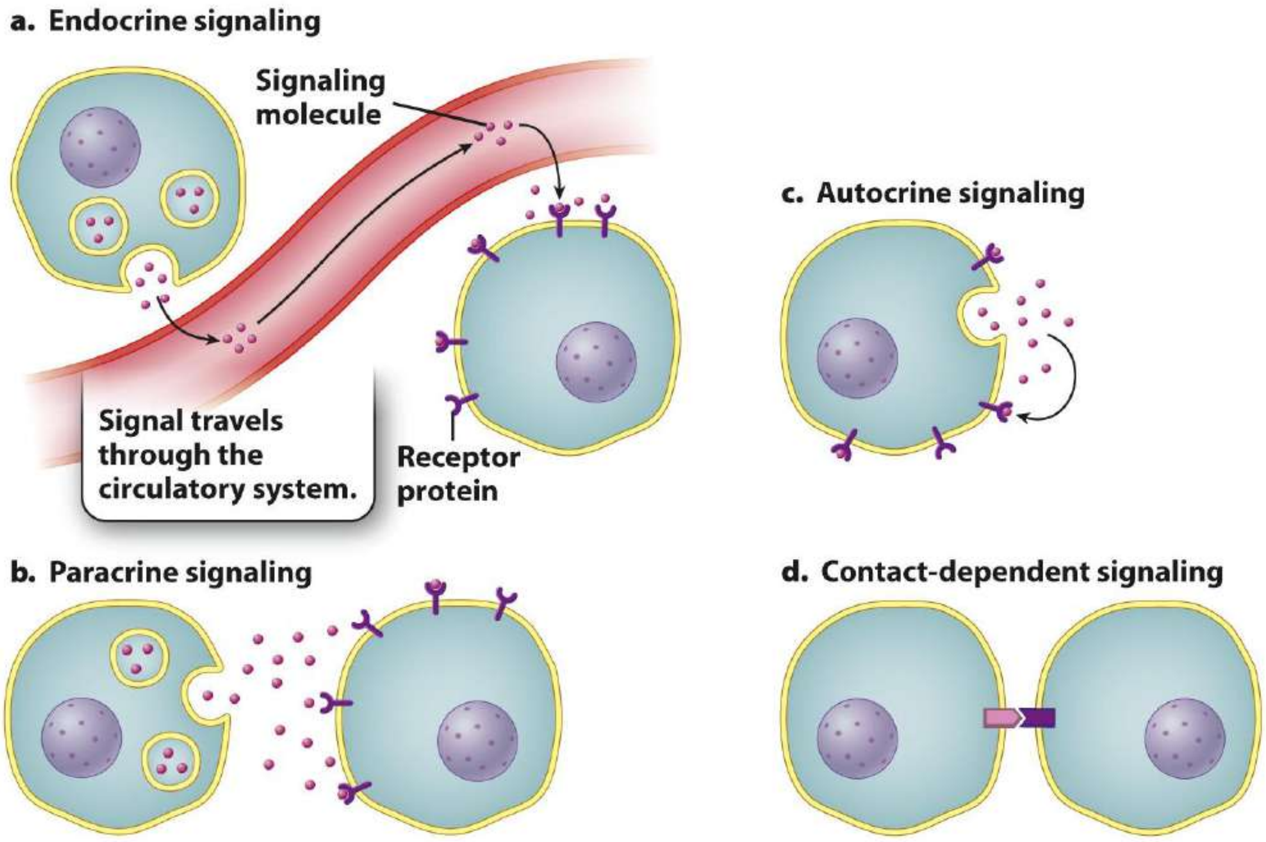
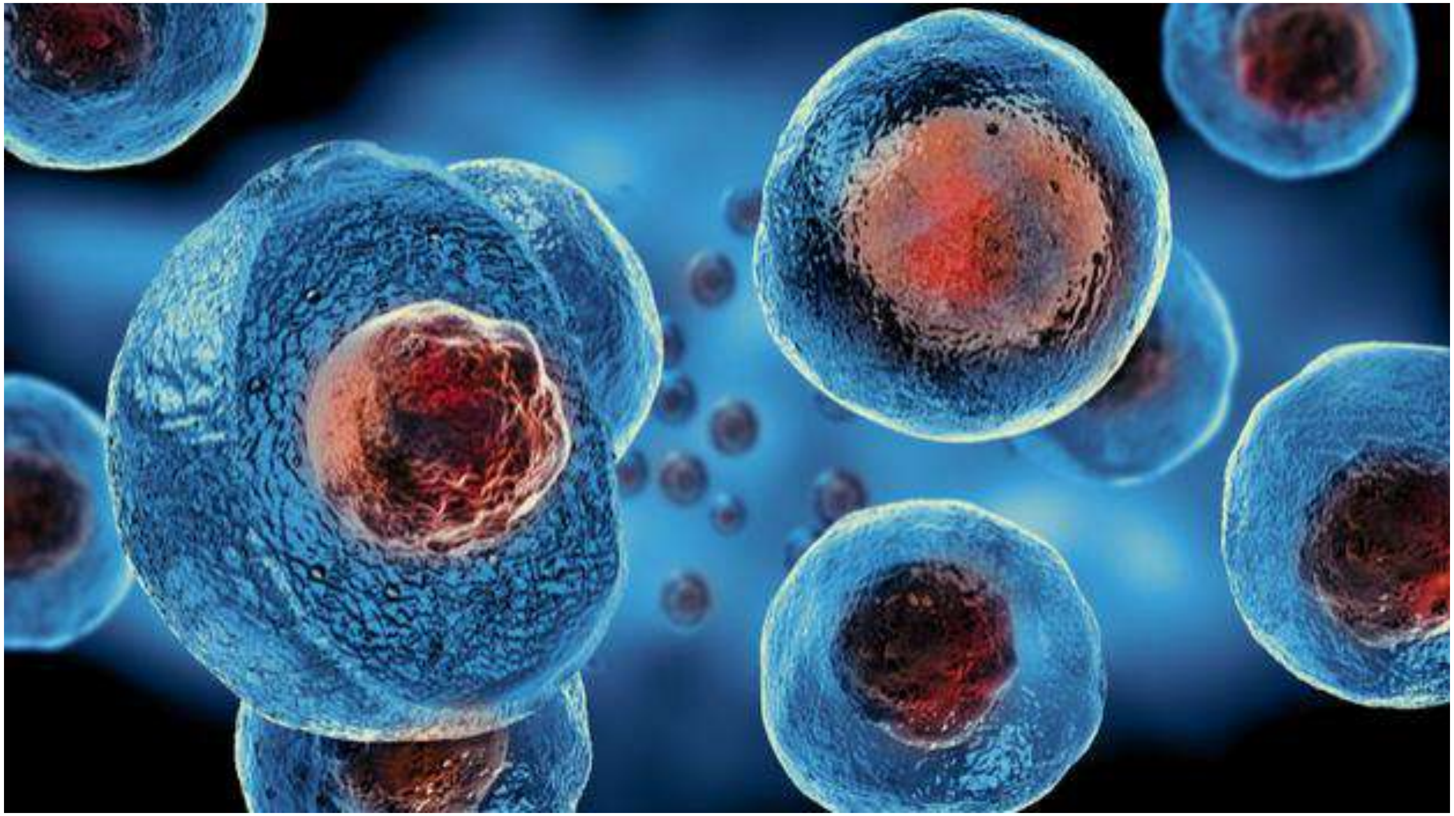
NOTES: CH 11, pt 1 – Cell Communication



Overview: Cellular Messaging

- Cell-to-cell communication is essential for both multicellular and unicellular organisms
- Biologists have discovered some **universal** mechanisms of cellular regulation ***(suggesting these evolved LONG AGO!)***
- Cells most often communicate with each other via **chemical signals**
- For example, the **fight-or-flight response** is triggered by a signaling molecule called **epinephrine**

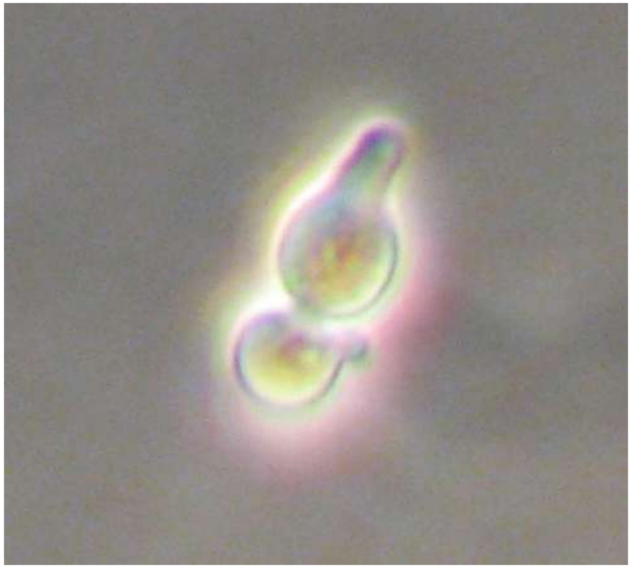
11.1 – External signals are converted to responses within the cell



What does a “talking” cell say to a “listening” cell?

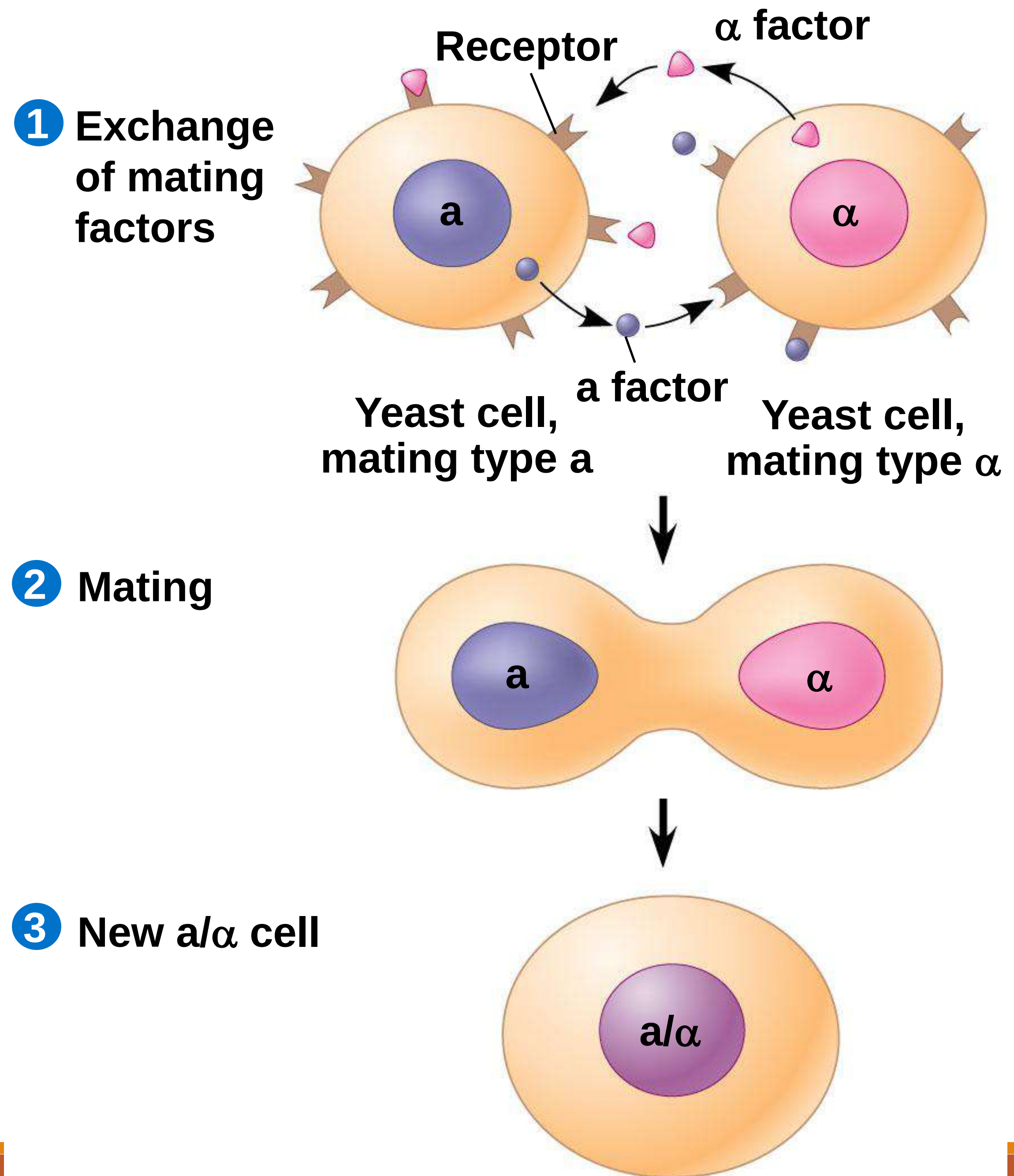
- Studying communication among microorganisms is a good place to start!
- One topic of cell “conversation” is: **<u>sex</u>**!
- **<u>Example</u>**: communication

between <u>mating yeast cells</u>



Evolution of Cell Signaling

- The yeast, *Saccharomyces cerevisiae*, has two mating types, **a and α ("alpha")**
- Cells of different mating types locate each other via secreted factors specific to each type
- A **signal transduction pathway** is a series of steps by which a signal on a cell's surface is converted into a specific cellular response

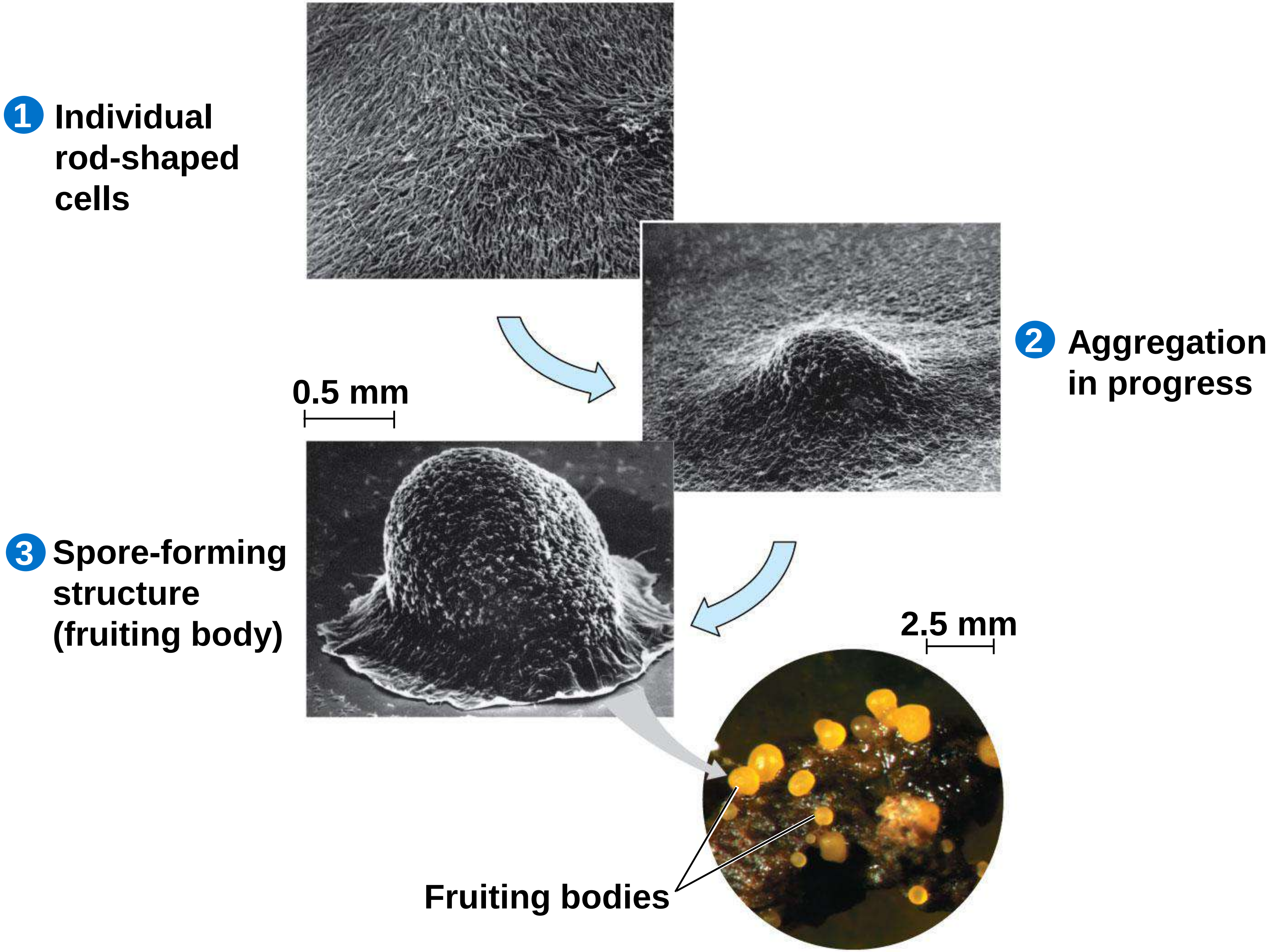


1 Exchange of mating factors
Receptor
α factor
a
α
a factor
Yeast cell, mating type a
Yeast cell, mating type α
2 Mating
a
α
3 New a/α cell
a/α

Cell Signaling: Bacteria

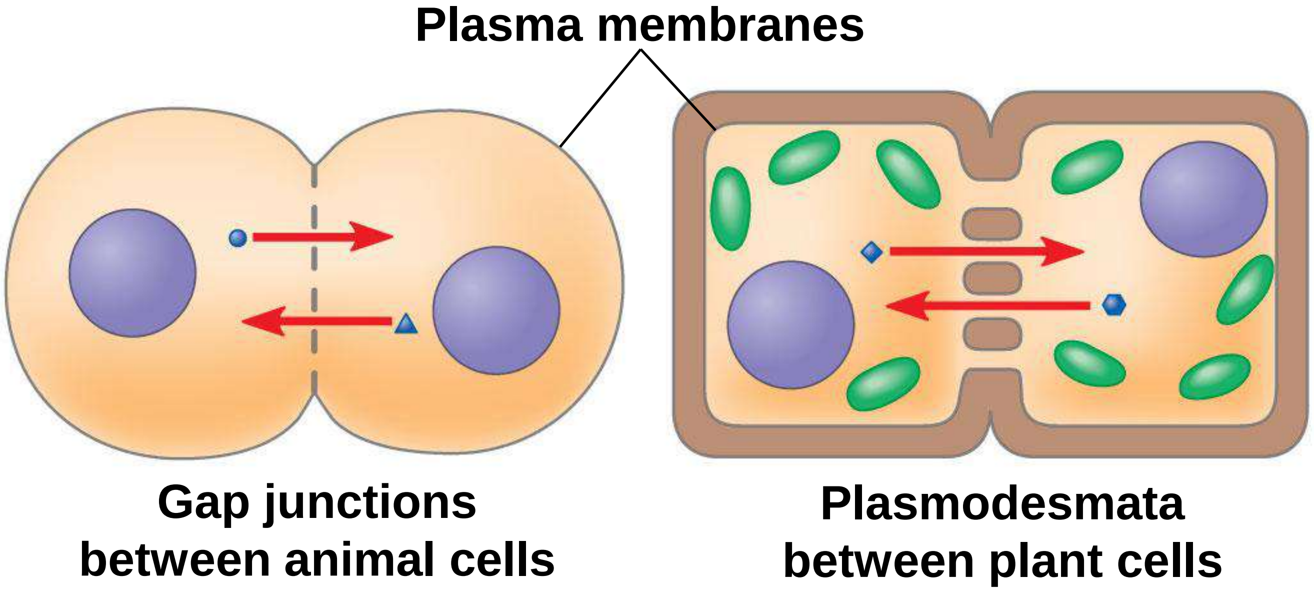
- Cell signaling is critical among microbes
- Bacterial cells secrete small molecules that can be detected by other bacteria
- The concentration of signaling molecules allows bacteria to sense local population density – ***quorum sensing***!
- example: **formation of a biofilm**

(i.e. the slimy coating on your teeth in the morning!)

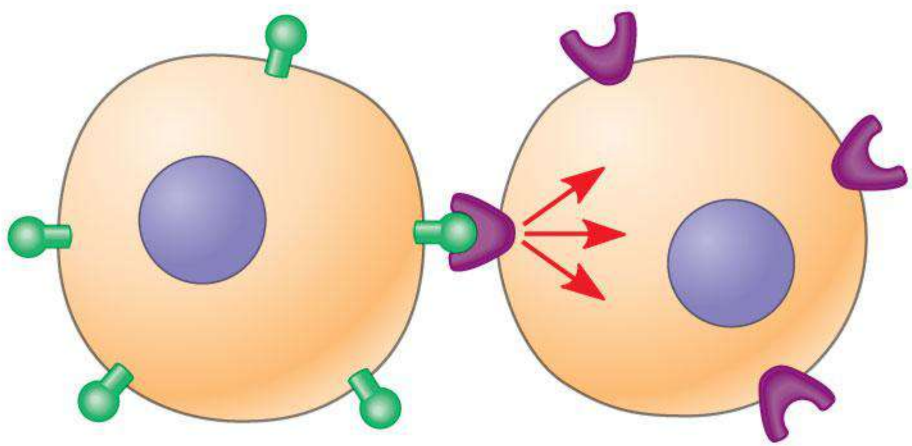

1 Individual rod-shaped cells
2 Aggregation in progress
0.5 mm
3 Spore-forming structure (fruiting body)
2.5 mm
Fruiting bodies

Local & Long-Distance Signaling

- Cells in a multicellular organism communicate by **chemical messengers**
- Animal and plant cells have **cell junctions** that directly connect the cytoplasm of adjacent cells
- In **local signaling**, animal cells may communicate by direct contact, or cell-cell recognition



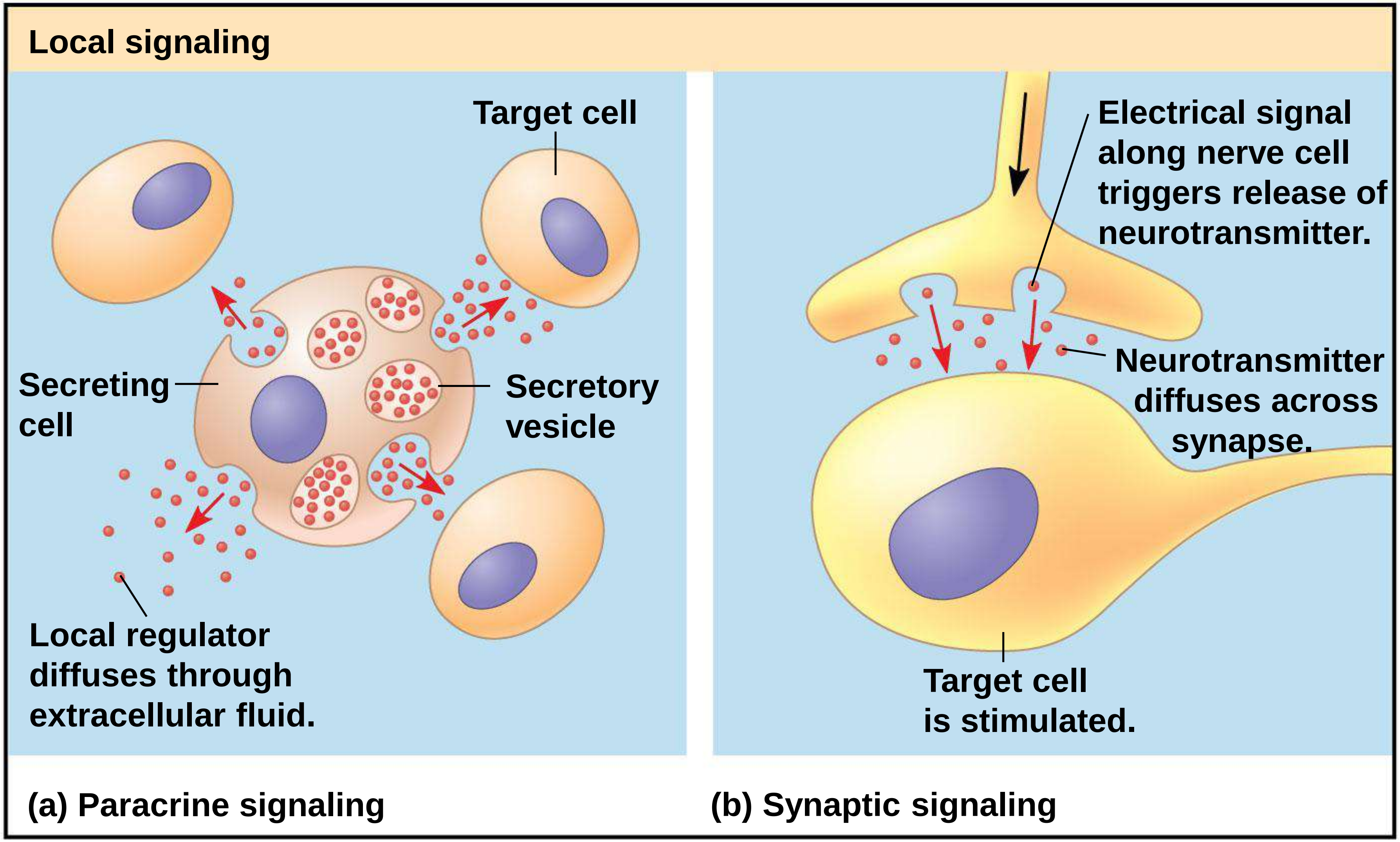
(a) Cell junctions

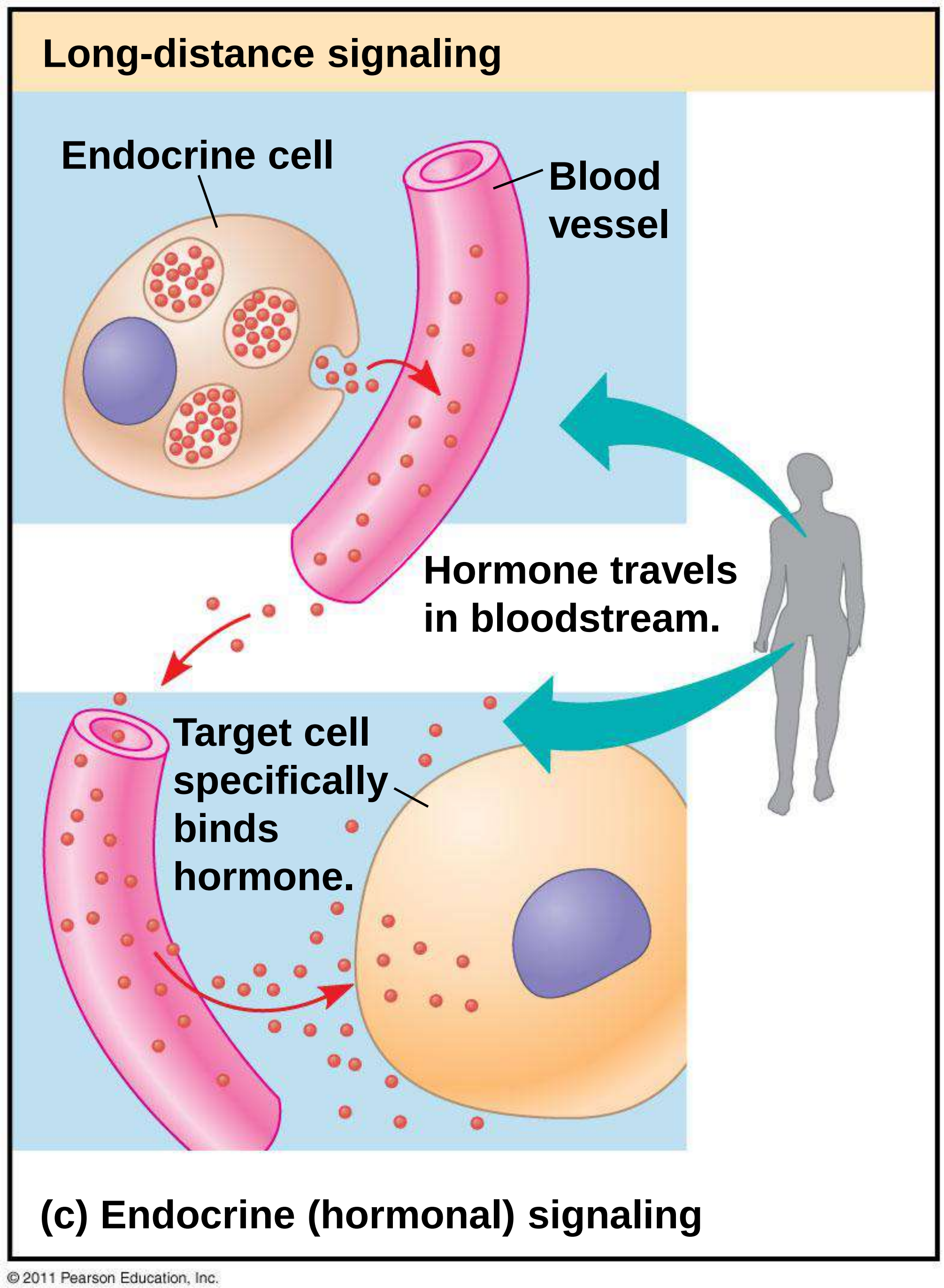


(b) Cell-cell recognition

Local & Long-Distance Signaling

- In many other cases, animal cells communicate using **local regulators**, messenger molecules that travel only short distances
- In long-distance signaling, plants and animals use chemicals called **HORMONES**
- The ability of a cell to respond to a signal depends on whether or not it has a receptor specific to that signal


Local signaling
Target cell
Secreting cell
Secretory vesicle
Local regulator diffuses through extracellular fluid.
(a) Paracrine signaling
Electrical signal along nerve cell triggers release of neurotransmitter.
Neurotransmitter diffuses across synapse.
Target cell is stimulated.
(b) Synaptic signaling


Long-distance signaling
Endocrine cell
Blood vessel
Hormone travels in bloodstream.
Target cell specifically binds hormone.
(c) Endocrine (hormonal) signaling
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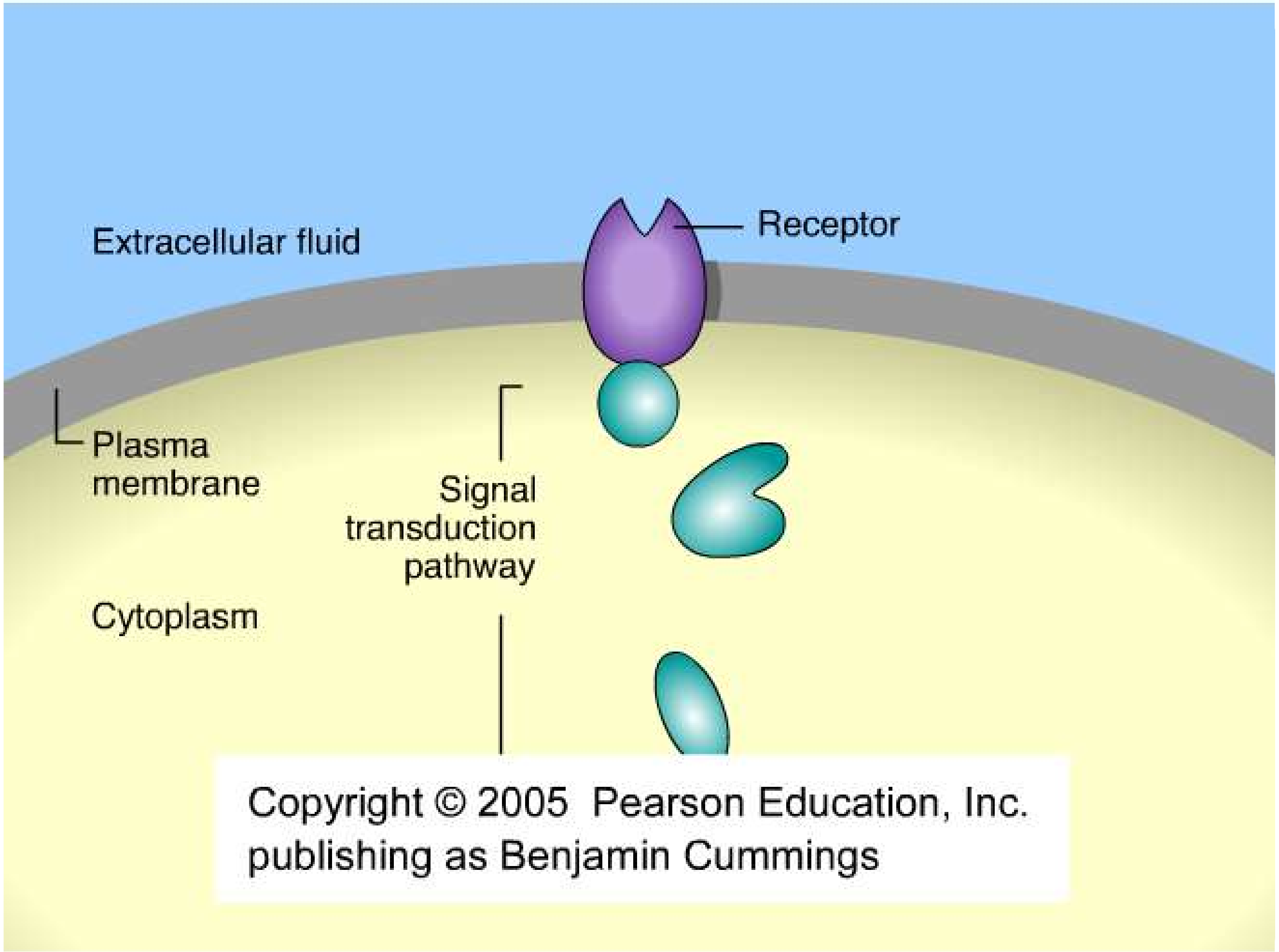
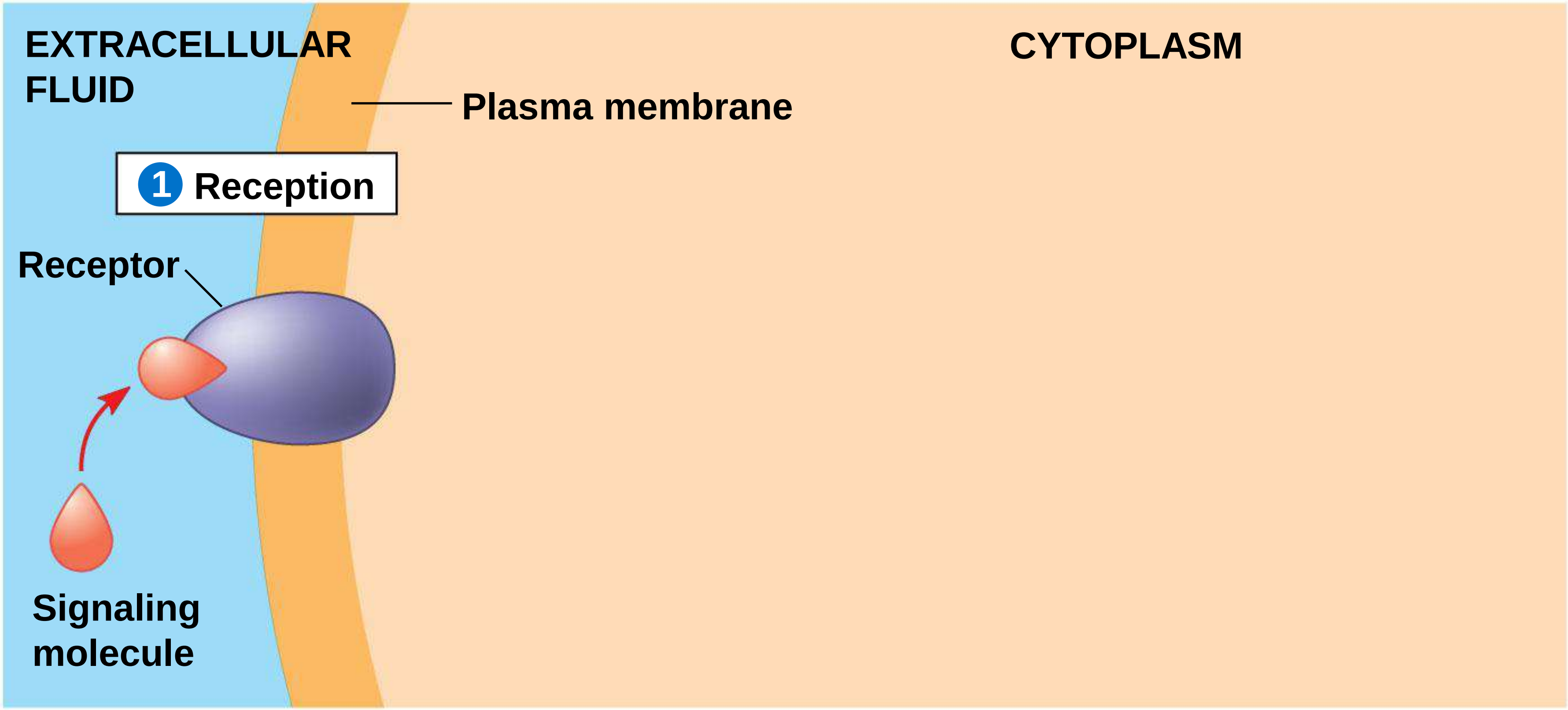
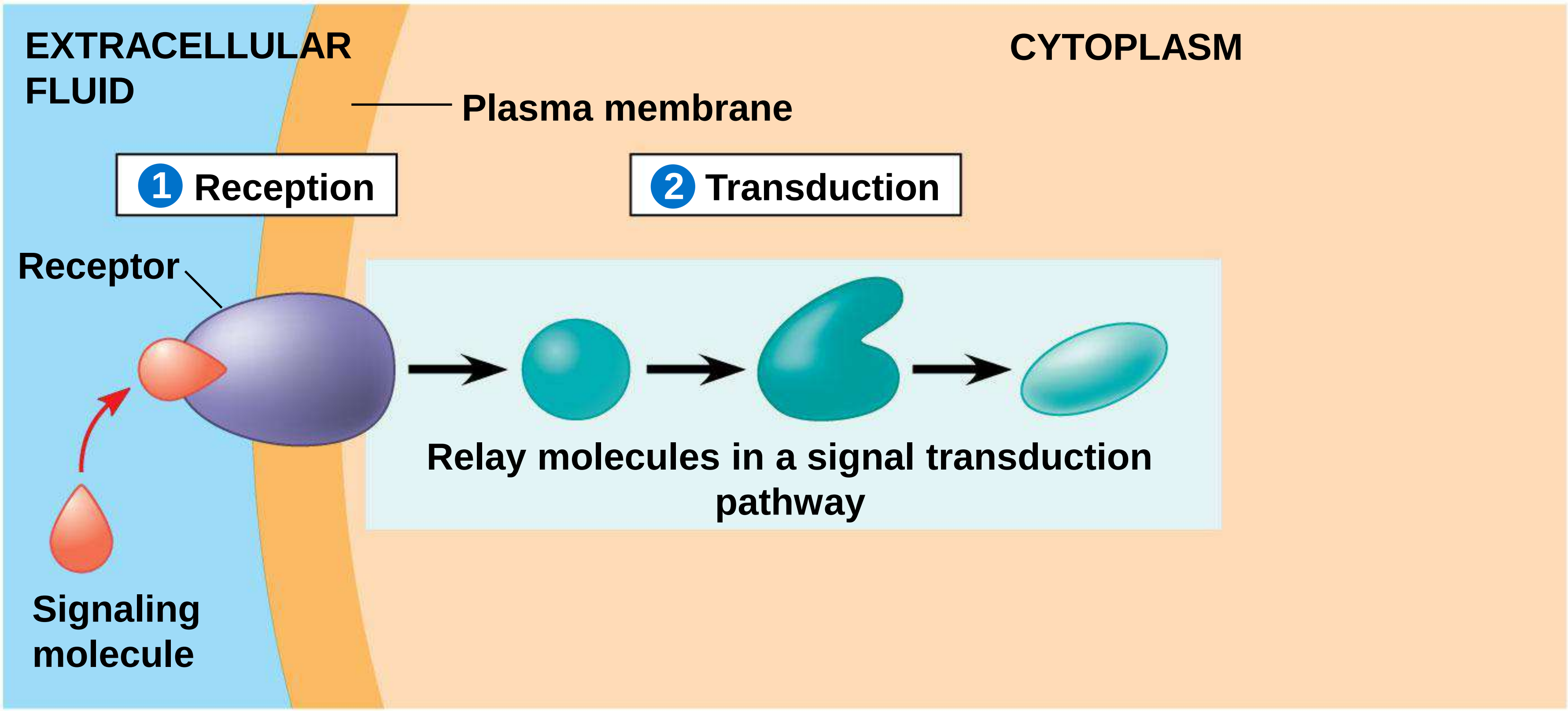
The Three Stages of Cell Signaling: *A Preview*

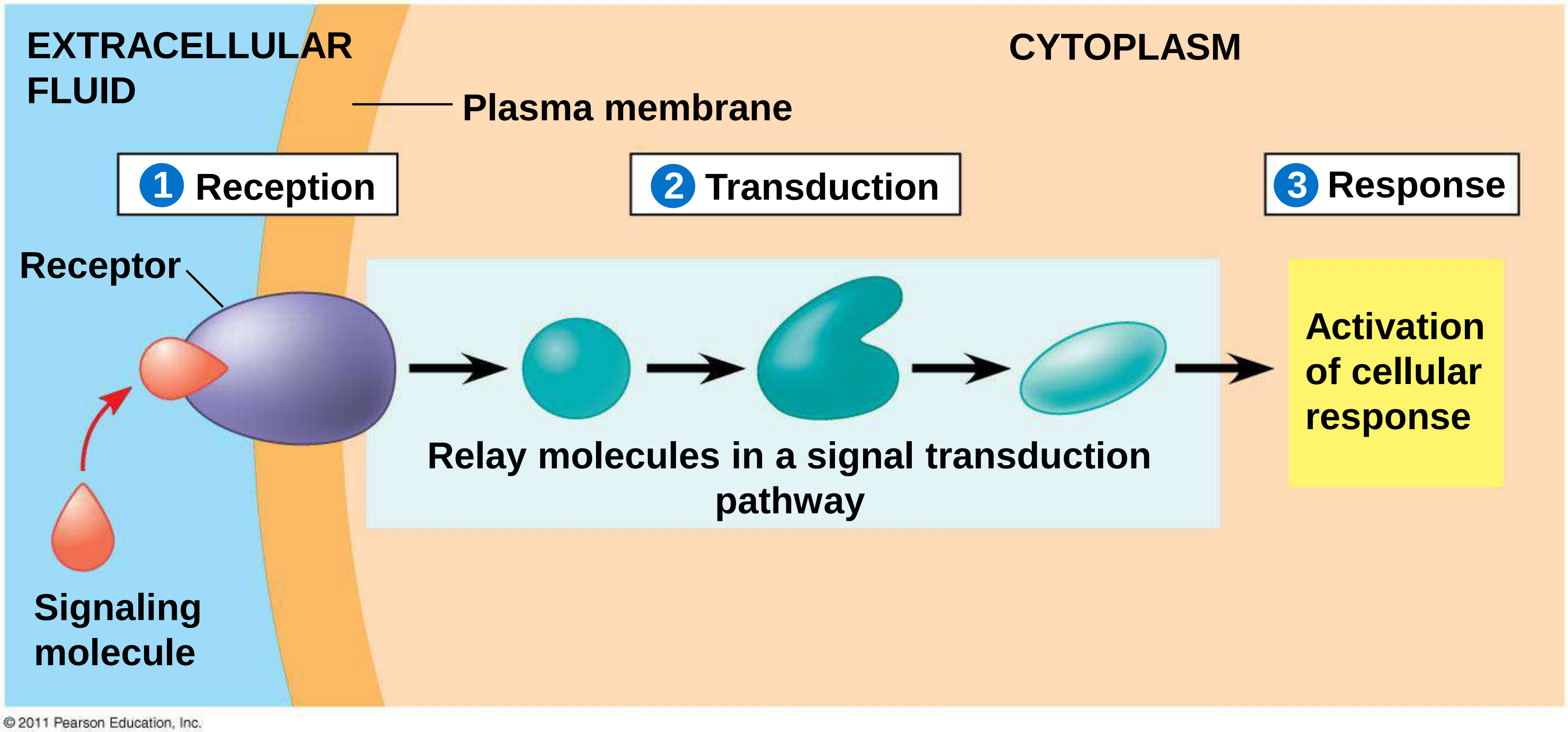
- **Earl W. Sutherland** discovered how the hormone epinephrine acts on cells *(Nobel Prize, 1971; Vanderbilt University)*
- Sutherland suggested that cells receiving signals went through three processes
  - ➔ **Signal Reception**
  - ➔ **Signal Transduction**
  - ➔ **Cellular Response**



Animation: Overview of Cell Signaling
Right-click slide / select “Play”


EXTRACELLULAR
FLUID
CYTOPLASM
Plasma membrane
1 Reception
Receptor
Signaling
molecule


EXTRACELLULAR FLUID
CYTOPLASM
Plasma membrane
1 Reception
2 Transduction
Receptor
Relay molecules in a signal transduction pathway
Signaling molecule


EXTRACELLULAR FLUID
CYTOPLASM
Plasma membrane
1 Reception
2 Transduction
3 Response
Receptor
Relay molecules in a signal transduction pathway
Activation of cellular response
Signaling molecule
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11.2 - Reception: A signaling molecule binds to a receptor protein, causing it to change shape

- The binding between a signal molecule (**ligand**) and receptor is **highly specific** *("lock and key"…again!)*
- A shape change in a receptor is often the initial transduction of the signal
- Most signal receptors are **plasma membrane proteins**

Receptors in the Plasma Membrane

- Most **water-soluble signal molecules** bind to specific sites on receptor proteins that span the plasma membrane
- There are three main types of membrane receptors
  - ➔ **G protein-coupled receptors**
  - ➔ **Receptor tyrosine kinases**
  - ➔ **Ion channel receptors**

G protein-coupled receptors (GPCRs)

- **G protein-coupled receptors (GPCRs)** are the largest family of cell-surface receptors
- A GPCR is a plasma membrane receptor that works with the help of a **G protein**

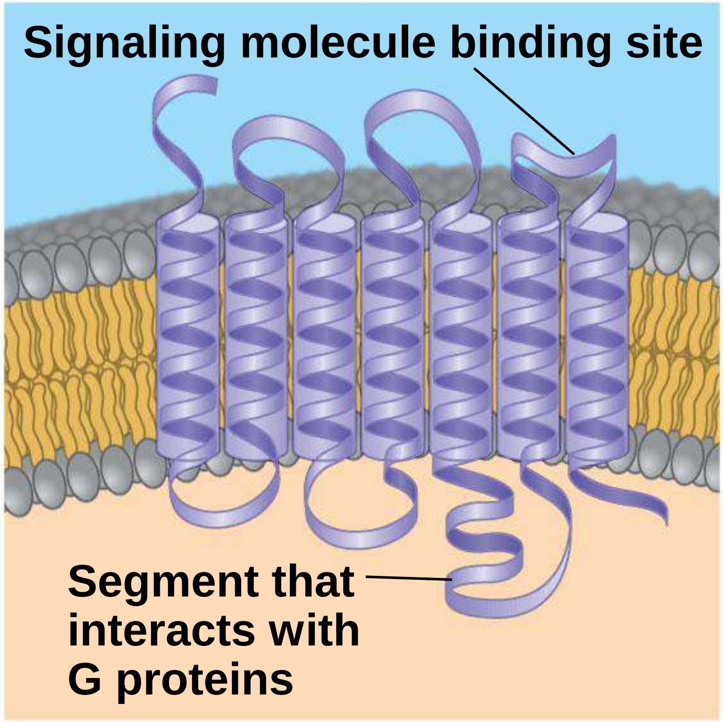
G protein-coupled receptors (GPCRs)

- The G protein acts as an **on/off switch**:

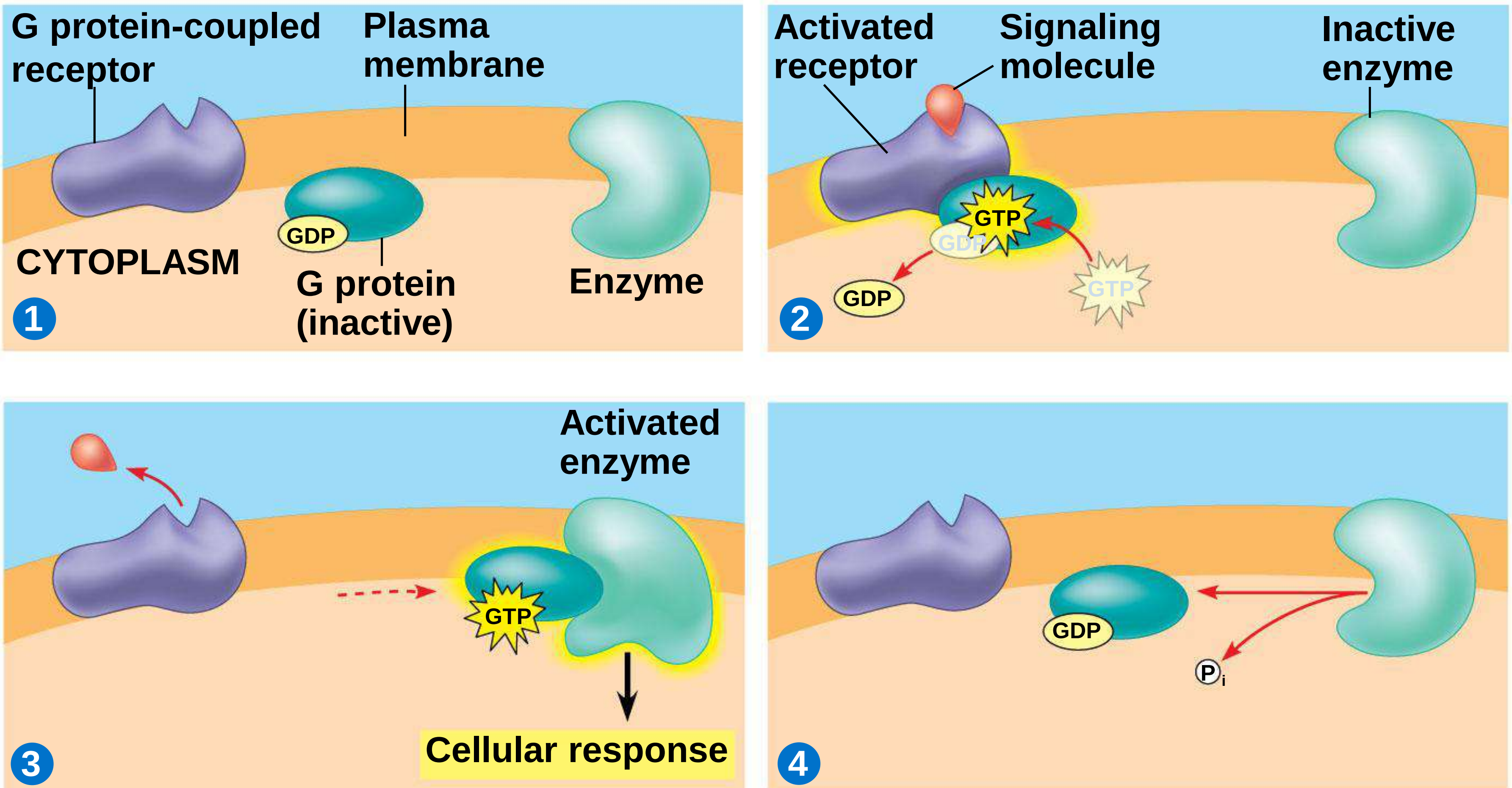
➔ If **GDP** is bound to the G protein, the G protein is **inactive**

➔If **GTP** binds to the G protein, the G protein is **ACTIVE!**

➔ once active, the G protein diffuses along the membrane, and binds to an enzyme, activating it…***this triggers the next step of the cell's response!***

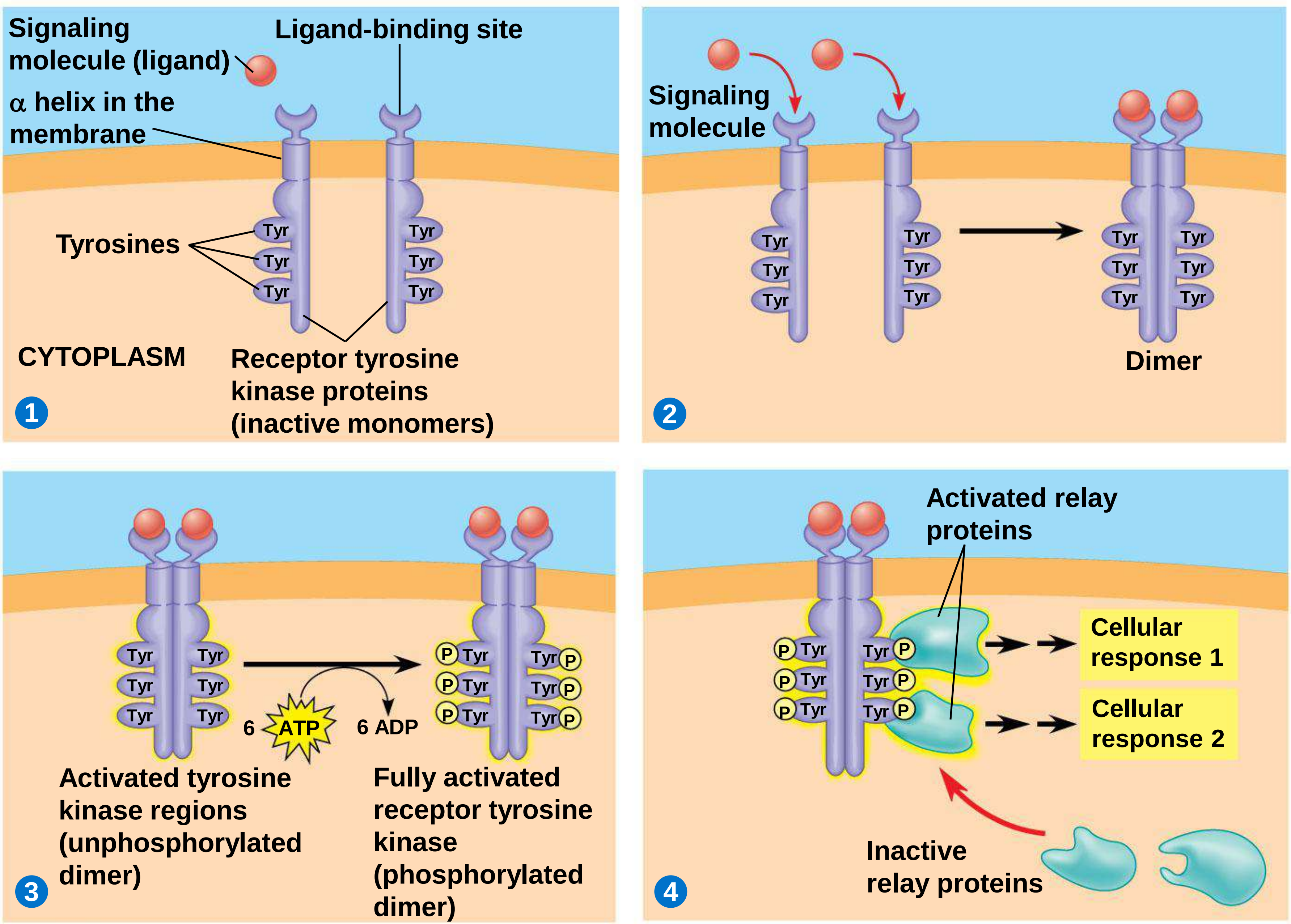


G protein-coupled receptor


G protein-coupled receptor
Plasma membrane
CYTOPLASM
GDP
G protein (inactive)
Enzyme
1
Activated receptor
Signaling molecule
Inactive enzyme
GTP
GDP
GDP
GTP
2
Activated enzyme
GTP
Cellular response
3
GDP
P_i
4

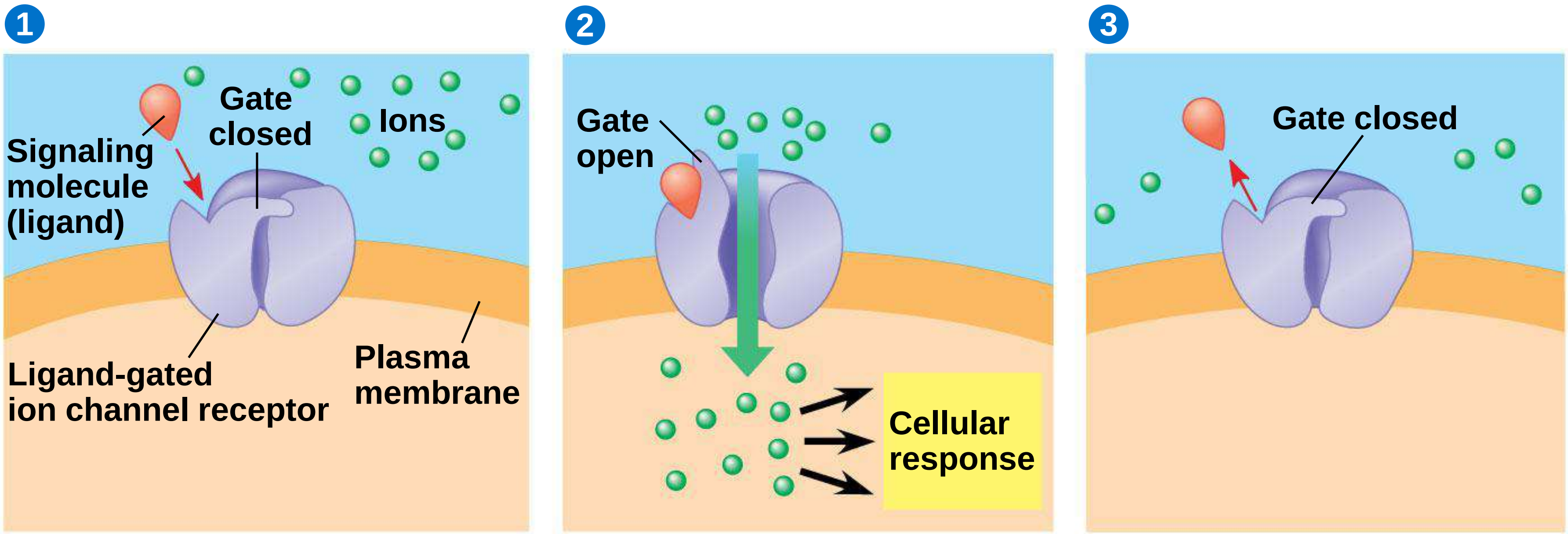
Receptor Tyrosine Kinases (RTKs)

- **Receptor tyrosine kinases (RTKs)** are membrane receptors that **attach phosphates to tyrosines**
- A receptor tyrosine kinase can trigger **multiple signal transduction pathways** at once
- Abnormal functioning of RTKs is associated with many types of cancers
- EX: many breast cancers have excessive levels of a receptor tyrosine kinase called **HER2**.


Signaling molecule (ligand)
Ligand-binding site
α helix in the membrane
Tyrosines
Tyr
CYTOPLASM
Receptor tyrosine kinase proteins (inactive monomers)
1
Signaling molecule
Dimer
2
Activated tyrosine kinase regions (unphosphorylated dimer)
6 ATP
6 ADP
P
Fully activated receptor tyrosine kinase (phosphorylated dimer)
3
Activated relay proteins
Cellular response 1
Cellular response 2
Inactive relay proteins
4

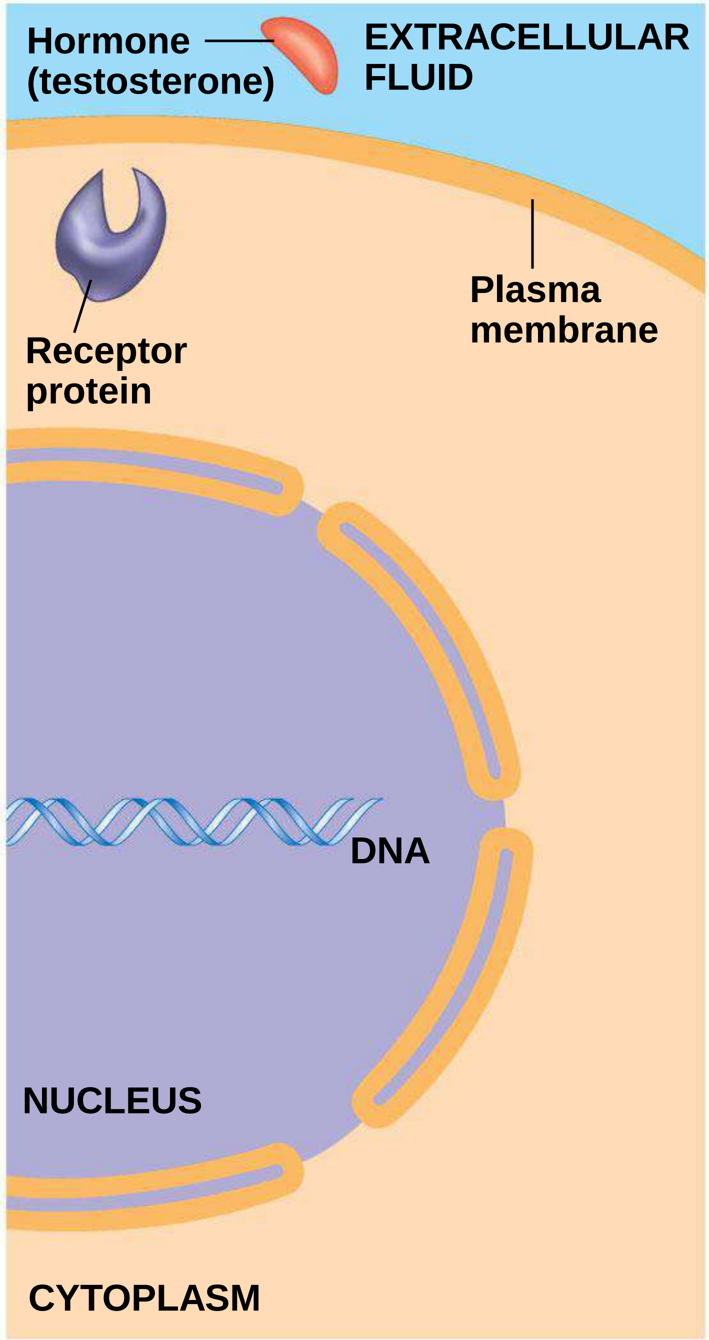
Ligand-Gated Ion Channel Receptors

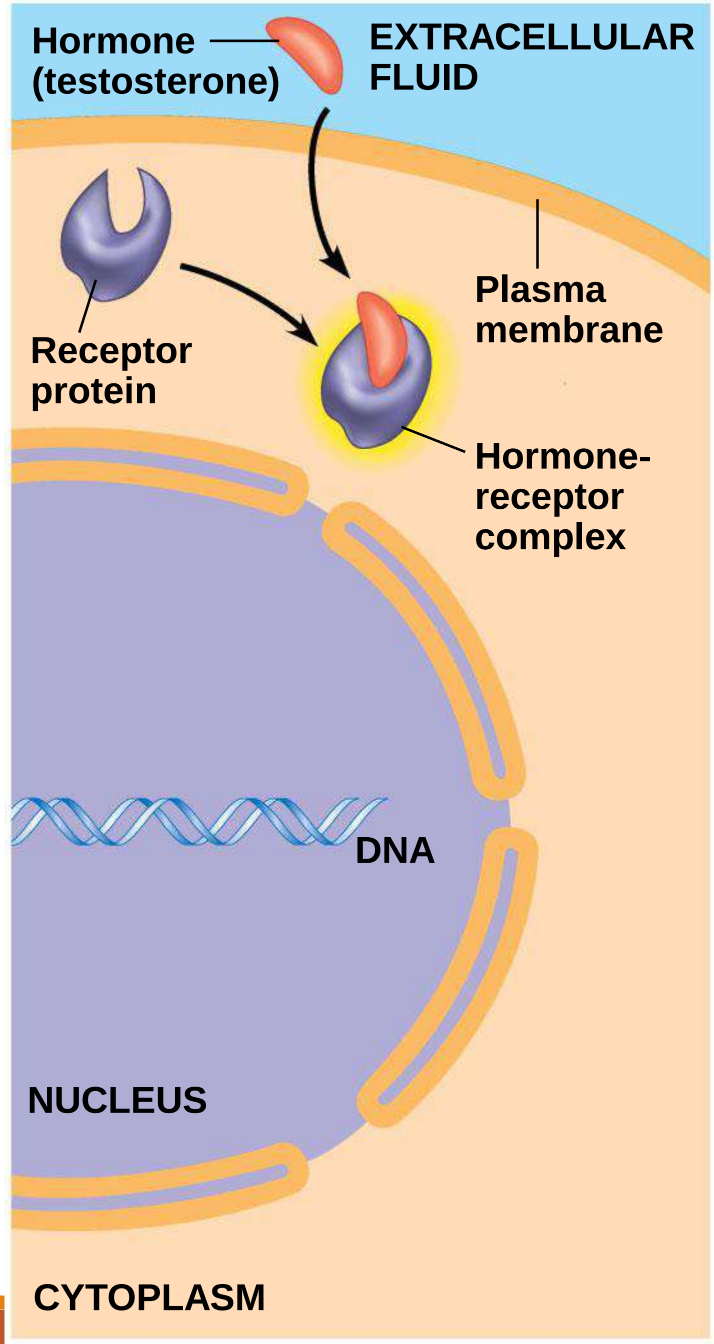
- A **ligand-gated ion channel receptor** acts as a "gate" when the receptor changes shape
- When a signal molecule binds as a ligand to the receptor, the gate opens and allows specific ions, such as Na^+ or Ca^{2+}, through a channel in the receptor
- As ions rush across the membrane, they change the membrane potential (**voltage**), which causes a cellular response!

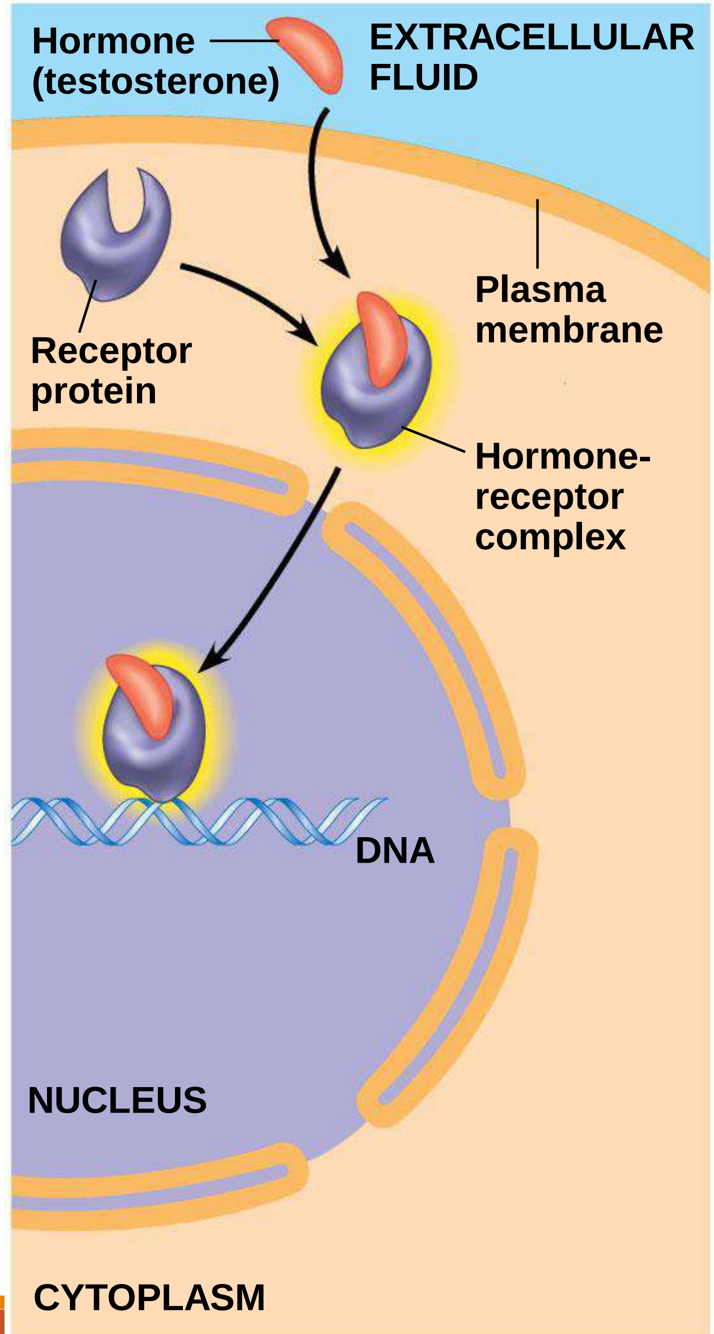

1
Signaling molecule (ligand)
Gate closed
Ions
Ligand-gated ion channel receptor
Plasma membrane
2
Gate open
Cellular response
3
Gate closed

Intracellular Receptors

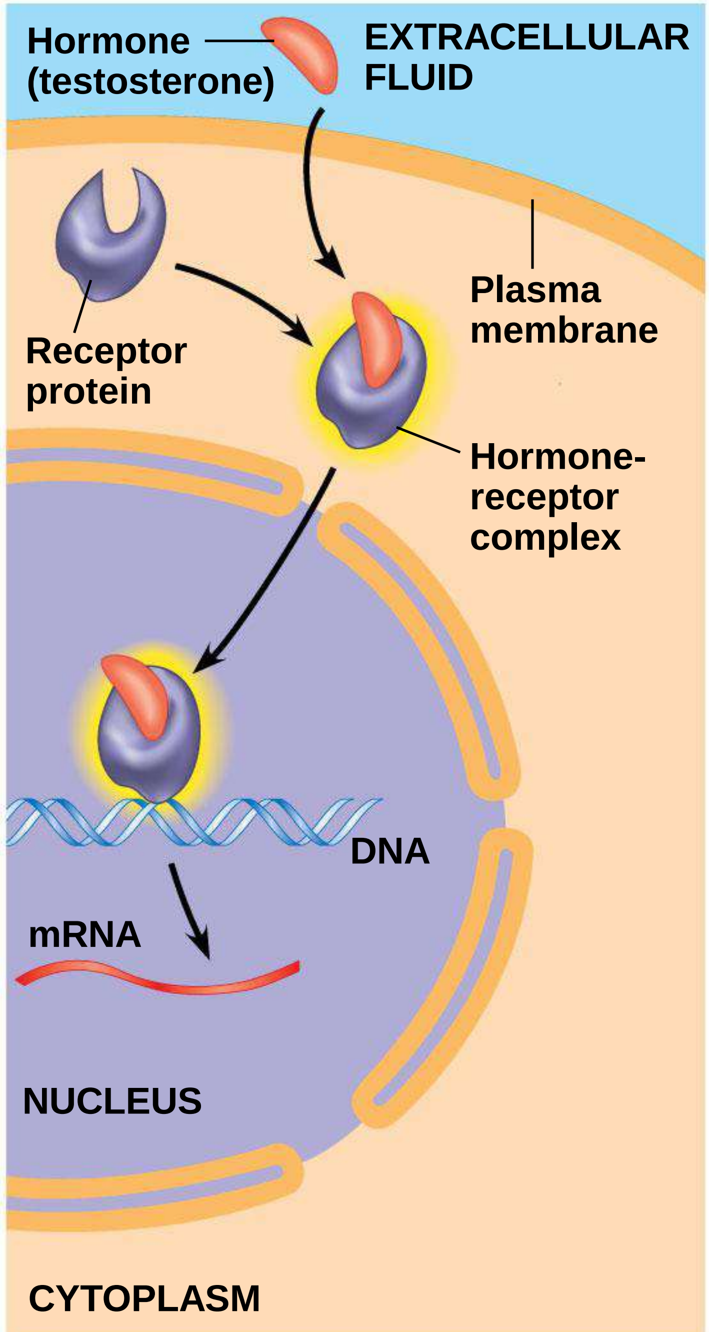
- **Intracellular receptor proteins** are found in the cytosol or nucleus of target cells
- Small or hydrophobic chemical messengers can readily cross the membrane and activate receptors
- Examples of hydrophobic messengers: steroid and thyroid hormones of animals
- An activated hormone-receptor complex can act as a **transcription factor**, **turning on specific genes**

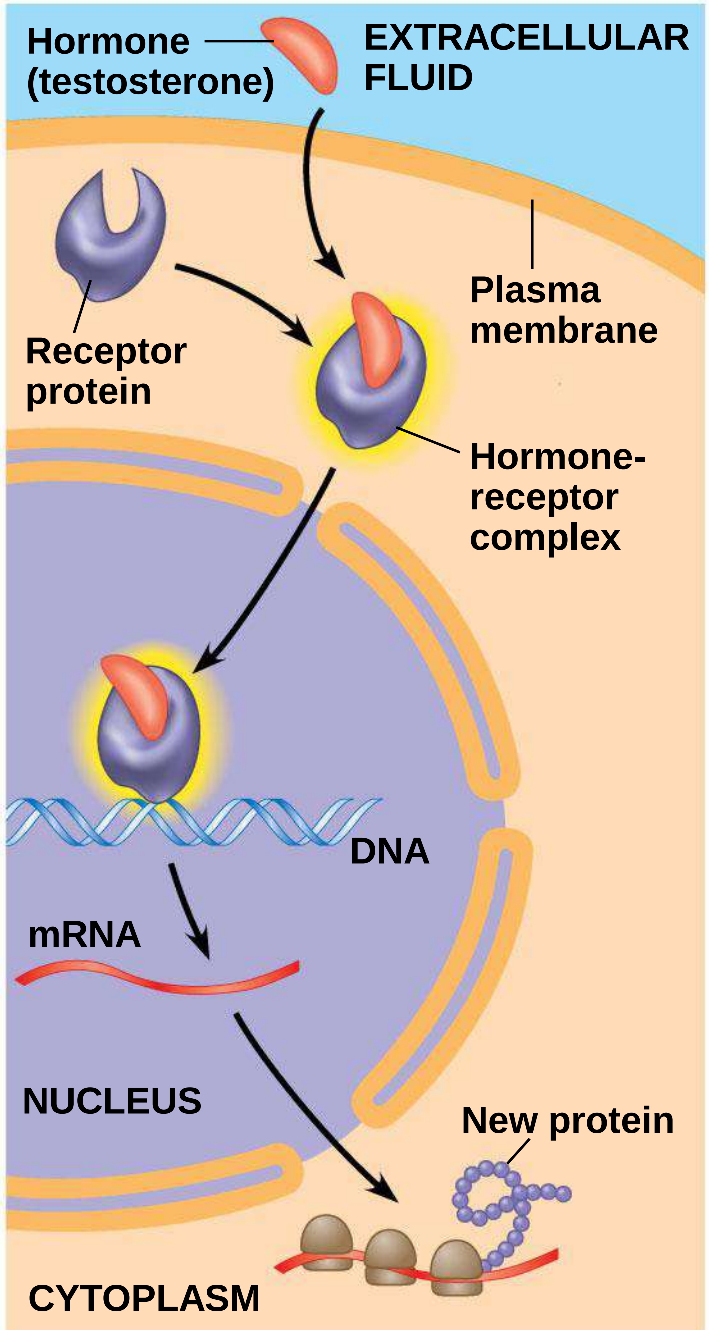

Hormone
(testosterone)
EXTRACELLULAR
FLUID
Plasma
membrane
Receptor
protein
DNA
NUCLEUS
CYTOPLASM


Hormone
(testosterone)
EXTRACELLULAR
FLUID
Plasma
membrane
Receptor
protein
Hormone-
receptor
complex
DNA
NUCLEUS
CYTOPLASM



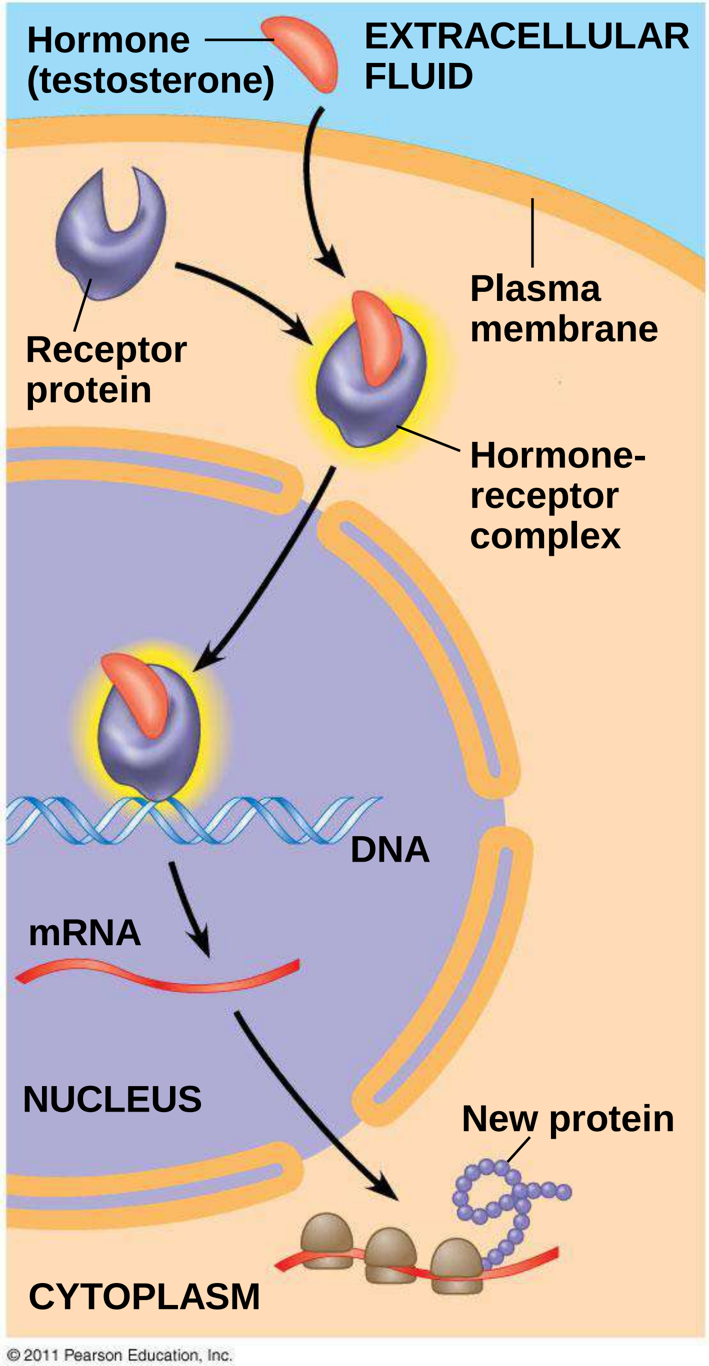
Hormone
(testosterone)
EXTRACELLULAR
FLUID
Plasma
membrane
Receptor
protein
Hormone-
receptor
complex
DNA
NUCLEUS
CYTOPLASM


Hormone
(testosterone)
EXTRACELLULAR
FLUID
Plasma
membrane
Receptor
protein
Hormone-
receptor
complex
DNA
mRNA
NUCLEUS
CYTOPLASM


Hormone
(testosterone)
EXTRACELLULAR
FLUID
Plasma
membrane
Receptor
protein
Hormone-
receptor
complex
DNA
mRNA
NUCLEUS
New protein
CYTOPLASM

<u>How does it “turn on” a gene?</u>

- In order for a gene to be used and result in a protein, it has to:
  - ➔ be <u>transcribed into mRNA</u> (**nucleus**)
  - ➔ exit the nucleus & be **translated** (**ribosome**)
- most genes require a **TRANSCRIPTION FACTOR** to attach to it and “turn it on” (trigger transcription)
- the <u>testosterone receptor</u>, once activated, does just that! (as do many intracellular receptors)
- ***so, in this case the cellular response is <u>to make a protein</u>!***


Hormone
(testosterone)
EXTRACELLULAR
FLUID
Plasma
membrane
Receptor
protein
Hormone-
receptor
complex
DNA
mRNA
NUCLEUS
New protein
CYTOPLASM
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