Cell To Cell communication

AP CONTENT - SBI4UP

MRS. FRANKLIN

Cellular Communication

The trillions of cells within an organism must communicate with one another to coordinate chemical reactions and activities that enables the organism to survive and develop.

The research in cell-to-cell communication allows scientists to understand cellular regulation but also shows evolutionary relationships

Signal Transduction pathway: the process by which a signal on a cell's surface is converted into a specific cellular response in a series of steps.

Local and Long-Distance Signaling

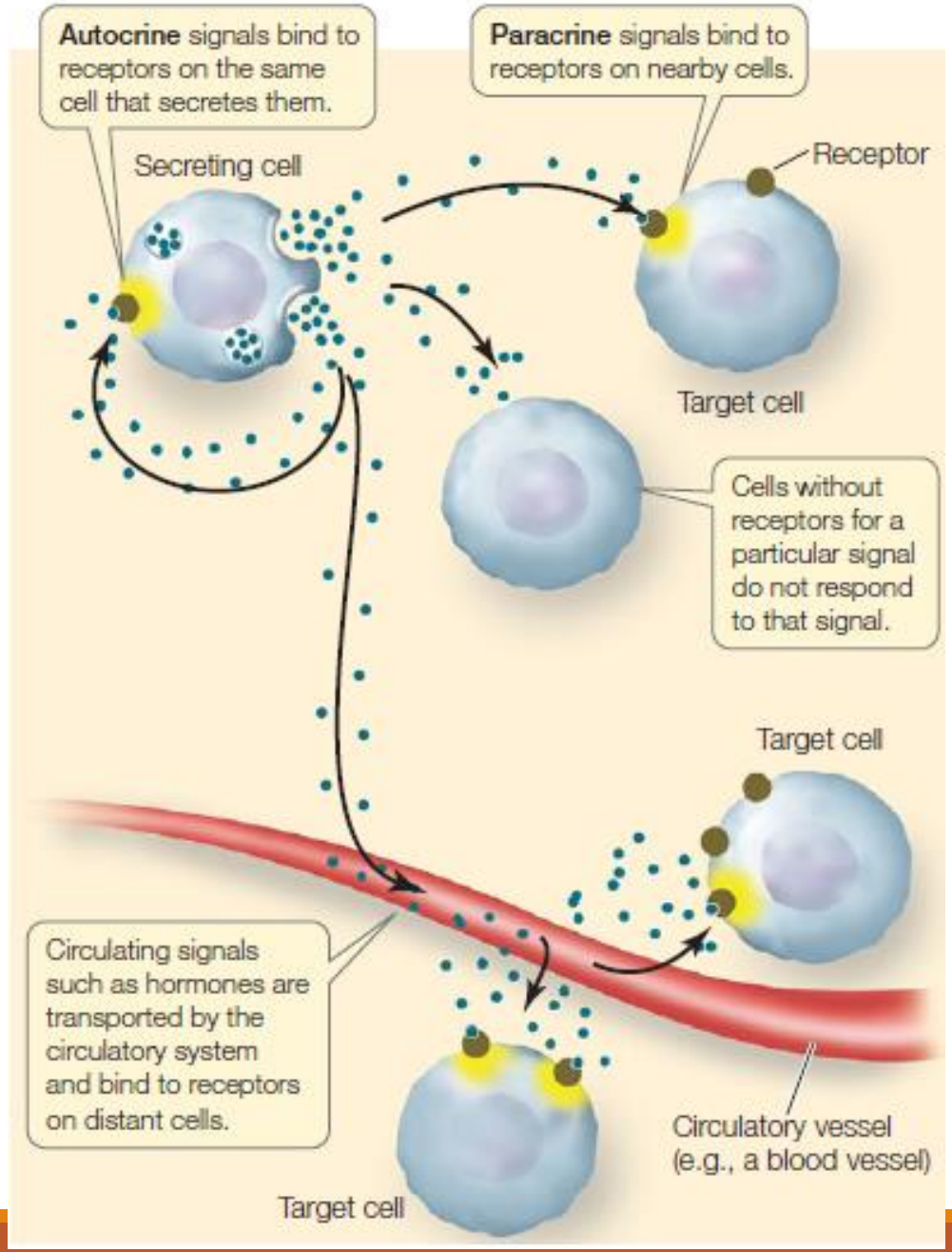
Chemical signaling may occur in two main ways:

1) Local signaling: chemical signal travels a short distance and targets cells in the vicinity.

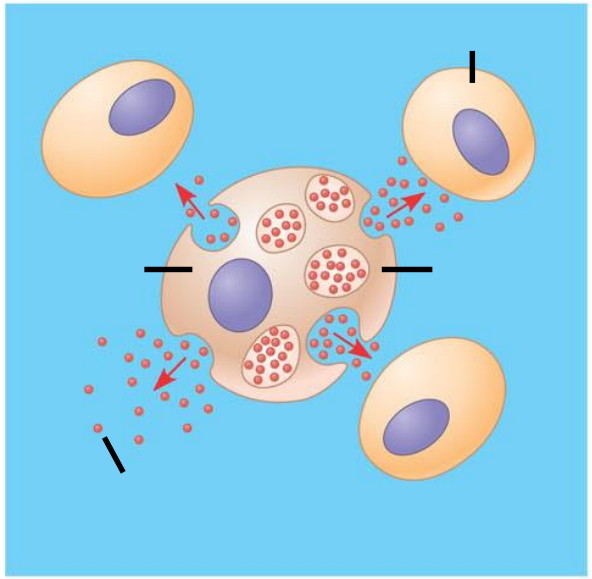
a) Autocrine

b) Paracrine

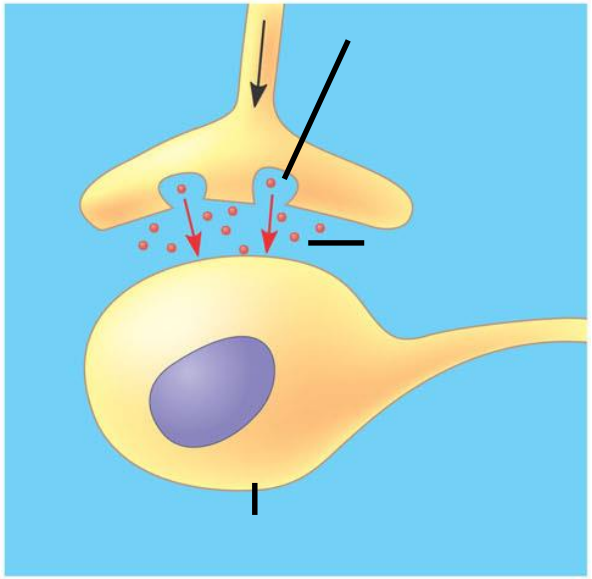
2) Long-distance signaling: the signal will travel through the bloodstream in vessels. a.k.a endocrine signaling (hormones)



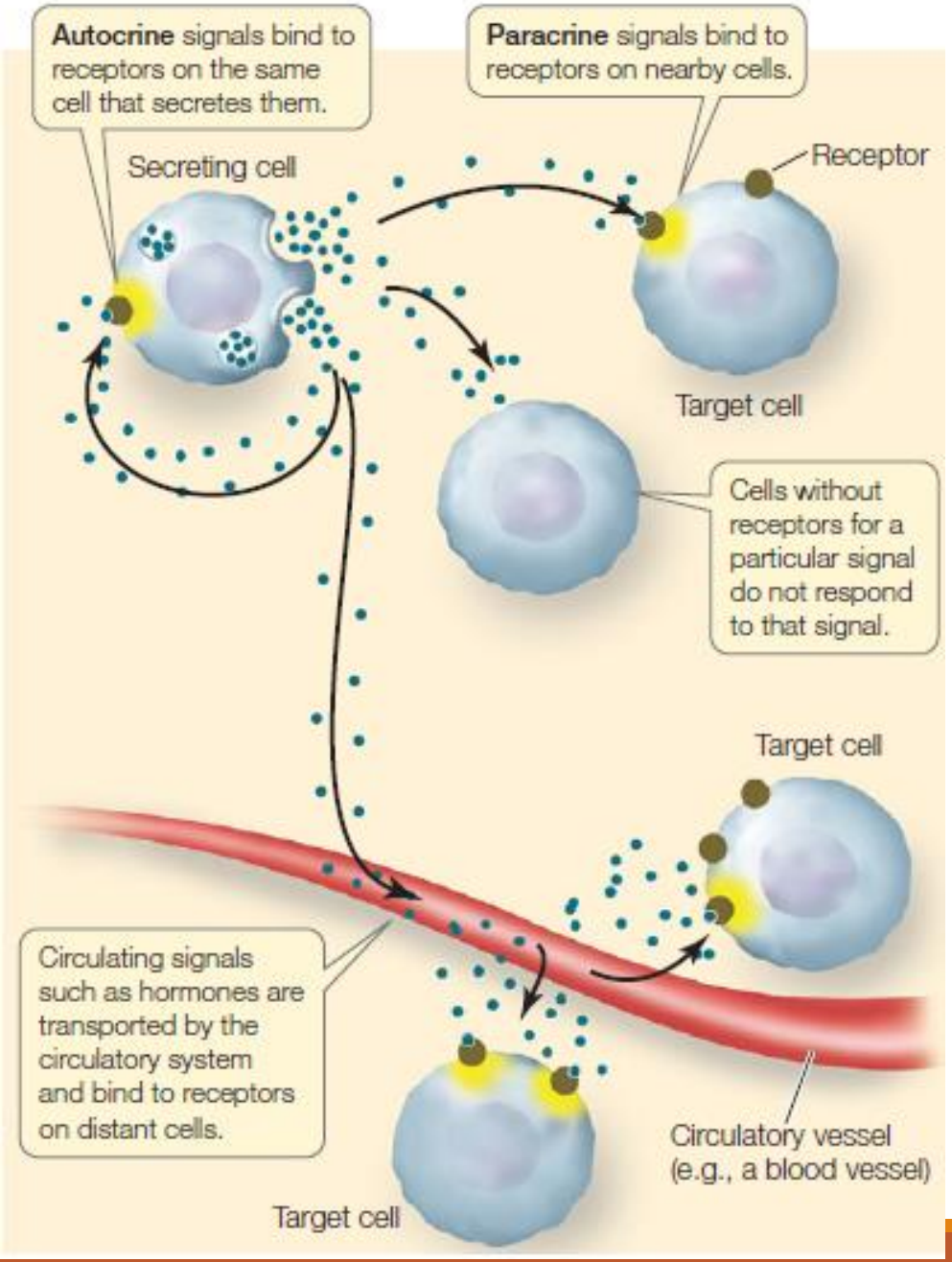
Local signaling



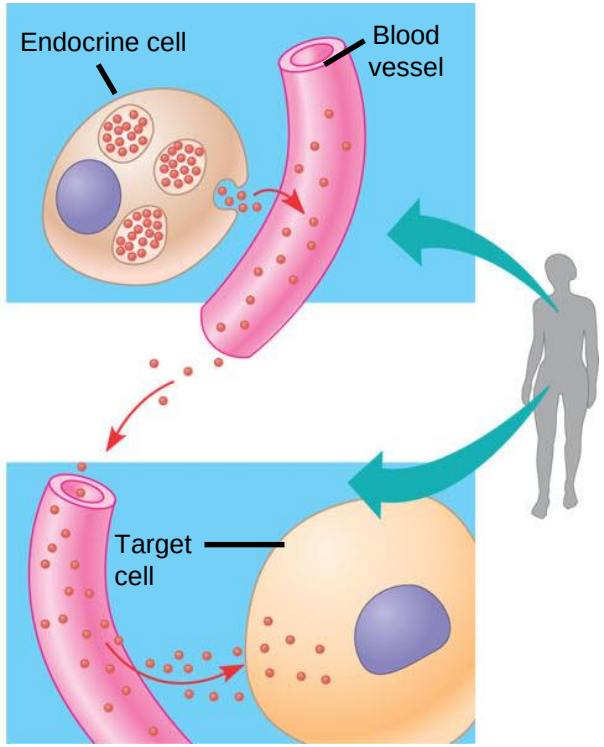
(a) Paracrine signaling



(b) Synaptic signaling.



Long-distance signaling



(c) Hormonal signaling.

Cell Signaling Overview

Cell Signaling occurs in 3 main steps:

1) Reception:

2) Transduction:

3) Response:

1) Reception
2) Transduction
3) Response

Cell Signaling Overview

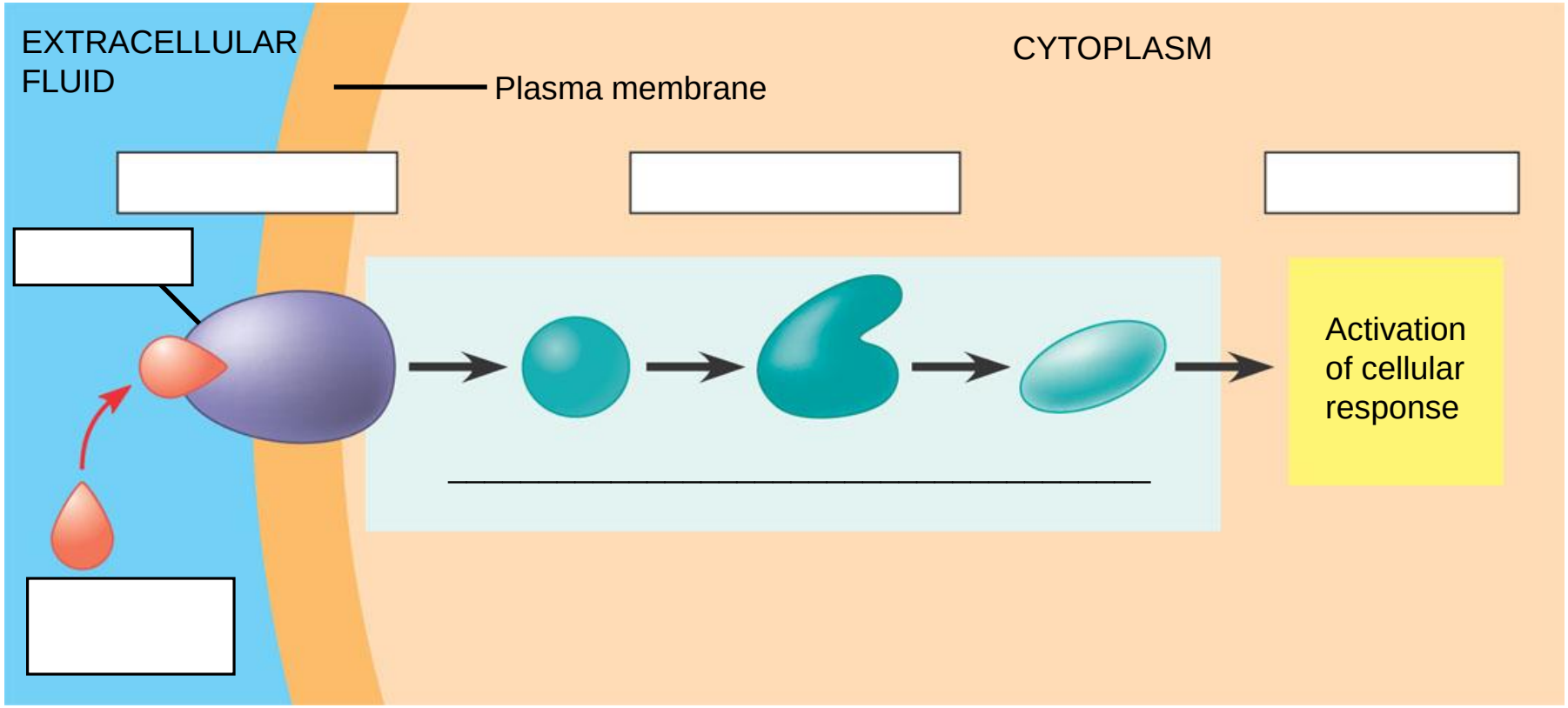
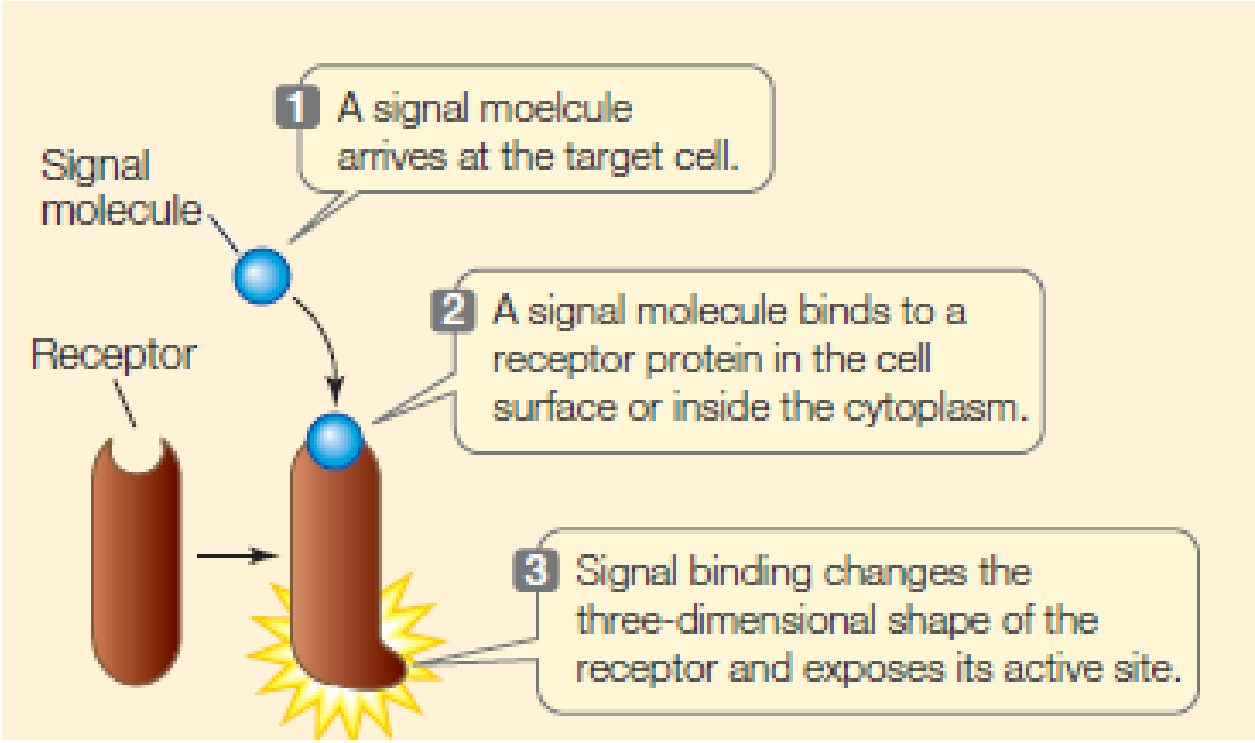


Figure 11.5

1) **RECEPTION**
2) Transduction
3) Response

Step 1: Reception

If the signaling molecule is hydrophilic, it must attach to protein receptors on the surface of the cell membrane.



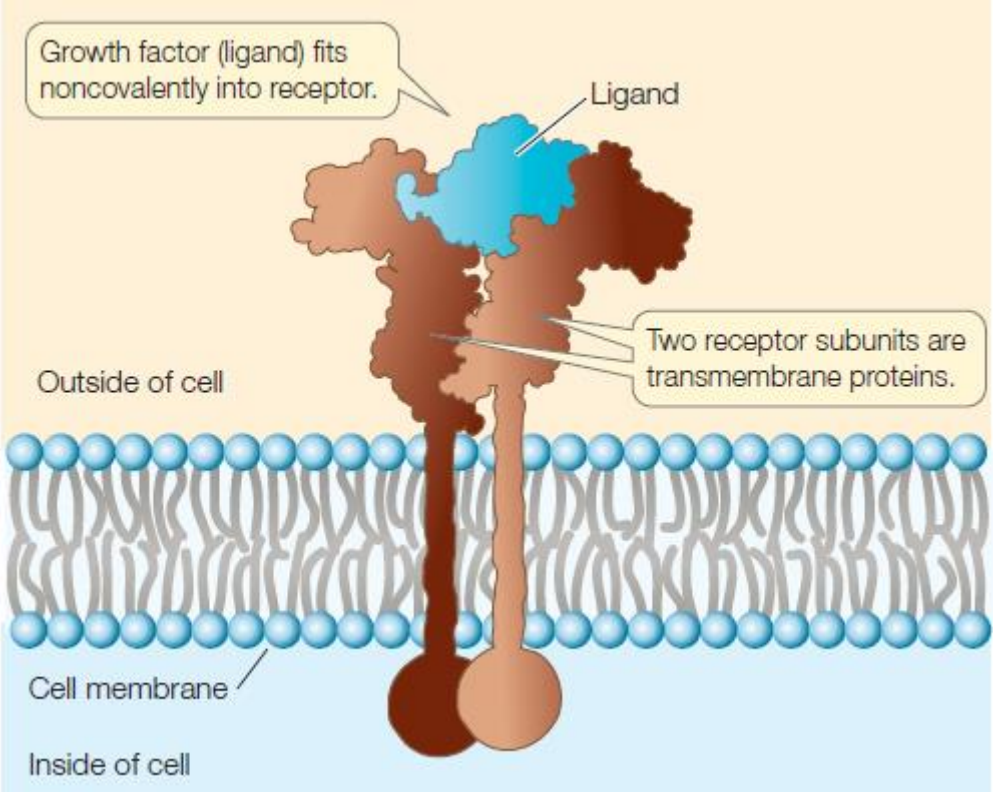
Ligand:

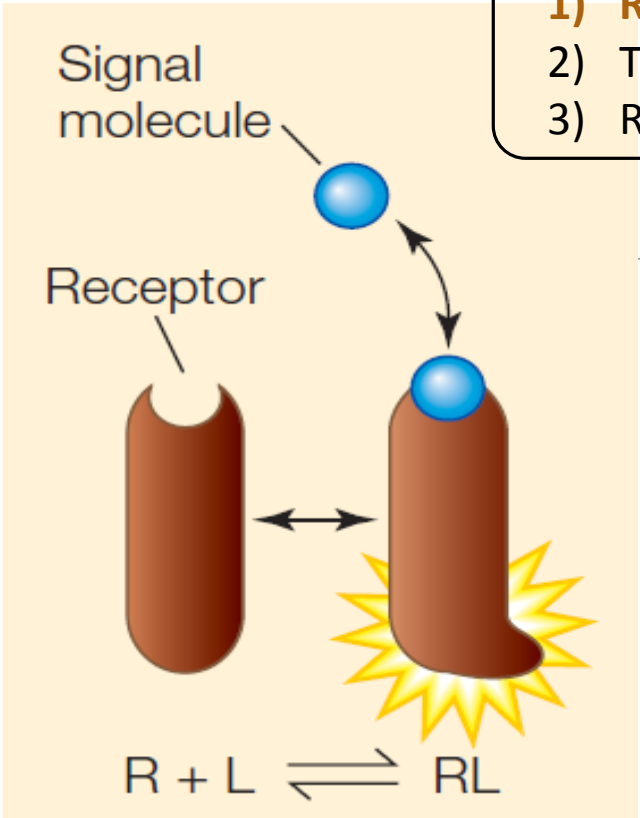
The ligand and protein receptor must be complementary in terms of their shape.

When the receptor is activated a cascade of reactions can be triggered.

1) **RECEPTION**
2) Transduction
3) Response

Cell Membrane Receptor





The binding of the ligand is reversible.

Why is this feature important for cell signaling?

1) **RECEPTION**
2) Transduction
3) Response

Not all receptors will be located on the cell membrane. Some may be intracellular and located within the cytoplasm or the nucleus of the cell.

What properties must the signaling molecule have that will allow it to cross the membrane?

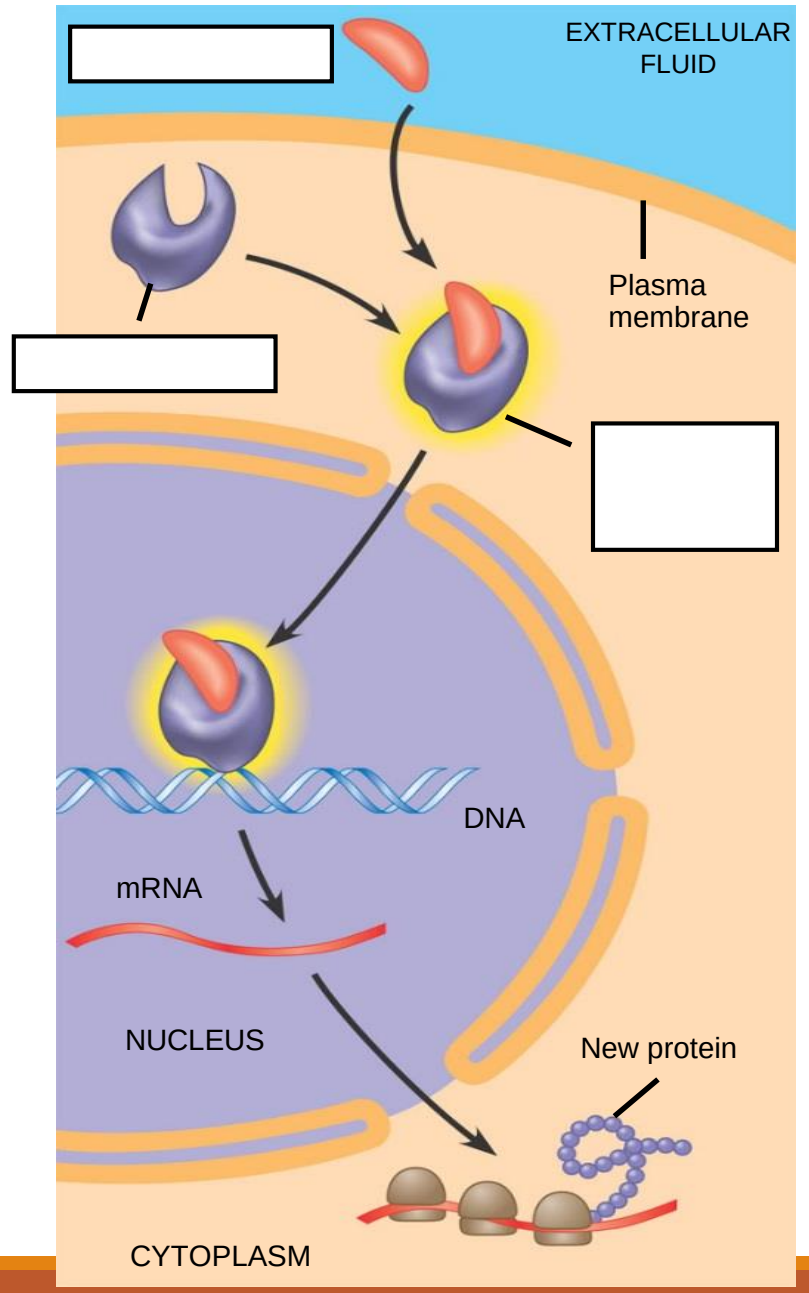


Figure 11.6

1) **RECEPTION**
2) Transduction
3) Response

Cell Membrane Receptor

There are three main types of membrane receptors

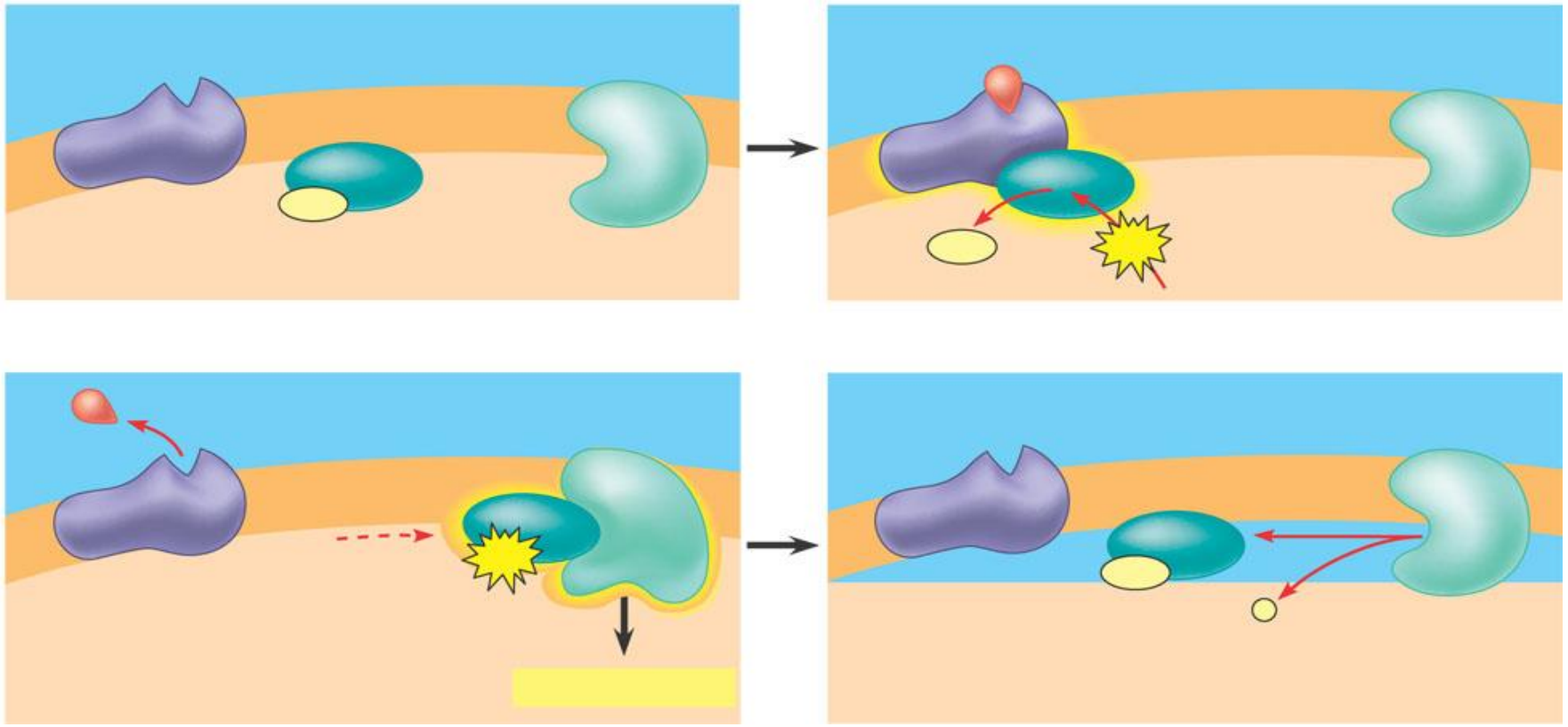
1) G-protein-linked

2) Tyrosine kinases

3) Ion channel

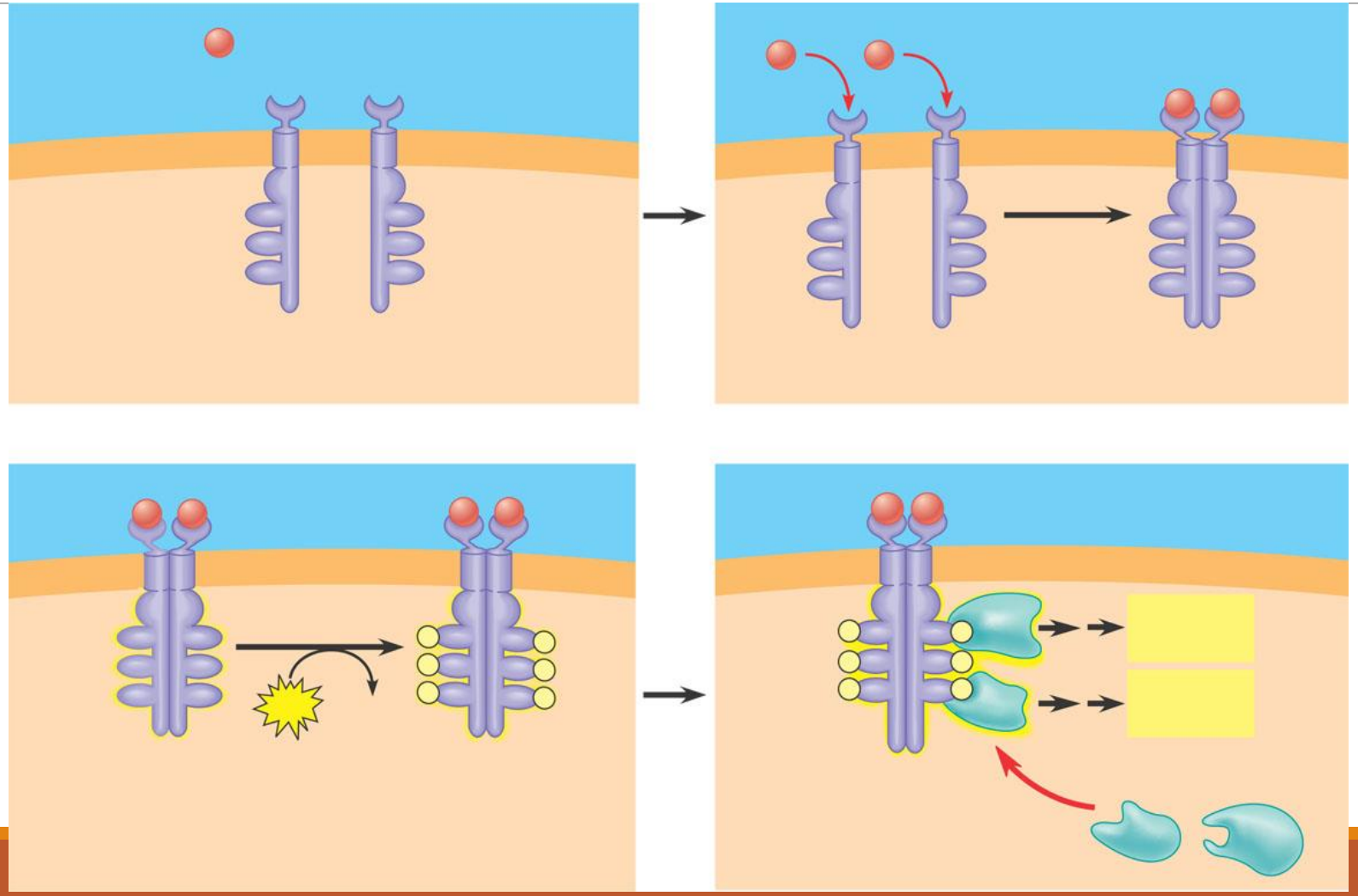
1) **RECEPTION**
2) Transduction
3) Response

1) G-protein Linked Receptor



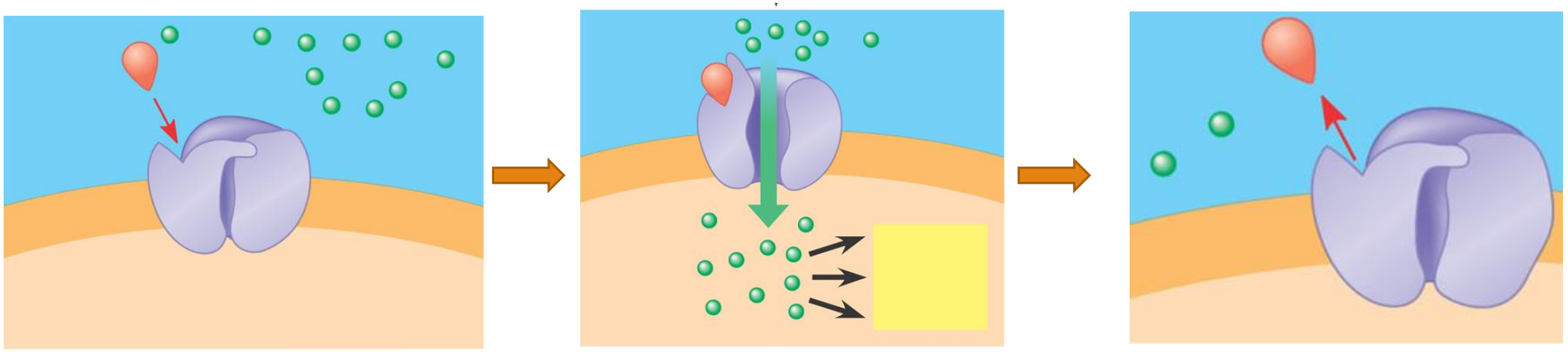
1) **RECEPTION**
2) Transduction
3) Response

2) Tyrosine Kinases



1) **RECEPTION**
2) Transduction
3) Response

2) Ion Channel Receptors



1) Reception
2) **TRANSDUCTION**
3) Response

Step 2: Transduction

The transduction in the cell is a multistep pathway that involves the activation of many proteins.

This is advantageous because only a small amount of signalling molecules is required to create a large intracellular response.

Most signalling molecules- if water soluble – never enter the cell. The signal must be relayed from the receptor.

Most proteins are activated and deactivated through phosphorylation.

1) Reception
2) **TRANSDUCTION**
3) Response

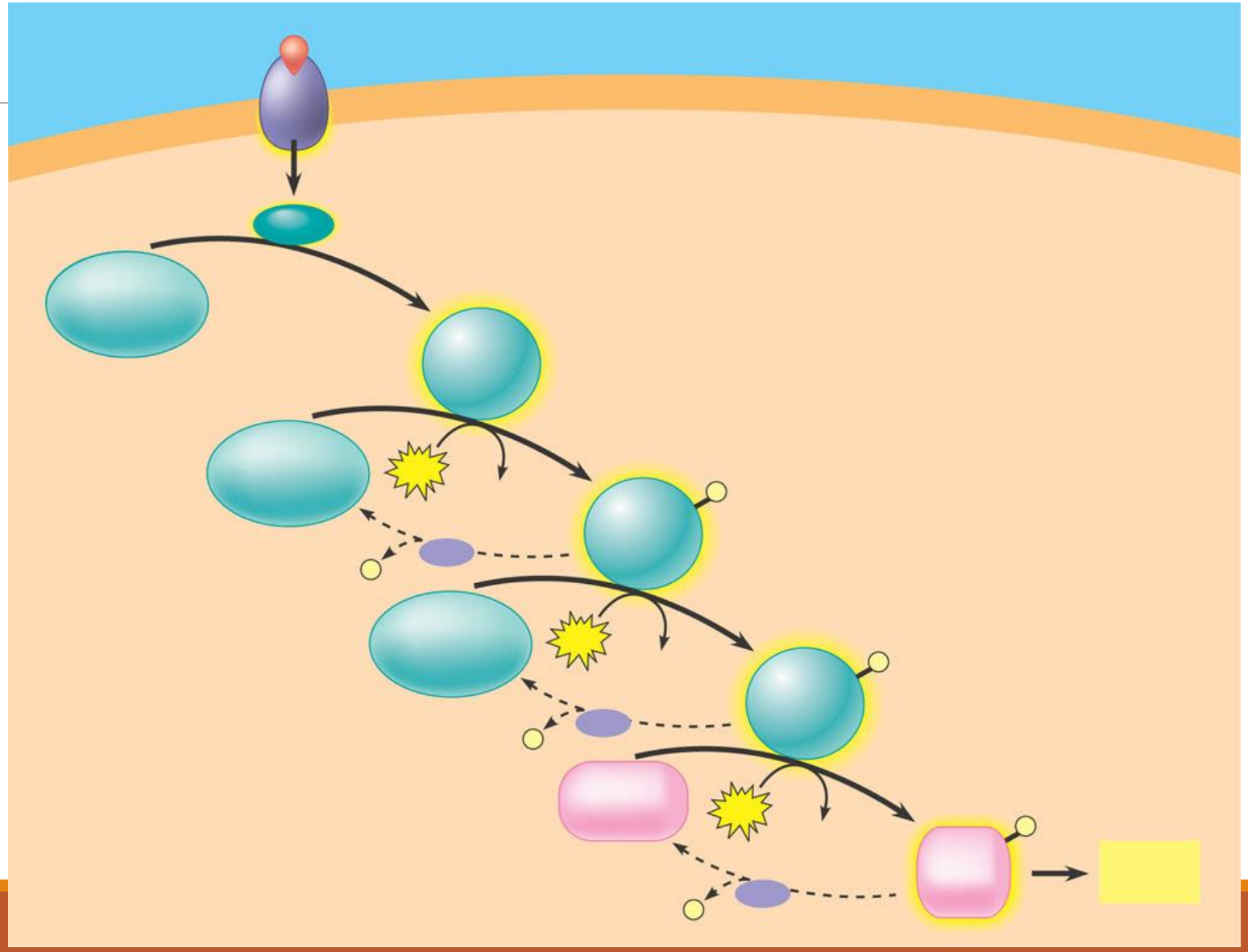
Step 2: Transduction

Protein Kinase:

Protein Phosphatases:

Most of the proteins in the pathway are protein kinases that act on one another.

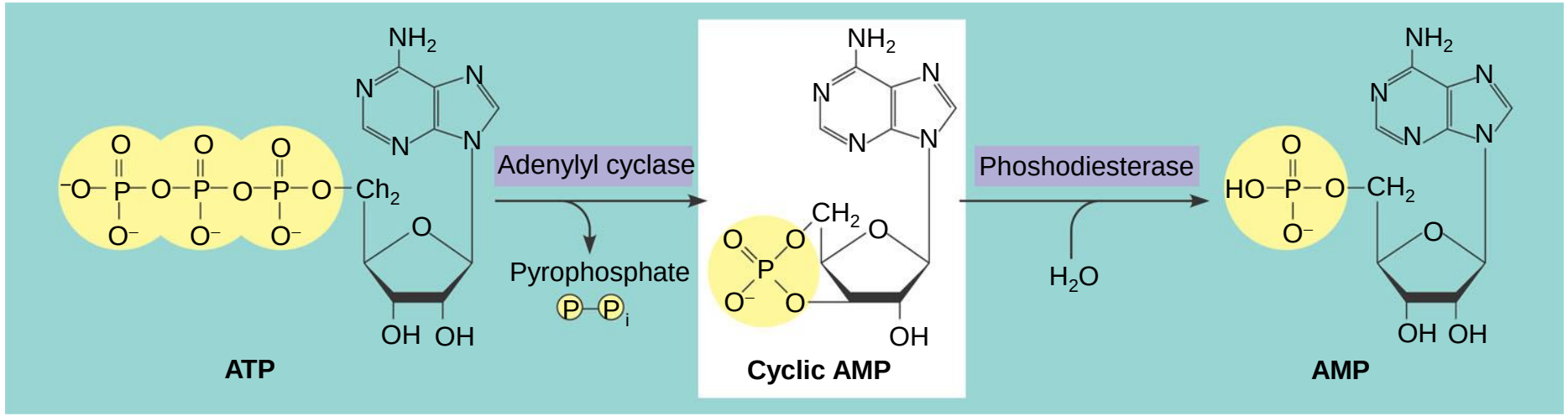
This pathway is also known as a ***'phosphorylation cascade'.***



1) Reception
2) **TRANSDUCTION**
3) Response

Step 2: Transduction

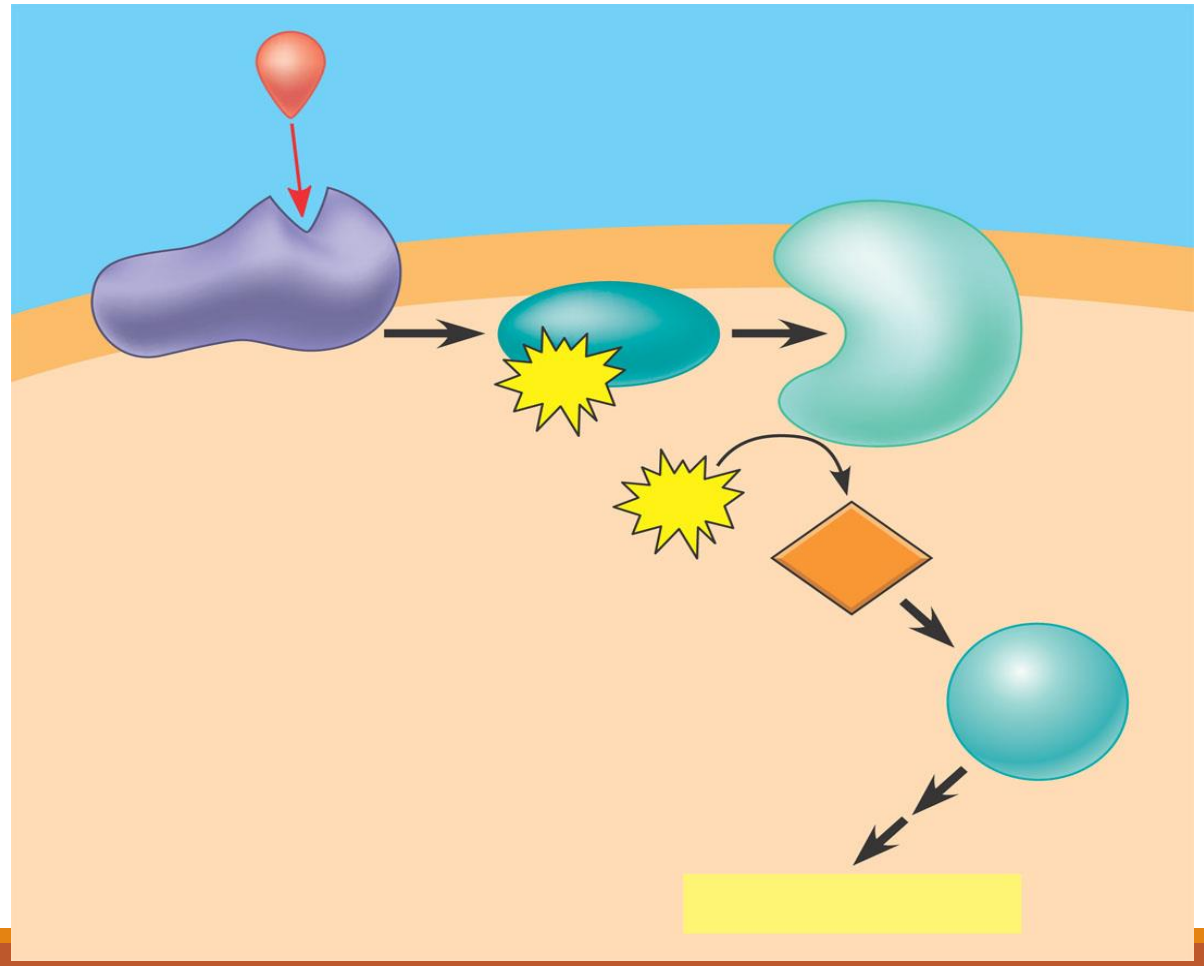
Many signaling pathways involve a 'secondary messenger' which are small and water-soluble (hydrophilic).



Cyclic AMP (cAMP) is an example of a secondary messenger found in most pathways.

1) Reception
2) **TRANSDUCTION**
3) Response

cAMP (cyclic AMP)



The enzyme ***adenylyl cyclase,*** helps to convert ATP to cAMP in response to an extracellular signal.

When the receptor protein is activated a G-protein will in turn activate adenylyl cyclase.

When the signal is removed, cAMP is converted back into AMP in the presence of ***phosphodiesterase.***

1) Reception
2) Transduction
3) **RESPONSE**

Step 3: Response

The response may occur in either the cytoplasm or the nucleus.

- ***Cytoplasmic Response:***

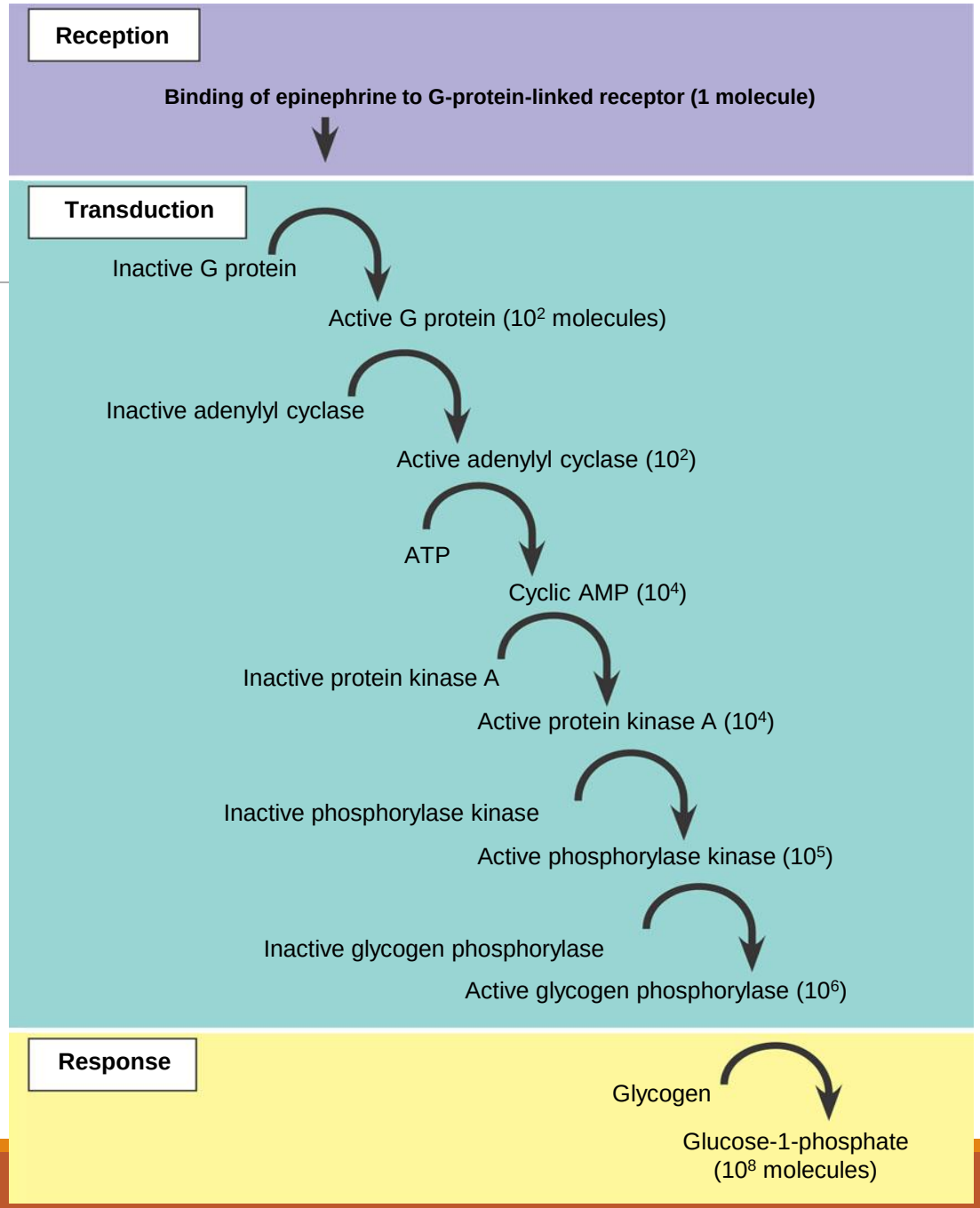
- ***Nuclear Response:***

1) Reception
2) Transduction
3) **RESPONSE**

Cytoplasmic Response

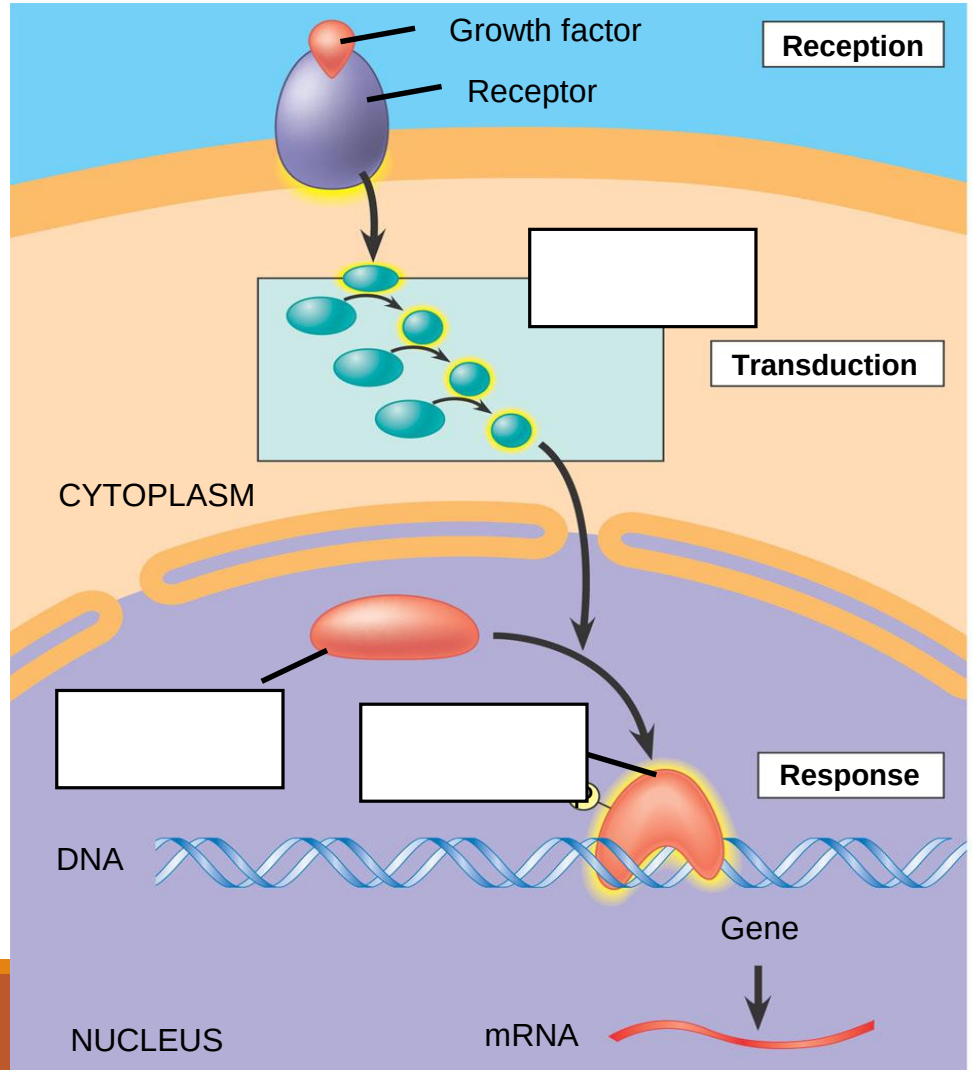
The transduction pathway may activate an enzyme involved in a specific biochemical reaction within the cytoplasm.

e.g. This diagram illustrates the pathway used to breakdown glycogen.



1) Reception
2) Transduction
3) **RESPONSE**

Nuclear Response

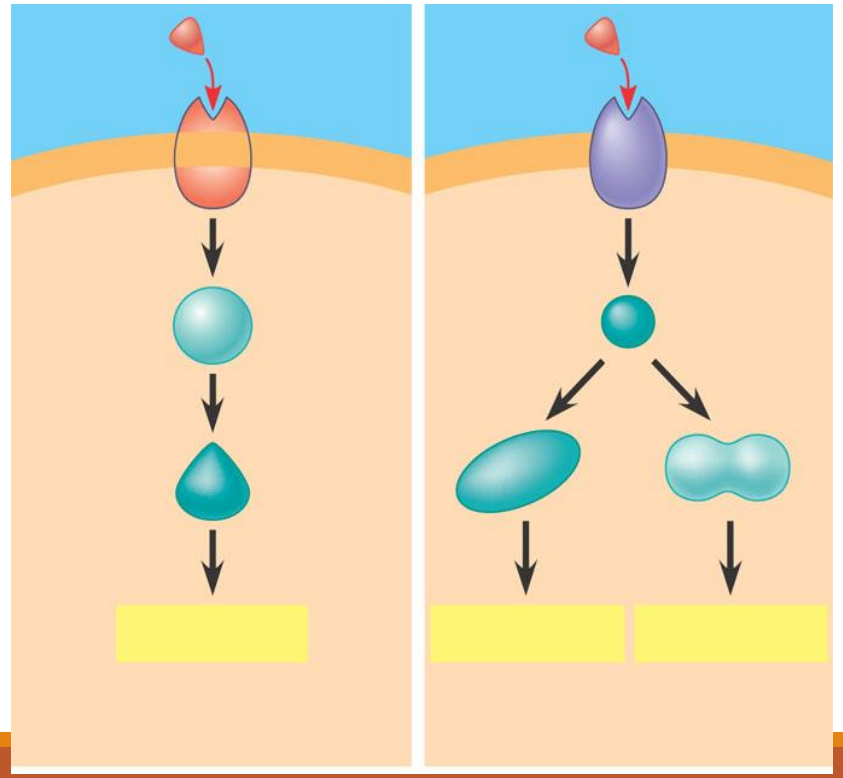


This type of pathway regulates the synthesis of enzymes or other proteins. The signaling pathway will active/deactivate the appropriate genes.

1) Reception
2) Transduction
3) **RESPONSE**

Specificity of Cell Signaling

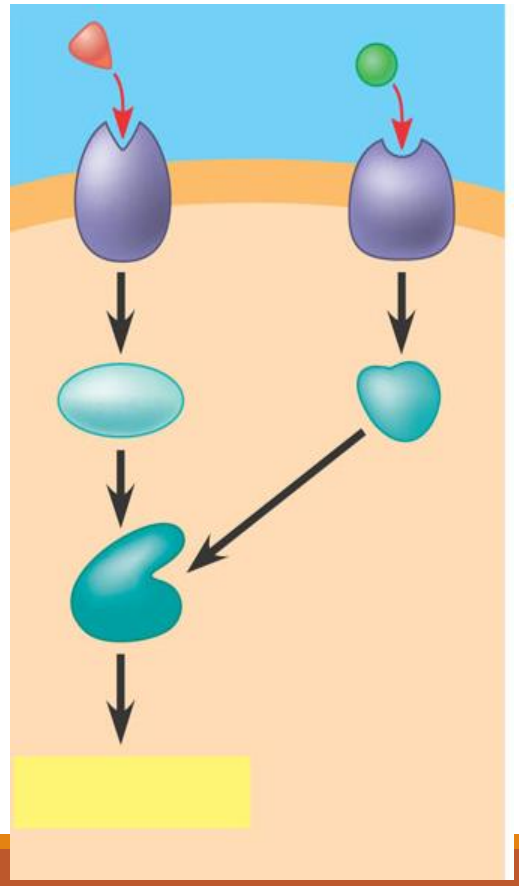
One signal may trigger a different response in many different cells. The different responses are due to the various proteins that are present in each cascade.



1) Reception
2) Transduction
3) **RESPONSE**

Specificity of Cell Signaling

At times, two pathways triggered by a different signal can converge and regulate one response.
a.k.a ***'Cross-talk'.***

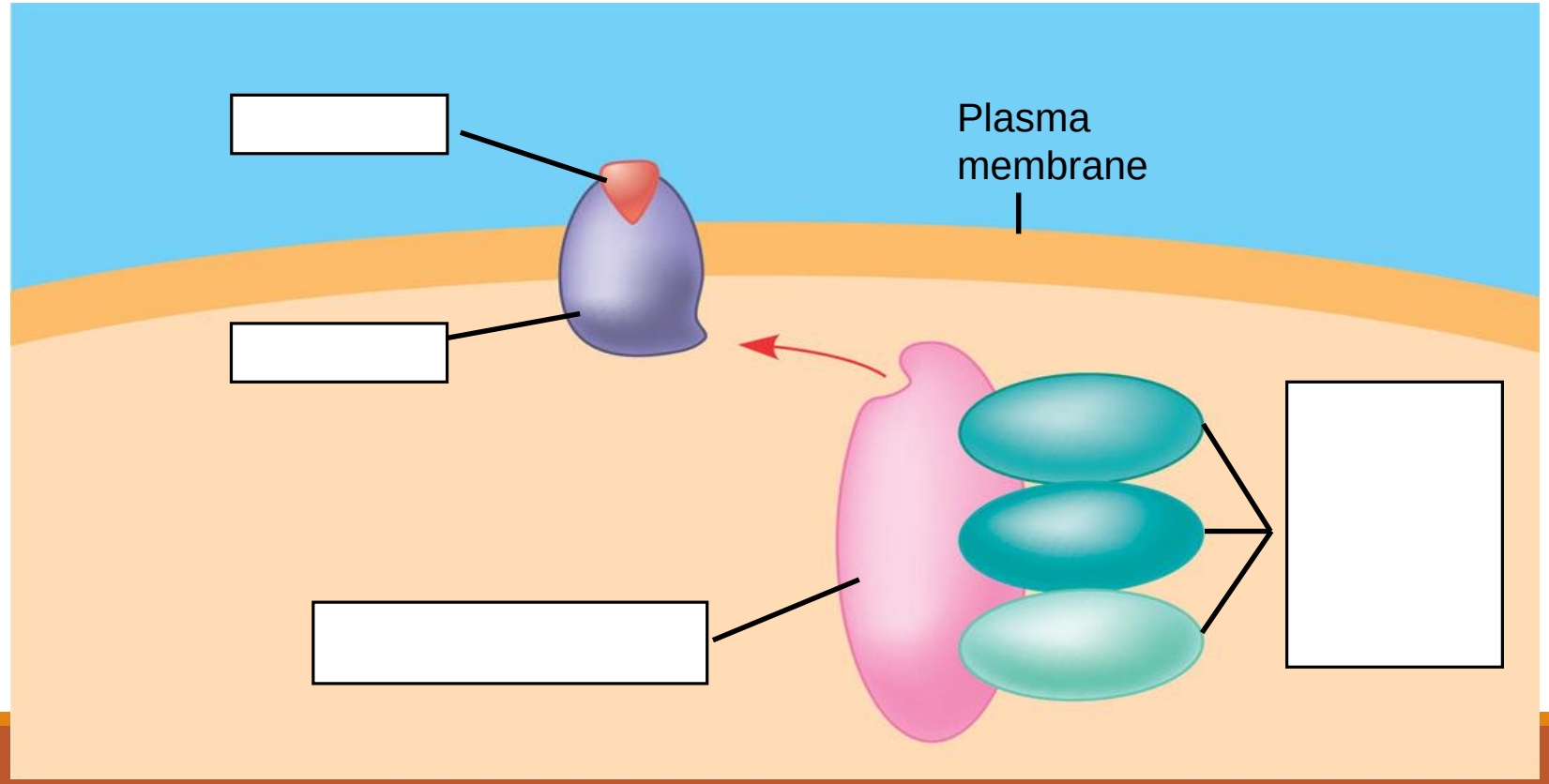


1) Reception
2) Transduction
3) **RESPONSE**

Scaffolding Proteins

Many scaffolding proteins have been found to permanently hold on to a large number of protein kinases for a quick , efficient and accurate response.

Scaffolding proteins:



1) Reception
2) Transduction
3) **RESPONSE**

Termination of the Signal

In order for cells to continuously respond to cell signals, the proteins must return to their original conformations.

As soon as the ligand leaves the receptor, the protein will assumes in inactive conformation.

Phosphatases will inactivate the protein kinases and the phosphodiesterases will convert cAMP to AMP.

Checking for Understanding

Phosphorylation cascades involving a series of protein kinases are useful for cellular signal transduction because

a) They are species specific

b) They always lead to the same cellular response

c) They counter the harmful effects of phosphatases

d) They counter the harmful effects of phosphatases

e) The number of molecules used is small and fixed

Checking for Understanding

Binding of a signal to which type of receptor leads directly to a change in the distribution of anions and/or cations on opposite sides of the membrane?

a) Receptor tyrosine kinase

b) G-protein linked receptor

c) Phosphorylated receptor tyrosine kinase dimer

d) Ligand-gated ion channel

e) Intracellular receptor

Checking for Understanding

Lipid-soluble signals, such as testosterone, cross the membranes of all cells but affect only target cells because

a) Only target cells retain the appropriate DNA segments

b) Intracellular receptors are present only in target cells

c) Most cells lack the Y chromosome required

d) Only target cells possess the cytosolic enzymes that transduce testosterone

e) Only in target cells is testosterone able to initiate the phosphorylation cascade leading to activated transcription factors.

Checking for Understanding

Signal transduction pathways benefit cells for all of the following reasons except

a) They help cells respond to signal molecules that are too large or too polar to cross the plasma membrane.

b) They enable different cells to respond appropriately to the same signal

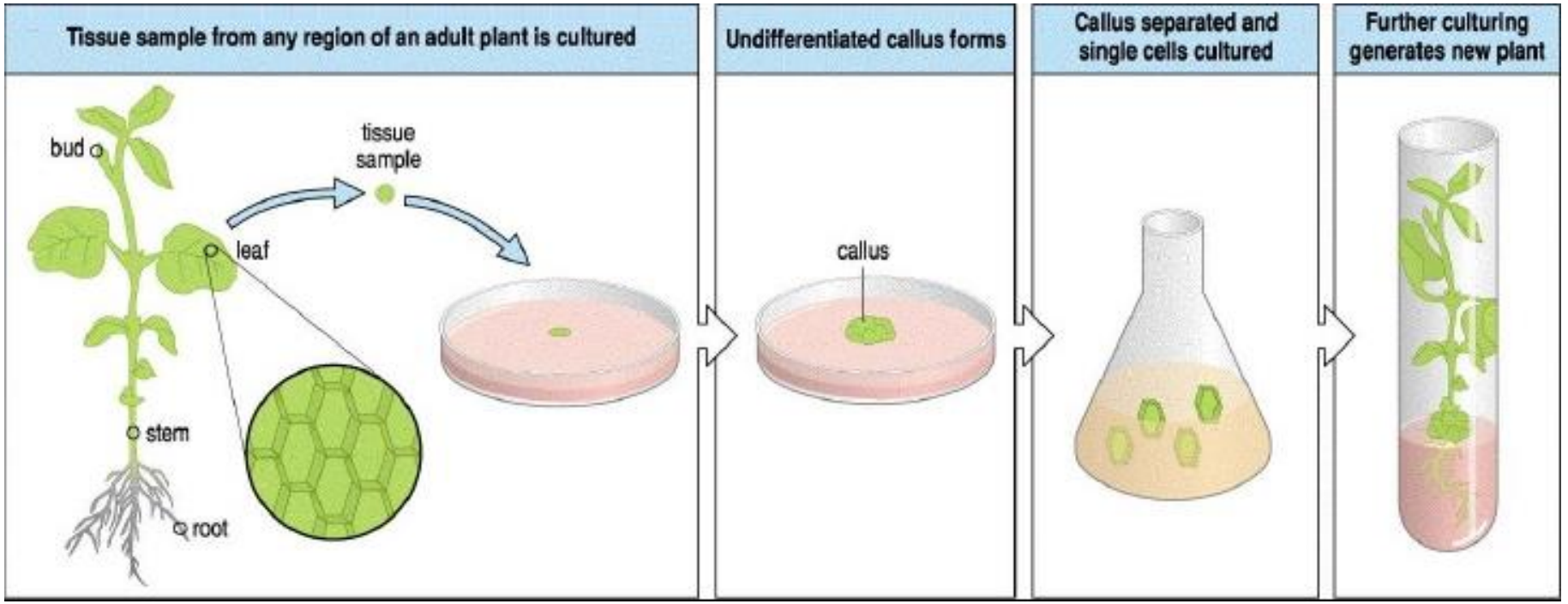
c) They help cells use up phosphate generated by ATP breakdown

d) They can amplify a signal

e) Variation in the signal transduction pathways can enhance response specificity

Cell-to-Cell Communication in Embryology

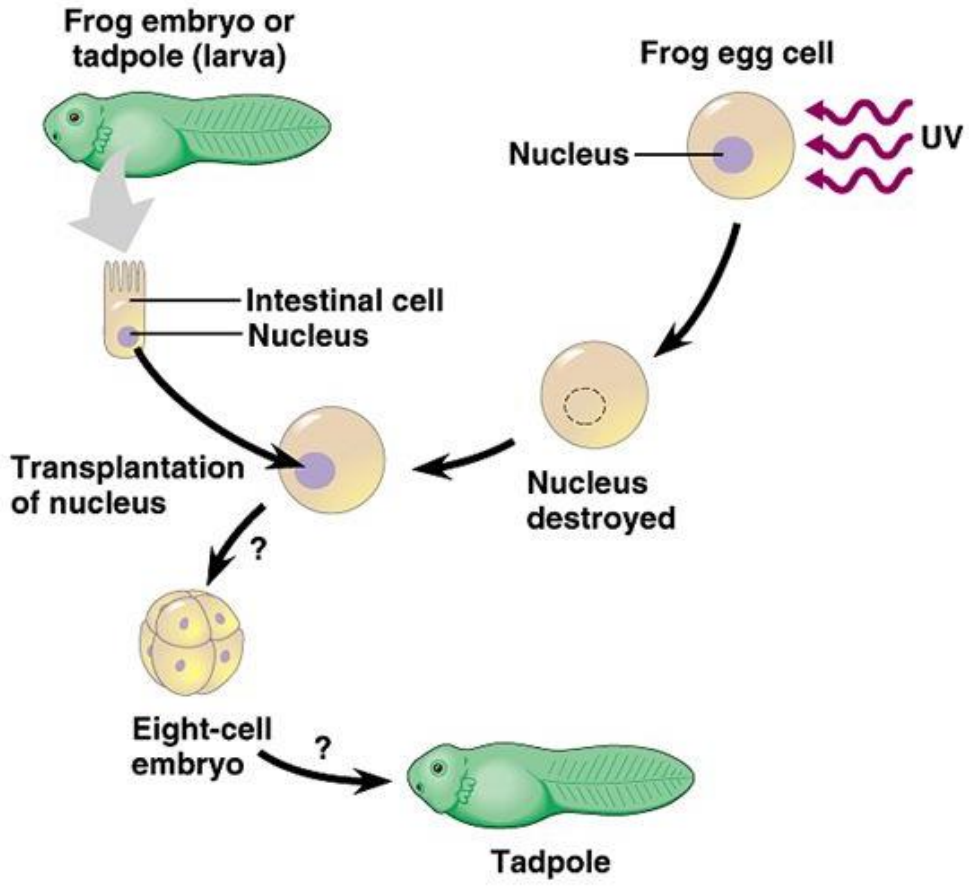
STUDY 1: Scientists have determined that nearly all of the cells within an organism contain the same genome ***(a.k.a genomic equivalence).*** Depending on the genes that are expressed, the cell will give rise to different structures and functions within the organism.



Totipotent cells: *cell that can give rise to all parts of an organism.*

Cell-to-Cell Communication in Embryology

STUDY 2: Not all differentiated cells have the ability to divide in culture. Scientists explored the possibility of totipotency through ***nuclear transplantation***.



'Most of the recipient egs developed into tadpoles when the transplated nuclei can from an early embryo. […] With the nuclei from the fully differentiated cells of a tradpole, less than 2% of the eggs developed into normal tadpoles. Most died earlier in development […]' (Campbell & Reece, 2005)

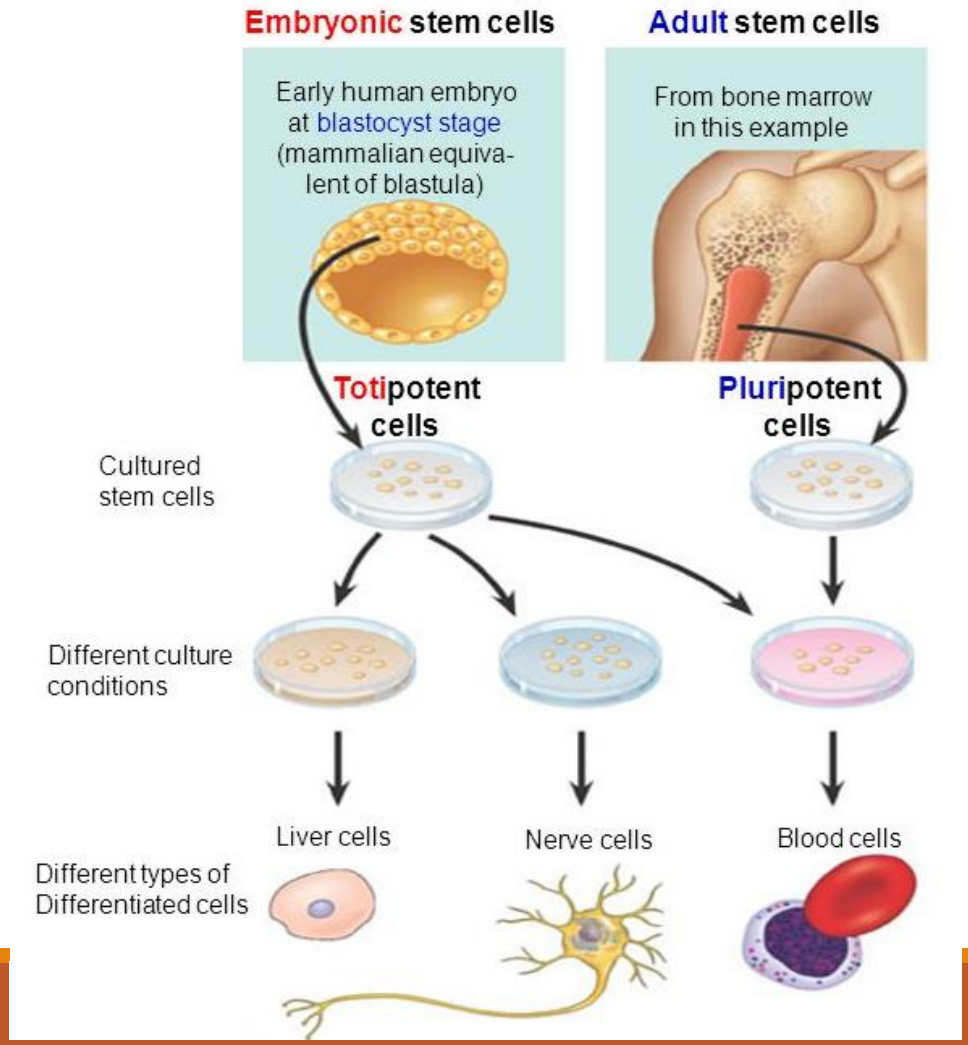
Remember . . . Stem cell have the ability to not only replenish their own population of cells but also create cells that can travel through their own differentiation pathway.

Stem Cells in Animals

Stem cell research has also shown that cells develop different functions due to the expression of different genes within the same genome.

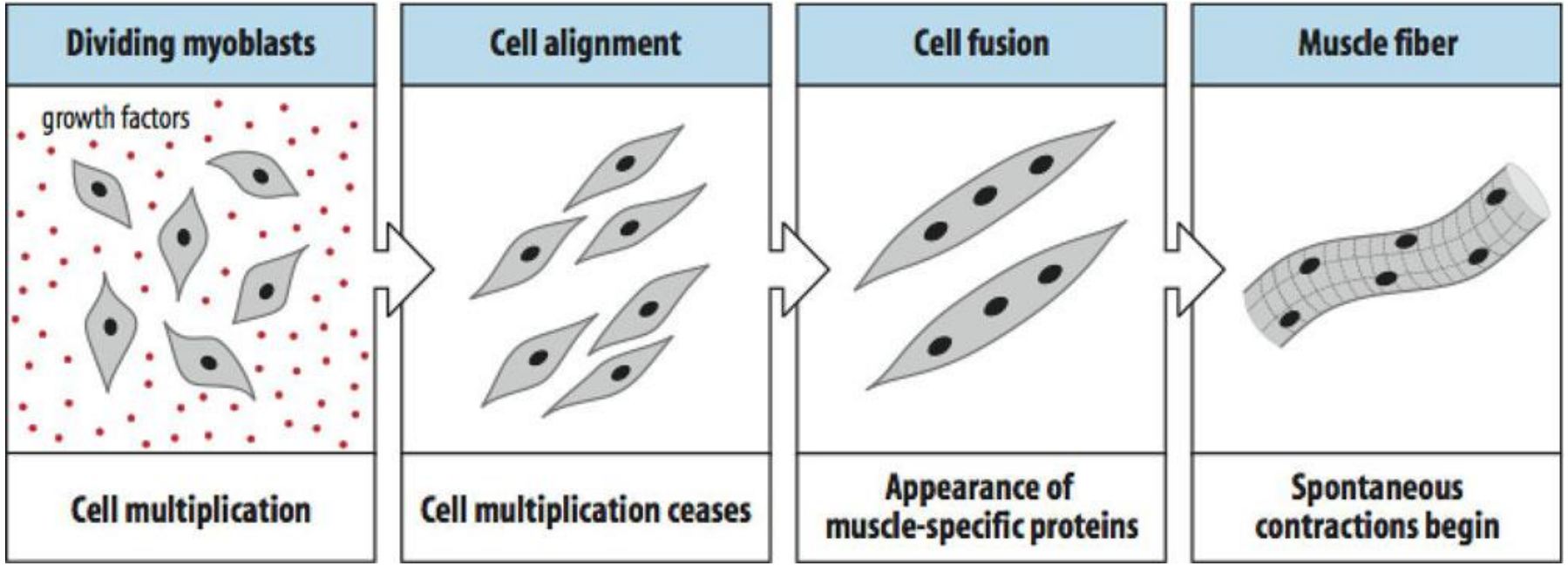
Embryonic Stem cells are found in the early stages of development during the blastocysts stage. These cells are *totipotent* and may give rise to different types of cells.

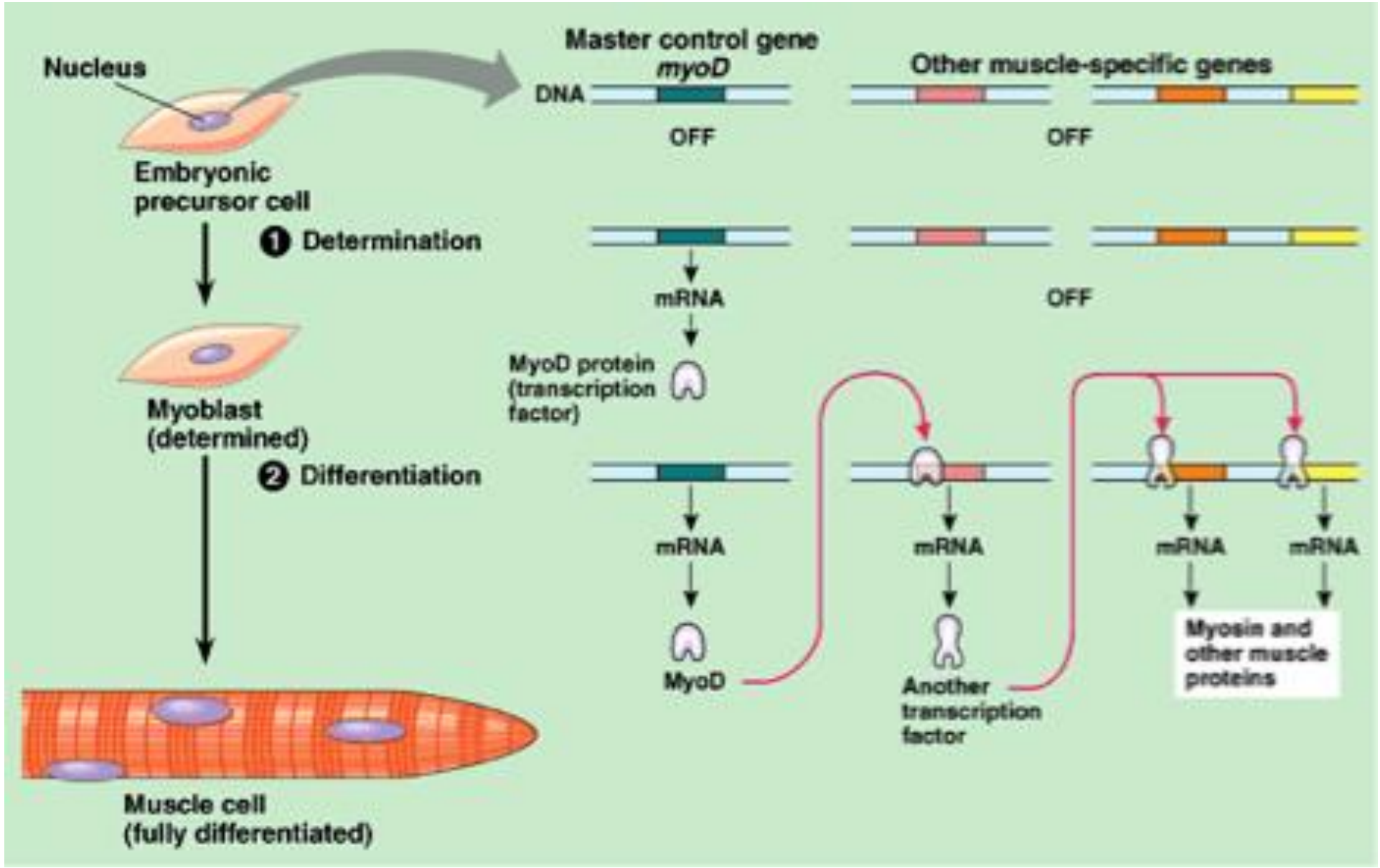
Adult stem cells are present when the organism is fully developed but these cells are *pluripotent* (able to give rise to multiple but not all cell types.



Gene Expression During Development

As the embryo develops, the cells that arise during mitosis begin to differ in terms of their ***structure and function***. This is a result of different genes that are expressed during the developmental stage.




Nucleus
Embryonic precursor cell
1 Determination
Myoblast (determined)
2 Differentiation
Muscle cell (fully differentiated)
Master control gene myoD
Other muscle-specific genes
DNA
OFF
OFF
mRNA
OFF
MyoD protein (transcription factor)
mRNA
mRNA
mRNA
mRNA
MyoD
Another transcription factor
Myosin and other muscle proteins

Cell Differentiation and Cell-Cell Communication

What the activation of the master gene during the process of ‘determination’? What generates the firs differences amongst the cells in an early embryo? What controls the differentiation of the different cells?

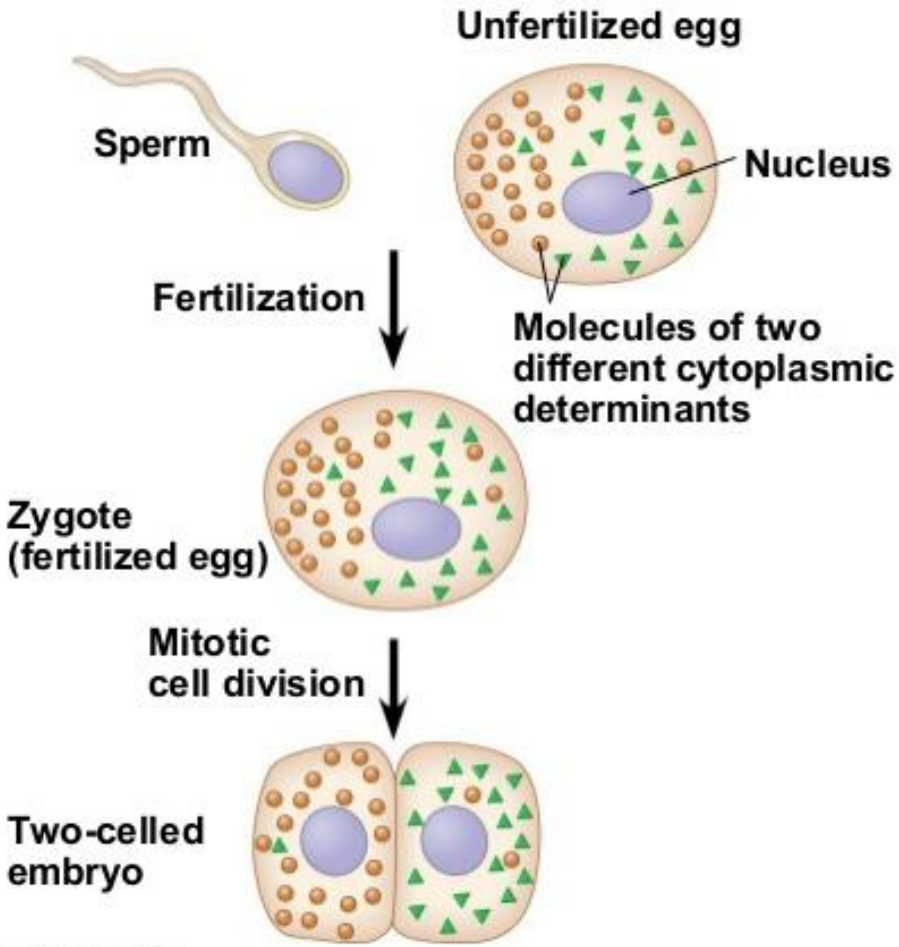
It all depends on the genes that are TRANSCRIBED!

The specific transcription will depend o the following two factors:

1) Cytoplasmic Determinants

2) Induction by Nearby Cells

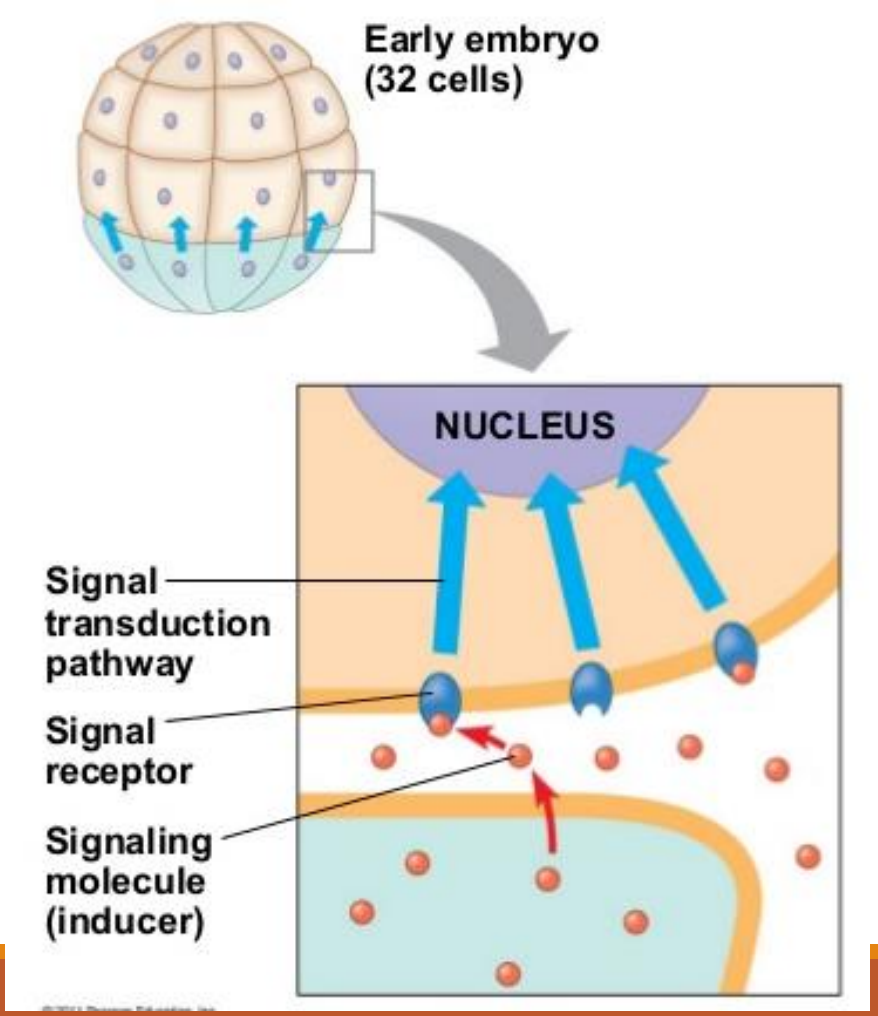
1) Cytoplasmic Determinants



The unfertilized egg contains specific RNA and protein molecules that influence the process of develop ***(cytoplasmic determinants)*** . They are distributed unevenly throughout the egg.

Once the egg is fertilized, the nucleus containing the DNA will be exposed to different 'cytoplasmic determinants' and target/express a variety of specific master genes.

2) Induction by Nearby Cells



The fate of a cell is also determined by the cell-surface molecules located on nearby cells or the release of growth factors from nearby cells.

Induction: proteins expressed by the genes in the embryonic cell cause a cascade of signals within nearby cells. This targets the expression of specific genes within these cells.