Metamorphosis and Hormones

Hormones
Integrate developmental and/or physiological processes
- Soluble signaling molecules
- Induce cellular responses at great distances
- Often transported via the circulatory system
- Typically active at low [ ]
- Responses are cell specific

Animal hormones—most common are peptides and steroids
Peptides
- not membrane soluble
- have cell surface receptors
- E.g. Growth hormone, Insulin
Steroids
- Cholesterol derivatives
- Membrane soluble
- Nuclear receptors—the hormone-bound receptor is a transcription factor
- E.g. Estrogen, testosterone, glucocorticoid

Plant Hormones—most are small organic molecules
- Eg, auxin is related to tryptophan, cytokinin is related to adenine

Metamorphosis
Different larval and adult forms = indirect development
Most species undergo metamorphosis
Hormonally controlled

Amphibians
Change from herbivorous aquatic organisms to terrestrial predators.
Sweeping developmental changes affect:
- Locomotion (legs replace tail)
- Respiration (lungs replace gills)
- Nervous system (eyes migrate and new neurons innervate brain)
- Nutrition, metabolism, skeleton, muscles, etc. all undergo dramatic changes

Controlled by thyroid hormones T3 and T4
- Signal the whole body
- tissue-specific responses intrinsic to various tissues
  - eg. tail degenerates even if transplanted while eye transplanted onto tail will not degenerate = cell autonomous programmed cell death

Coordination of metamorphosis
• need sequential changes in proper order—lungs must be functional before gills regress and so forth
• during metamorphosis there is a progressive increase in [T3]
• processes have different hormone sensitivities
• processes with lower thresholds occur earlier than those with high thresholds
• eg low [T3]→hindleg formation, high [T3]→tail regression

Insects
3 types of insects
1. ametabolous—no difference in juvenile and adult morphology
2. hemimetabolous—gradual metamorphosis to adult (eg. cockroach and grasshopper)
3. holometabolous—complete (eg. butterflies)
Undergo a series of molts—shed cuticle and grow a larger one
Stages between molts called instars
In holometabolous, last 2 molts = metamorphic molts → pupa→ adult
Most of the insect body undergoes apoptosis
Small patches of undifferentiated cells called imaginal discs are present in the larva
• identity and axes of imaginal discs are specified during embryogenesis (hox genes etc)
• undergo growth and differentiation into adult structures
• concentric folds of epidermal tissue that telescopes out to form organs
neurons that innervate larval legs die and new ones innervate adult appendages

Metamorphosis is induced by the hormone 20-hydroxy ecdysone (steroid)
Can be blocked by actinomycinD (transcriptional inhibitor), cycloheximide
(translational inhibitor) cytochalasin (actin inhibitor) or protease inhibitors
Regulated by a gland called the corpus allatum
• most insects undergo 5 larval molts then a metamorphic molt
• if remove corpus allatum from 3rd instar larva, next molt get metamorphosis and a precocious adult
• if implant a 3rd instar corpus allatum into a 5th instar larva, get a 6th larval instar
• corpus allatum secretes Juvenile Hormone which inhibits metamorphosis
Molting is initiated in the brain. Secretes PTTH (peptide hormone) that induces production of ecdysone in the prothoracic gland.
At each successive molt, the level of JH produced declines.
• 20-hydroxy ecdysone + high [JH]→ larval molt
• 20-hydroxy ecdysone + low [JH]→ pupation (metamorphosis)
• 20-hydroxy ecdysone + no [JH]→ adult metamorphosis
Different tissues respond differently to ecdysone. The ecdysone receptor gene is alternatively spliced and different cells express different forms of the receptor protein. This contributes to the different action of ecdysone on different cells.
Mammary Gland Development

There are 4 key developmental stages, each hormonally regulated: embryonic, adolescence, pregnancy, birth.

Embryonic stage
Female:
- 2 bands of raised epidermis form on either side of the ventral midline = mammary ridge
- cells collect at centers = mammary buds
- epithelial cells proliferate to form the mammary cord
- an opening then forms at the surface and extends internally to form a lumen cavity
- development arrests until puberty

Male
- Development is identical up to the mammary cord stage.
- Mesenchyme condenses around the cord and cord cells die

Cultured mammary buds form a lumen
- Female mammary buds; if add testosterone, no lumen forms
- Male mammary buds cultured without testosterone form a lumen
- Therefore testosterone inhibits lumen formation and promotes cord cell death

Androgen insensitivity syndrome
- XY individuals have testes and produce testosterone
- Lack a functional testosterone receptor
- Develop female secondary sex characteristics, including mammary glands

Mixed cultures
- Normal mesenchyme + AIS epithelium + testosterone → arrest
- AIS mesenchyme + normal epithelium + testosterone → lumen development
- Therefore mesenchyme responds to testosterone and destroys the cord

Adolescence
- Proliferation of the duct system—lots of cell division at duct tips
- Induced by estrogen and growth hormone

Pregnancy
- Estrogen and progesterone induce more duct formation and the differentiation of secretory tissues

Birth (lactation)
- Prolactin (a peptide hormone) induces expression of casein gene