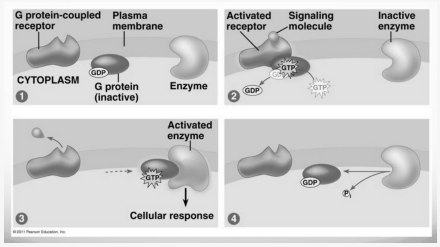
## Cell Signals

| | |
|---|---|
| **1. Direct Contact** | |
| ↳ *plasmodesmata of plants~* | open channels through the cell wall connecting adjacent cells allowing substances to pass between |
| ↳ *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**

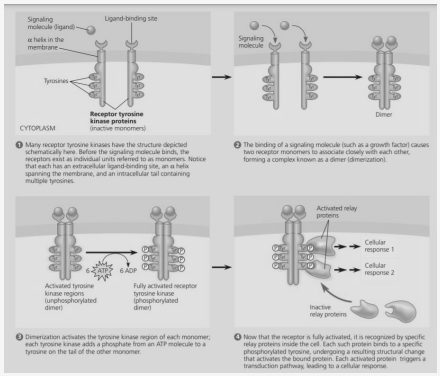
**↳ binds to inactive G protein = GTP to replace GDP (activating G protein)**

**↳ G protein binds to an enzyme (change in shape/activity)**

**↳ enzyme triggers next step for response**

**↳ G protein inactivates by hydrolyzing bound GATP 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*

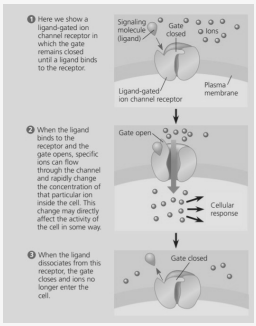
*↳ tyrosine kinase region activated by ATP (adds a phosphate group)*

*↳ 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 |

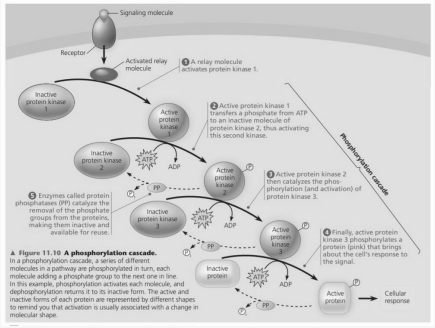
- once receptor protein is activated the signal molecules enter the nucleus and turn on specific genes

## 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




▲ **Figure 11.10 A phosphorylation cascade.** In a phosphorylation cascade, a series of different molecules in a pathway are phosphorylated in turn, each molecule adding a phosphate group to the next one in line. In this example, phosphorylation activates each molecule, and dephosphorylation returns it to its inactive form. The active and inactive forms of each protein are represented by different shapes to remind you that activation is usually associated with a change in molecular shape.

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

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

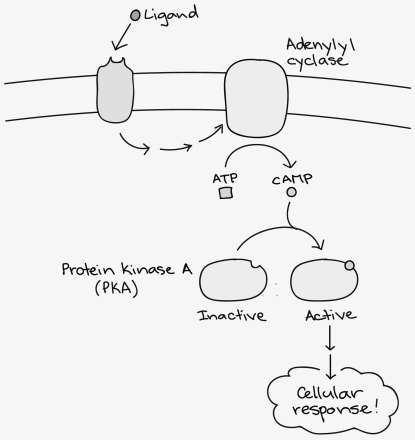
***Phosphorylation Sequence***

↳ *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 contration 2. secretion of substances 3. cell division

↳ calcium released from ER when signal molecule (IP3) 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 (first gap)=* | cell growth |
| ↳ *S phase (synthesis)=* | DNA replication |
| ↳ *G2 phase (second gap)=* | cell components double (prep to divide) |

**- different rates of division~**

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

**- 3 major checkpoints~**

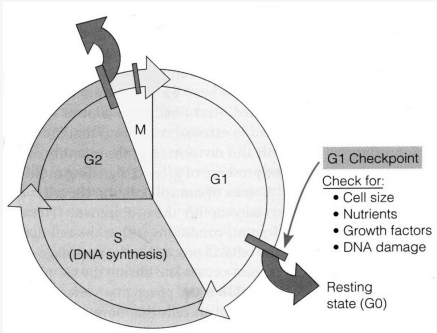
*1. G1*

*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

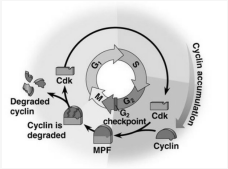



- a.k.a. 'restriction point'

↳ **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

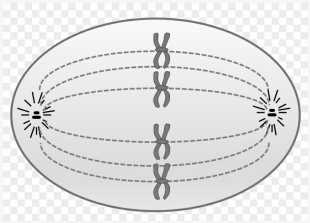
**- cyclins:** attach to kinases to make them active

↳ **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 = | *20-50 times* |
| - cancer cell cycle amount = | *continuous* |
| **- benign tumor:** | cells that are NOT capable of surviving at a new site (slow growing; small; localized) |
| **- malignant tumor:** | cancerous tumor capable of surviving in a new site (fast growing; large; invasive) |
| **- metastasis:** | the spread of cancer cells to a different location from the original site |