to receptors on ligand-gated sodium ion channels, opening the channels and allowing Na+ ions to diffuse into nerve cells; this reverses membrane potential***

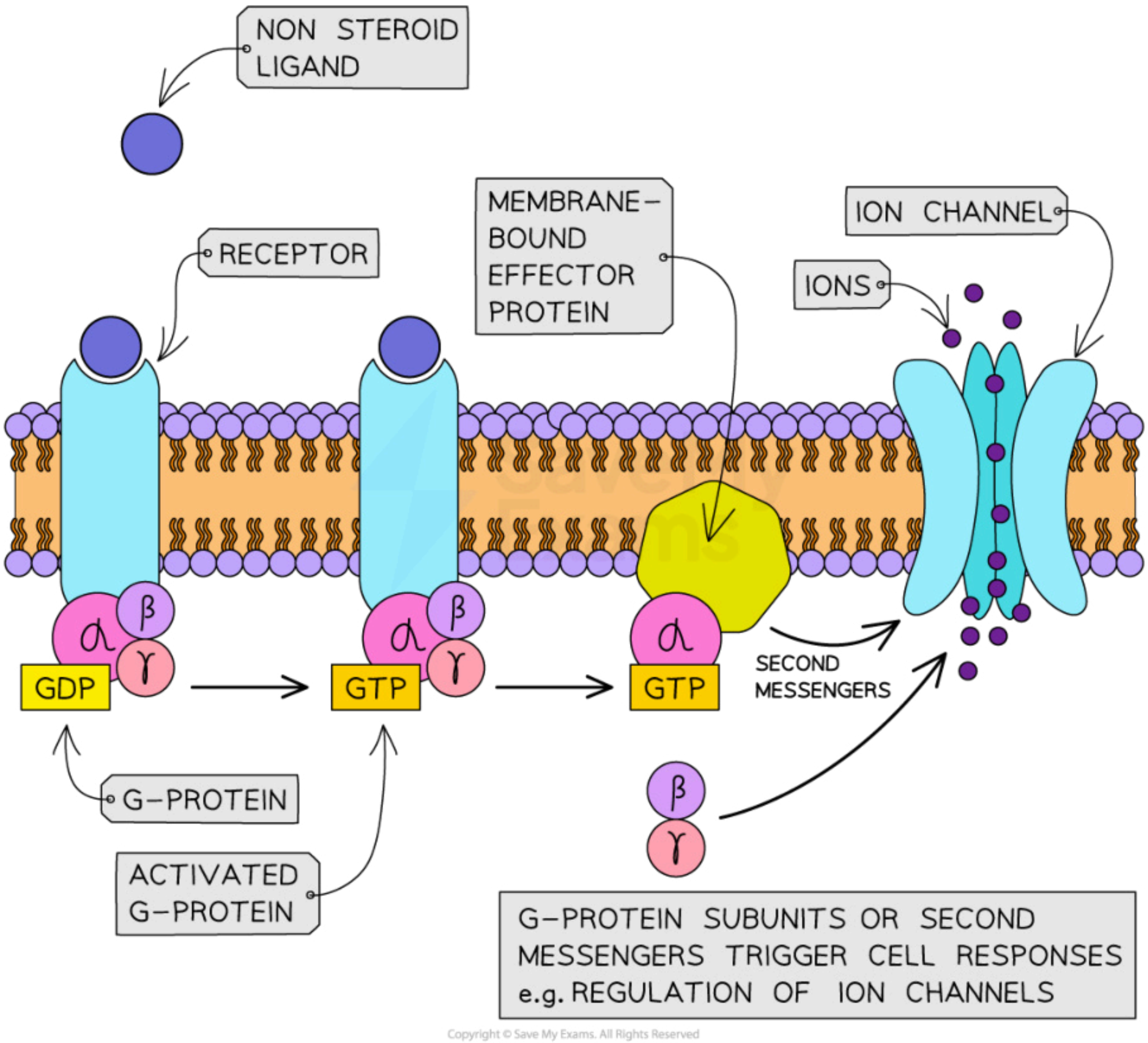
## Activation of G Proteins



- A **G-protein-coupled-receptor** (GPCR) is a transmembrane receptor protein responsible for the activation of a special intracellular protein molecule called a **G-protein**, which then initiates changes inside a cell
  - GPCRs are the largest and most diverse groups of membrane receptors in eukaryotes
- **G-proteins** are specialised proteins that bind to either **GTP** or **GDP**; they act as a switch, being activated or deactivated by signals at the membrane surface
  - GTP = guanine triphosphate (active G proteins)
  - GDP = guanosine diphosphate (inactive G-proteins)
  - These molecules are very similar to ATP, but contain guanine rather than adenine
- **Inactive** G-proteins are attached to the **internal side of a GPCR**, and are bound to **GDP**
- Signal transduction involves the **activation** of G-proteins as follows:
  - A non-steroid **ligand** binds to the GPCR on the outside of a cell
  - A **conformational**, or shape, **change** occurs which **activates** the attached G-protein
  - **GTP replaces GDP** on the G-protein, which then dissociates from the GPCR in two parts:
    - A **GTP-bound alpha subunit**
    - A **beta-gamma** dimer
  - Once dissociated, these subunits can interact with other **membrane proteins**, and can cause the release of second messengers
- Some of the targets of the activated G protein include
  - **Enzymes**
  - **Ion channels**
- G-proteins return to their inactive state when GTP is hydrolysed to GDP and they associate once again with the GPCR

**G-protein activation diagram**

Your notes




***G-proteins are activated when a ligand binds to a GPCR on the cell surface membrane. When activated, GDP is replaced by GTP and the G-protein dissociates and interacts with other proteins in the cell membrane.***

### Examiner Tip

GPCRs are not found in prokaryote cells, only in eukaryotes. Humans use many different GPCRs.

# Receptors with Tyrosine Kinase Activity

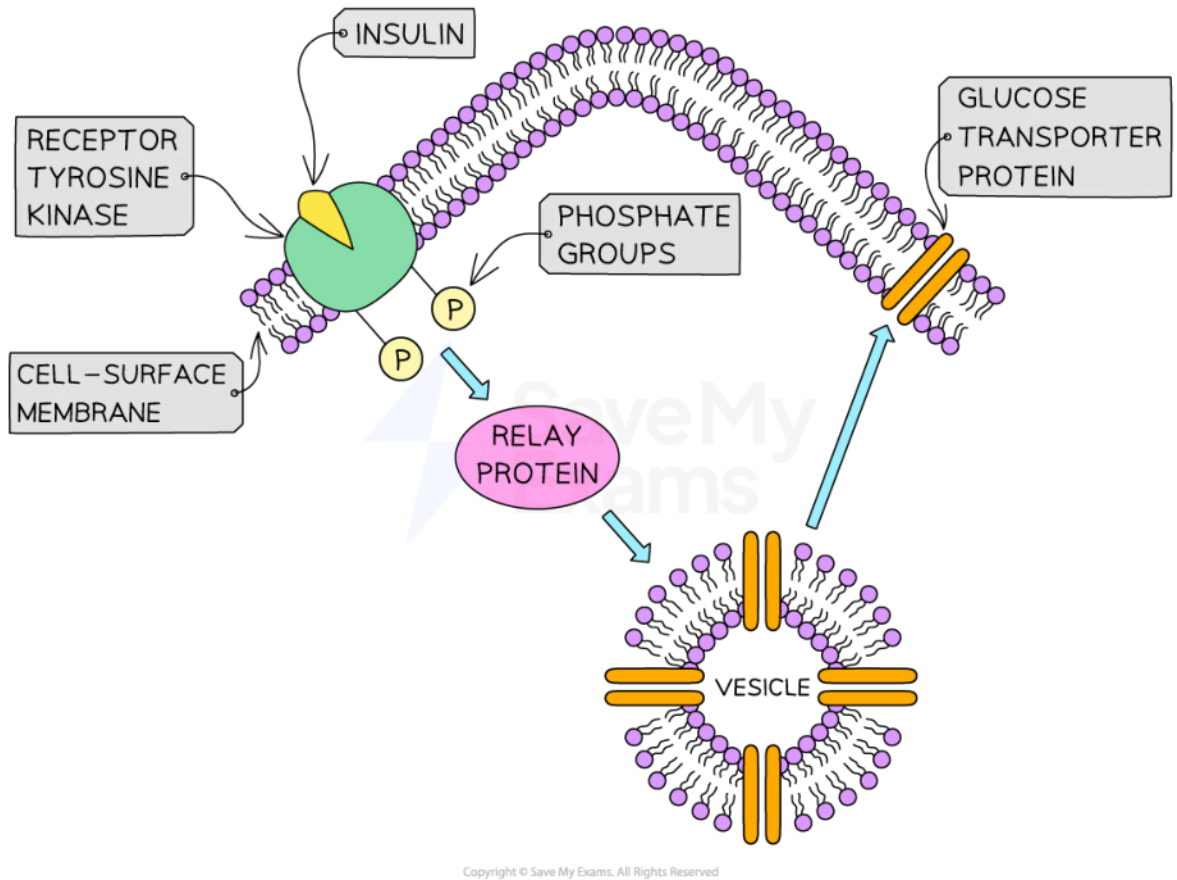
## What is a receptor tyrosine kinase?

- **Receptor tyrosine kinases (RTKs)** are a class of **transmembrane receptors** responsible for many different signal transduction pathways and cellular responses
- An RTK is activated by a **ligand** on the external region of the cell membrane where the binding site is found
- After binding, the intracellular portion of the receptor becomes **phosphorylated** using phosphate groups from ATP
- This activated RTK then stimulates the assembly of **relay proteins** which are responsible for the onward signal transduction pathway
- One RTK can trigger **multiple** different signal transduction pathways simultaneously

## The action of insulin

- **Insulin** is a hormone which triggers an increased uptake of **glucose in target cells** such as fat storage cells, adipose cells, muscle cells and liver cells
- RTKs in the cell membranes of these **target cells are activated** when insulin binds to the extracellular **binding site**
- This triggers the **phosphorylation of tyrosine** which then stimulates production of **relay proteins**
- The relay proteins then cause **vesicles containing glucose transporter proteins** in the cell cytoplasm to fuse to the cell surface membrane, **adding more glucose transporter proteins** to the membranes
  - This increases the **permeability** of the cells to glucose
  - The rate of facilitated diffusion of glucose into the cell increases

**Insulin and tyrosine kinase diagram**




***Insulin binds to RTKs, resulting in the phosphorylation of tyrosine and a series of reactions that end with the fusion of vesicles that contain glucose transporter proteins with the cell surface membrane***

# Epinephrine Receptors (HL)

Your notes

## Epinephrine Receptors

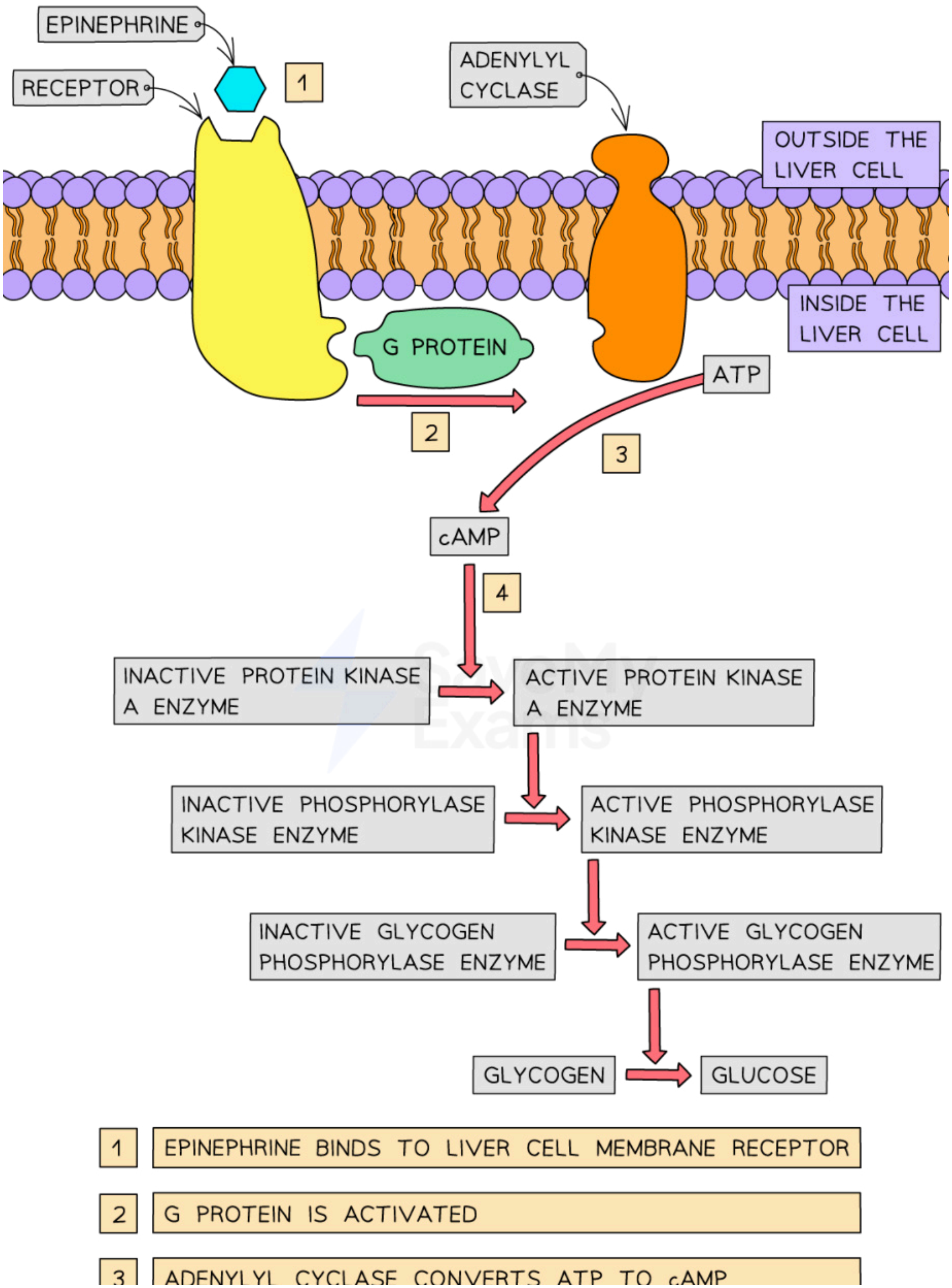
- A hormone called **epinephrine** (also known as **adrenaline)** can act to increase blood glucose concentration in response to biological stress
- Epinephrine binds to **receptors** on the outside of a cell and brings about an intracellular response using a mechanism of action known as the **second messenger model**
  - Second messengers are molecules/ions inside cells that **relay signals** received by cell-surface receptors

### The second messenger model

- **Epinephrine** binds to specific receptors on the membrane of liver cells
- This causes the enzyme **adenylyl cyclase** to change shape and become **activated**
- Active adenylyl cyclase catalyses the conversion of **ATP** to the second messenger, **cyclic AMP** (**cAMP**)
- cAMP binds to **protein kinase A enzymes**, activating them
- Active protein kinase A enzymes activate **phosphorylase kinase enzymes** by adding **phosphate groups** to them
- Active phosphorylase kinase enzymes activate **glycogen phosphorylase enzymes**
- Active glycogen phosphorylase enzymes **catalyse the breakdown of glycogen to glucose**
  - This process is known as **glycogenolysis**
- The enzyme cascade described above results in the **release of glucose by,** e.g. cells in the liver, to increase blood glucose concentration

**Epinephrine receptors diagram**

Your notes


EPINEPHRINE
RECEPTOR
1
ADENYLYL CYCLASE
OUTSIDE THE LIVER CELL
INSIDE THE LIVER CELL
G PROTEIN
ATP
2
3
cAMP
4
INACTIVE PROTEIN KINASE A ENZYME
ACTIVE PROTEIN KINASE A ENZYME
INACTIVE PHOSPHORYLASE KINASE ENZYME
ACTIVE PHOSPHORYLASE KINASE ENZYME
INACTIVE GLYCOGEN PHOSPHORYLASE ENZYME
ACTIVE GLYCOGEN PHOSPHORYLASE ENZYME
GLYCOGEN
GLUCOSE
1 EPINEPHRINE BINDS TO LIVER CELL MEMBRANE RECEPTOR
2 G PROTEIN IS ACTIVATED
3 ADENYLYL CYCLASE CONVERTS ATP TO cAMP

Your notes




***The effect of adrenaline is amplified so that each molecule can stimulate many molecules of cAMP, which in turn activate many enzymes***

## NOS: Students should be aware that naming conventions are an example of international cooperation in science for mutual benefit

- The work of scientists does not take place within the **confines of a laboratory**, or even a **single country**, but can have implications for the work of other scientists around the world
- Because of the **international nature of scientific research**, it is essential that scientists are able to **communicate with each other clearly** about their work
- For scientific communication to be **effective** and **allow collaboration**, it is essential that scientific language enables scientists to be sure that they are **talking about the same thing**
- With this in mind, when new names are coined, there are mechanisms which are applied to construct a **logical** and **universal** term.
- In the case of **adrenaline** and **epinephrine**, the two terms were coined using the idea that the **hormone** is produced from the **adrenal glands** located just at the top of the kidneys'
  - Adrenaline comes from the **Latin** translating to 'at kidney'
    - 'ad' which means 'at'
    - 'ren' which means 'kidney'
  - Epinephrine comes from ancient **Greek** translating to 'above kidney'
    - 'epi' which means 'above'
    - 'nephros' which means 'kidney'
- In the case of adrenaline/epinephrine, **both names are in common use** by scientists in different parts of the world; this is very **unusual**

Your notes

# Intracellular Receptors (HL)

## Receptors Affecting Gene Expression

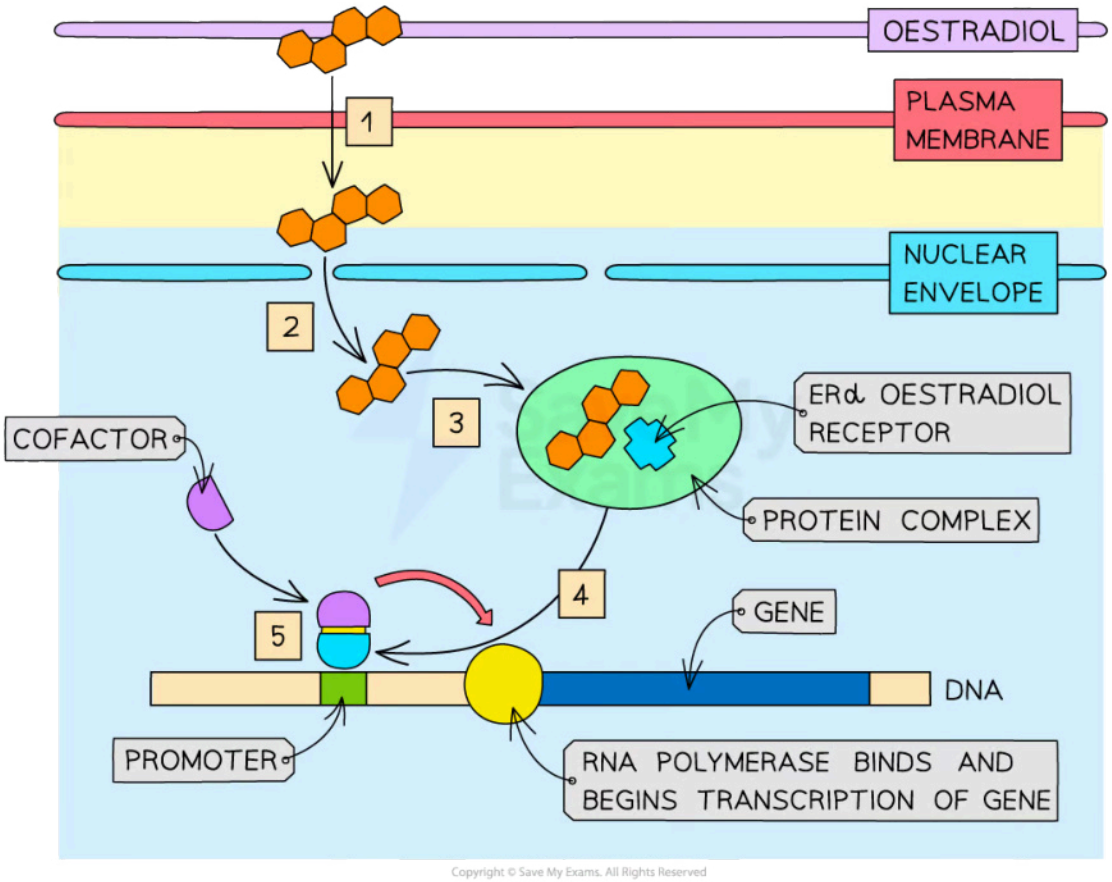
- Eukaryotes use **transcription factors** to control **gene expression**
  - A transcription factor is a protein that **controls the transcription of genes** by binding to a specific region of DNA
  - If a gene is transcribed and translated then it is **expressed** in the cell or individual

### Ligand activation of gene expression

- Steroid hormones are **small, hydrophobic, lipid-based** hormones that can **diffuse** through the cell membrane and can pass directly into the nucleus through **nuclear pores**
  - Once inside the cell, they can bind to **intracellular receptors**
- **Steroid hormones** such as testosterone, progesterone and oestradiol (also known as oestrogen) are ligands responsible for the expression of many genes within a cell
  - **Oestradiol** is involved in controlling the female fertility cycle and is also responsible for stimulating sperm production in males
  - Up to **100 different genes** are controlled by oestradiol

### The oestradiol stimulation pathway:

1. Oestradiol diffuses through the cell surface membrane into the **cytoplasm**
2. Oestradiol diffuses through a nuclear pore into the **nucleus**
3. Within the nucleus, oestradiol attaches to an **ERα oestradiol receptor** that is held within a **protein complex**, this causes the ERα oestradiol receptor to undergo a **conformational change**
4. The new shape of the ERα oestradiol receptor allows it to **detach from the protein complex** and diffuse towards the gene to be expressed
5. The ERα oestradiol receptor binds to a **cofactor** which enables it to bind to the **promoter region** of the gene, this stimulates **RNA polymerase binding and gene transcription**




*The oestradiol stimulation pathway*

Your notes

### Examiner Tip

Note that the oestradiol stimulation pathway is given as an example of how steroid hormones can act as signalling chemicals. Progesterone and testosterone will follow a similar path by binding to and activating an intracellular receptor. The activated receptor will then bind to specific DNA sequences to stimulate gene transcription.

# Effects of Oestradiol & Progesterone

Your notes

## Oestradiol

- Oestradiol is a **steroid hormone** responsible for regulation of **female sexual characteristics** amongst other roles
- It is produced in the **ovaries, placenta and testes** but is regulated by levels of other hormones released from the hypothalamus
- **Gonadotropin releasing hormone** is first released from the **hypothalamus**
- This stimulates the release of **lutenising hormone (LH)** and **follicle stimulating hormone (FSH)** from the **pituitary gland**
- These hormones together are responsible for control of the **menstrual cycle** with target cells found in the uterus, breasts and bone marrow of females
- Oestradiol can either **inhibit or promote** the release of **gonadotropin-releasing hormone** throughout the menstrual cycle which results in either a **positive or negative feedback response**

## Progesterone

- Progesterone is a **steroid hormone** responsible for the maintenance of the **endometrial lining** in preparation for implantation of a fertilised ovum and development of a foetus
- Progesterone also **prevents** further **ovulation** during pregnancy
- It is produced by the **corpus luteum** and **placenta**
- On entering the cytoplasm of a target cell, progesterone forms a **ligand-receptor complex**, leading to **expression of a range of genes**
- One example of a gene transcribed and translated as a result of progesterone is a **growth factor** which promotes **cell proliferation** required to continuously replenish the endometrial cells of the uterus

Your notes

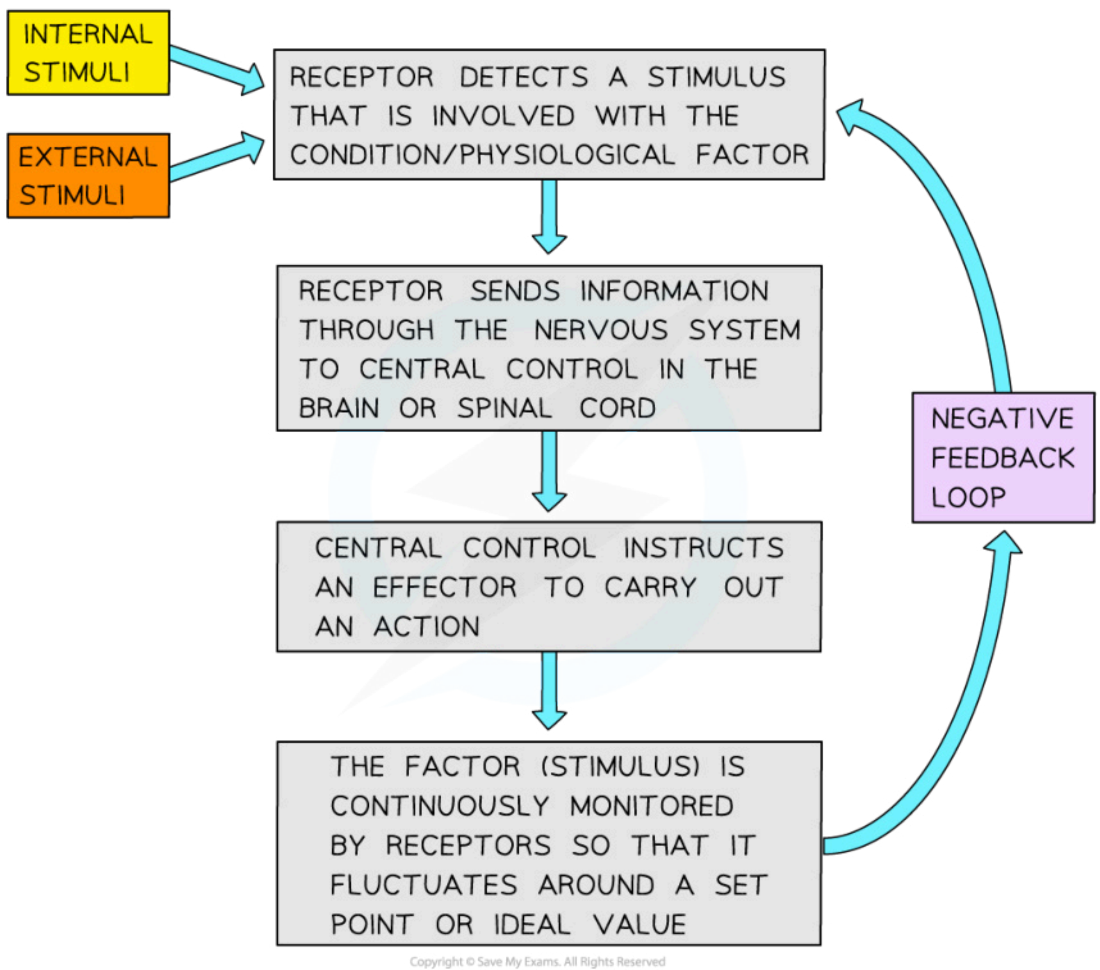
# Regulating Cell Signalling (HL)

## Regulation by Positive & Negative Feedback

### Negative feedback

- The majority of homeostatic control mechanisms in organisms use **negative feedback** to maintain **homeostatic balance,** i.e. to keep certain **physiological factors**, such as internal temperature or blood glucose concentration, **within certain limits**
- Negative feedback control loops involve the following steps:
  - A **receptor** detects a **stimulus** that is involved with a **physiological factor**
    - E.g. a change in temperature or blood glucose level
  - A **coordination system** transfers information between different parts of the body
    - This could be the nervous system or the hormonal system
  - An **effector** carries out a **response**
    - Effectors are **muscles** or **glands**
- The outcome of a negative feedback loop is
  - If there is an **increase** in the factor the body responds to make the factor **decrease**
  - If there is a **decrease** in the factor the body responds to make the factor **increase**
- Negative feedback systems work by **reversing a change** in the body to bring it back within **normal limits,** e.g.
  - If body temperature rises a negative feedback system will act to lower body temperature, bringing it back to normal
  - If blood glucose levels drop a negative feedback system will act to raise blood glucose, bringing it back to normal

Your notes




***Negative feedback loops involve the monitoring of physiological factors and act to reverse any changes, keeping the factors within normal limits. Information can be transferred via nerve signals, as shown here, or by hormonal signals.***

## Positive feedback

- In **positive** feedback loops the original stimulus produces a response that causes the factor to **deviate even more** from the normal range
  - They **enhance** the effect of the original stimulus
- An example of this is the **dilation of the cervix** during labour
  - The cervix stretches as baby pushes against it
  - Stretch receptors in the cervix are stimulated and send impulses to the brain
  - The pituitary gland is stimulated to release oxytocin which increases the intensity of uterine contractions
  - This pushes the baby further down the birth canal and stretches the cervix even further
- Positive feedback loops are useful to **quickly activate** a process, e.g. blood clotting to close up a wound

- When the body is injured, **platelets become activated**
- They **release chemicals** which will **activate more platelets**, which in turn, will release chemicals that will activate even more platelets etc.
- This ensures that the **wound is quickly closed up** by a blood clot before too much blood is lost or too many pathogens enter the bloodstream
- The body will **revert to negative feedback mechanisms** once the blood clot has formed

- Positive feedback may also kick in when **homeostatic mechanisms break down**
  - E.g. during prolonged exposure to extreme cold hypothermia can occur; body temperature drops, resulting in decreased metabolism which in turn causes body temperature to drop further
- Since these mechanisms do not maintain a constant internal environment, they are **not involved in homeostasis**

Your notes