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- Auxin-induced proton extrusion involves activation and protein mobilization 566

### **Actions of Auxin: Plant Tropisms 566**

- Phototropism is mediated by the lateral redistribution of auxin 566
- Gravitropism involves lateral redistribution of auxin 568
- Dense plastids serve as gravity sensors 569
- Gravity sensing may involve pH and calcium ions ( $\text{Ca}^{2+}$ ) as second messengers 571

Auxin is redistributed laterally in the root cap 572

### **Developmental Effects of Auxin 573**

- Auxin regulates apical dominance 574
- Auxin transport regulates floral bud development and phyllotaxy 576
- Auxin promotes the formation of lateral and adventitious roots 576
- Auxin induces vascular differentiation 576
- Auxin delays the onset of leaf abscission 577
- Auxin promotes fruit development 577
- Synthetic auxins have a variety of commercial uses 578

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- Gibberellins were discovered by studying a disease of rice 584
- Gibberellic acid was first purified from *Gibberella* culture filtrates 584
- All gibberellins are based on an *ent*-gibberellane skeleton 585

### **Effects of Gibberellins on Growth and Development 586**

- Gibberellins promote seed germination 586
- Gibberellins can stimulate stem and root growth 586
- Gibberellins regulate the transition from juvenile to adult phases 587
- Gibberellins influence floral initiation and sex determination 588
- Gibberellins promote pollen development and tube growth 588
- Gibberellins promote fruit set and parthenocarpy 588
- Gibberellins promote early seed development 588
- Commercial uses of gibberellins and GA biosynthesis inhibitors 588

### **Biosynthesis and Deactivation of Gibberellins 589**

- Gibberellins are synthesized via the terpenoid pathway 589

- Some enzymes in the GA pathway are highly regulated 591
- Gibberellin regulates its own metabolism 592
- GA biosynthesis occurs at multiple plant organs and cellular sites 592
- Environmental conditions can influence GA biosynthesis 593
- $\text{GA}_1$  and  $\text{GA}_4$  have intrinsic bioactivity for stem growth 594
- Plant height can be genetically engineered 595
- Dwarf mutants often show other phenotypic defects 595
- Auxins can regulate GA biosynthesis 595

### **Gibberellin Signaling: Significance of Response Mutants 596**

- GID1 encodes a soluble GA receptor 596
- DELLA-domain proteins are negative regulators of GA response 600
- Mutation of negative regulators of GA may produce slender or dwarf phenotypes 600
- Gibberellins signal the degradation of negative regulators of GA response 601
- F-box proteins target DELLA domain proteins for degradation 601
- Negative regulators with DELLA domains have agricultural importance 602

### **Gibberellin Responses: Early Targets of DELLA Proteins 602**

DELLA proteins can activate or suppress gene expression 603

DELLA proteins regulate transcription by interacting with other proteins such as phytochrome-interacting factors 603

### **Gibberellin Responses: The Cereal Aleurone Layer 605**

GA is synthesized in the embryo 605

Aleurone cells may have two types of GA receptors 605

Gibberellins enhance the transcription of  $\alpha$ -amylase mRNA 605

GAMYB is a positive regulator of  $\alpha$ -amylase transcription 607

DELLA-domain proteins are rapidly degraded 607

### **Gibberellin Responses: Anther Development and Male Fertility 607**

GAMYB regulates male fertility 609

Events downstream of GAMYB in rice aleurone and anthers are quite different 611

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GAs regulate the transcription of cell cycle kinases 613

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### **Cell Division and Plant Development 622**

Differentiated plant cells can resume division 622

Diffusible factors control cell division 622

Plant tissues and organs can be cultured 622

### **The Discovery, Identification, and Properties of Cytokinins 623**

Kinetin was discovered as a breakdown product of DNA 623

Zeatin was the first natural cytokinin discovered 623

Some synthetic compounds can mimic cytokinin action 624

Cytokinins occur in both free and bound forms 625

Some plant pathogenic bacteria, fungi, insects, and nematodes secrete free cytokinins 625

### **Biosynthesis, Metabolism, and Transport of Cytokinins 625**

Crown gall cells have acquired a gene for cytokinin synthesis 626

IPT catalyzes the first step in cytokinin biosynthesis 628

Cytokinins can act both as long distance and local signals 628

Cytokinins are rapidly metabolized by plant tissues 628

### **Cellular and Molecular Modes of Cytokinin Action 629**

A cytokinin receptor related to bacterial two-component receptors has been identified 629

Cytokinins increase expression of the type-A response regulator genes via activation of the type-B ARR genes 630

Histidine phosphotransfer proteins are also involved in cytokinin signaling 632

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Cytokinins interact with other hormones and with several key transcription factors 634

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Cytokinins regulate specific components of the cell cycle 636

The auxin:cytokinin ratio regulates morphogenesis in cultured tissues 637

Cytokinins modify apical dominance and promote lateral bud growth 638

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The receptors of *never-ripe* mutants of tomato fail to bind ethylene 660

Leaf epinasty results when ACC from the root is transported to the shoot 660

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The hooks of dark-grown seedlings are maintained by ethylene production 662

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Ethylene promotes the elongation growth of submerged aquatic species 663

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ABA is translocated in vascular tissue 677



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- Receptor candidates include diverse classes of proteins 678
- Secondary messengers function in ABA signaling 680
- Ca<sup>2+</sup>-dependent and Ca<sup>2+</sup>-independent pathways mediate ABA signaling 680
- ABA-induced lipid metabolism generates second messengers 681
- Protein kinases and phosphatases regulate important steps in ABA signaling 682
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- ABA promotes seed storage reserve accumulation and desiccation tolerance 686
- Seed dormancy can be regulated by ABA and environmental factors 686
- Seed dormancy is controlled by the ratio of ABA to GA 687
- ABA inhibits GA-induced enzyme production 688
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- Phenotypic plasticity allows plants to respond to environmental fluctuations 756

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- Soil salinity occurs naturally and as the result of improper water management practices 761
- The toxicity of high Na<sup>+</sup> and Cl<sup>-</sup> in the cytosol is due to their specific ion effects 761

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