# APPLICATIONS

## Stress Inducible Promoters

- Hormones as mediator of stress signaling
- ABA, GA, other hormone signaling

# Hormones regulate Growth, Development, Reproduction and Stress response in Plants

# Phytohormones

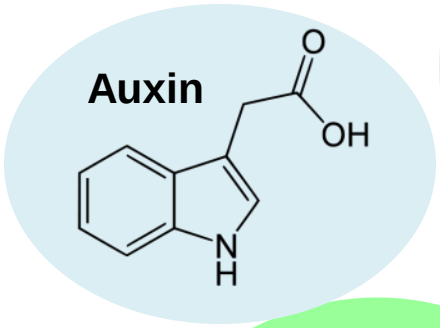
Phytohormones regulate cellular activities (division, elongation and differentiation), pattern formation, organogenesis, reproduction, sex determination, and responses to abiotic and biotic stress.

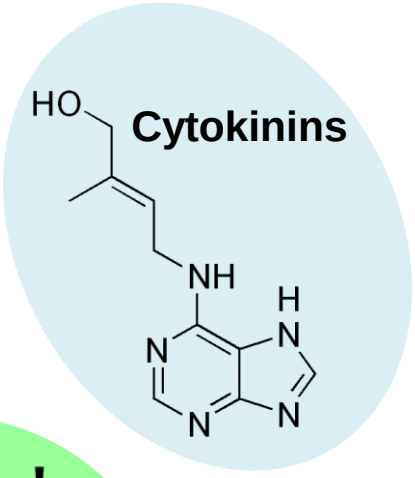


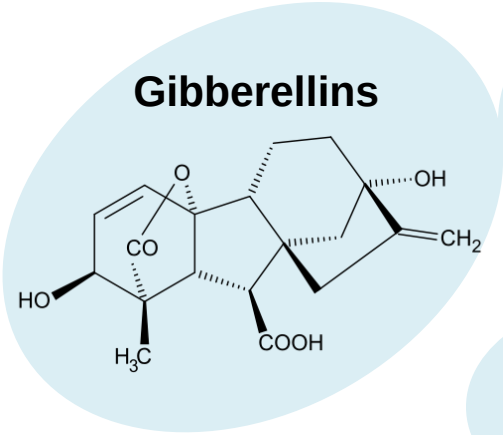


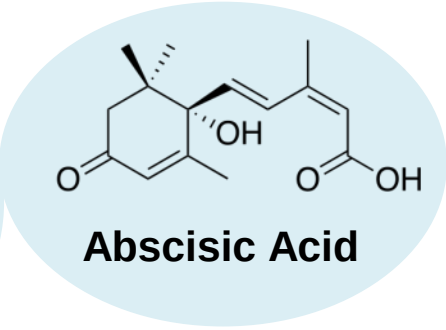
*Notholaena standleyi* © 2008 Carl Rothfels

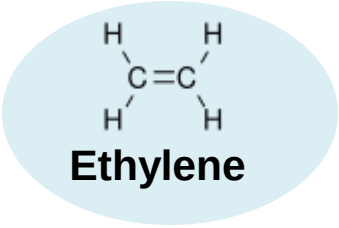
# Phytohormones – old timers and newcomers

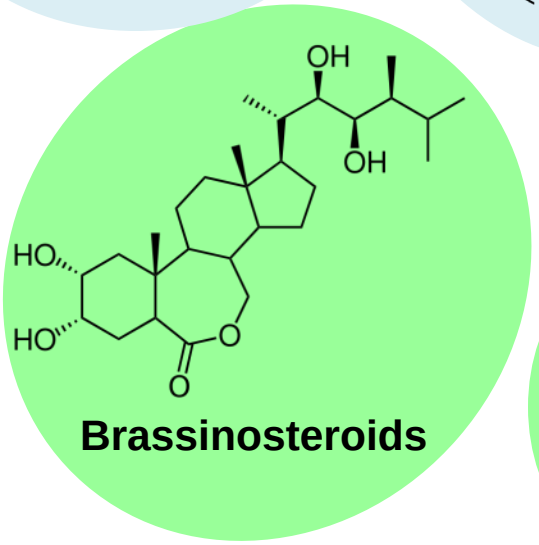


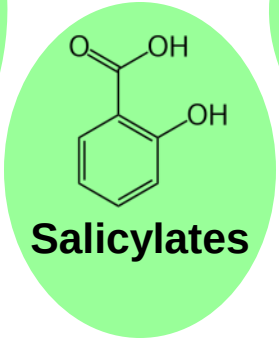



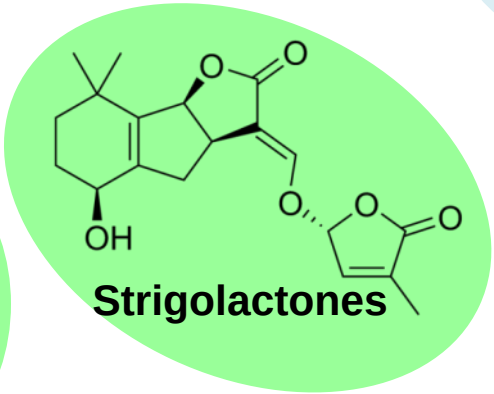



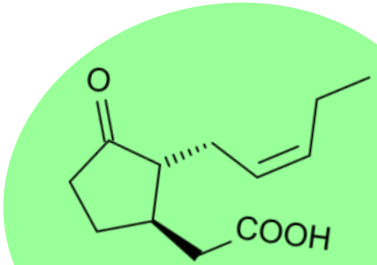



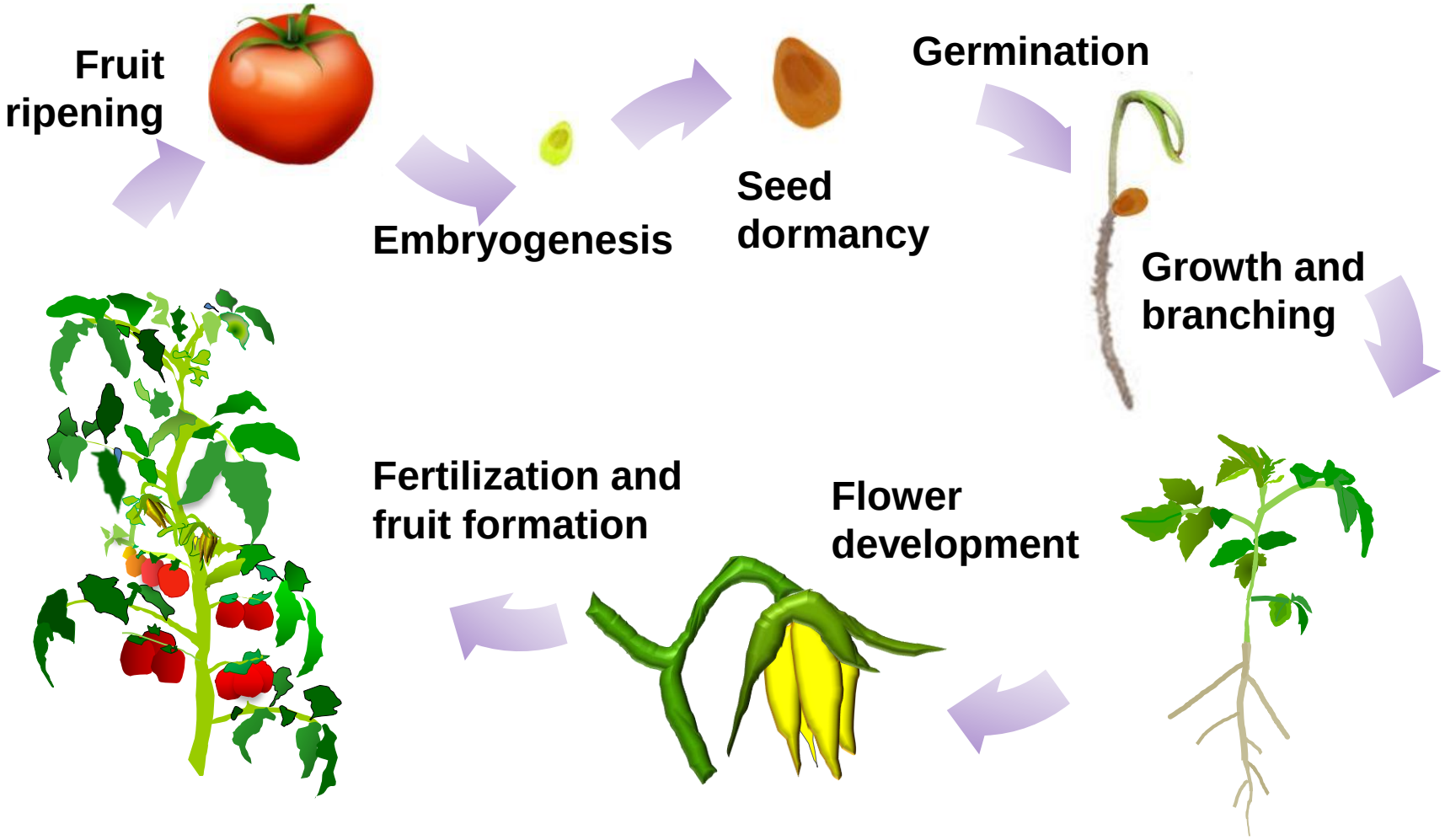



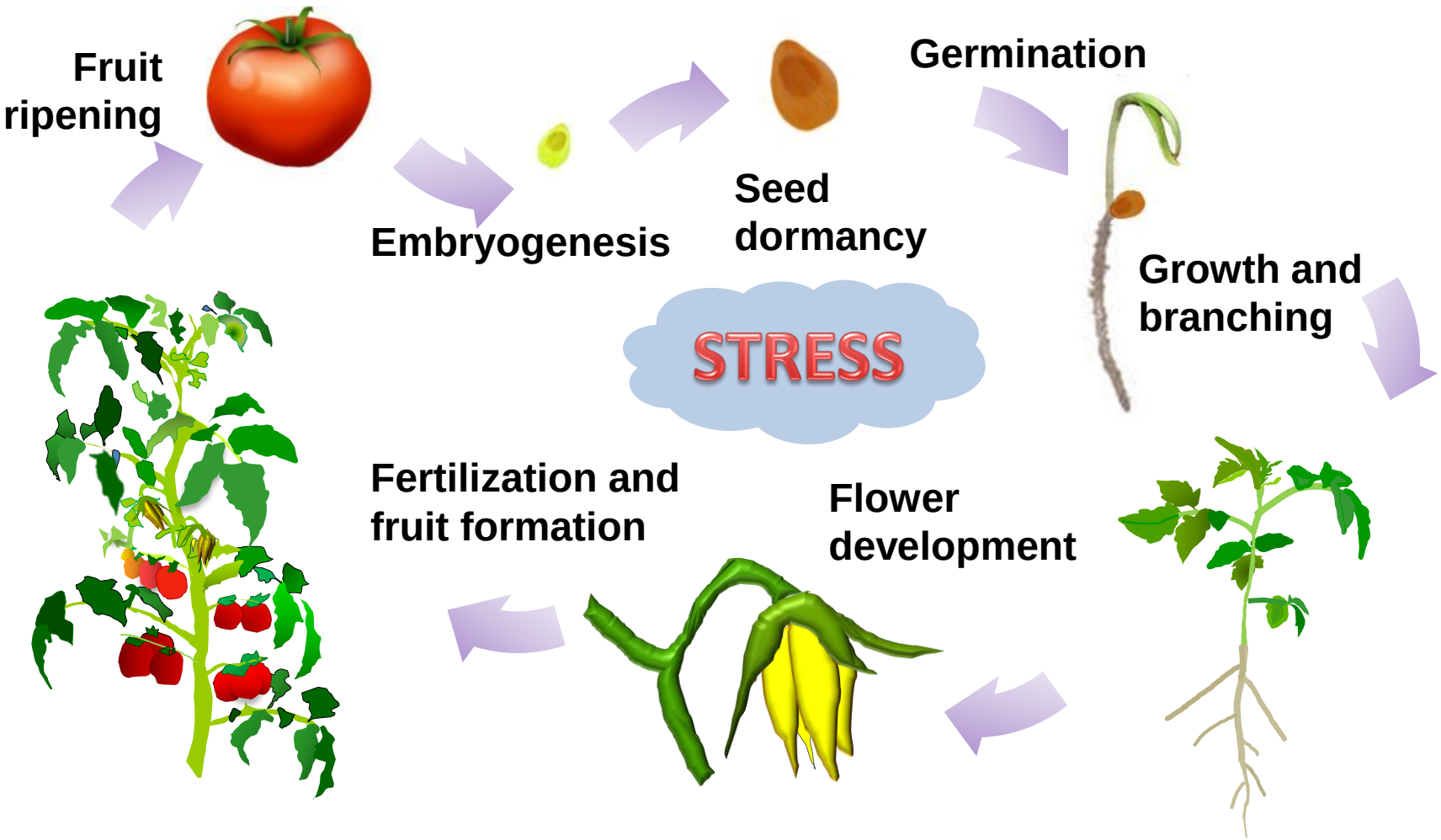



# Phytohormones regulate all stages of the plant life cycle



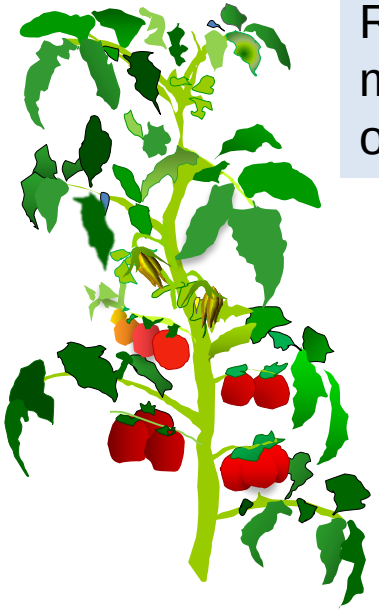
# Hormones also help plants cope with stress throughout their life

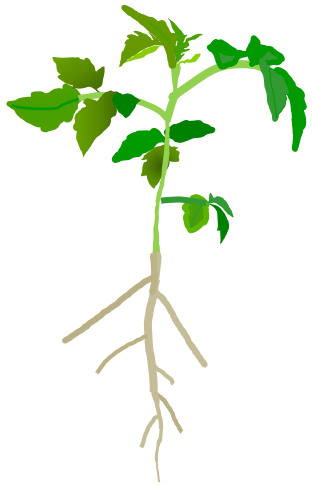


# Most hormones affect most stages of the plant life cycle

We will examine each hormones within the context of one of its roles.

Remember that these are merely examples; most hormones affect most processes in one way or another.





# Lecture outline

**How hormones work**

**Hormonal control of vegetative development**

- Auxin
- Cytokinins
- Strigolactones
- Gibberellins
- Brassinosteroids

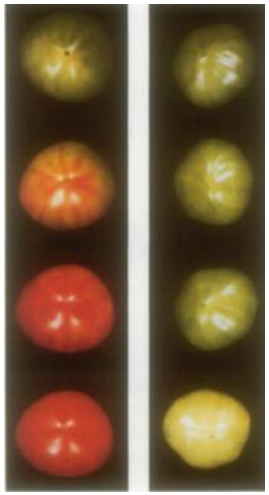
**Hormonal control of reproduction**

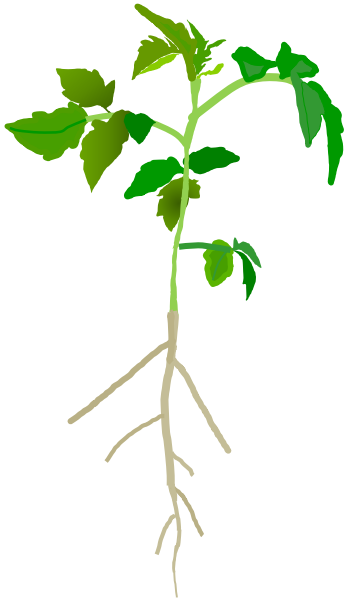
- Ethylene
- Abscisic Acid

**Hormonal responses to stress**

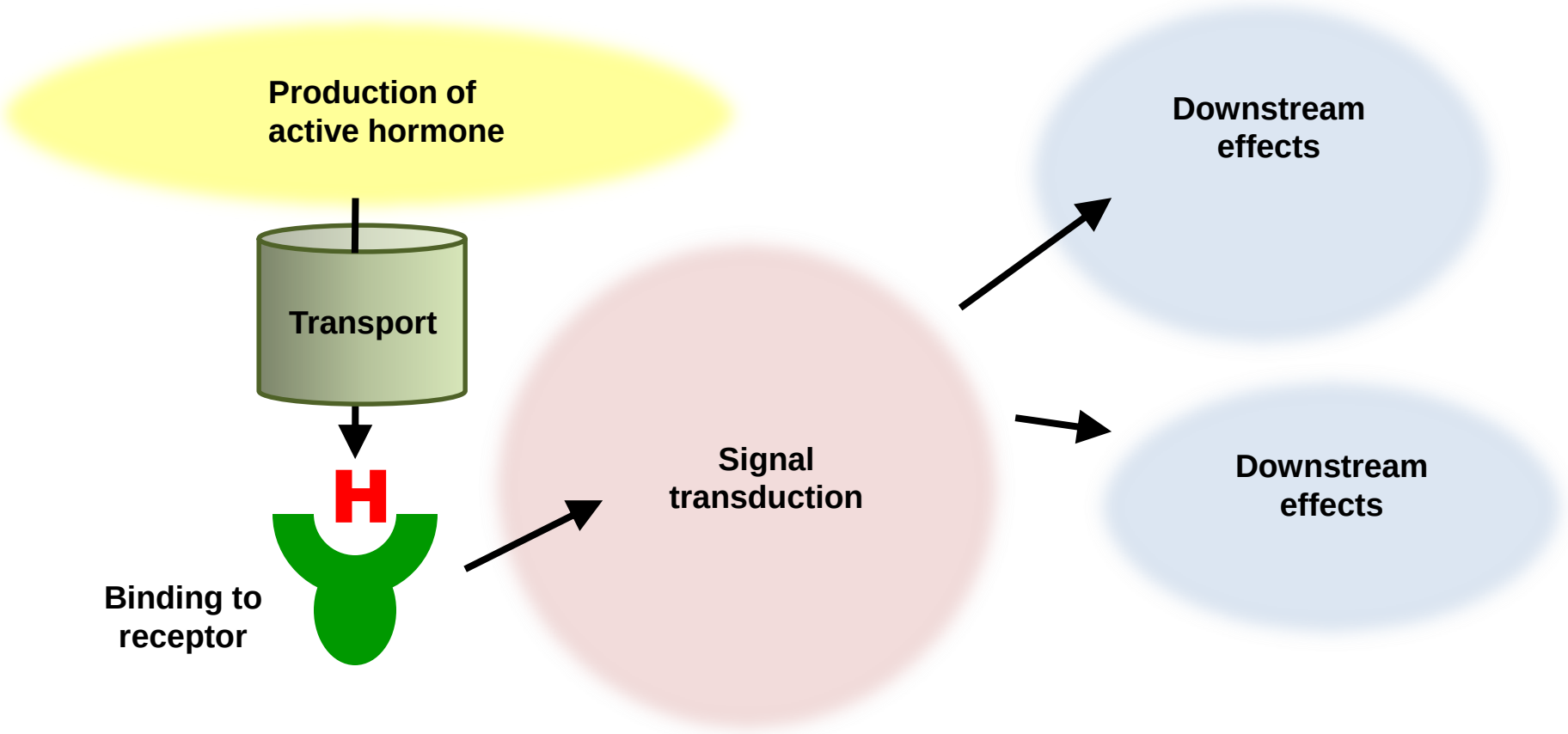
- Salicylates
- Jasmonates

**Cross-regulation of hormonal effects**

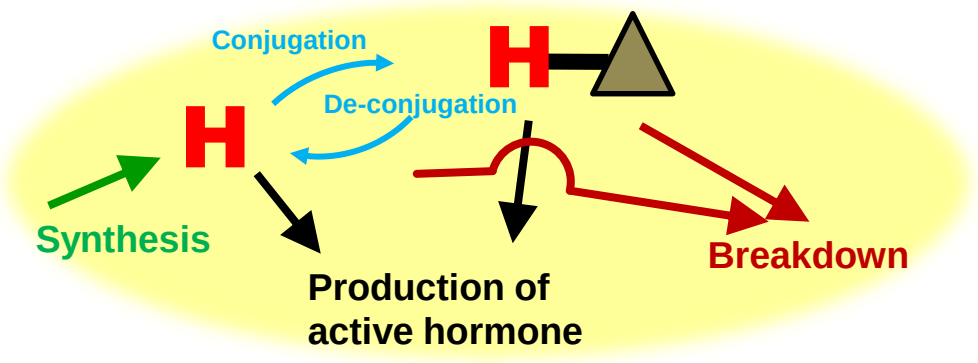




# Hormones: Synthesis, transport, perception, signaling and responses

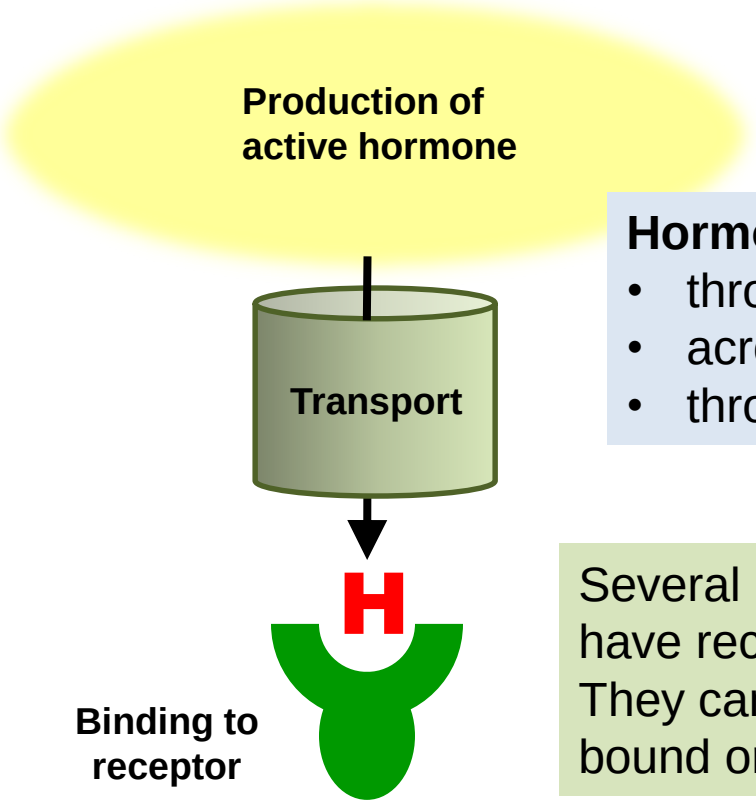


# Synthesis




Many tightly regulated **biochemical pathways** contribute to active **hormone accumulation**. Conjugation can temporarily store a hormone in an inert form, lead to catabolic breakdown, or be the means for producing the active hormone.

# Transport and perception



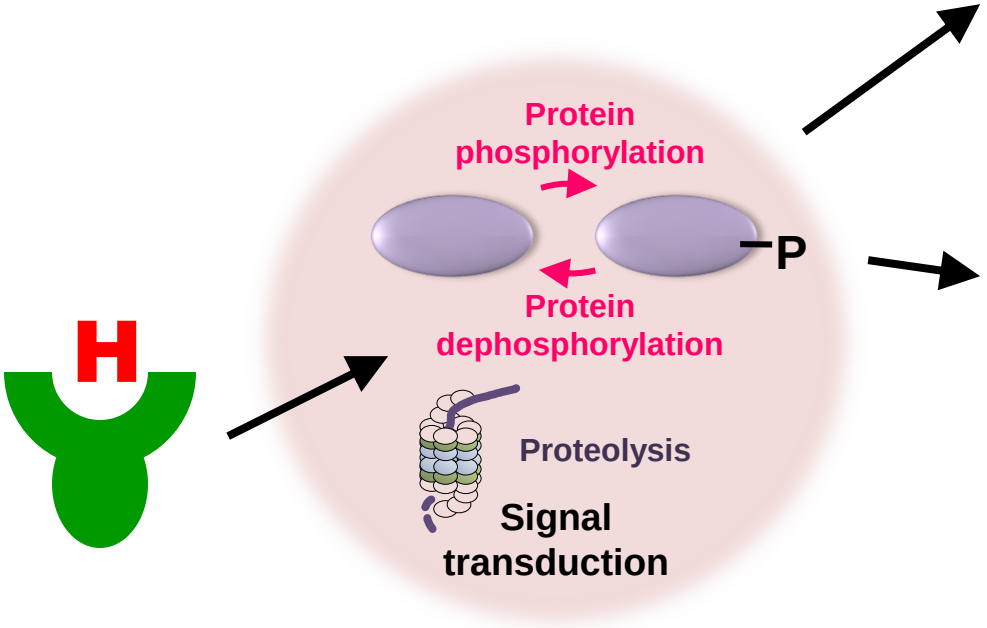

**Hormones can move**:

- through the xylem or phloem
- across cellular membranes
- through regulated transport proteins

Several **hormone receptors** have recently been identified. They can be membrane bound or soluble

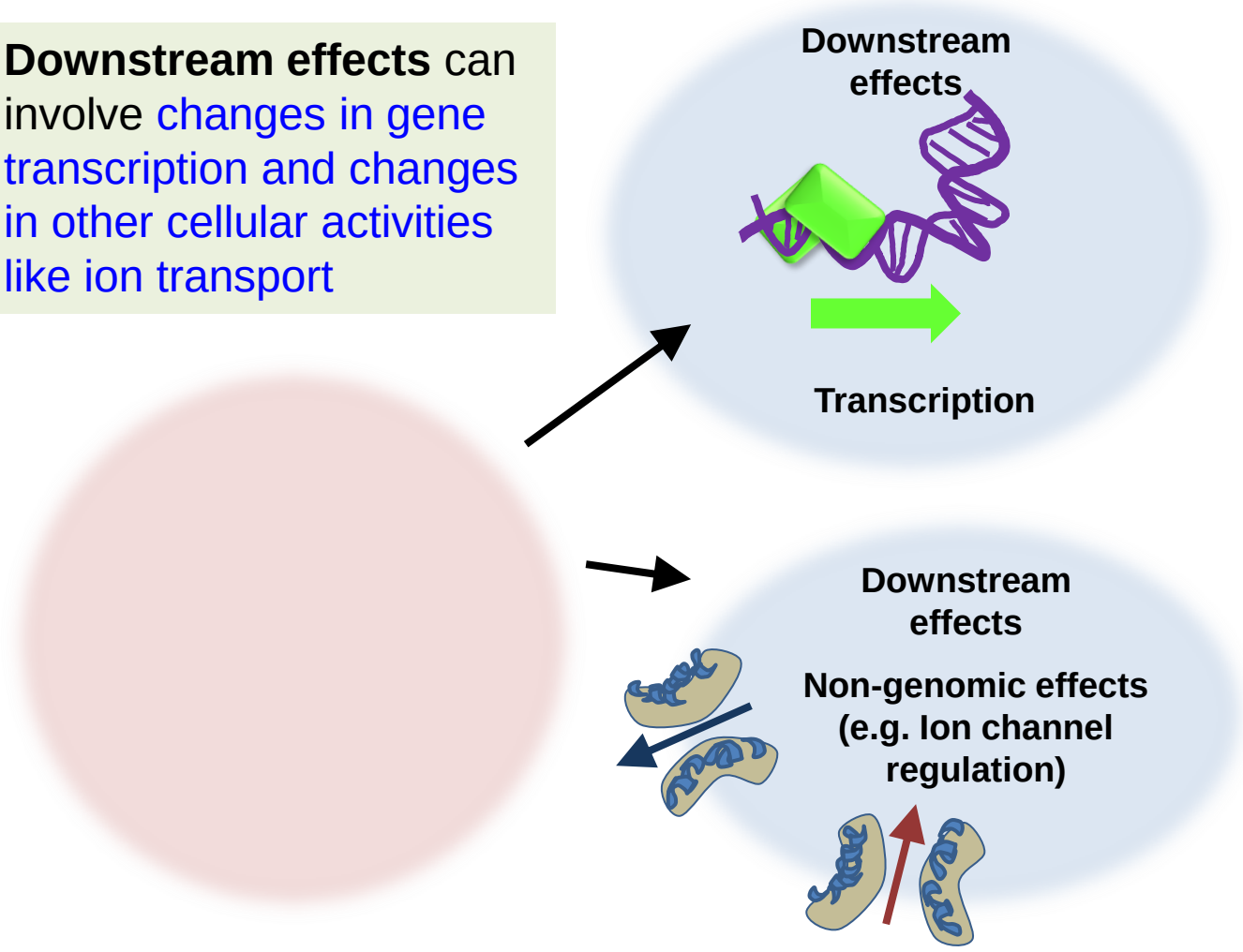
# Signal transduction

**Hormonal signals are transduced** in diverse ways. Common methods are reversible protein phosphorylation and targeted proteolysis

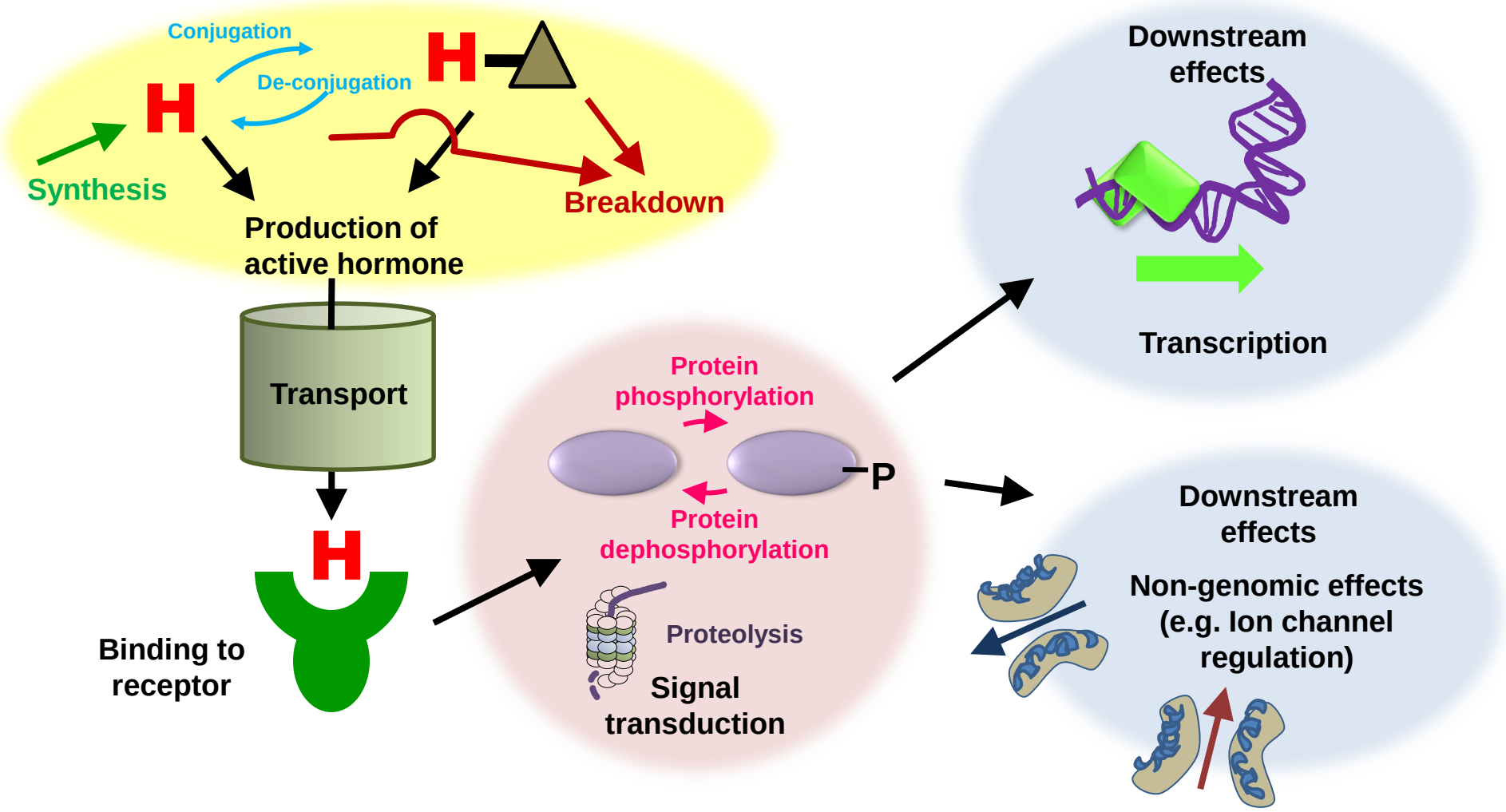


# Responses

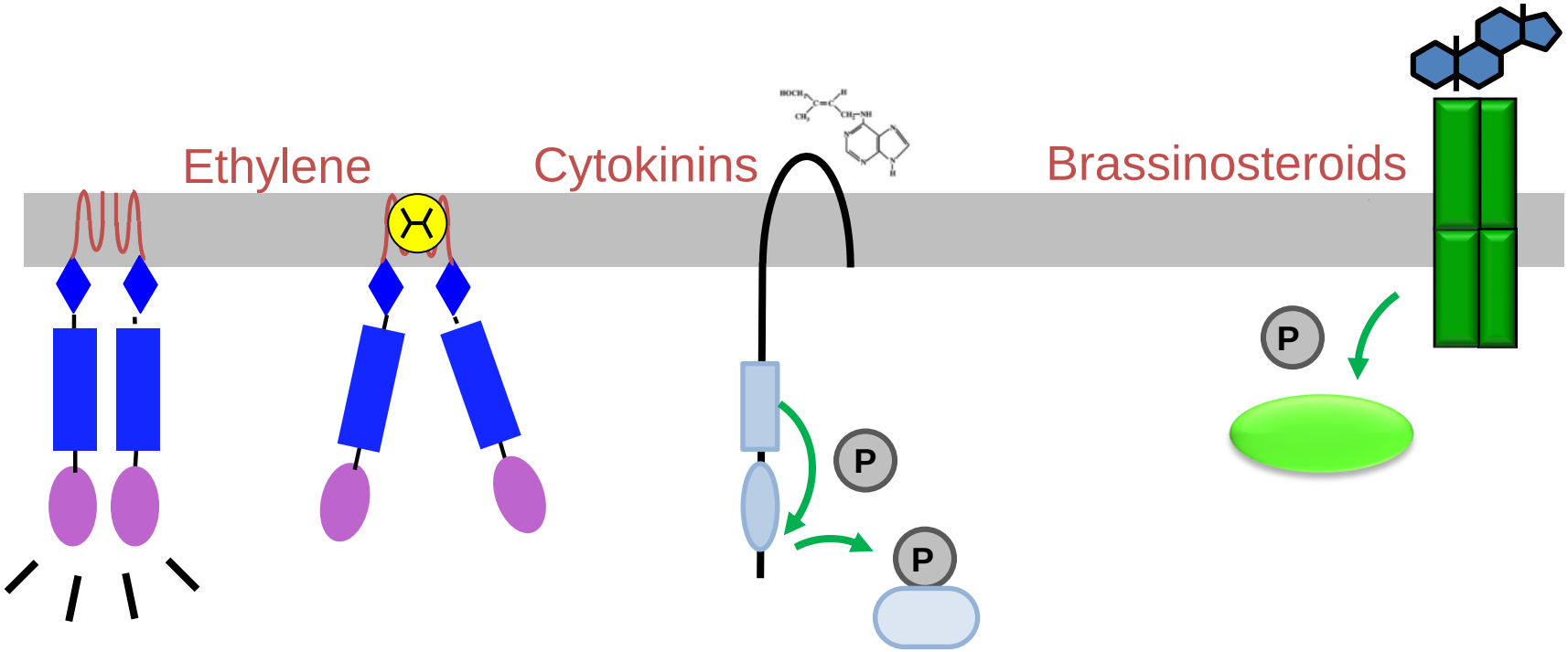
**Downstream effects** can involve changes in gene transcription and changes in other cellular activities like ion transport



# Hormones: Synthesis, transport, perception, signaling and responses



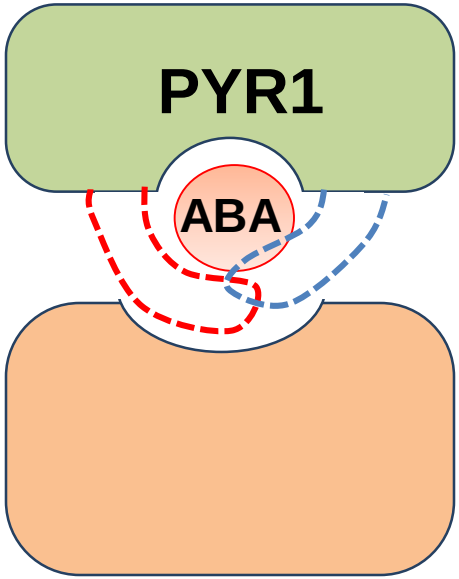
# Receptors can be membrane-bound

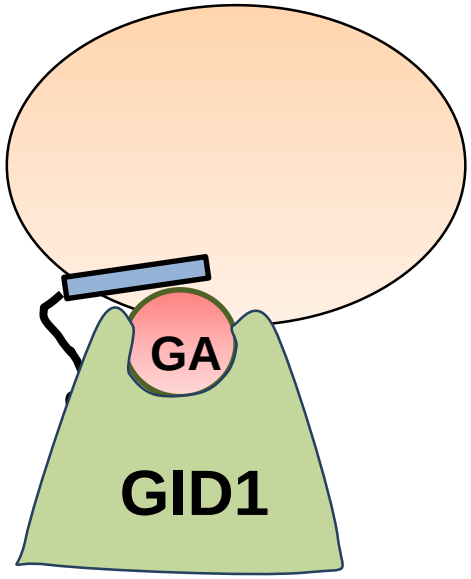


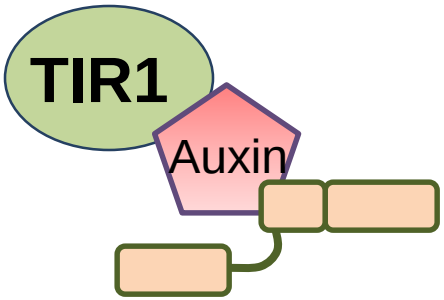

Hormone binding initiates an information relay

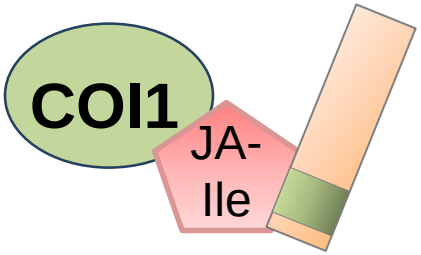
# Soluble receptors can facilitate interactions between proteins

Hormones can act like “molecular glue”



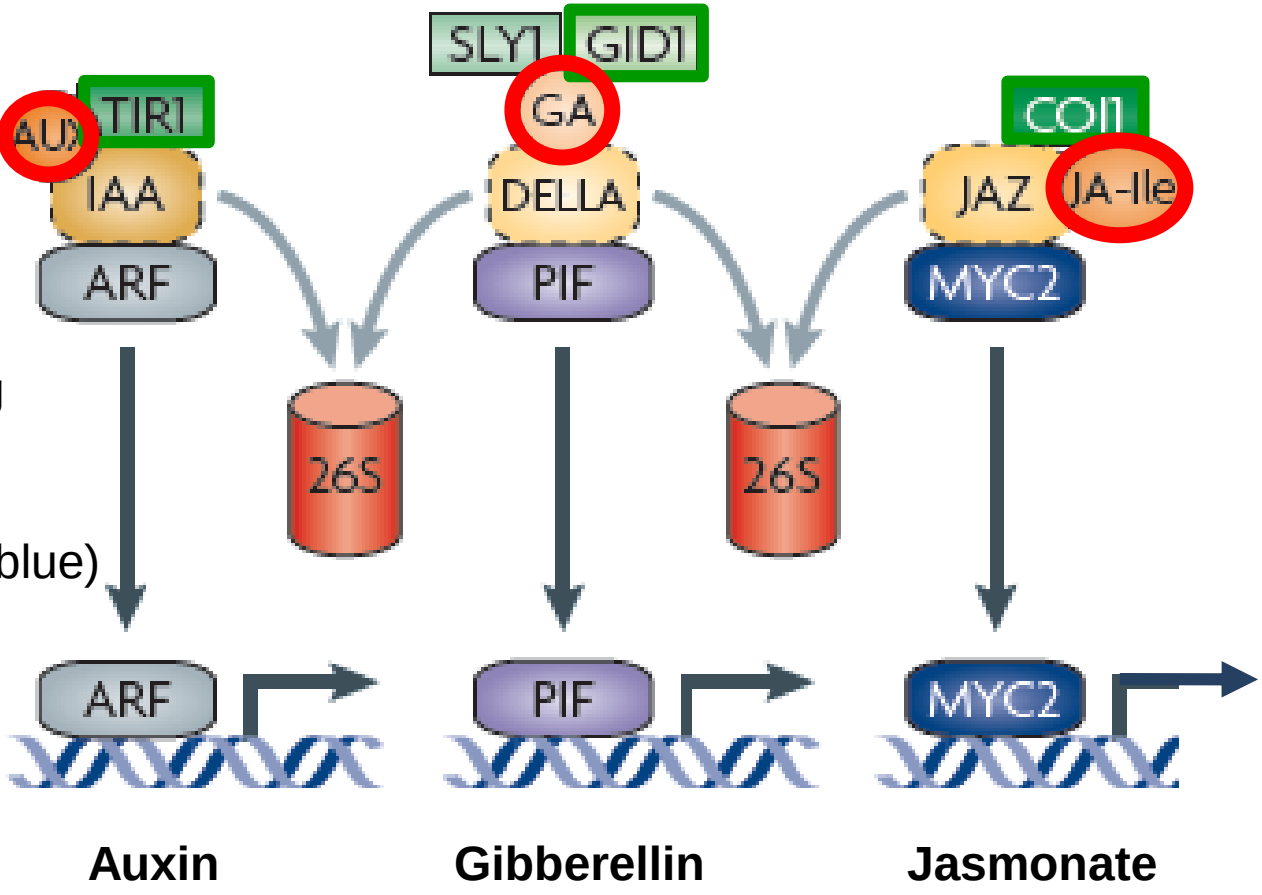



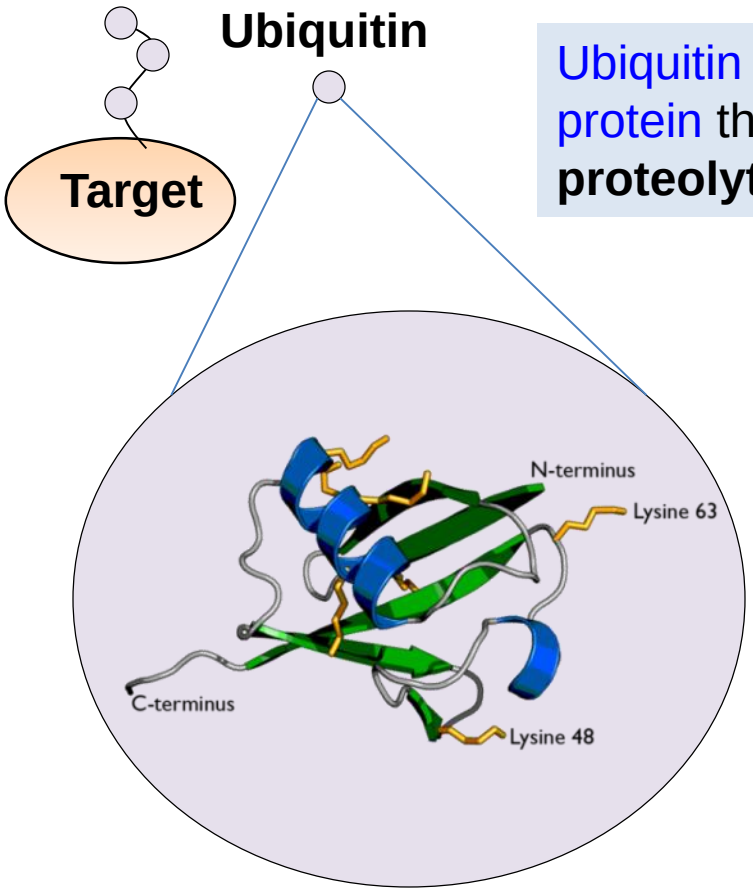



# Some receptors initiate protein proteolysis

The hormones (red) bind to receptors (green), **initiating proteolysis of repressors** (yellow) **to activate a transcriptional regulator** (blue)

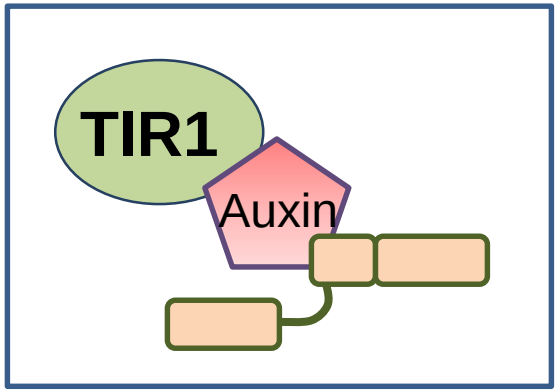


# Proteolytic targets are covalently linked to ubiquitin

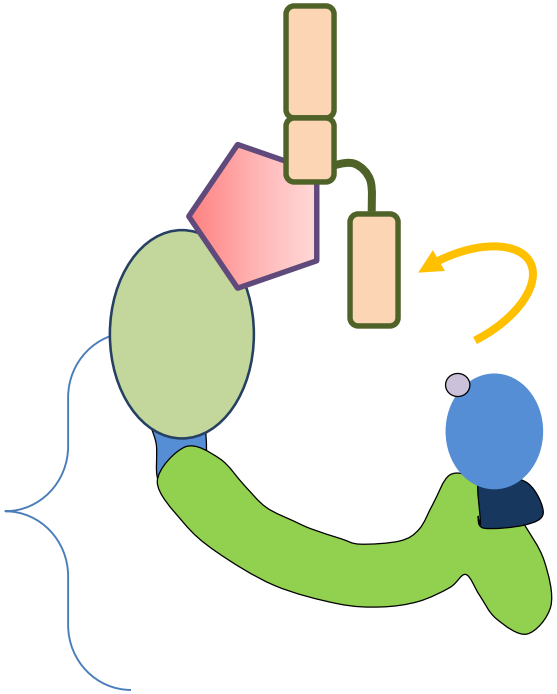



Ubiquitin is a small (76 aa) protein that **targets proteins for proteolytic cleavage**.

# Ubiquitin ligase complexes ubiquitinate target proteins

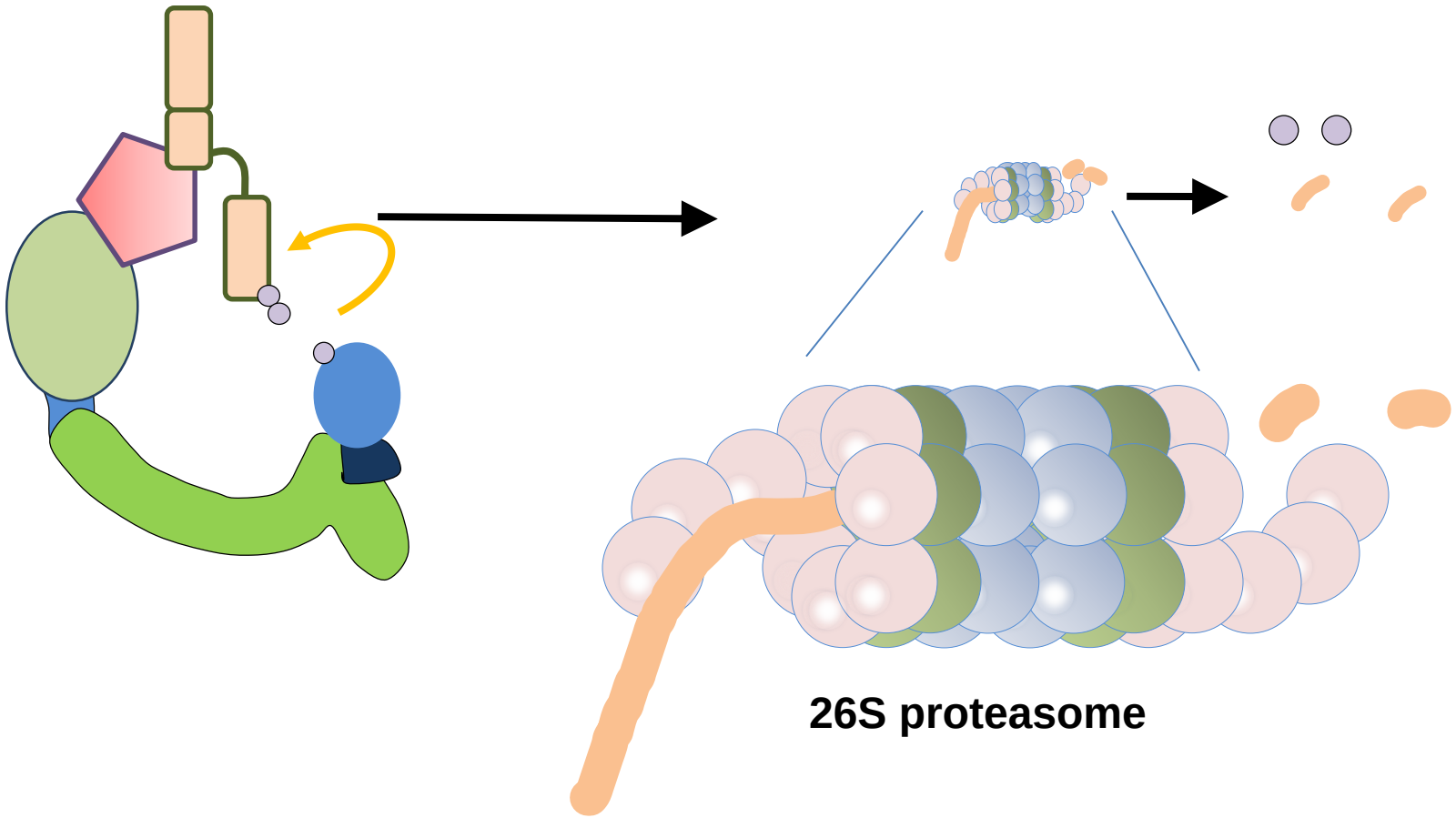



The auxin and jasomonate receptors are F-box proteins, part of an SCF ubiquitin ligase complex



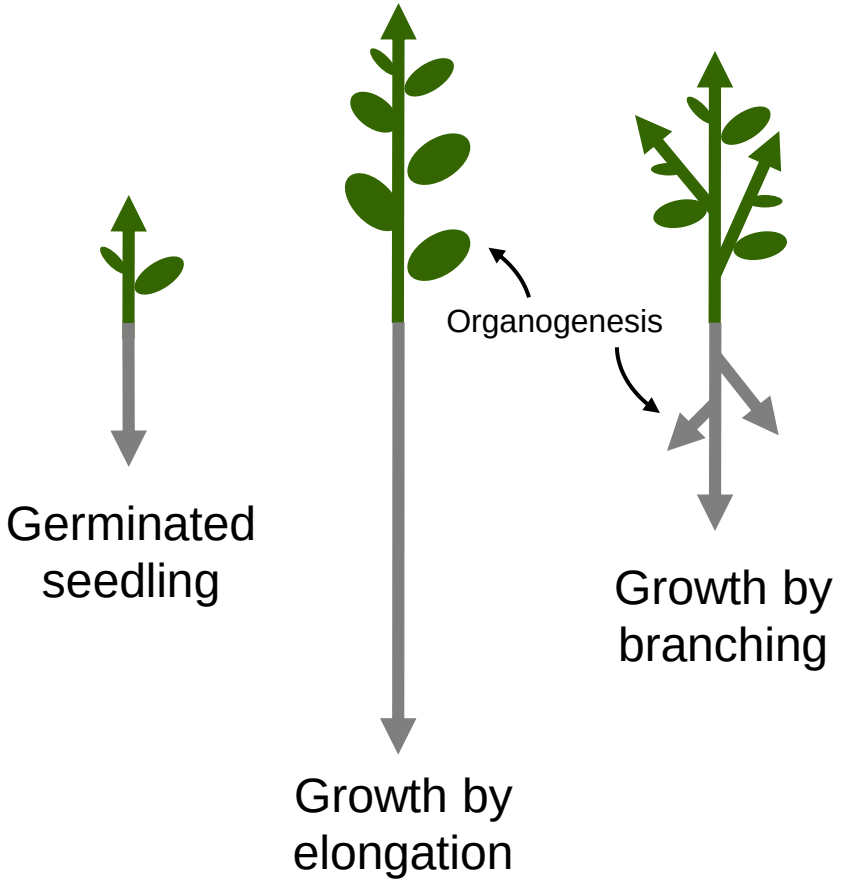
Ubiquitin is ligated to the target

# Ubiquitinated proteins are targeted for proteolysis

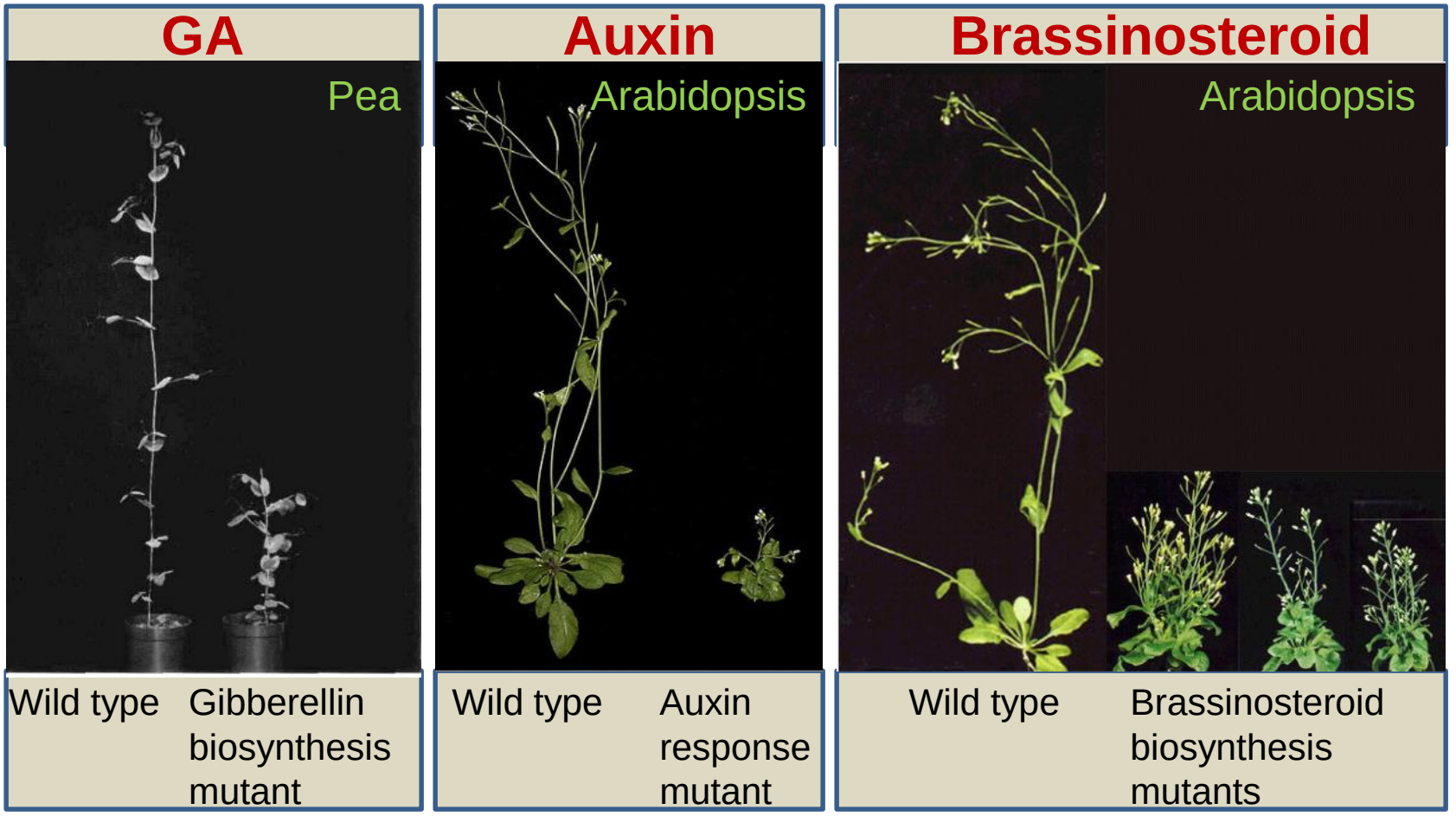


# Hormones affect vegetative growth: elongation, branching and organogenesis

Elongation in the shoot and root of a germinating soybean

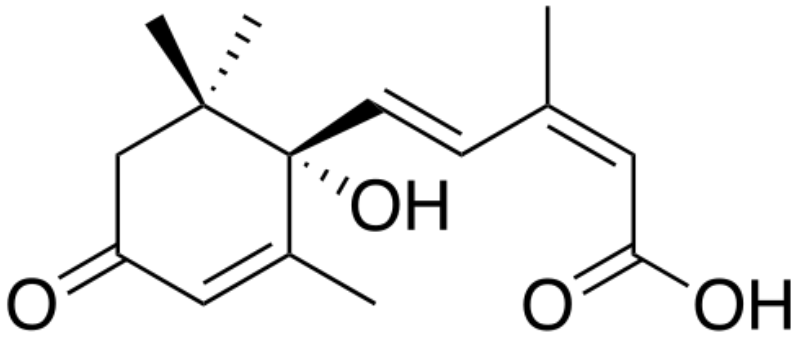



# Disrupting hormone synthesis or response interferes with elongation



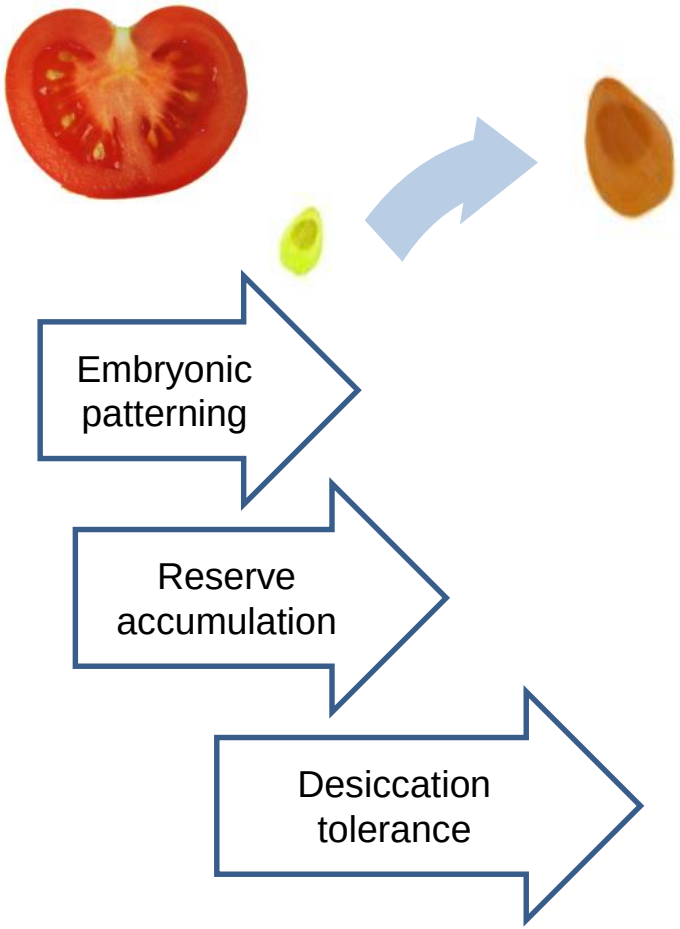

Lester, D.R., Ross, J.J., Davies, P.J., and Reid, J.B. (1997) Mendel's stem length gene (*Le*) encodes a gibberellin 3β-hydroxylase. Plant Cell 9: 1435-1443.;Gray WM (2004) Hormonal regulation of plant growth and development. PLoS Biol 2(9): e311; Clouse SD (2002) Brassinosteroids: The Arabidopsis Book. Rockville, MD: American Society of Plant Biologists. doi: 10.1199/tab.0009

# Abscisic acid



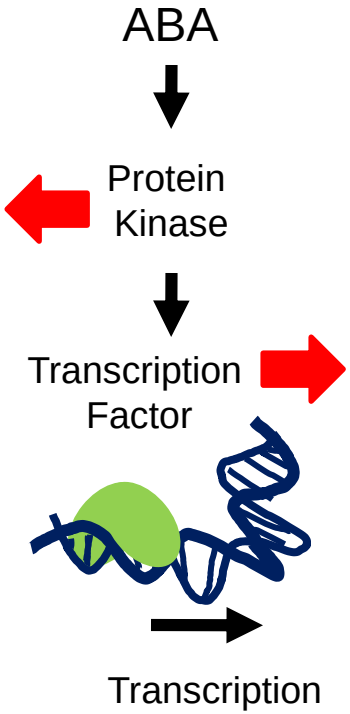

- Seed maturation and dormancy
- Desiccation tolerance
- Stress response
- Control of stomatal aperture

# ABA accumulates in maturing seeds




Seed maturation requires ABA synthesis and accumulation of specific proteins to confer desiccation tolerance to the seed.

# ABA synthesis and signaling is required for seed dormancy




**Loss of function of ABA signaling** (protein kinase or transcription factor function) interferes with ABA-induced dormancy and causes precocious germination.

# Once dormant and dry, seeds can remain viable for very long times

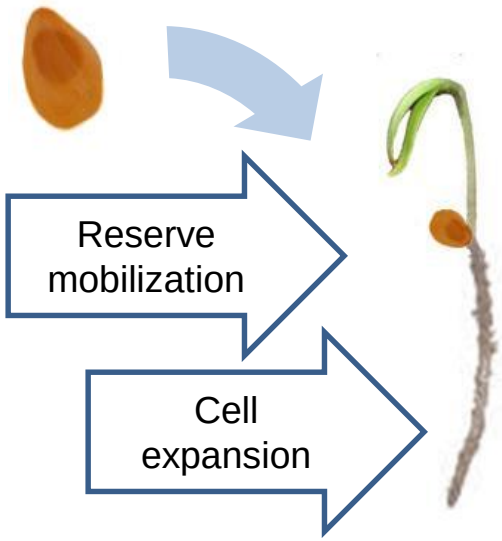
**These date palm seeds are nearly 2000 years old, but still viable and capable of germination**.

**Five -hundred year old lotus seeds** have also been **successfully germinated**. Having a thick seed coat may help these super seeds retain viability.


Date palm growing from 2000 year old seed.

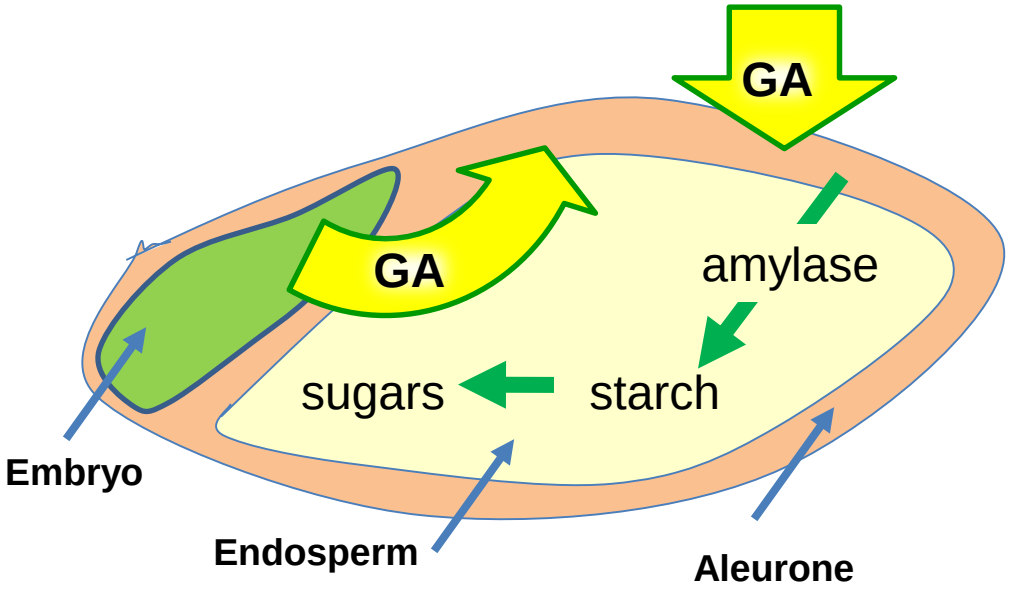
# GA is required for seed germination

Seed germination requires elimination of ABA and production of GA to promote growth and breakdown of seed storage products.




# GA is used by brewers to promote barley germination

**Breakdown of starch in the endosperm** is initiated by GA produced by the endosperm or added during the malting process.




# Summary – hormonal regulation of reproductive development

GA and ethylene promote flowering in some plants.

Fruit growth, maturation and ripening are regulated by auxin, GA and ethylene.

Seed maturation and germination are regulated by ABA and GA.

Understanding the roles of hormones in plant reproduction is important for food production, because most of our caloric intake is derived from seeds.