

## Cell Signals

### 1. Direct Contact

- ↳ *plasmodesmata of plants*~ open channels through the cell wall connecting adjacent cells allowing substances to pass between plants~
- ↳ *cell-cell recognition*~ interaction between molecules protruding from their surfaces (immune cells)

### 2. Local Signaling

- ↳ *paracrine signaling*~ secreting cell acts on nearby target cells by discharging growth factor molecules
- ↳ *synaptic signaling*~ nerve cells release neurotransmitter molecules into synapse

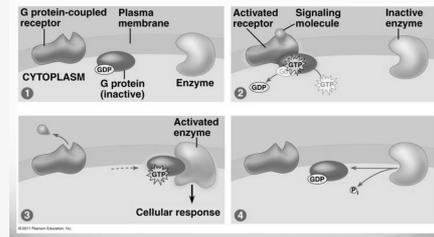
### 3. Long Distance

- ↳ *animal hormones*~ cells secrete hormones into body fluids to target cell
- ↳ *plant hormones*~ hormones move through the cells (by xylem) or diffuse through the air as a gas

## Step 1: Reception

- **ligand:** molecule that binds specifically to another molecule
- plasma membrane receptors: transmit information from extracellular environment to inside of the cell by changing shape or aggregating when a ligand binds
- ↳ cell surface receptors~
  1. *G protein-coupled receptors (GPCRs)*
  2. *receptor tyrosine kinases (RTK)*
  3. *ligand gates ion channels*
- ↳ intracellular receptor proteins

## G Protein-Coupled Receptor (GPCR)

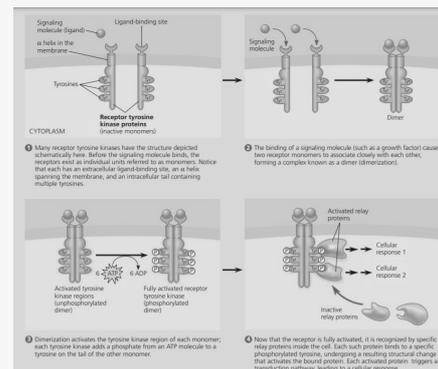


- *function/activity:* 1. embryonic development 2. sensory reception (smell, vision, etc.)

### \*GPCR Sequence\*

- ↳ **receptor is activated & changes shape**
- ↳ **binds to inactive G protein = GTP to replace GDP (activating G protein)**
- ↳ **G protein binds to an enzyme (change in shape/activity)**
- ↳ **enzyme triggers next step for response**
- ↳ **G protein inactivates by hydrolyzing bound GTP to GDP**

## Receptor Tyrosine Kinases (RTK)



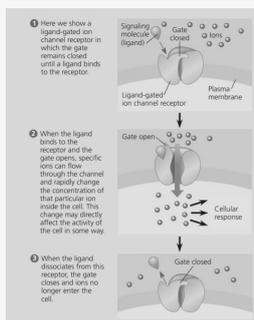
- **kinase:** enzyme that catalyzes the transfer of phosphate groups  
- differs from GPCR by triggering *many pathways*

### \*RTK Sequence\*

- ↳ **binding of signal causes 2 receptor monomers to come together = dimer**
- ↳ **tyrosine kinase region activated by ATP (adds a phosphate group)**
- ↳ **receptor recognized by relay proteins**
- ↳ **proteins bind (change shape) & activates protein**
- ↳ **transduction/response triggered**



### Ligand Gated Ion Channels



- for larger/hydrophilic molecules
- can be controlled by electrical conditions -- *voltage-gated ion channels*

#### \*Ligand Channel Sequence\*

- ↳ signal molecule causes receptor gate to open/close
- ↳ ions flow through ( $Na^+$  or  $Ca^+$ )

### Intracellular Receptor Proteins

2 areas present~ cytoplasm  
nucleus of target cells

3 signal molecule types~  
1. steroid hormones  
2. thyroid hormones  
3. nitric oxide

- once receptor protein is activated the signal molecules enter the nucleus and turn on specific genes

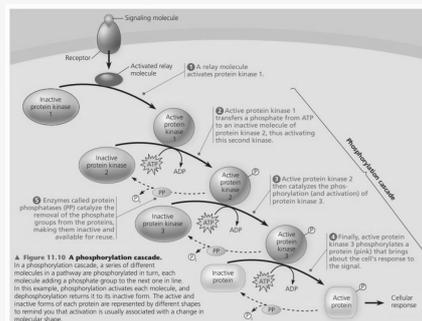
### Step 2: Transduction

molecular interactions relay signals from receptors to target molecules in the cell

ex) phosphorylation cascade; second messengers

- *signal amplification*: molecules in a pathway transmit the signal to many molecules at the next step
- advantage of multistep pathway responses~ more coordination & regulation (fine-tuning of response)

### Protein Phosphorylation



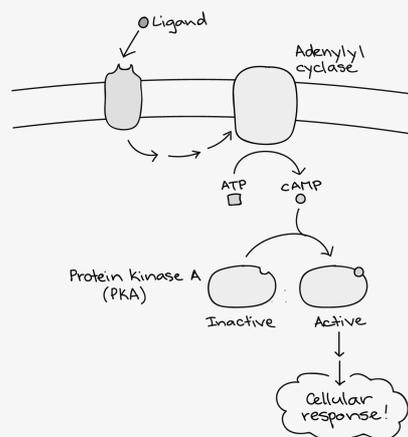
- **protein phosphatases**: enzymes that remove phosphate groups (dephosphorylation)

- acts as a molecular switch to turn activities on/off or up/down

#### \*Phosphorylation Sequence\*

- ↳ a molecules receive phosphate group from ATP (serine & threonine) = phosphorylation
- ↳ next molecule is activated in the pathway
- ↳ process continues to trigger response

### Second Messengers



- **second messenger**: small, nonprotein, water-soluble molecule/ion in transduction pathways

- ex) cAMP,  $Ca^{2+}$
- cAMP level rise when epinephrine binds to liver membrane receptors
- ↳ causing a break down of glucose
- ↳ levels go back down from phosphodiesterase (cAMP to AMP)
- 3 possible responses to *calcium* =
- ↳ 1. muscle cell contraction 2. secretion of substances 3. cell division
- ↳ calcium released from ER when signal molecule (IP<sub>3</sub>) binds to cell



### Step 3: Response

- cell signaling leads to *regulation of transcription*/cytoplasmic activities

- many pathways *regulate protein synthesis* by turning specific genes on/off

#### 4 FINE TUNING RESPONSE

**1. signal amplification~** # of activated products gets increasingly bigger

proteins process many molecules

**2. specificity of signaling & coordination of response~** different kinds of cells have different collections of proteins (diff. responses from same signal)

**3. efficiency~** *scaffolding proteins*: large relay proteins w/ several relay proteins attached

creates more than one pathway

**4. termination of signal~** reverse change from prior signal to receive new one

by dephosphorization of relay proteins

### Apoptosis

"programmed cell death"

- **general process~**

↳ DNA chopped up & organelles fragmented

↳ cell shrinks & becomes lobe shaped

↳ cell's parts are packaged into vesicles

↳ cell parts engulfed & digested by scavenger cells

- **processes this is needed for~**

1. development of nervous system

2. operation of immune system

3. morphogenesis of hands/feet/paws

### Cell Cycle Background

- what two organism have cell division the same as reproduction?

1. prokaryotes 2. unicellular eukaryotes

- what are the roles of cell division?

↳ growth, repair, reproduction, & replacement

- how do the genomes of prokaryotes & eukaryotes differ?

↳ eukaryotes~ # of DNA molecules; larger; linear DNA; lots of non-coding DNA

↳ prokaryotes~ single DNA molecule; smaller; looped DNA; more coding DNA

- **somatic cell:**

any cell in an organism except reproductive cells (body cells)

- **sister chromosome:**

2 copies of a duplicated chromosome attached at the centromere

- **mitosis:**

process of nuclear division (P, PM, M, A, T)

- **cytokinesis:**

division of the cytoplasm to form 2 separate daughter cells

- *centromeres*

produce microtubules (in plants & animals)

- *centrioles*

microtubules that spindle fibers attach to (in animals only)

- **binary fission:**

asexual reproduction by "division in half" (prokaryotes & unicellular eukaryotes)

- **origin of replication:**

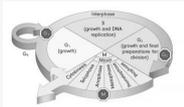
site where replication of DNA molecule begins



## Cell Cycle Background (cont)

- **density-dependent inhibition:** cell stop dividing when in contact with one another
- **anchorage dependence:** cell must attach to a substance in order to divide

## Cell Cycle Diagram



## Interphase

### - 3 sub phases of interphase~

- ↳ **G1 phase** cell growth  
(first gap)=
- ↳ **S phase** DNA replication  
(synthesis)=
- ↳ **G2 phase** cell components double (prep to divide)  
(second gap)=

### - different rates of division~

- ↳ **skin cells** = divide frequently
- ↳ **liver cells** = divide when needed
- ↳ **nerve/muscle cells** = don't divide at all

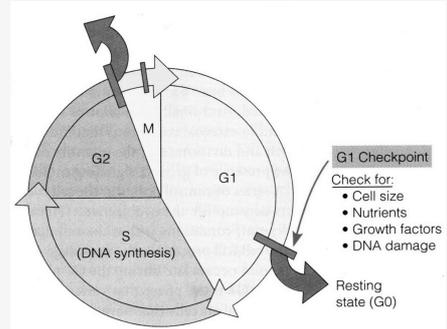
### - 3 major checkpoints~

1. G1
2. G2
3. Metaphase

- **platelet-derived growth factor (PDGF):** made by platelets to help heal wounds

PDGF bind to membrane receptor → transduction pathway triggered → cell passes G1 checkpoint → cell division

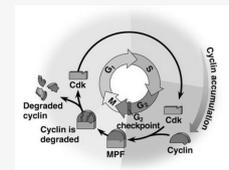
## G1 Checkpoint



- a.k.a. 'restriction point'

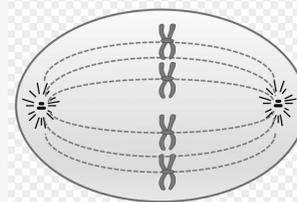
- ↳ if gets go-ahead signal... continues on to divide
- ↳ if doesn't get go-ahead signal... exits cycle/goes into G0 phase (nondividing)

## G2 Checkpoint



- **protein kinases:** give go-ahead signal at G1 & G2 checkpoints
- **cyclins:** attach to kinases to make them active
- ↳ **cyclin-dependent kinases (cdk) & cyclin combine to form...MPF (maturation-promoting factors)**
- ↳ **MPF formation occurs when cyclin accumulates = mitosis initiated**
- ↳ **MPF breaks down during anaphase** (cyclin destroyed; cdk stays to be reused)

## Metaphase Checkpoint



- anaphase won't begin until *chromosomes are properly attached to spindles*

### Cancer

- cancer cells are a change in 1+ genes that result in...	faulty cell cycle control
- normal cell cycle amount =	<i>20-50 times</i>
- cancer cell cycle amount =	<i>continuous</i>
- <b>benign tumor:</b>	cells that are NOT capable of surviving at a new site (slow growing; small; localized)
- <b>malignant tumor:</b>	cancerous tumor capable of surviving in a new site (fast growing; large; invasive)
- <b>metastasis:</b>	the spread of cancer cells to a different location from the original site



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