IB BIOLOGY | C2.1 | HL

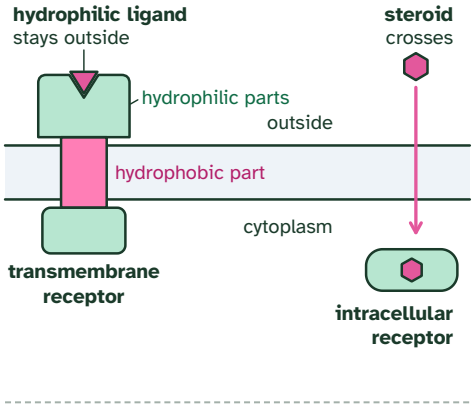
REVISION ON TWO PAGES

How cells read *signals*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

A ligand binds a receptor that fits it, and the receptor sets off a response inside the cell. Only target cells respond.



Draw it like this. The ligand fits a site on the receptor; only a steroid gets inside.

C2.1.1 and 6 START HERE

A *ligand* and its receptor

- A receptor is a **protein with a binding site** whose shape and charge fit one signalling chemical: the **ligand**.
- Binding changes the receptor's shape and starts a response. Only **target cells**, with the right receptor, respond.
- **Hydrophilic ligand** (a peptide, adrenaline): cannot cross the bilayer, so it binds a **transmembrane receptor**, with **hydrophobic amino acids** in the bilayer and hydrophilic ones either side.
- **Hydrophobic ligand** (a steroid): diffuses through the bilayer and binds an **intracellular receptor** in the cytoplasm or nucleus.

FOUR RECEPTOR TYPES, ONE EXAMPLE EACH

C Ion channel acetylcholine	**G** G protein adrenaline	**T** Tyrosine kinase insulin	**I** Intracellular steroid hormones

C2.1.3 and 5 FUNCTIONAL CATEGORIES IN ANIMALS

Four kinds of *signal*, near and far

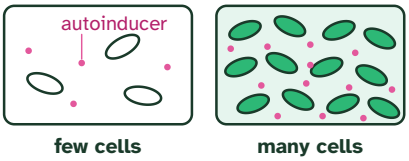
CATEGORY	RELEASED BY	HOW IT TRAVELS	RANGE AND TIMING
Hormone	An endocrine gland.	In the **blood**, to target cells anywhere in the body.	**Distant.** Slow, and often lasts hours or longer.
Neurotransmitter	A neuron.	**Diffuses** across a synaptic gap, about 20 nm wide.	**Local.** Acts in milliseconds; quickly removed.
Cytokine	Immune and other cells.	To nearby cells, sometimes distant ones.	**Mostly local.** Changes cell behaviour to coordinate a defence.
Calcium ions	Stores inside a cell.	Into the cytoplasm.	**Inside cells.** A signal within and between cells.

The four differ in where they are made, how far they go and how long they last.

C2.1.2 SIGNALS IN BACTERIA

Bacteria that *count*

- **Quorum sensing:** each bacterium releases an **autoinducer**; the more cells, the higher its concentration.
- At a **threshold concentration** it binds receptors in the bacteria and switches genes on.
- *Vibrio fischeri*, packed in a squid's light organ, switches on genes for **luciferase**: **bioluminescence**.



few cells
below threshold:
dark

many cells
above threshold:
luciferase on, glow

C2.1.4

Many kinds of *chemical*

- Each chemical has **its own receptor**, so thousands of signals work at once without confusion.
- A **steroid** crosses membranes and lasts; a **peptide** waits in vesicles, ready to release.

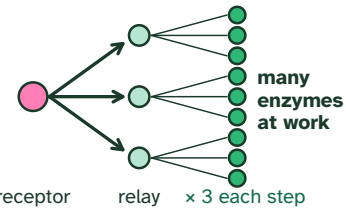
Hormones three groups
Amines (adrenaline, thyroxin), **proteins** (insulin, ADH), **steroids** (oestradiol, testosterone).

Neurotransmitters four kinds
Amino acids (glutamate, GABA), **peptides** (endorphins), **amines** (dopamine, serotonin), the gas **nitric oxide**.

C2.1.7

A *chain* of events

- Binding **switches the receptor on**; the ligand need not enter the cell.
- This starts a **signal transduction pathway**: each molecule activates the next, until the cell responds.
- Each step activates many of the next, so the **signal is amplified**.

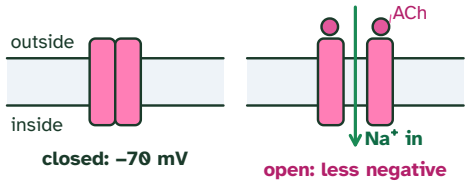


Four receptors at *work*, and feedback

C2.1.8

A receptor that is a *gate*

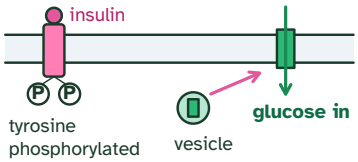
- The **acetylcholine receptor** is itself an **ion channel**: no pathway is needed.
- Acetylcholine binds, the receptor changes shape and the channel opens.
- **Positive ions**, mostly sodium, diffuse in. The inside becomes less negative (**depolarises**), which may trigger an action potential.



C2.1.11

Insulin: a *tyrosine kinase*

- Insulin, a protein, binds a receptor in the membrane; its inside part **phosphorylates tyrosine**.
- A **sequence of reactions** moves **vesicles of glucose transporters** to the membrane: more glucose enters.



C2.1.14

Feedback: *down* or up

- The **result of a pathway acts back on it**, so a cell does not keep on responding.

Negative opposes the change
Keeps a variable steady. Insulin lowers blood glucose; as glucose falls, beta cells release less insulin.

Positive amplifies the change
Oxytocin makes the uterus contract, causing more oxytocin. It needs an end: here, the birth.

C2.1.9 and 10

G proteins and adrenaline

- Humans have **hundreds** of **G protein-coupled receptors**, for hormones, neurotransmitters, light and smells.
- A G protein is off holding GDP. The ligand-bound receptor makes it **swap GDP for GTP**: on.
- **Adrenaline** on a liver cell: **cAMP is the second messenger**, and each step amplifies.
- **Two names:** adrenaline and epinephrine both mean "on the kidney". Shared names let scientists everywhere share findings.

THE ADRENALINE PATHWAY, IN ORDER

RGACK: rack up the glucose

R Receptor adrenaline binds	**G** G protein GDP out, GTP in	**A** Adenylyl cyclase switched on	**C** cAMP made from ATP	**K** Kinases glycogen to glucose

C2.1.12 and 13

Steroids switch on *genes*

- **Oestradiol, progesterone, testosterone** cross the membrane and bind a site on an intracellular receptor, **activating it**.
- The active receptor **binds specific DNA sequences** and **promotes transcription**.

OESTRADIOL
GnRH cells, hypothalamus
Low levels early in the cycle reduce GnRH release; high levels for long enough raise it, so LH surges.

PROGESTERONE
Endometrium
Switches on genes that thicken the lining, with more glands and blood vessels, ready for implantation.

WATCH OUT

Six mistakes that *cost marks*

- ✕ **The gas is nitric oxide, NO.** N_2O is laughing gas.
- ✕ **A transmembrane receptor's ligand stays outside.** The receptor, not the ligand, switches on the G protein.
- ✕ **cAMP is the second messenger.** Adrenaline is the first.
- ✕ **Insulin does not carry glucose.** It brings more transporters to the membrane.
- ✕ **No receptor, no response.** Progesterone enters every cell, but only target cells respond.
- ✕ **Positive feedback is not "good" feedback.** It amplifies a change, so it needs an end.

COVER THE SHEET

Can you *answer these?*

1. State what is meant by a ligand.
2. Outline quorum sensing in *Vibrio fischeri*.
3. Distinguish between hormones and neurotransmitters.
4. State an amine, a protein and a steroid hormone.
5. Explain why a steroid binds an intracellular receptor.
6. Describe how acetylcholine changes membrane potential.
7. Outline how adrenaline acts on a liver cell.
8. Explain how insulin increases glucose uptake.
9. Describe the effect of progesterone on its target cells.
10. Distinguish positive from negative feedback.

IN THE EXAM

Write the adrenaline chain in order; each link can earn a mark: receptor, G protein, adenylyl cyclase, **cAMP (second messenger)**, kinases, glycogen to glucose.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.