Chapter 8

Cells Respond to Their External Environments

Response to External Environments

- Single-celled organisms
  - Respond to environmental changes
  - Temperature, salinity, pH, toxins, mating factors
- Multicellular organism
  - Environment is the inside of the organism
  - Respond to external conditions and maintain cellular homeostasis

Signals and Receptors

- Response to signal
  - Signal
    - Chemicals, light, sound, electrical impulses, solutes concentration, pressure
  - Detection of signal
    - Receptors
  - Induction of cellular response
    - Cellular changes
      - Activation or suppression of enzyme activity
      - Activation or suppression of transcription or translation
      - Changes in the permeability of the cell
      - Release of stored proteins
    - Cellular responses
      - Generation of nerve impulse
      - Metabolizing nutrient
      - Migration
      - Growing and dividing
      - Differentiation
      - Dying

Types of Receptors

- Receptors of the five senses

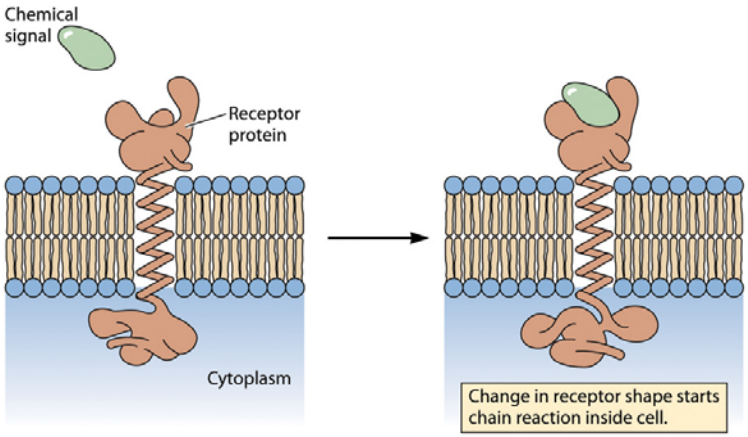
Table 8.1 Receptors and the five senses

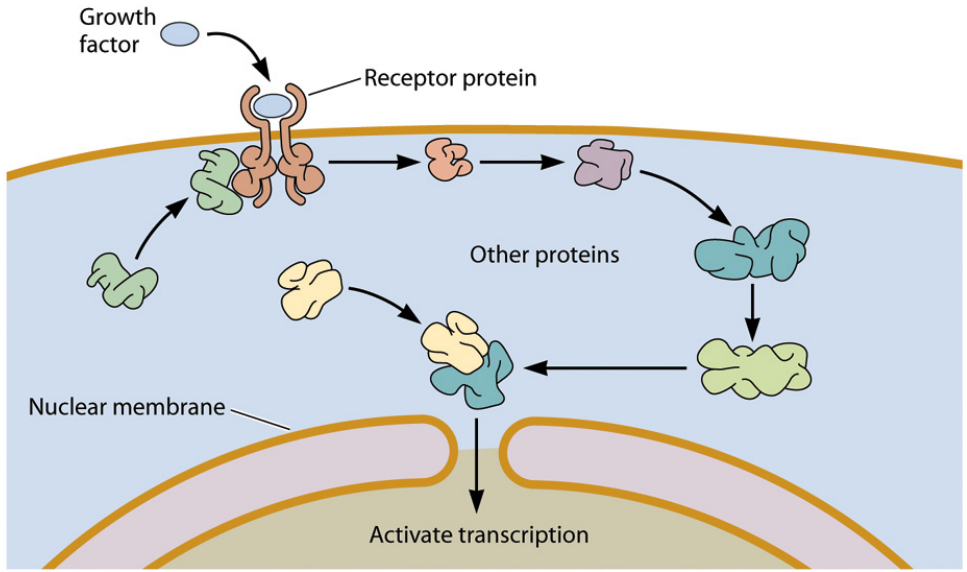
Type of receptor	Activating stimulus	Cellular response	Brain's interpretation of nerve impulse
Photoreceptor	Light	Change in membrane channels	Vision
Auditory receptors	Vibration	Release of stored neurotransmitters	Sound
Olfactory receptors	Various molecules in the air	Change in membrane channels	Smell
Taste receptors for sweet and bitter	Various dissolved molecules	Change in membrane channels	Sweet or bitter taste
Taste receptors	Na^+, $C1^-$, K^+ (salty) H^+ (sour)	Release of stored neurotransmitters	Salty or sour taste
Baroreceptor	Deformation of cell	Change in membrane channels	Touch, pressure

- Osmoreceptors
  - Opening of ion channels in respond to changes in salt concentration

Signal Transduction

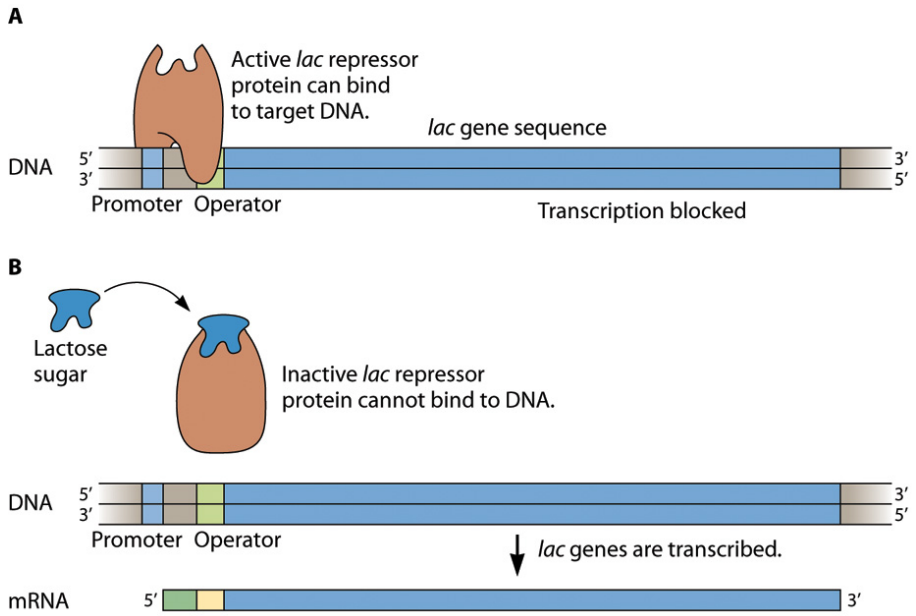
- Receptors
  - Membrane receptor: Binding of signal molecules which cannot cross the membrane
  - Intracellular receptors: Binding of signal molecule which can cross the membrane (small and hydrophobic)
- Signal transduction
  - Conformational change of receptor upon binding to the signal
  - Triggering cascade of reactions





Responses of Single-Celled Organisms

- Lactose breakdown in *E.coli*
  - Turning on lactose utilizing genes (lac genes) only in the presence of lactose
  - In the absence of lactose
    - Lac repressor represses lac genes by binding to operator of lac operon
  - In the presence of lactose
    - Lactose binding to Lac repressor leading to release from the lac operator → Transcription



Coordination of Cellular Responses in Multicultural Organisms

- Hormones
  - Produced in various glands and secreted into blood stream
- Growth factors
- Neurotransmitters
  - Transmit nerve impulses across gaps between nerve cells

Table 8.2 Examples of human hormones

Hormone	Where secreted	Target(s)	Primary effect(s)
Thyroxine	Thyroid	Many tissues	Stimulates and maintains metabolism; necessary for normal growth and development
Growth hormone	Anterior pituitary	Bones, liver, muscle	Stimulates protein synthesis and growth
Follicle-stimulating hormone	Anterior pituitary	Gonads	Stimulates growth and maturation of eggs in females; stimulates sperm production in males
Melanocyte-stimulating hormone	Anterior pituitary	Melanocytes	Controls pigmentation
Insulin	Pancreas	Muscles, liver, fat	Stimulates uptake and metabolism of glucose; increases glycogen and fat synthesis; reduces blood sugar
Glucagon	Pancreas	Liver	Stimulates breakdown of glycogen; raises blood sugar
Somatostatin	Pancreas	Digestive tract, pancreas	Inhibits release of insulin and glucagon; decreases activity in the digestive tract
ADH	Posterior pituitary	Kidneys	Stimulates water resorption and raises blood pressure
ANH	Heart	Kidneys	Increases sodium ion excretion; lowers blood pressure
Aldosterone	Adrenal cortex	Kidneys	Stimulates excretion of potassium and resorption of sodium ions
Estrogens	Ovaries	Breast, uterus, and other tissues	Stimulate development and maintenance of female sexual characteristics; necessary for proper bone development in males and females; proper seminal fluid formation in males
Androgens	Testes	Various tissues	Stimulate development and maintenance of male sexual characteristics

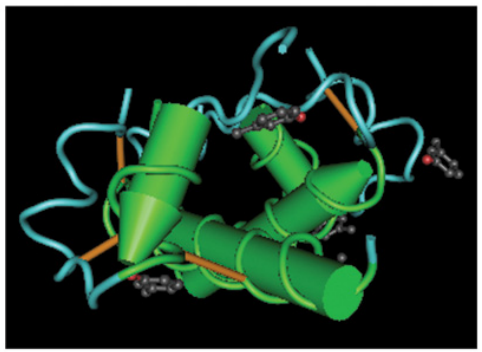
Hormones

- Hormone receptors
  - Membrane receptors
  - Intracellular receptors for steroid hormones (derived from cholesterol)
    - DNA binding and induce transcription upon binding to hormones
- Estrogen
  - Female hormone
    - Stimulation of transcription for proteins involved in the generation of new blood vessels and lactoferrin (protein in breast milk)
  - Proper production of seminal fluid and development of skeletons in male

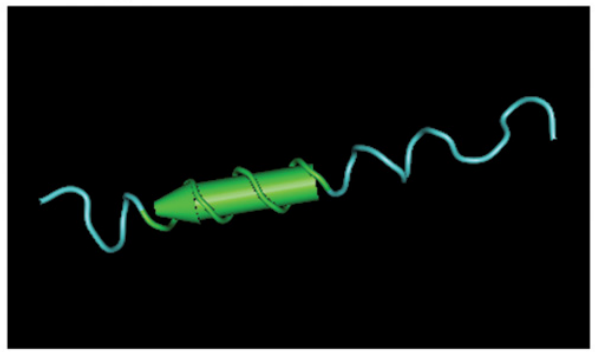
Regulation of Blood Glucose Concentration

- Importance of regulating glucose levels in blood stream
  - Low glucose: no energy source in the brain → unconsciousness, comma, and death
  - High glucose: mental confusion, dehydration etc.
- Hormones regulating blood glucose levels
  - Generated from pancreas
    - Insulin : decrease glucose levels
    - Glucagon: increase glucose levels

A. Insulin

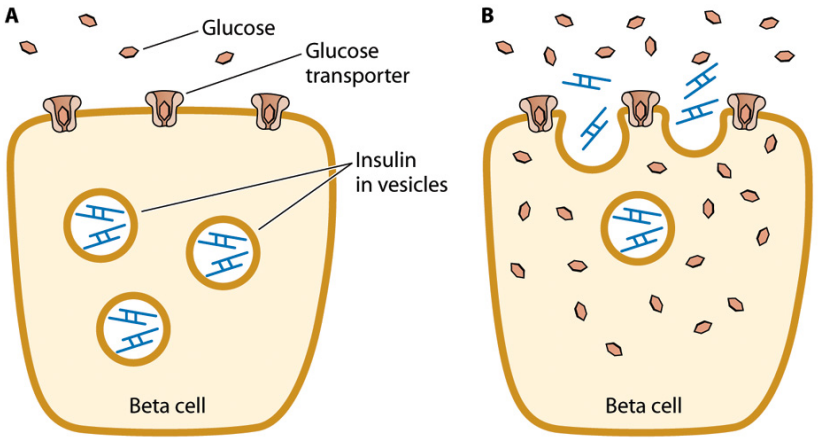


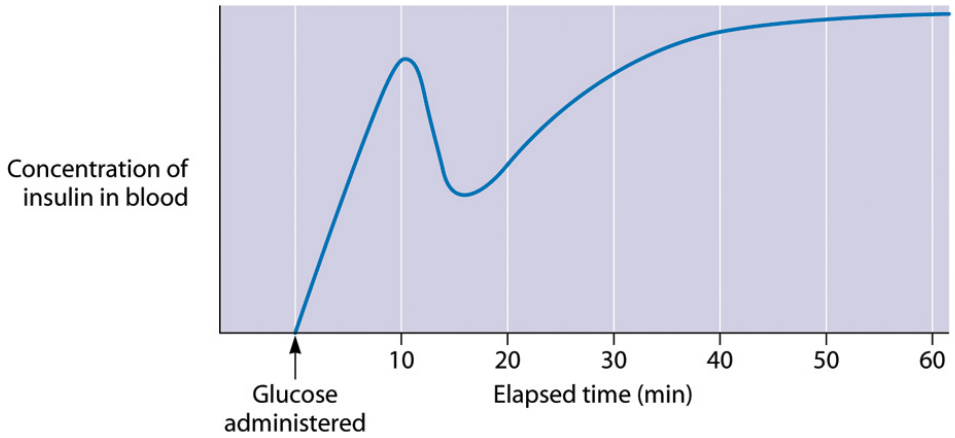
B. Glucagon



Insulin

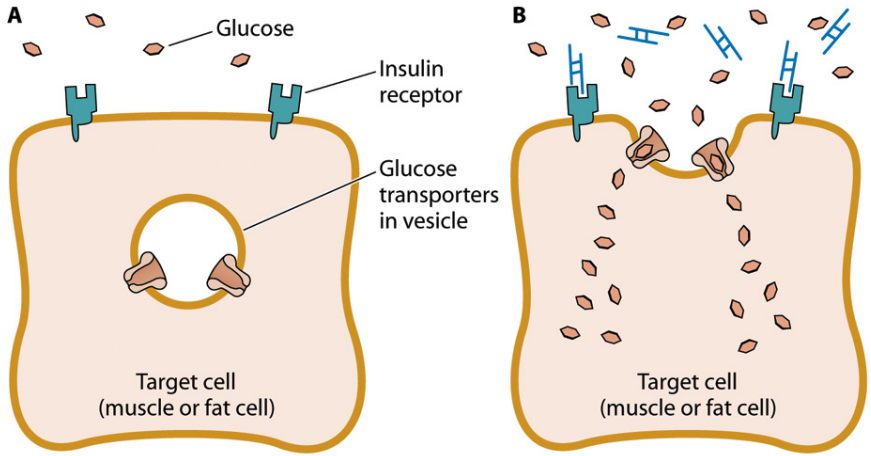
- Synthesize in the pancreatic β cells
- Increase in insulin levels upon high glucose
  - Release from pancreatic β cells
    - Packed into vesicles through secretory pathway
    - Fusion of insulin vesicle in response to high glucose levels
  - Increase in transcription of insulin gene





Roles of Insulin

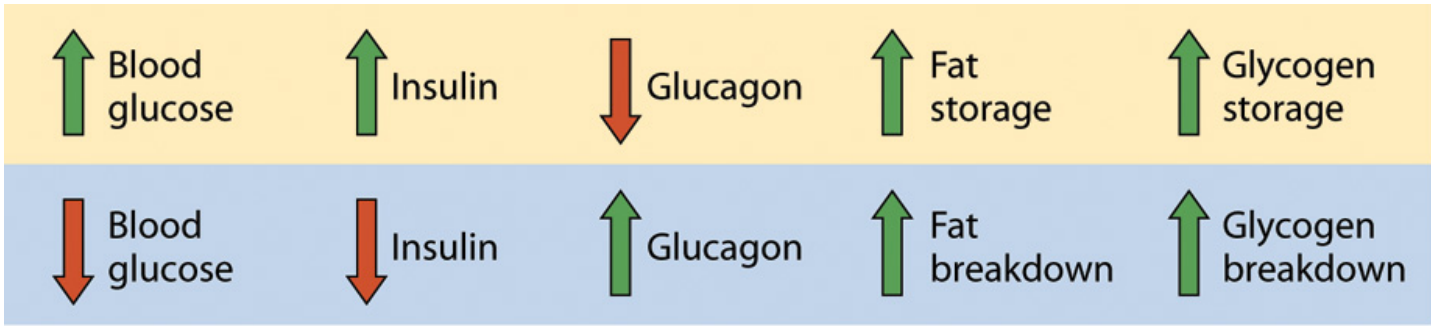
- Binding to cell type-specific insulin receptors
  - Muscle and fat cells
    - Increase in fusion of vesicles containing glucose transporters (GLUT4)
    - Stimulation of uptake of glucose from the blood
    - c.f. liver and brain: insulin-independent glucose transporter (GLUT1)
  - Muscle and Liver cells
    - Activation of glycogen synthesis
    - Activation of fatty acid synthesis in liver after saturation of glycogen
      - Synthesis of fat in fat cells by combing to glycerol



Glucagon

- Release of glucagon upon low glucose levels
- Binding to cell type-specific glucagon receptors
  - Liver
    - Inhibition of glycogen synthesis
    - Stimulation of breakdown of glycogen

    → Release of glucose
  - Fat cells
    - Activation of breakdown of fats
    - Fatty acids are used as E source
- In cats
  - Stimulation of gluconeogenesis
    - Making glucose form other C sources (amino acids and fats)



80 to 100 mg glucose/ 100 ml of plasma

Diabetes

- Diabetes mellitus
  - Diabetes: excessive urination in Greek
  - Mellitus: honey in Latin
- Problem in controlling blood glucose
  - Insufficient glucose absorption in the presence of high blood glucose → high concentration of glucose in the urine
- Types of diabetes
  - Type 1, Juvenile, insulin-dependent diabetes
    - No insulin production
    - Autoimmune response to pancreas cells
  - Type II, insulin-resistant, non-insulin-dependent diabetes
    - No response to insulin
    - 90~95% of diabetes
- Other diseases
  - Cancer in glucagon or insulin producing cells

Biotechnology Application

- Insulin production to treat diabetes
  - 1920's
    - isolation of insulin from pig and cow pancreases
  - 1980's
    - Recombinant human insulin expressed in E. coli