Plant Growth & Development

•Plant body is unable to move.

•To survive and grow, plants must be able to alter its growth, development and physiology.

•Plants are able to produce complex, yet variable forms that are best suited to their local environment.

•[Free Movies!]

Questions: 1. What are the changes in form & function?

2. What are the molecular and biochemical bases of the changes?

Development

1. What is development?
   Changes during the life history of an organism.
   E.g. How? zygote → embryo

   embryo→ seedling

   Cells differentiate.
   e.g. root hair, epidermis, guard cell

   Tissues form a specific pattern.

2. What mechanisms control development?
   - Genes, hormones, environment
   - Cellular changes

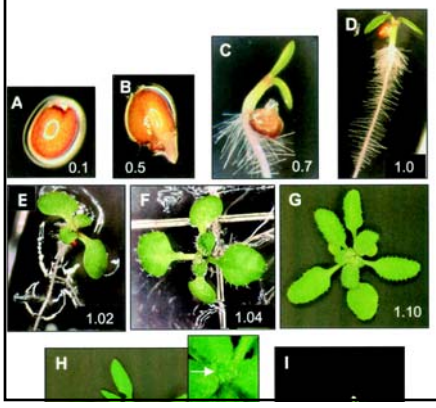
Differences in the Developmental Mechanisms of Plants and Animals

1. *Post-embryonic vs embryonic development*
   zygote--> embryo
   Animals- most of the organs are formed at this stage
   Plants- organs are formed after germination.
2. *Cell commitment for differentiation*
   Animal cell is irreversibly committed to a particular fate
   Plant cell commitment is rarely irreversible.
3. *Fate of plant cell is determined by its position in the organism*.
   Cells do not move, so its position is determined by the plane of division. Positional information comes from chemical signals via cell-cell communication.

Growth Stages

1. Embryogenesis [part of seed development]
   zygote --> embryo
2. Vegetative development includes
   a. Seed germination
   From a heterotrophic to a photosynthetically-competent seedling

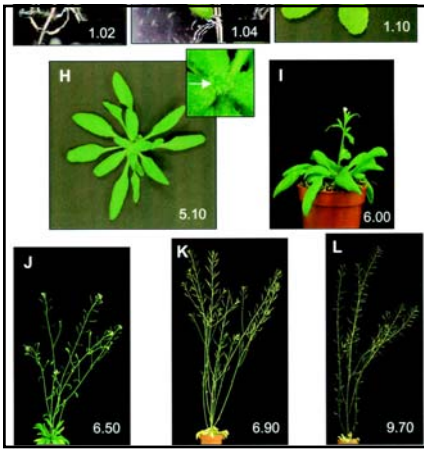
   b. Development of the Vegetative plant
   Indeterminate growth regulated by environmental factors
3. Reproductive development
   flowering
   pollination
   fertilization → zygote



Life cycle
Growth stages of Arabidopsis, a model plant.

1. Germination: seed to seedling
2. Development of the vegetative plant

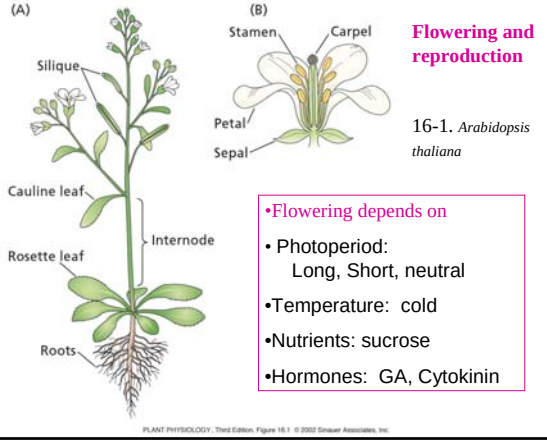
Boyes et al 2001 Plant Cell



3. Development of the reproductive plant

   flowering
   pollination
   fertilization

4. Development of the seed
   (protected embryo)
   zygote -> embryo
   embryogenesis



Flowering and reproduction

16-1. *Arabidopsis thaliana*

•Flowering depends on

• Photoperiod:
Long, Short, neutral

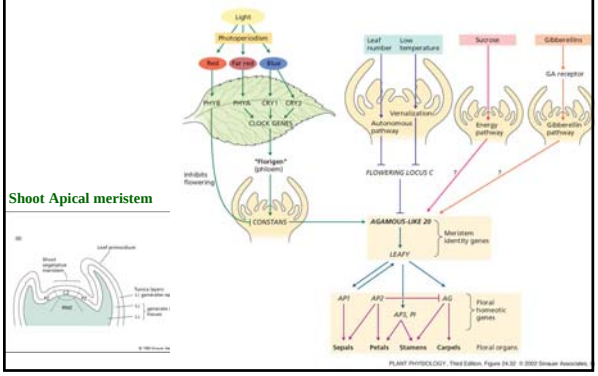
•Temperature: cold

•Nutrients: sucrose

•Hormones: GA, Cytokinin

***Shoot* apical meristem –→ *Floral* apical meristem**

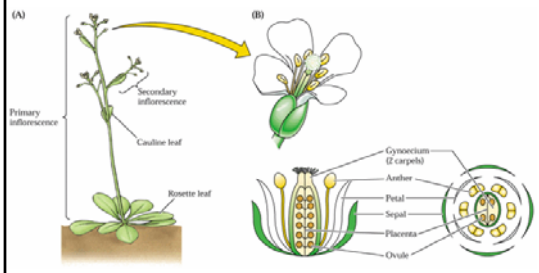
Four developmental pathways for flowering



Shoot Apical meristem

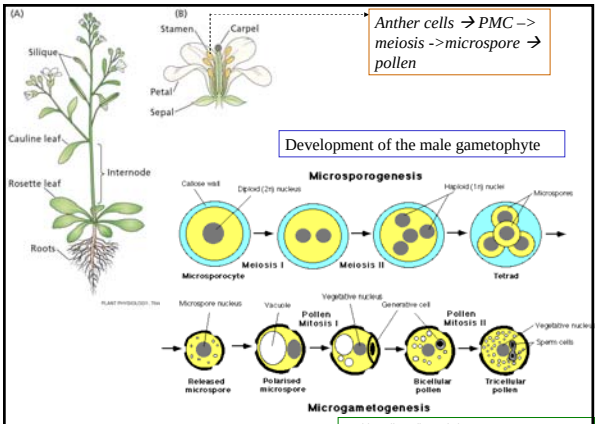
4 organs of a flower:

sepal,
petal,
stamen (male), --> pollen (sperm)
pistil (female) ---> ovule (egg)



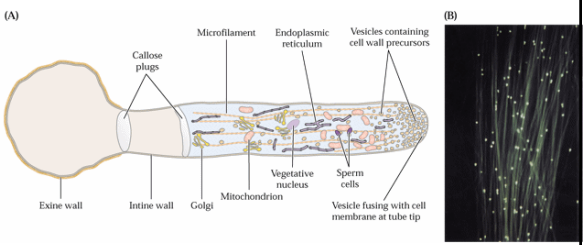
Anther cells → PMC –> meiosis ->microspore → pollen

Development of the male gametophyte

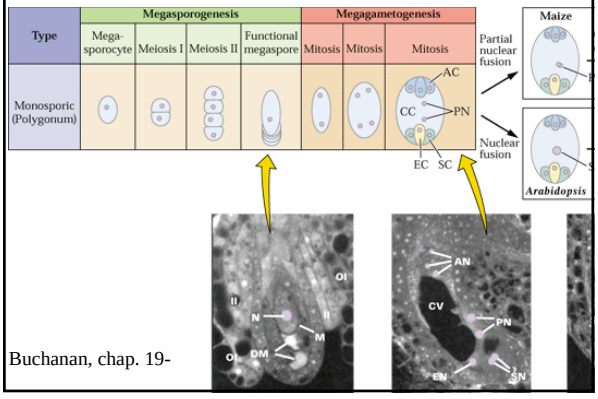


David Twell's Pollen website
http://www.le.ac.uk/biology/research/pollen/pollen.html

Growing pollen tube



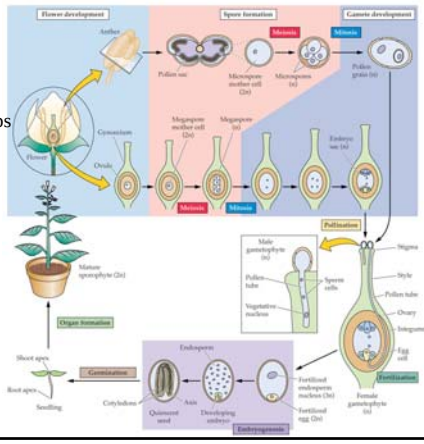
Development of the female gametophyte



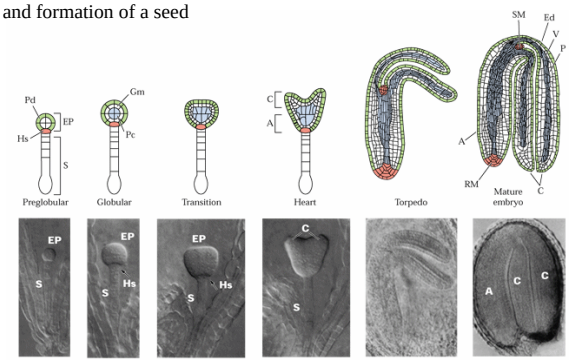
Buchanan, chap. 19-

Pollination & fertilization.

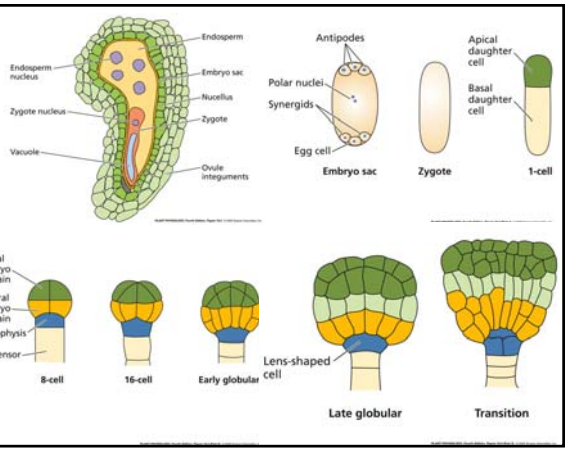
Zygote develops into an embryo



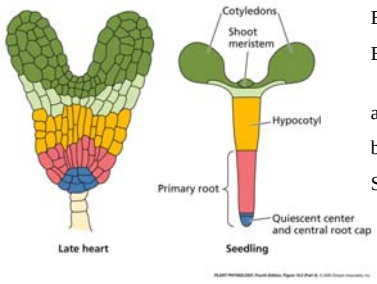
Embryo development (embryogenesis) and formation of a seed



Buchanan. Ch 19-36



Embryogenesis



Embryo in a seed.

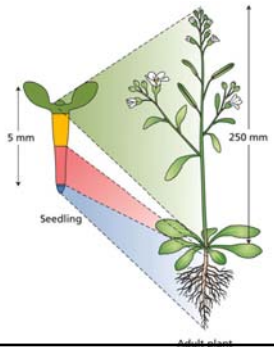
Establish a shoot-root polarity.

a. Shoot meristem

b. Root meristem

Seed dehydrates. Dormant

Postembryonic development derive from the root and shoot apical meristems



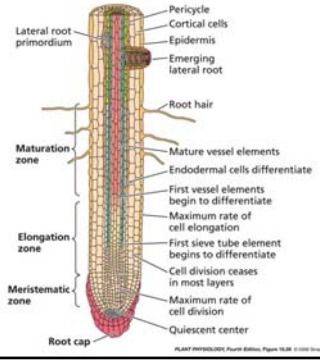
Shoot apical meristem produce
-stem, leaves, flower
-tissues
-Cell types

Root apical meristem

-root
-tissues
-cell types

Development of seedling depends on environmental signals

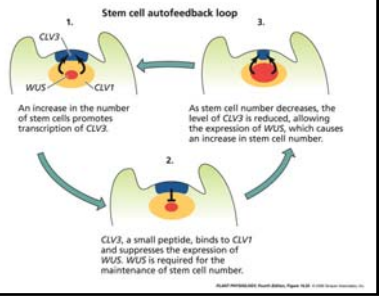
Shaping of each new structure depends on the oriented cell division and expansion



Cell signaling maintains the meristem

Q? How does the apical meristem maintain itself?

Cells divide but meristem remains constant at ~100 cells.



Long-range hormonal signals coordinate development in separate parts of the plant.

e.g. separate parts of plant experience different environments, but they must communicate with one another in order to function as one body.

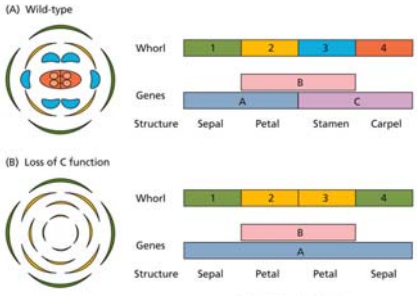
Homeotic genes specify the parts of a flower

Cells acquire tissue identity as a result of specific gene expression

e.g. Floral meristem-identity genes

ABC model

Homeotic genes encode proteins that bind to DNA and enable protein to regulate transcription. They act as developmental switches.



Growth, Development and Adaptation

I. What is development? Development is the sum of all changes that an organism goes through in its life cycle.
Development = growth + differentiation

- Growth is an irreversible increase in size or volume.
- Differentiation occurs when cells take on a special form and function.
- Pattern formation is determined by the plane of cell division

II. **What controls development**? The orderly development of the plant depends on coordination and are subject to control at 3 distinct levels:

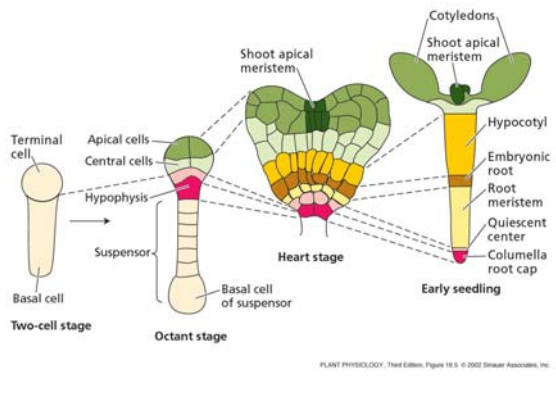
1. Genetic control: developmental program
2. Environmental stimuli [or extrinsic factors]
3. Hormones (or intrinsic factors) communicate signals long distance.

III. How is gene expression regulated? Changes in gene expression is a principal factor in regulating development.

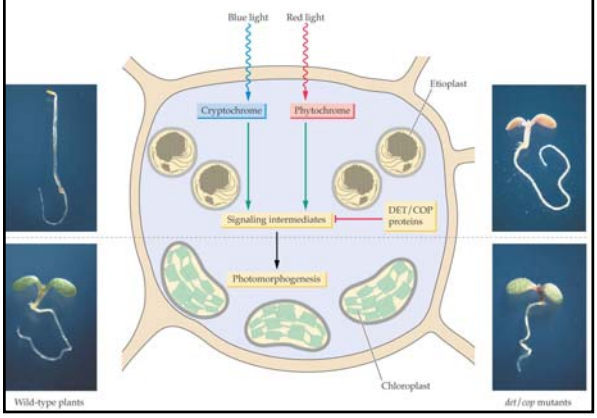
A. Transcription
B. RNA processing
C. Translation
D. Protein Modification or post-translation

Most if not all environmental and hormonal stimuli act in part on modifying gene expression.

16-5 Taiz. Development of an embryo from a zygote

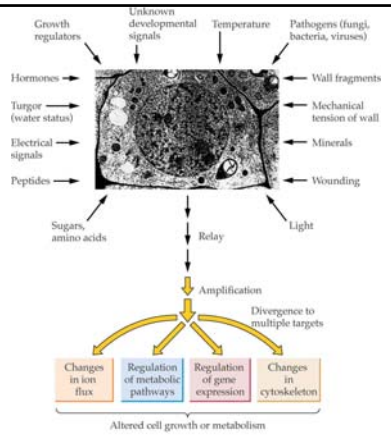


18-4 Buchanan. Light-regulated seedling development is controlled by genes



Environmental & hormonal signals affect growth & development.

18-2 Buchanan



Review of gene expression.

Information flows from
DNA → RNA → protein

Q: Do root hair cells contain the gene for rubisco?

How is gene expression controlled?

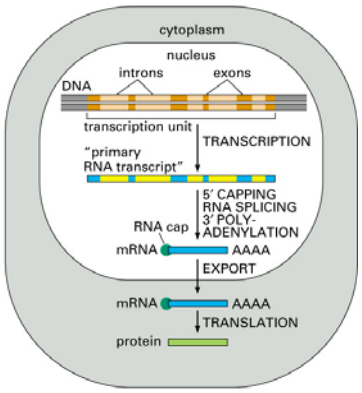
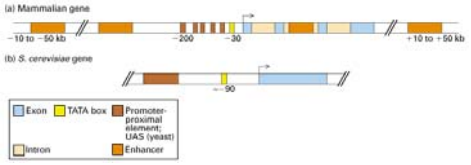


Figure 6–21 part 1 of 2. Molecular Biology of the Cell, 4th Edition.

Regulation of gene expression in eukaryotes by cis-acting elements



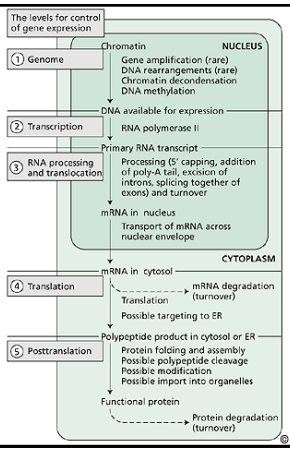
Cis-acting control elements:
regions of **DNA** that bind to protein transcription factors and the binding activates or represses transcription. Two types

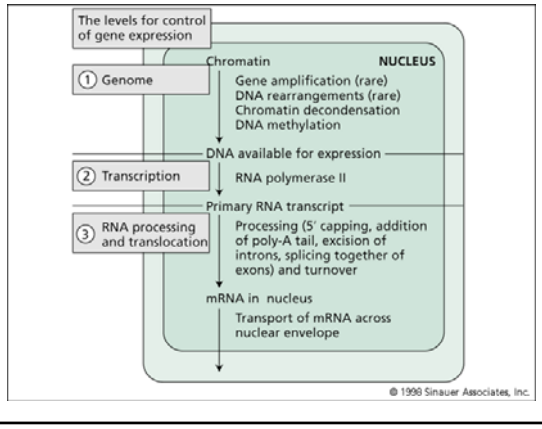
a. Upstream of structural gene or **promoter**
b. **Enhancer**: upstream, downstream or within introns

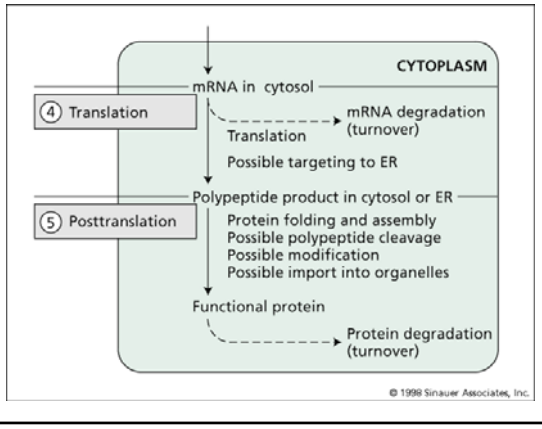
[e.g. guard-cell specific promoter- will control expression of protein in GC only]

14-5 Taiz

Many levels of control of gene expression

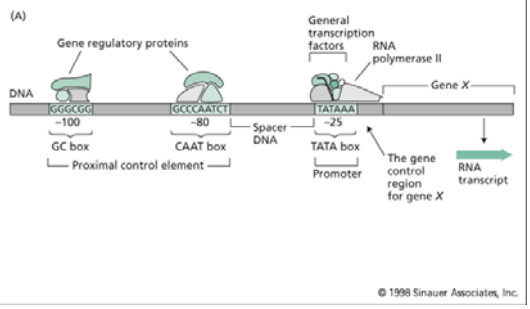




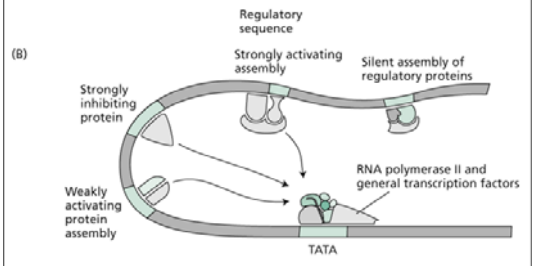


14-7 Taiz. Regulation of Transcription

Regulatory DNA defines the program of development.
Complexes of gene regulatory proteins bind to promoter and enhancer DNA to switch on [or off] gene expression

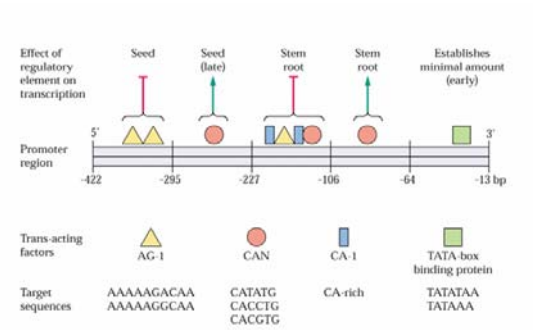


14-7 Taiz



Gene Regulatory proteins are also called **transcription factors**

Example of Spatial and temporal regulation of gene expression by Transcription Factors (trans-acting factors)



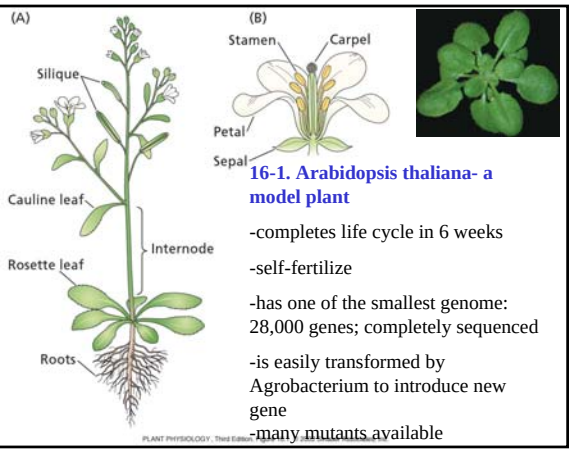
Power of mutants

Studies of mutants have identified genes that control development.

e.g. *Cop* mutants are not responsive to light

det mutants are deetiolated in the dark.

Hormone receptor identified from a mutant insensitive to a hormone.



16-1. Arabidopsis thaliana- a model plant

-completes life cycle in 6 weeks

-self-fertilize

-has one of the smallest genome: 28,000 genes; completely sequenced

-is easily transformed by Agrobacterium to introduce new gene

-many mutants available

Class will emphasis light and hormonal cues on plant growth and development.

Will not focus on embryogenesis or cell fate determination or patterning. [ch. 16]

Principles of plant development.

1. Expression of genes that encode transcription factors determine cell, tissue, and organ identity.
2. Fate of cell is determined by its position, not its clonal history.
3. Development pathways are controlled by networks of interacting genes
4. Development is regulated by cell-to-cell signaling.
   Ligand- small proteins, CHO
   Hormone signaling