ANP201

- Physiology of Growth
- Homeostasis

Lecture Notes : Compiled from various sources by Prof. O.A. Osinowo
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PHYSIOLOGY OF GROWTH

- *What is growth?*

  Growth is a characteristic of living things and can be defined as an increase in body size or mass of part or all of the body over a specific period of time.

PHYSIOLOGY OF GROWTH, contd.

- Growth results from any or all of the following processes:
  - Increase in body weight till mature size is reached
  - Increase in cell number and size accompanied by protein deposition
  - Increase in structural tissues and organs. Structural tissues include:
    - Bone
    - Muscle
    - Other connective tissues such as fat, tendons, etc.

PHYSIOLOGY OF GROWTH, contd.

- *Development*

  Development often accompanies growth as cells and tissues become differentiated, increasing in complexity. Development involves the directive coordination of all diverse processes until maturity is reached. It involves:

  – Growth
  – Cellular differentiation
  – Changes in body shape and form

PHYSIOLOGY OF GROWTH, contd.

- **Growth and Development**

  In studying growth and development in mammals, two broad stages are considered, namely the:

  - Prenatal (before birth), and
  - Postnatal (after birth), periods.

PHYSIOLOGY OF GROWTH, contd.

Prenatal growth and development

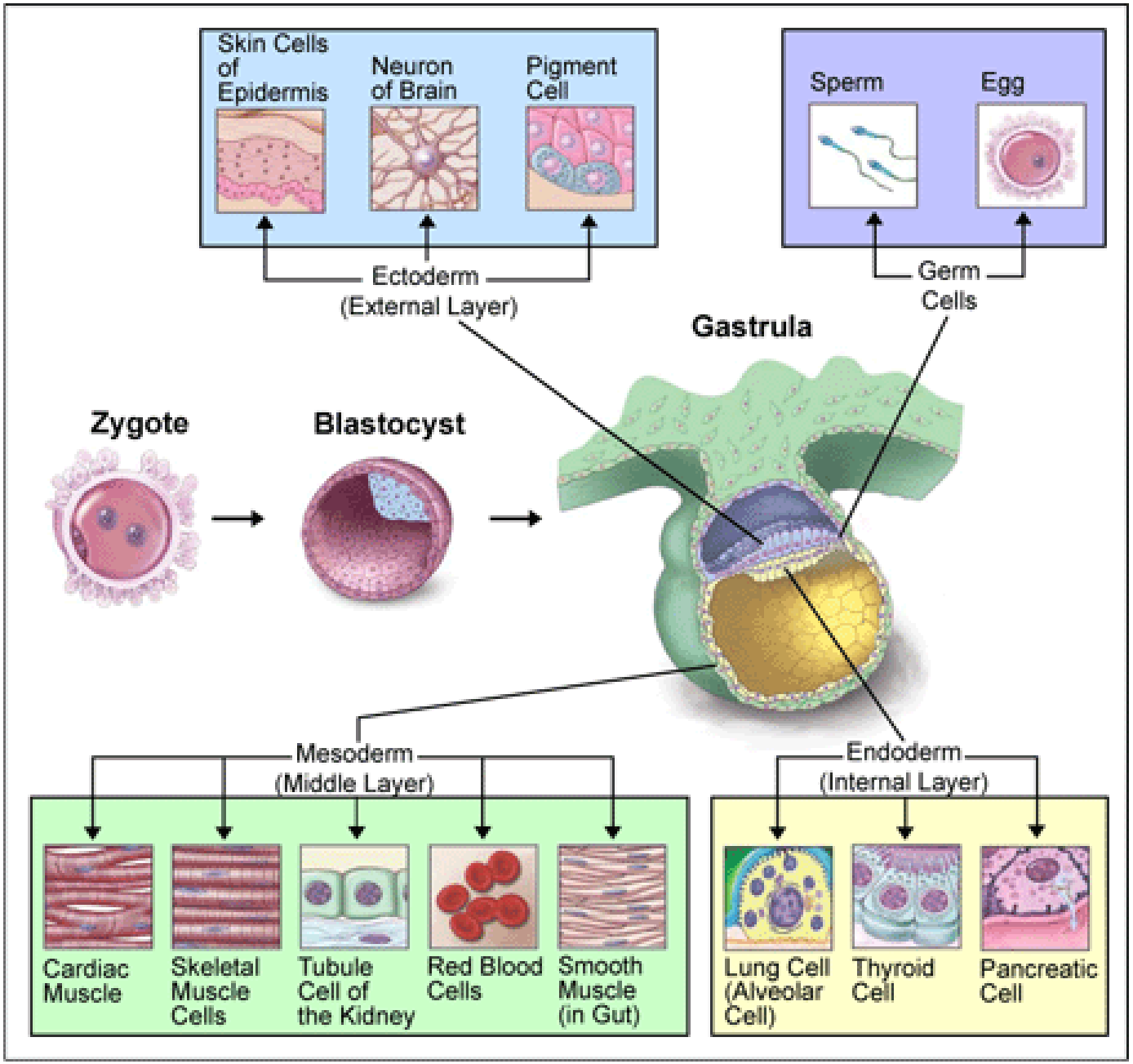
1. Tissues arise from three embryonic cell layers

A. Endoderm
--Digestive tract, Lungs, and Bladder

B. Mesoderm
--Skeleton, Skeletal muscle, and Connective tissues

C. Ectoderm
--Skin, Hair, Brain, Spinal Cord

PHYSIOLOGY OF GROWTH, contd.

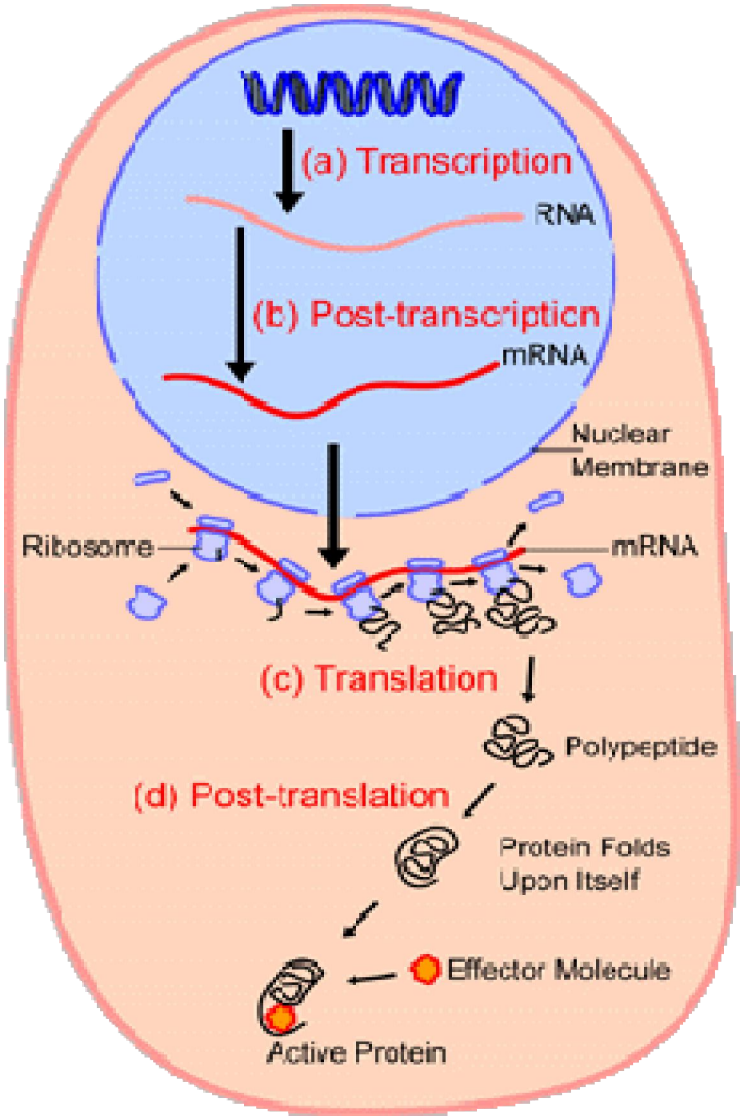


PHYSIOLOGY OF GROWTH, contd.

2. The nucleus directs the growth and development process by gene expression

   A. Transcription
      ✓DNA to mRNA

   B. Translation
      ✓mRNA to Protein



PHYSIOLOGY OF GROWTH, contd.

3. Order of tissue growth follows a sequential trend determined by physiological importance
   - A. Central Nervous System
   - B. Bones
   - C. Tendons
   - D. Muscles
   - E. Inter-muscular Fat
   - F. Subcutaneous Fat

PHYSIOLOGY OF GROWTH, contd.

Muscle Growth and Development

1. *Embryonic Skeletal Muscle Development*

A. Develop from embryonic masses of mesoderm called somites
   a. Myotome --Portion of somite that differentiates into muscle cells
   b. Located dorsally along axial skeleton
   c. Spread between skin and body cavity on left and right sides
   d. Doesn't include muscles of head and limbs

B. Head muscles
   a. Develop from mesoderm of that region

C. Limbs
   a. Develop from mesoderm that migrates to limb buds

PHYSIOLOGY OF GROWTH, contd.

D. Myoblasts

a. Precursors to muscle cells
b. Fibroblast-like
c. Fuse to form multi-nucleated muscle fibers
d. Myoblast fusion is how cells grow in length

E. Fibroblast Growth Factor (FGF)

a. Controls Myoblasts
b. Stimulate proliferation and inhibit fusion
c. Removal stimulates fusion and differentiation

PHYSIOLOGY OF GROWTH, contd.

2. *Prenatal Muscle Growth*

- A. Hyperplasia
  - a. Increase in number of fibers
  - b. First 2 trimesters
- B. Hypertrophy
  - a. Increase in size of fibers
  - b. Last trimester

PHYSIOLOGY OF GROWTH, contd.

3. *Postnatal Muscle Growth and Development*

A. Total number of fibers (Muscle cells) are obtained prenatally

B. Increases in length
   a. Myoblasts added to ends of multinucleated fibers

C. Increase in size of fibers
   a. Increase in size and number of myofibrils
   b. Due to Protein synthesis (Gene Expression)

D. Muscle Repair
   a. Dormant myoblasts called satellite cells
   b. Stimulated by FGF

PHYSIOLOGY OF GROWTH, contd.

Connective Tissue Growth and Development

1. *Fibroblasts*
    - A. Precursor to Connective tissue cells
        - a. Osteocytes (-blasts)
        - b. Adipocytes
        - c. Smooth Muscle cells
        - e. Chondrocytes
    - B. Secrete components of connective tissue
        - a. Fibers
            - i. Collagen Fibers
            - ii. Elastic Fibers
            - iii. Reticular Fibers
        - b. Ground Substance
            - i. Fluid to Gel to Solid
    - C. Stimulated by a number of growth factors

PHYSIOLOGY OF GROWTH, contd.

2. Adipocytes (Fat Cells)

A. Store Fat

a. Energy Reserve

B. Differentiation

a. Lipogenic Enzyme Production (Gene Expression)
b. Accumulation of fat droplets
c. Coalescence of fat droplets into one large droplet

C. Hormonal Control

a. Growth hormone
--Stimulates Differentiation
b. Insulin-like Growth Factor (IGF)
--Stimulates Proliferation
c. Insulin
--Stimulates lipogenesis
d. Glucagon
--Stimulate lipolysis

PHYSIOLOGY OF GROWTH, contd.

3. *Postnatal Fat Deposition*

A. Four major deposits of fat
- a. Subcutaneous fat
  - i. Under the skin
  - ii. Backfat
- b. Intermuscular fat
  - i. Between muscles
  - ii. Seam fat
- c. Intramuscular fat
  - i. Within muscles
  - ii. Marbling
- d. Abdominal Fat
  - i. Mostly around kidneys and in pelvis

B. Order of fat deposition
- a. Abdominal
- b. Intermuscular
- c. Subcutaneous
- d. Intramuscular

PHYSIOLOGY OF GROWTH, contd.

4. *Growth and Development of Bone*

A. Early Development of bone

--Embryonic connective tissue is transformed by two methods

a. Intramembranous Ossification

i. Skull bones

ii. Formation of bone from mesoderm

b. Endochondral Ossification

i. Most bones in body

ii. Formation of bone from hyaline cartilage

B. Increase in Bone Length

a. Cartilage Cells

i. Undergo mitosis

ii. Increase size of epiphyseal plate

b. Epiphyseal Plate

i. Diaphysis side undergoes calcification

ii. Increase length of bone

PHYSIOLOGY OF GROWTH, contd.

C. Hormones that effect bone growth.

a. Parathyroid hormone

--Bone reabsorption

b. Calcitonin

--Bone formation

c. Growth Hormone

--Bone Growth

d. Sex Steroids

--Cause union of the epiphysis withthe diaphysis of long bones, ceasing growth of long bones

e. Growth Factors

PHYSIOLOGY OF GROWTH, contd.

Measurement of growth

Growth parameters such as height, length, mass, volume and number when plotted against time give rise to sigmoid or S-shaped curves of the type shown in Fig. 1.

PHYSIOLOGY OF GROWTH, contd.

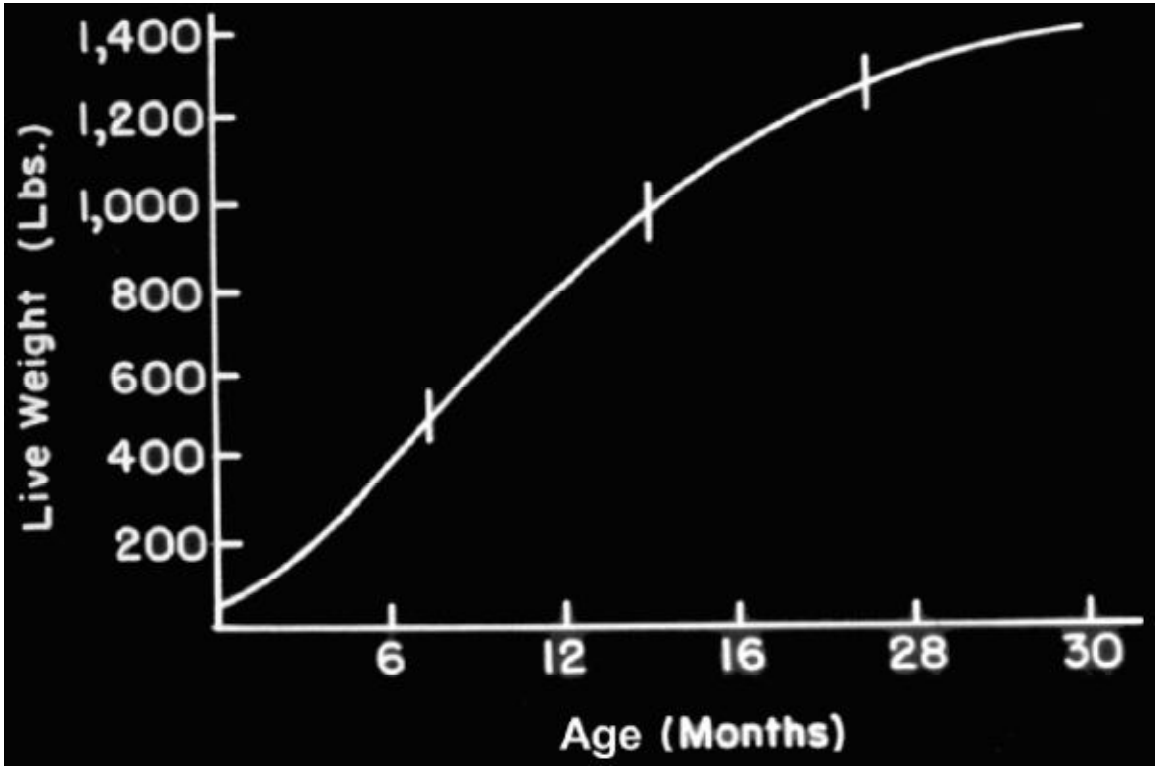


Figure 1. Growth curve

PHYSIOLOGY OF GROWTH, contd.

A **Sigmoid curve** can be divided into the following four phases:

- Lag phase, during which little growth occurs
- Logarithmic or log phase, during which growth proceeds exponentially. During this phase the rate of growth accelerates and at any point is proportional to the amount of material or number of cells already present. In all cases of growth the exponential increase eventually declines and the rate of growth begins to decrease. The point at which this occurs is known as the inflexion point, which represents the maximum rate of growth.
- Decelerating phase, during which growth becomes limited as a result of the effect of some internal or external factor, or the interaction of both
- Plateau or stationary phase. This phase usually marks the period where overall growth has ceased and the parameter under consideration remains constant.

Growth Curves

1. Curves are sigmoidal in shape

2. Bone, muscle, and fat are the tissues of primary concern in the livestock industry

3. *Order of tissue maturity*
   A. Bone
   B. Muscle
   C. Fat

4. *Factors effecting growth*

A. Maturation rate

a. Late maturing grow more

B. Sex

a. Intact males heavier and leaner at a given age than castrates and females

--Mature later

b. Castrates tend to be heavier and leaner than females

--Mature slightly later

C. Nutrition

a. Good nutrition needed for proper growth and development

b. Excess Protein or energy feed increase fattening in the livestock industry.

HOMEOSTASIS

- Homeostasis is the maintenance of constant internal environment. Ability to maintain a steady state within a constantly changing environment is essential for the survival of a living system.

HOMEOSTASIS, contd

- In order to maintain the condition, organisms from the simplest to the most complex have developed a variety of structural, physiological and behavioural mechanisms designed to maintain the preservation of a constant internal environment.

- Organisms live within an **external environment**, while individual cells of the organism live in an **internal environment** which in mammals is tissue fluid.

HOMEOSTASIS, contd

- Homeostatic mechanisms maintain the stability of the cell environment and they provide the organism with a degree of independence of the environment.
- They prevent large fluctuations from the optimum which are caused by changes in external and internal environments.

HOMEOSTASIS, contd

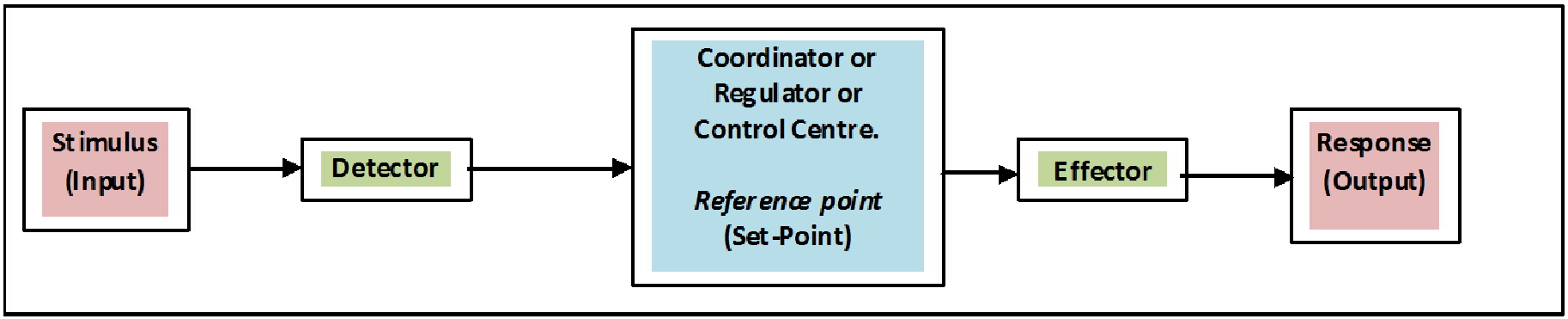
- Organisms which are able to maintain relatively constant levels of activity despite fluctuation in environmental condition are referred to as **'Regulators'**.
  - They are able to exploit a wider range of environments and habitats. Examples are mammals and flowering plants.

- **"Non-Regulators"** tend to be confined to environments which are more stable, such as oceans or lakes.
  - Examples are seaweeds and phytoplankton.

HOMEOSTASIS, contd

- *Control systems in biology*
  - Living systems are **"Open System"**; they require a continuous exchange of matter between the environment and themselves.
  - They are in a steady state with their environment but require a continuous input of energy in order to prevent them coming to equilibrium with the environment.

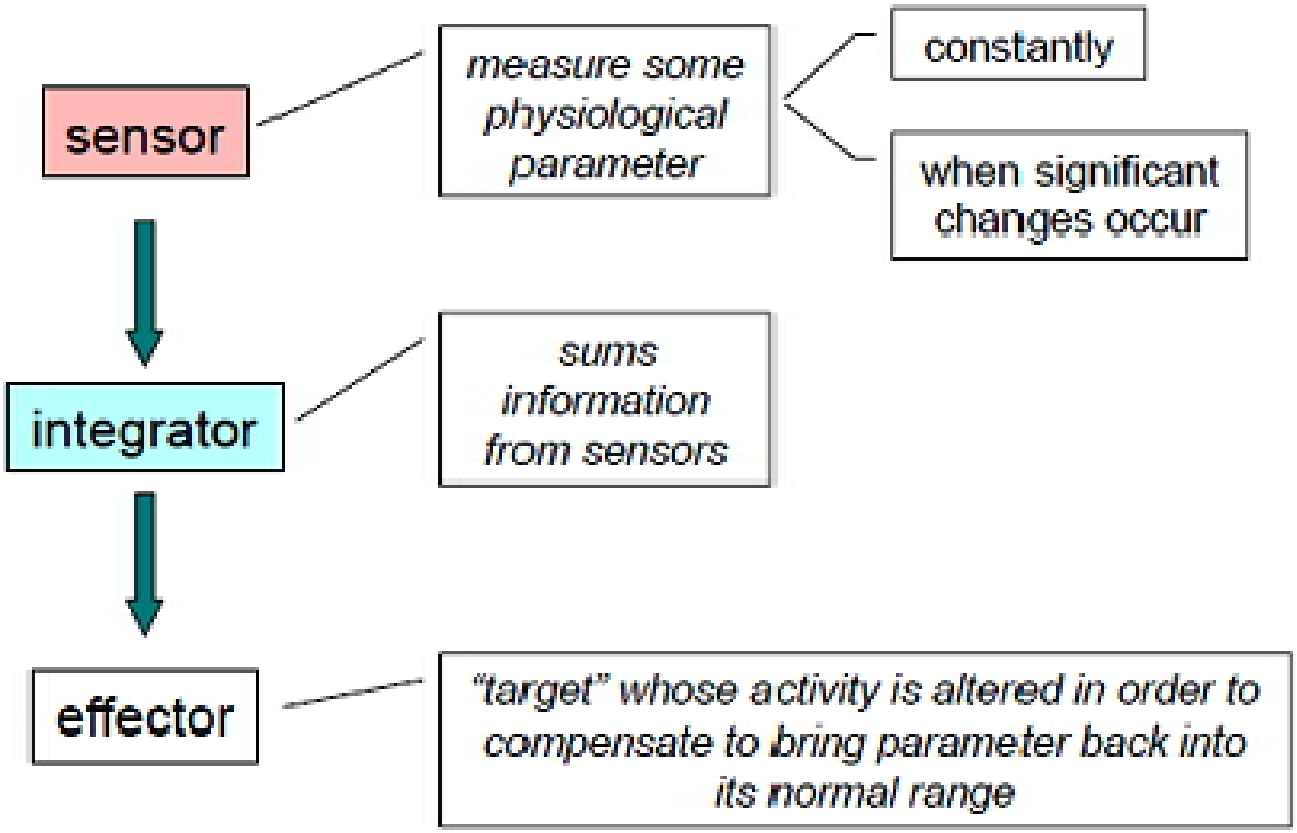
HOMEOSTASIS, contd



Basic components of a control system

- The 'Regulator' in mammals is either an endocrine gland producing hormone or part of the nervous system, often the brain or spinal cord.

HOMEOSTASIS, contd



•Components of a Homeostatic Control System

HOMEOSTASIS, contd

- Any change from the set-point activates the control systems and returns conditions towards their optimum level.
  - As conditions return to the optimum the corrective processes can be switched off, a process known as 'Negative Feedback'.
- There are 2 forms of feedback,
  - "negative" and
  - "positive",
- Negative feedback is more common.
- Negative feedback is associated with increasing the stability of system.
  - If the system is disturbed, the disturbance sets in motion a sequence of events which tends to restore the system to its original state.

HOMEOSTASIS, contd

- Examples of biological negative feedback mechanism include the control of:
  - Oxygen and CO_2 levels in the blood by controlling rate and depth of breathing
  - Heart rate
  - Blood pressure
  - Hormone levels, e. g sex hormones, thyroxin
  - Metabolite levels, e. G. Glucose
  - Water balance
  - Regulation of PH
  - Body temperature
- Example of positive feedback mechanism is the increased muscular contractions during parturition.

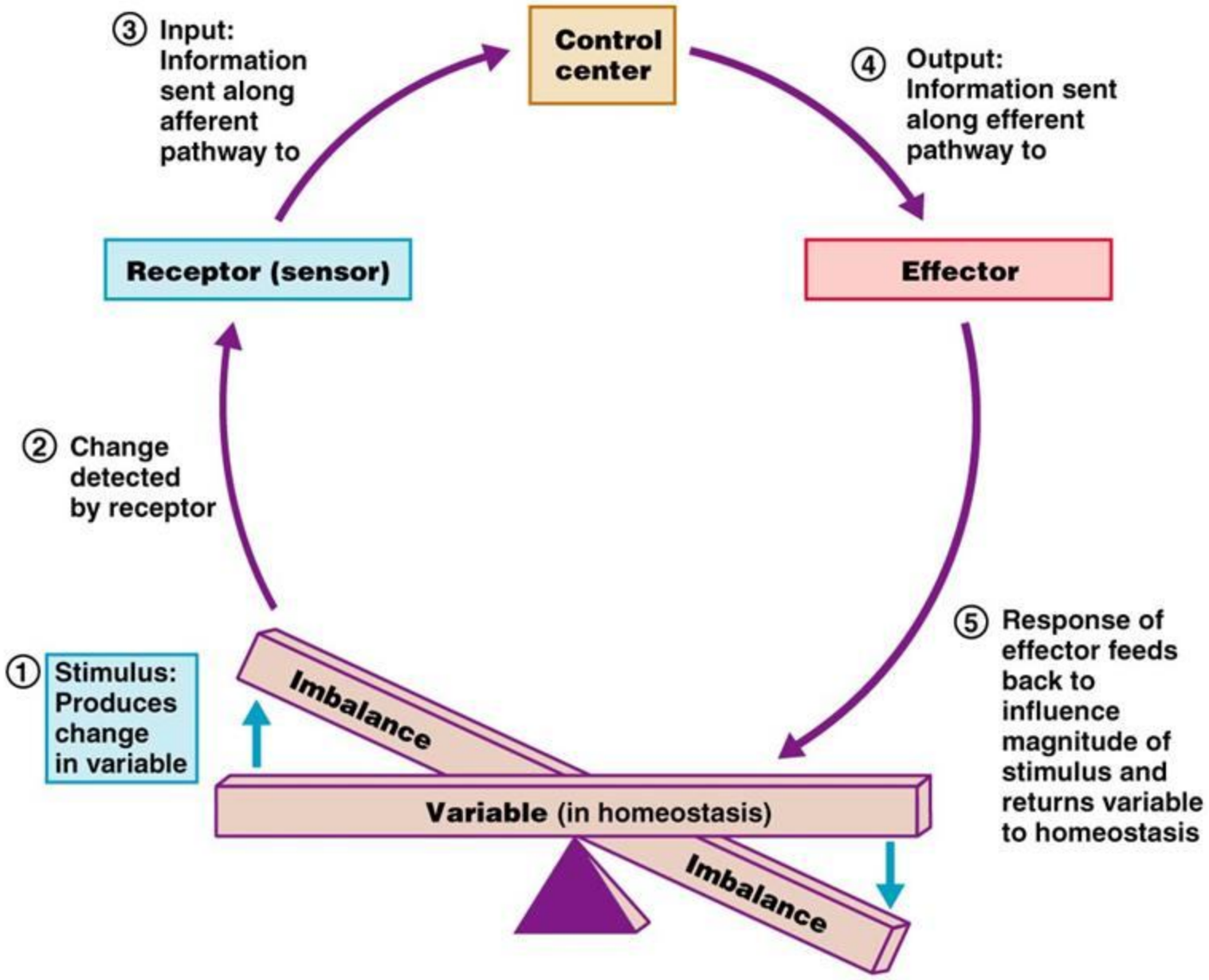


Figure 1.4

HOMEOSTASIS, contd

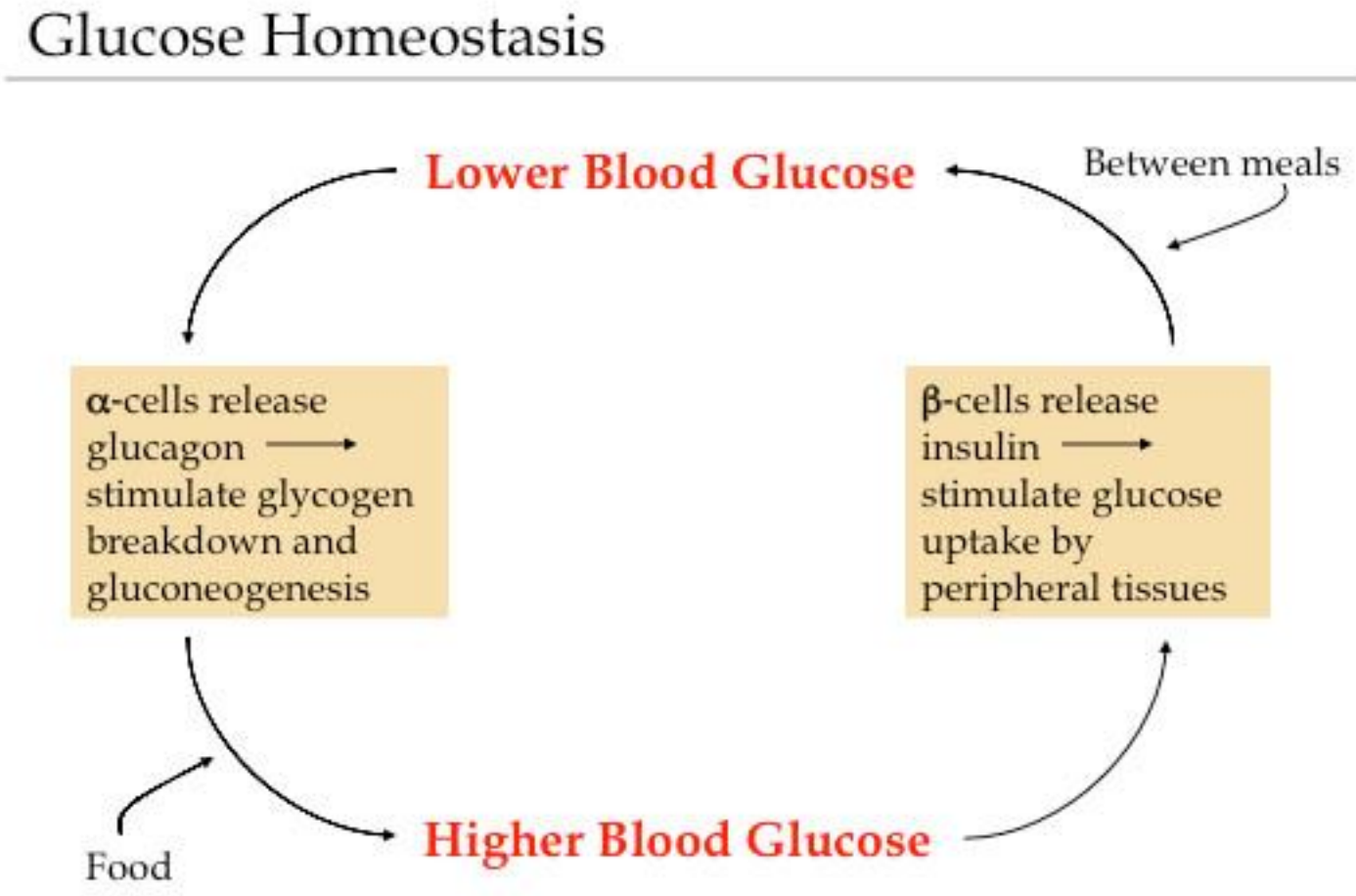
Glucose Homeostasis Chart

Condition	High Blood Sugar Toxic	Low Blood Sugar Do not meet energy requirements of cell
Receptor	Glucose transporter	Glucose transporter
Control Center	β-cell of the pancreas	α-cell of the pancreas
Effector	Insulin	Glucagon
Result	Glucose uptake by muscle/ fat tissue Lowers blood-glucose	Liver breaks down glycogen to create glucose Raises blood-glucose

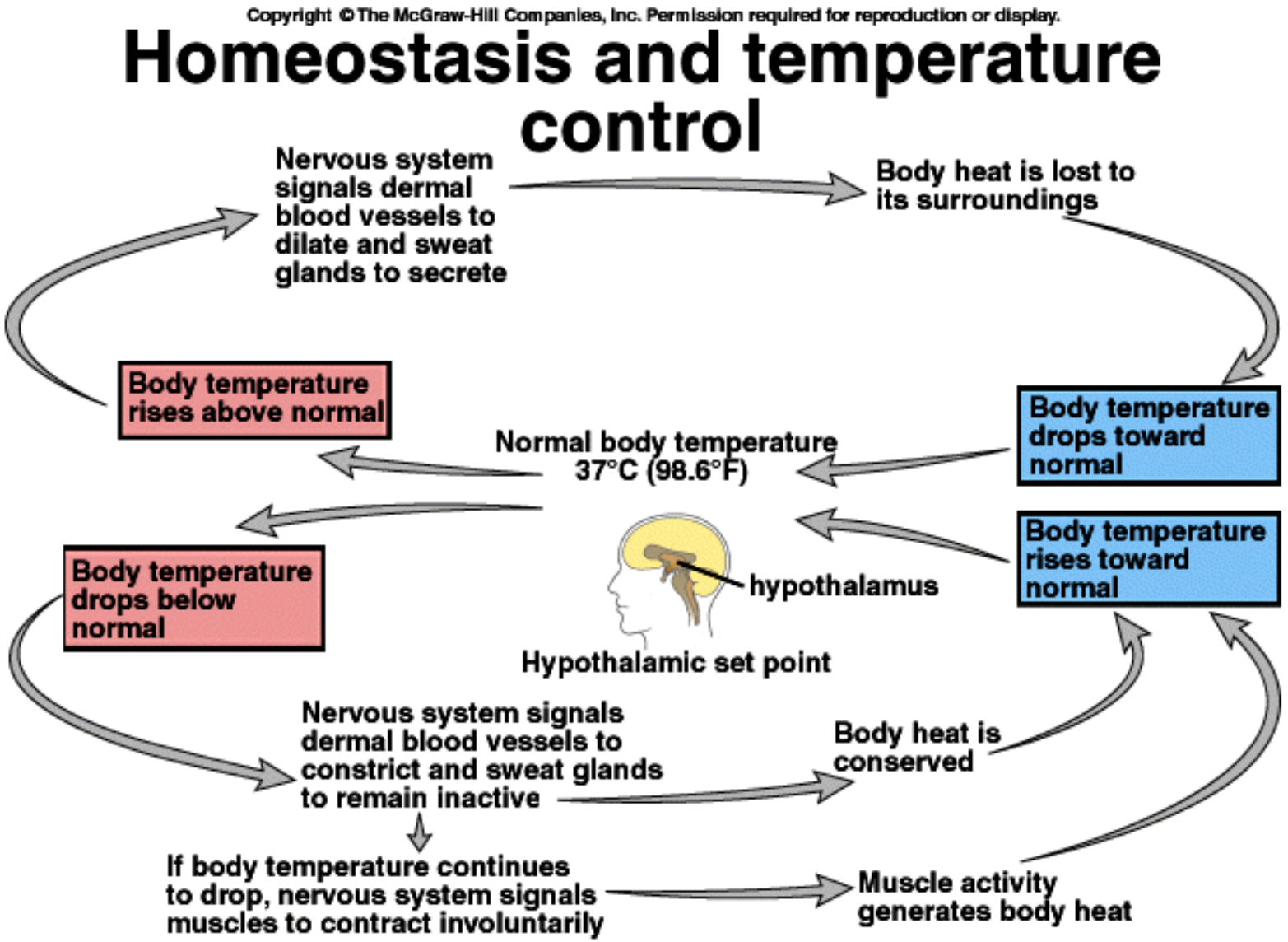
HOMEOSTASIS, contd

Hormone	Molecular Type	Site of Production	Physiological Actions
Insulin	Polypeptide of 51 amino acids	Pancreas (β-cells)	Lowers plasma glucose and is the principal regulator of glucose homeostasis (more detailed information is given immediately below this table)
Glucagon	Polypeptide of 29 amino acids	Pancreas (α_2-cells)	Opposes insulin action by stimulating glycogenolysis, gluconeogenesis and lipolysis
Adrenalin	Catecholamine	Adrenal medulla	Promotes hyperglycaemia by stimulating glycogenolysis and depressing insulin secretion; also increases lipolysis.
Cortisol	Steroid	Adrenal cortex	Glucocorticoid which promotes hyperglycaemia by stimulating gluconeogenesis from amino acids; may also depress glycolysis and the cellular uptake of glucose.
Growth Hormone	Polypeptide	Pituitary	Exerts an anti-insulin effect by inhibiting cellular glucose uptake. Its secretion is suppressed by hyperglycaemia and stimulated by hypoglycaemia.

HOMEOSTASIS, contd



HOMEOSTASIS, contd



HOMEOSTASIS, contd

Example of Positive Feedback:

Muscular Contractions During Parturition