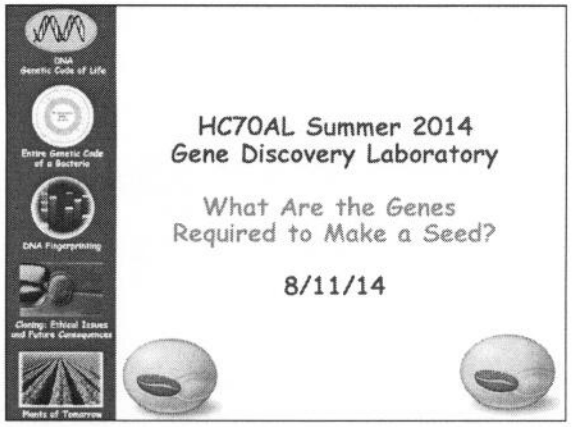
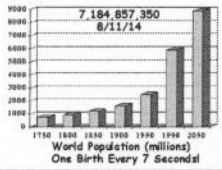


We Face Major Challenges in Agriculture

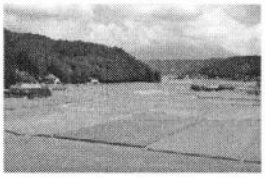


OVER THE NEXT 50 YEARS WE WILL NEED TO PRODUCE MORE FOOD THAN IN THE WHOLE OF HUMAN HISTORY

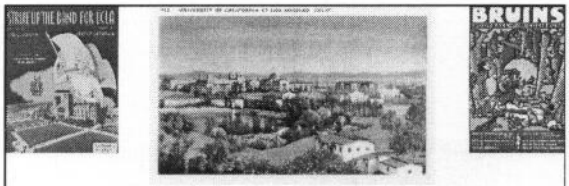
AND DO IT WITH FEWER INPUTS ON LESS ARABLE LAND!!!

CROP YIELDS NEED TO BE INCREASED SIGNIFICANTLY!!

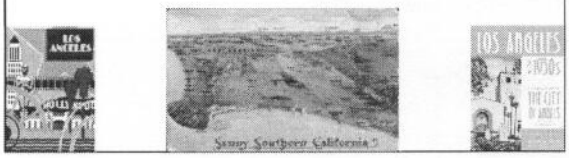
3,000 Acres/Day of Productive Farmland is Lost to Development Each Day in the United States



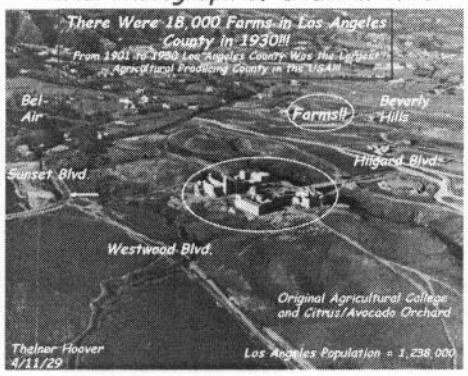
"Major Land Uses Overview." USDA, Economic Research Service, Web, April 3, 2013.



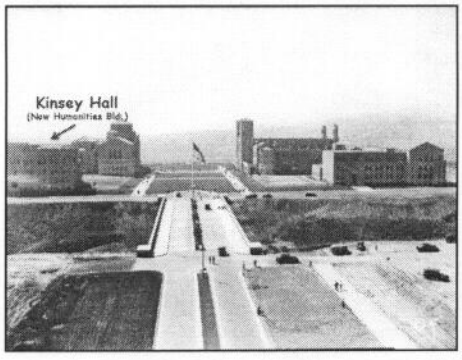
An Example From UCLA & Los Angeles History....

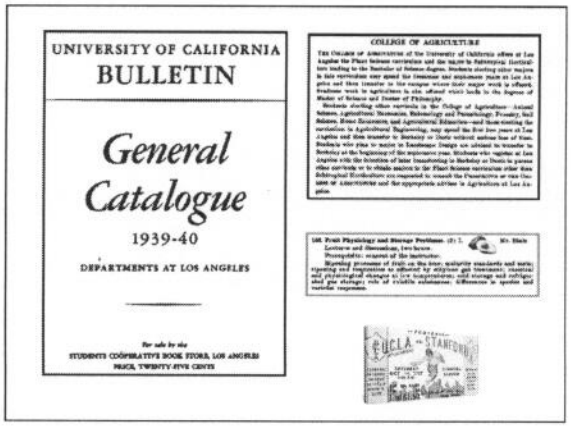


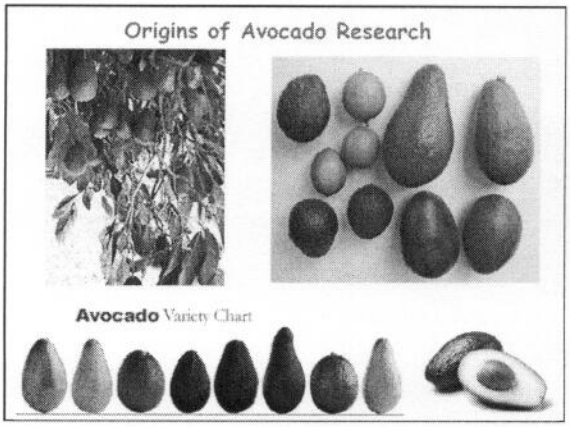
Aerial Photograph of UCLA in 1929

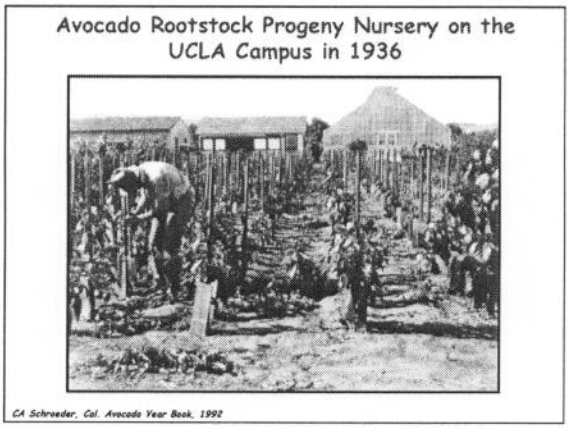


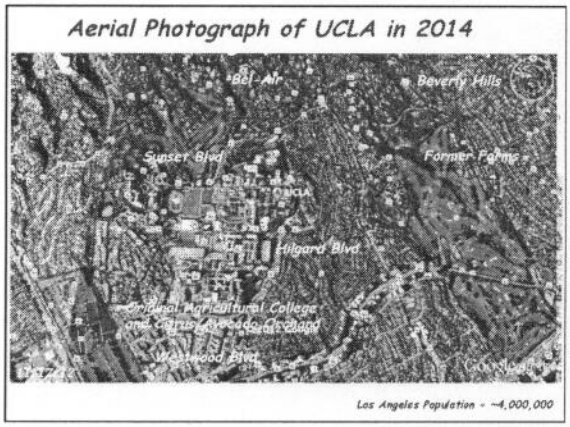
Original UCLA College of Agriculture-1930

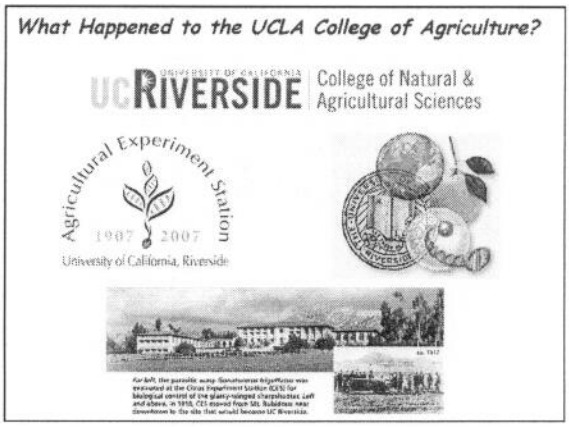


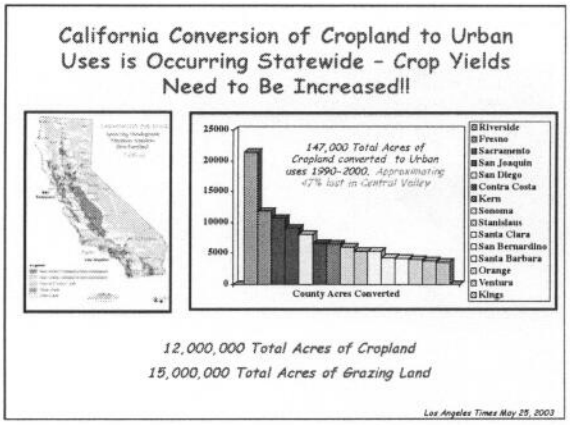

UNIVERSITY OF CALIFORNIA
BULLETIN
General Catalogue
1939-40
DEPARTMENTS AT LOS ANGELES
COLLEGE OF AGRICULTURE


Origins of Avocado Research
Avocado Variety Chart


Avocado Rootstock Progeny Nursery on the UCLA Campus in 1936
CA Schroeder, Cal. Avocado Year Book, 1992

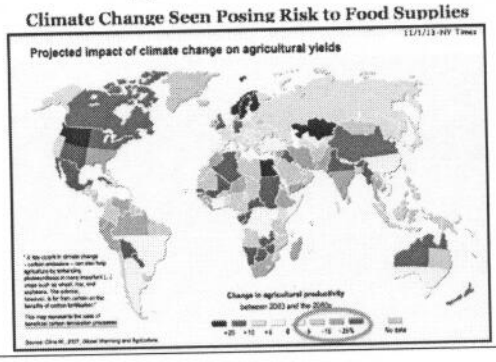

Aerial Photograph of UCLA in 2014
Bel-Air
Beverly Hills
Sunset Blvd
Former Farms
UCLA
Hilgard Blvd
Original Agricultural College and Citrus/Avocado Orchard
Westwood Blvd
Los Angeles Population ~ 4,000,000

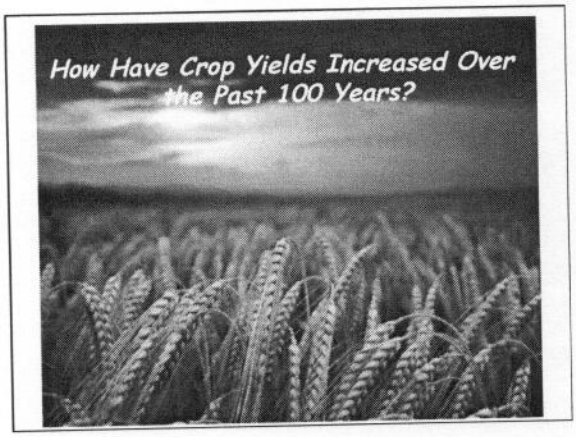

What Happened to the UCLA College of Agriculture?
UC RIVERSIDE College of Natural & Agricultural Sciences
Agricultural Experiment Station
1907 2007
University of California, Riverside


California Conversion of Cropland to Urban Uses is Occurring Statewide - Crop Yields Need to Be Increased!!
147,000 Total Acres of Cropland converted to Urban uses 1990-2000. Approximating 47% lost in Central Valley
County Acres Converted
12,000,000 Total Acres of Cropland
15,000,000 Total Acres of Grazing Land
Los Angeles Times May 25, 2003

Climate Change Will Also Have a Major Impact on Crop Yields in the Future!

Climate Change Seen Posing Risk to Food Supplies





THE ADMINISTRATION'S PROMISES HAVE BEEN KEPT

Big Changes in the US Over The Past 100 Years
"We've Come a Long Way Baby"

	1900	2014
Life Expectancy	48 (women)	81 (women)
Average Family Income (20114 Dollars)	$8,000	$50,000
Gasoline Use Per Capita	34 gallons	1,100 gallons
Flush Toilets Per Housing Unit	10%	99%
High School Grads	13%	90%
Farm Workers	55%	1.5%

CROP YIELD INCREASES HAVE "ROCKETED UPWARDS" OVER THE LAST 100 YEARS AND CONTRIBUTED TO A LONGER AND "BETTER" LIFE

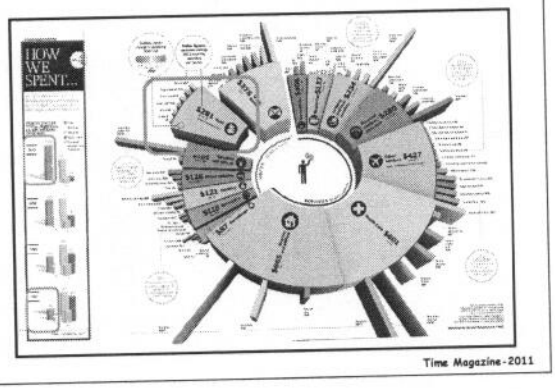
% Farm Workers	% Income on Food		Bushels/Acre	Life Span
55%	50% →	• 1900	30	← 48 Years
		• 1920	30	
		• 1940	40	
	22% →	• 1960	60	
		• 1980	100	
1.5%	7% →	• 2014	155	← 80 Years

1930: 30 bushels/acre
1930: 1 farmer fed 10 people

2014: 170 bushels/acre
2014: 1 farmer feeds 200 people

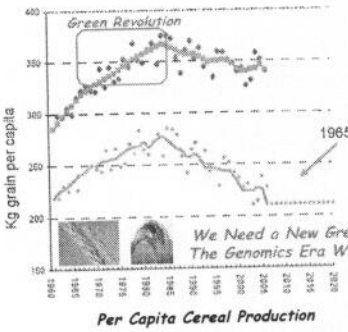
Conclusion: Crop yields increased >500% over the past 100 years and lead to a similar reduction in food costs!!!!

Only 7% of Our Monthly Budget is Spent on Food!



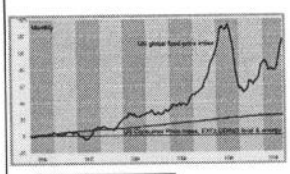
Time Magazine - 2011

World Crop Production is Leveling Off on a Per Capita Basis-a Warning Sign!



Per Capita Cereal Production

World Crop Production is Leveling Off on a Per Capita Basis-Higher Prices Ahead?

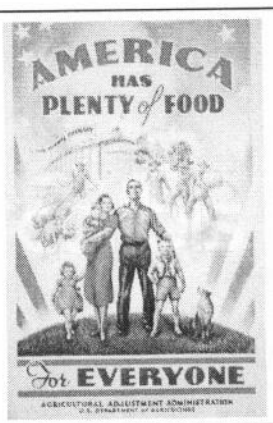


Food riots fear after rice price hits a high

Rising food prices: A global crisis

Action needed now to avert poverty and hunger

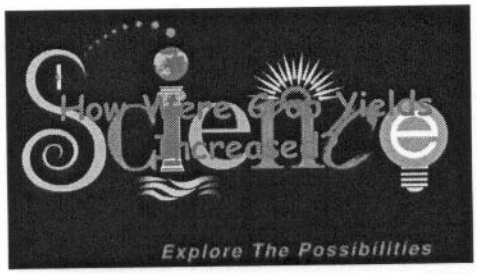
Yields Need to Increase to Produce More Food & Grow More on Less Land



How Was This Accomplished Over the Past 100 Years?

What Role Did Science & Technology Play in Increasing Crop Yields?

What About in the Future When There are 350 Million People in the USA and 9 Billion in the World?



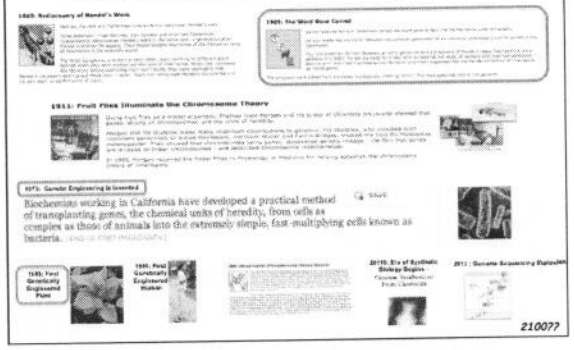
WHAT TECHNOLOGIES CAUSED AN INCREASE IN CROP YIELDS OVER THE PAST 100 YEARS?

- *PLANT BREEDING (New Hybrids-Green Revolution)*
- *IRRIGATION*
- *FERTILIZERS*
- *PESTICIDES & HERBICIDES*
- *MECHANIZATION (e.g., Tractor)*
- *GLOBAL POSITIONING AND SATELLITE IMAGING*
- *GENOMICS & GENETIC ENGINEERING (New Traits)*

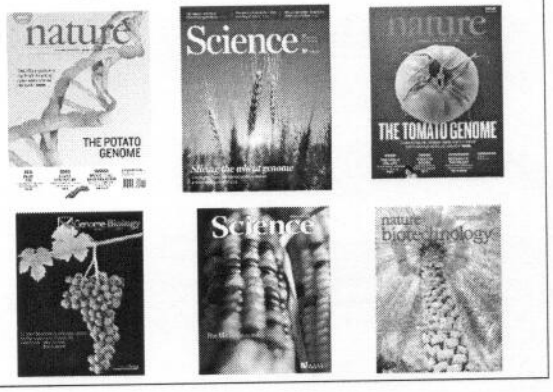
These technologies have resulted in a >400% increase in US crop productivity!

Need to sustain this yield increase by applying the best technology and agricultural practices!

The Past 100 Years Has Produced a Revolution in Genetic Research and Knowledge Leading to Remarkable Advances in Medicine and Agriculture



2014 - All Major Crop Genomes Have Been Sequenced!!



How Will Crop Yields Be Increased in the Future?

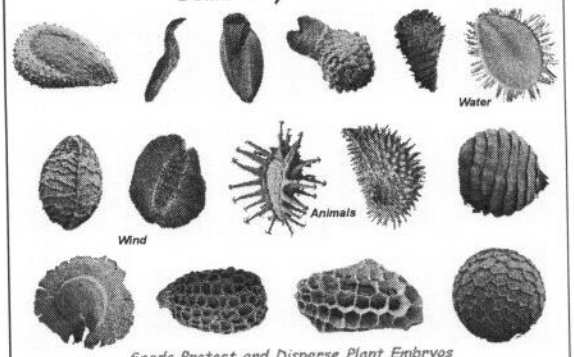
...By Using a Variety of Approaches to Identify Genes and Processes That Will Help Increase Crop Yields and Food Production Significantly in the 21st Century....

Yield (Developmental Traits)
- Seed Number
- Seed Size
- **Growth Rate**
- **Organ Size** (More Seeds)
- **Plant Architecture**
- **Flowering Time**
- **Senescence**
- **Maturity**
- **Stature**

Yield (Stress Traits)
- **Nutrient Uptake**
- **Drought Resistance**
- **Heat Resistance**
- **Cold Tolerance**
- **Salt Tolerance**
- **Shade Tolerance**
- **Disease Resistance**

.....And by Using Genomics, Breeding, and Genetic Engineering to Introduce These "Yield" Genes Into Crops ***(One thing we can be sure of-we can't predict what new technology will be the driver 10-25 years out!)***

So.....Why Seeds??



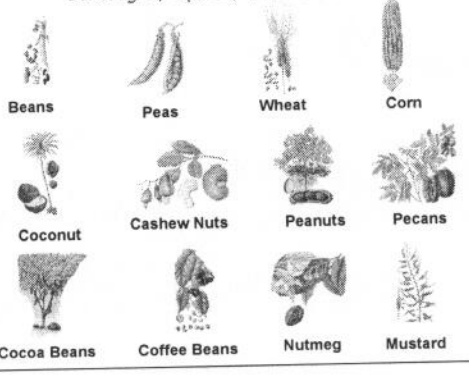
Seeds Protect and Disperse Plant Embryos and Come in Many Shapes and Sizes!

SEEDS

- 22,300 Seed-Bearing Plant Species
  - 90% of all known plants
  - 1,000 species produce "naked" seeds (gymnosperms)
  - Remainder are from flowering plants
- 2,938 Seed Species Stored in the Svalbard Seed Vault
- Global Seed Vault in Norway
  - 320,552 seed samples from around the world
  - Bank can hold 2.25 billion seeds!
- 55 Pounds is the Weight of the Largest Seed - Fruit of the Double Coconut Palm
- Smallest Seeds Come From Orchids and Weigh ~10 Billionths of an Ounce
- 385 Million Years is the Age of the Oldest Seed Fossil
- 2,000 Year-Old Date is the Oldest Viable Seed
- 150 Miles per hour is the Speed of Seeds Released by the Tropical Sand Box Tree
- $36.5 Billion Dollars is the Value of the World Seed Market (2008)

References: Discover Magazine, April, 2009

Seeds Are Used in Many Ways as Food, Beverages, Spices, and Fuels!



Most Importantly..... Our Food is Derived From Fifteen Crops & Over Half Produce Seeds For Human and Animal Consumption

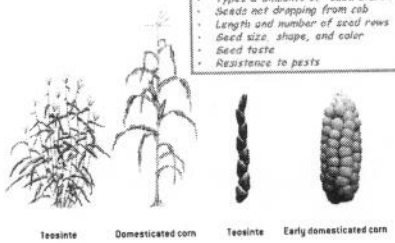
Seed Crops
- Wheat
- Rice
- Corn
- Barley
- Sorghum
- Soybean
- Common Bean
- Coconut
- Canola

Non-Seed Crops
- Potato
- Sweet Potato
- Cassava
- Sugar Beet
- Sugar Cane
- Banana

In Some World Populations 75% of Calories Are Derived From Seeds!

All Crops Have Been Engineered - Turning Wild Teosinte Into Domesticated Corn 10,000 Years Ago - Seed & Pant Engineering!!

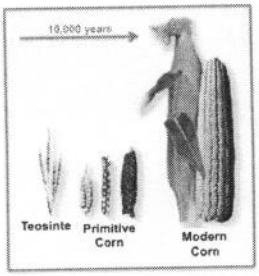
- Types & amounts of seed starch production
- Seeds not dropping from cob
- Length and number of seed rows
- Seed size, shape, and color
- Seed taste
- Resistence to pests

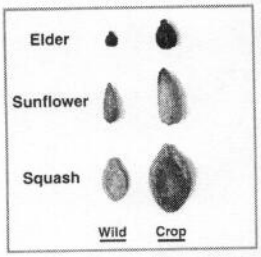


Note: Architecture and Fruit (cob) Size

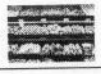
Only Five Genes Cause These Plants to Differ & We Now Know What They Are

"Manipulating" Plants to Increase Seed Yield Is Not New..... Seed Size!





All Vegetables in Grocery Store are "GMOs!!"



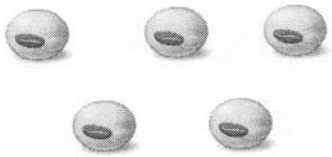
Goldberg Lab Research

Diversity of Oil Seed Plants

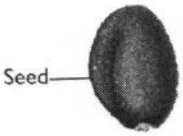
Soybean - A Reminder

- Second Major US Crop
- Total Crop Value $32Billion (50% Value Exported)
- Important Biofuel Source (Biodiesel~20% of US Soybean Oil Production)
- Excellent Model Plant (Transformation, Knockdowns, Genetics)
- Genome Sequenced
- Major Food Source

How Is a Seed Formed?

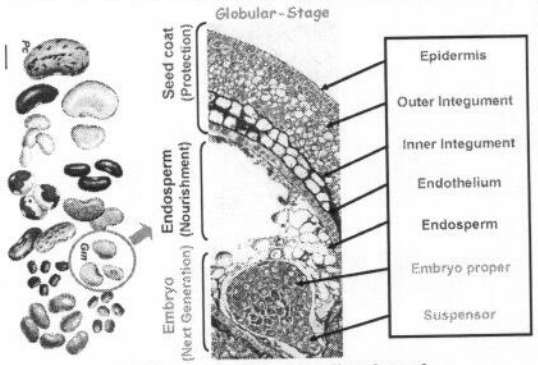


In the Beginning....



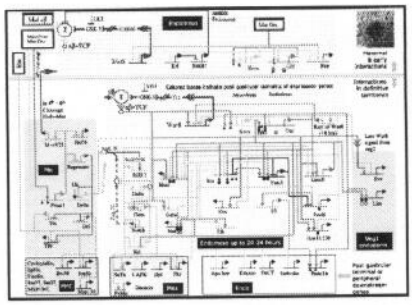
http://estdb.biology.ucla.edu/seed/presentation

Goal - What Are the Genes Required to Make a Seed?



And How Are They Wired in a Plant Genome?

Ultimate Goal.....To Uncover Regulatory Genes and Circuits Driving Seed Differentiation and Development Using Genomics



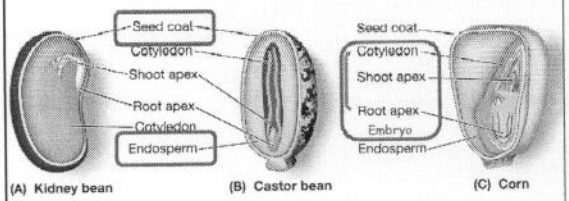
Learn How To Make a Seed!!

- Big Seeds
- More Seeds
- More Yield
- Increased Food and Fuel

Eric Davidson et al. Science, 2007

Knowledge of Cell-Specific TF mRNAs and Knock-Down Effects On Embryo Phenotype and TF mRNAs

What is a Seed?



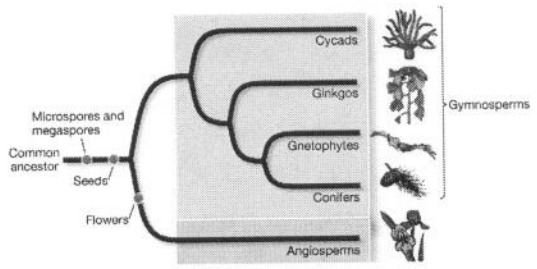
A Seed Consists of Three Parts With Distinct Genetic Origins

1. *A Seed Coat From Maternal Floral Tissue*
2. *An Endosperm From Fertilization of Embryo Sac Central Cell*
3. *An Embryo From Fertilization of the Egg*

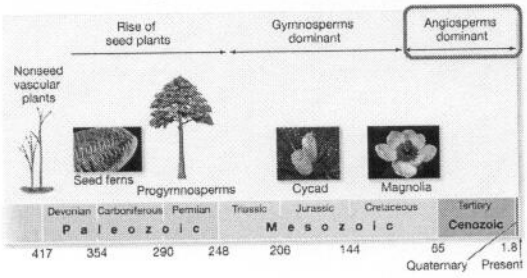
The Embryo Becomes the Next Plant Generation

29.2 The Major Groups of Living Seed Plants

The Plant Kingdom



Seed Producing Plants Are ~300 Million Years Old

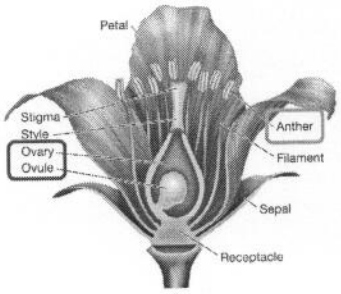


Major Crops (Soybean and Corn) Are Flowering Plants

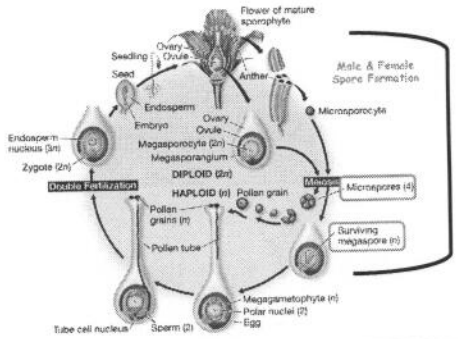
Major Characteristics of Plants

1. *Alternation of Spore and Gamete-Producing Generations*
2. *Meiotic Products Are Spores*
3. *Gametes Produced By Mitosis*
4. *Double Fertilization (Two Sperm Cells)*
5. *Cellulose Cell Walls*
6. *Autotrophic-Covert Light Energy to Chemical Energy by Photosynthesis (Ultimate Source of Food on Earth!)*
7. *Morphogenesis in Absence of Cell Movement*

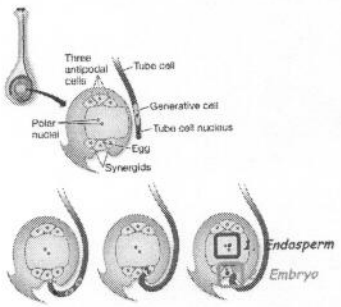
The Plant Life Cycle Begins in the Flower



Life Cycle of a Flowering Plant

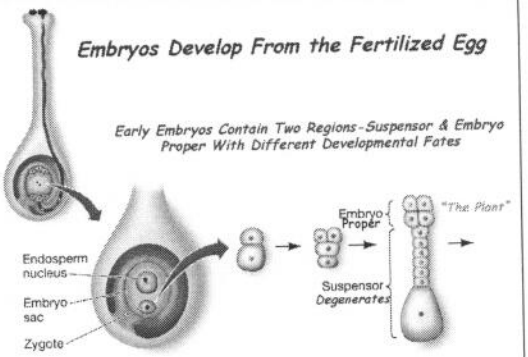


Double Fertilization Leads to the Three Parts of the Seed

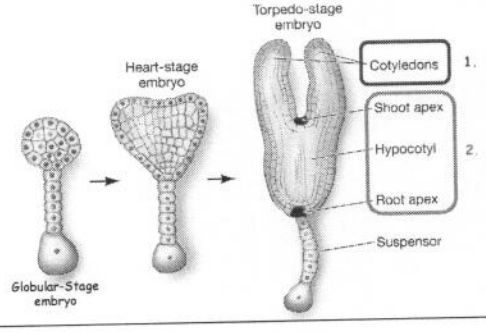


Embryos Develop From the Fertilized Egg

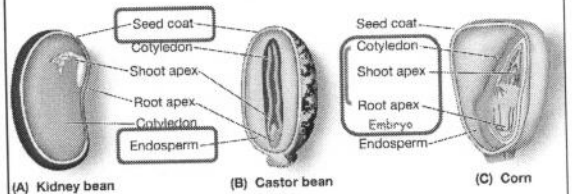
Early Embryos Contain Two Regions - Suspensor & Embryo Proper With Different Developmental Fates



Embryos Undergo a Series of Events Leading to a Dormant Embryo in a Mature Seed



The "End Product" is Dormant Seed With a Mature Embryo?



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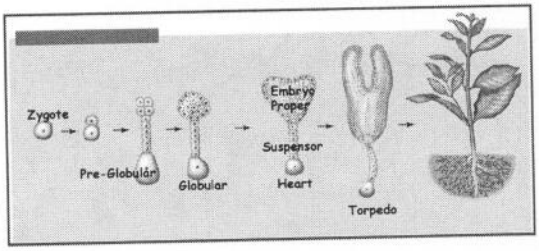
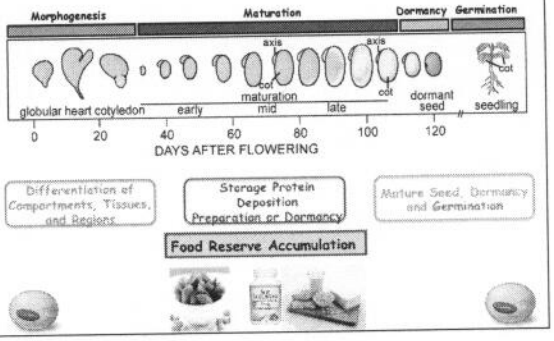
The Embryo Becomes the Next Plant Generation

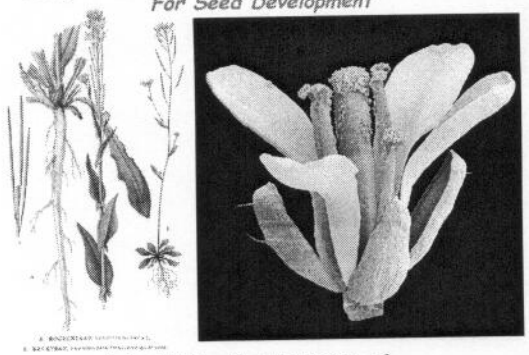
Plant Embryo Development



Major Processes in Seed Development

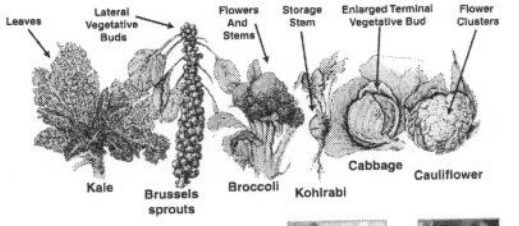


Using Arabidopsis To Uncover Genes Important For Seed Development



A Model "Crop" and Relative of…….

…Broccoli, Cauliflower, Cabbage, and Brussels Sprouts…. Striking Examples of Crop Engineering!



…….Brassicas or Crucifers

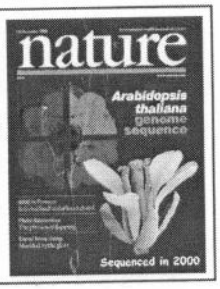
Arabidopsis Features That Make It a Model Plant & Crop

1. Fast Generation Time
2. Small Size
3. Small Genome (~120 Mb & 25,000 Genes)
4. Sequenced Genome
5. Large Scientific Community-Many Resources For Genomics & Functional Studies
6. Knock-Out in Every Gene

The Arabidopsis Genome

- High quality sequence with few gaps
- TIGR did initial genome annotation
- TAIR took over responsibility in 2005
- Current stats:

27,379 protein coding genes
4827 pseudogenes or transposable elements
1312 ncRNAs



Arabidopsis Has Same Number of Genes as Humans

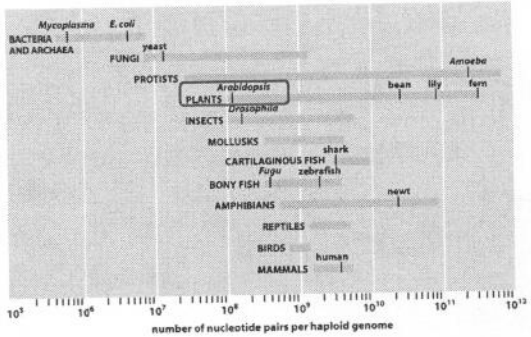
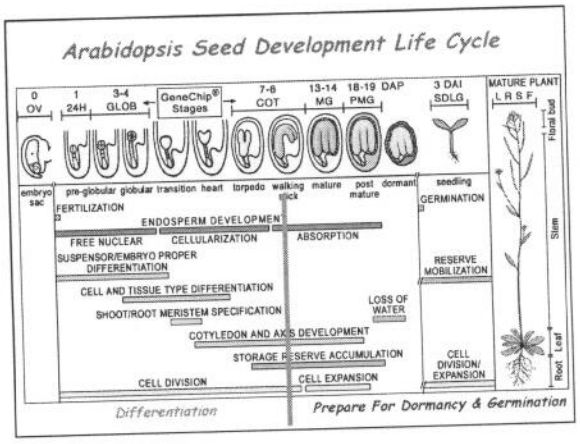
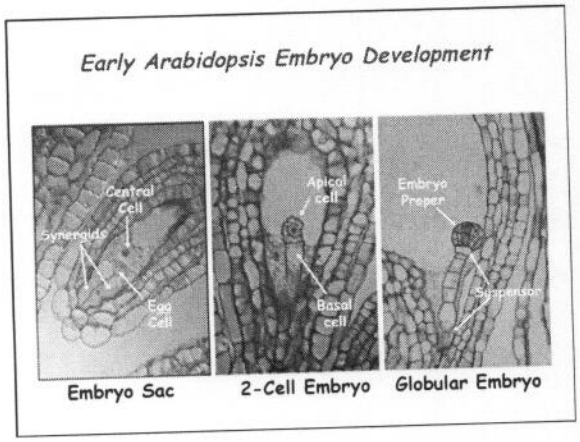
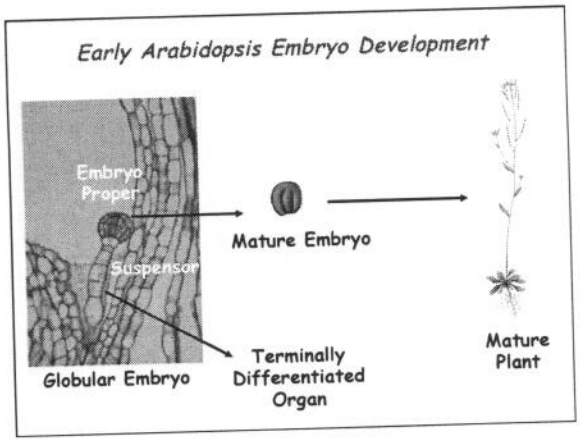
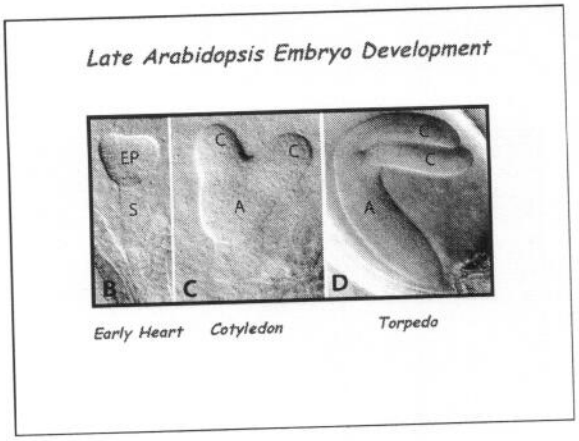


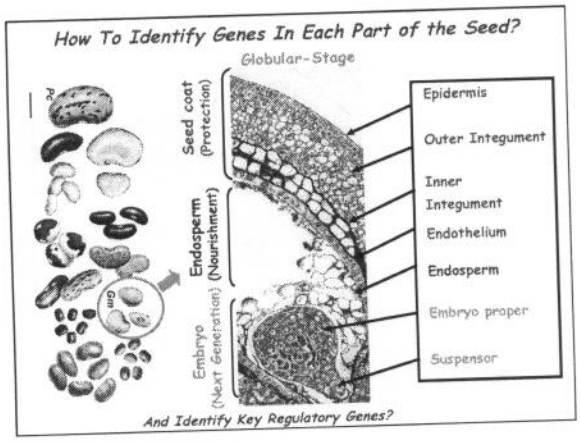
Figure 1-37 Molecular Biology of the Cell, Fifth Edition (© Garland Science 2008)

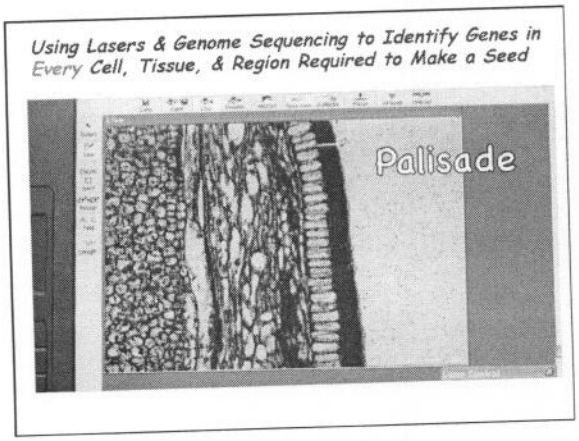

Arabidopsis Seed Development Life Cycle
0 OV
1 24H
3-4 GLOB
GeneChip® Stages
7-8 COT
13-14 MG
18-19 DAP PMG
3 DAI SDLG
MATURE PLANT L R S F
Floral bud
Stem
Root Leaf
embryo sac
pre-globular globular transition heart torpedo walking stick mature post mature dormant seedling
FERTILIZATION
ENDOSPERM DEVELOPMENT
FREE NUCLEAR
CELLULARIZATION
ABSORPTION
GERMINATION
SUSPENSOR/EMBRYO PROPER DIFFERENTIATION
RESERVE MOBILIZATION
CELL AND TISSUE TYPE DIFFERENTIATION
LOSS OF WATER
SHOOT/ROOT MERISTEM SPECIFICATION
COTYLEDON AND AXIS DEVELOPMENT
STORAGE RESERVE ACCUMULATION
CELL DIVISION/ EXPANSION
CELL DIVISION
CELL EXPANSION
Differentiation
Prepare For Dormancy & Germination


Early Arabidopsis Embryo Development
Central Cell
Synergids
Egg Cell
Apical cell
Basal cell
Embryo Proper
Suspensor
Embryo Sac
2-Cell Embryo
Globular Embryo

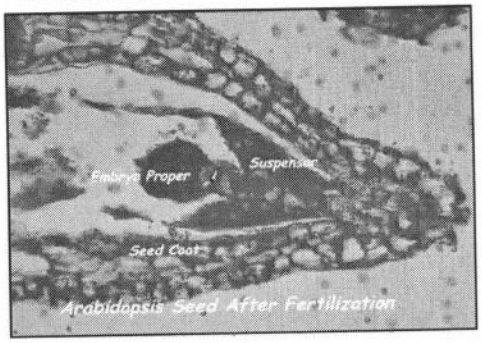

Early Arabidopsis Embryo Development
Embryo Proper
Suspensor
Mature Embryo
Globular Embryo
Terminally Differentiated Organ
Mature Plant


Late Arabidopsis Embryo Development
EP
S
C
C
A
C
C
A
B
C
D
Early Heart
Cotyledon
Torpedo

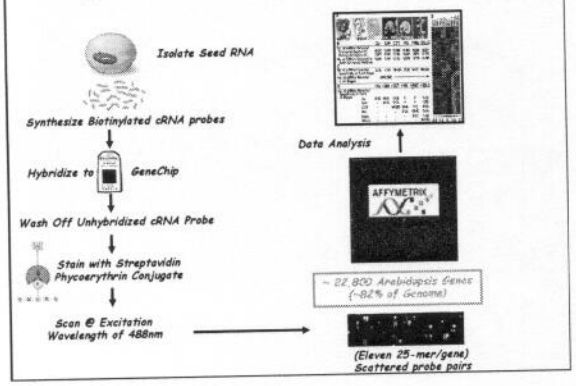

How To Identify Genes In Each Part of the Seed?
Globular-Stage
Seed coat (Protection)
Endosperm (Nourishment)
Embryo (Next Generation)
Epidermis
Outer Integument
Inner Integument
Endothelium
Endosperm
Embryo proper
Suspensor
And Identify Key Regulatory Genes?


Using Lasers & Genome Sequencing to Identify Genes in Every Cell, Tissue, & Region Required to Make a Seed
Palisade

Using Laser Capture Microdissection (LCM) to Isolate Specific Seed Tissues and Compartments

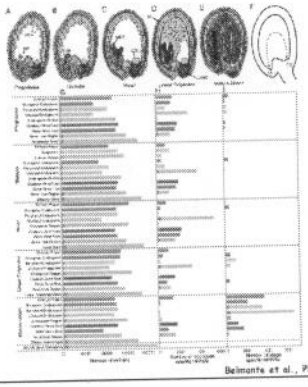


Using Genomics to Analyze Seed mRNA Populations



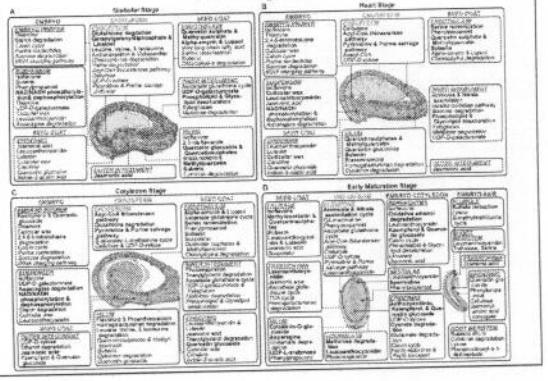
What Are the Genes Required to Make an Arabidopsis Seed?

Seed Gene Regulatory Circuits Are Conserved



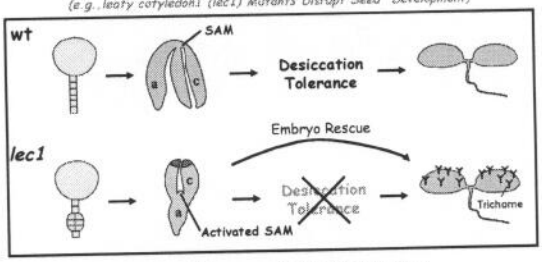
Belmonte et al., PNAS. January, 2013

What Metabolic Pathways Are Prevalent in Different Seed Regions?



How to Identify the Functions of Seed Transcription Factor Genes?

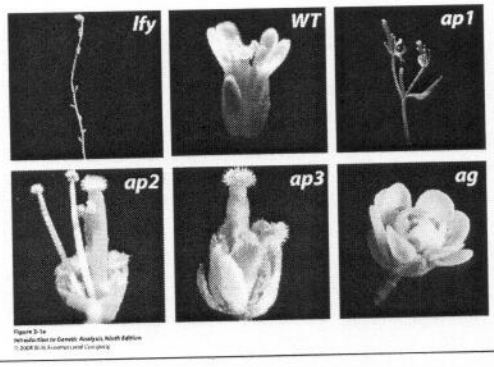
(e.g., leafy cotyledon1 (lec1) Mutants Disrupt Seed Development)



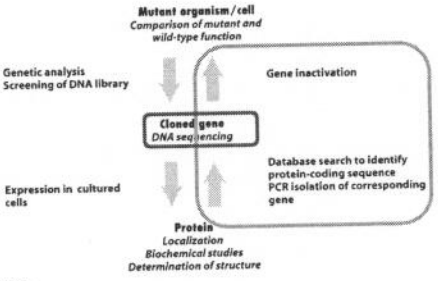
- Suppression of Suspensor Embryonic Potential
- Development of Cotyledon Identity
- Initiation and Maintenance of Seed Maturation
- Inhibition Germination

Lotan et al., Cell, 1998

Examples of Arabidopsis Mutants



Reverse Genetics Starts With Gene Sequence and Searches For a Mutant Phenotype (i.e., Function)



Knock-Out Mutations Are Loss-of-Function or Null Mutations

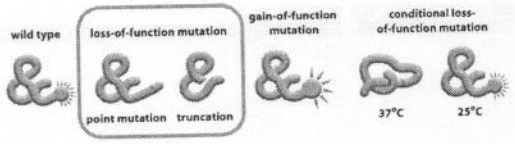


Figure 8-56 Molecular Biology of the Cell (© Garland Science 2008)

Knock-Out Mutations Are Loss-of-Function or Null Mutations

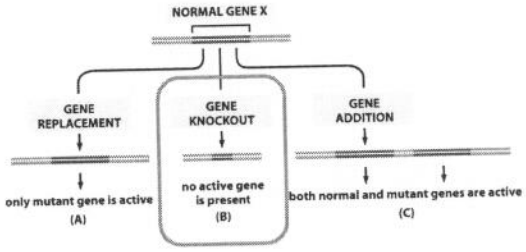
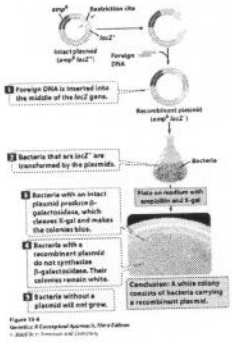
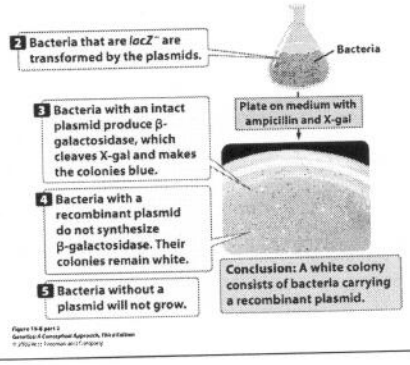


Figure 8-64 Molecular Biology of the Cell (© Garland Science 2008)

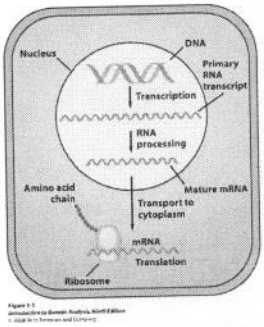
Inserting Foreign DNA Into the LacZ Gene is a Knock-Out Mutation



Inserting Foreign DNA Into the LacZ Gene is a Knock-Out Mutation



A Null Mutation Can Affect Any Part of the Flow From DNA to Protein



Simple Mendelian Genetics...a Review

Table 3.1 Summary of important genetic terms

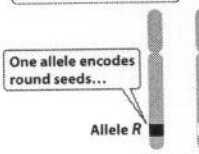
Term	Definition
Gene	A genetic factor (region of DNA) that helps determine a characteristic
Allele	One of two or more alternate forms of a gene
Locus	Specific place on a chromosome occupied by an allele
Genotype	Set of alleles possessed by an individual organism
Heterozygote	An individual organism possessing two different alleles at a locus
Homozygote	An individual organism possessing two of the same alleles at a locus
Phenotype or trait	The appearance or manifestation of a character
Character or characteristic	An attribute or feature

Chromosomes & Alleles...a Review

Genes exist in different versions called alleles.

One allele encodes round seeds...

...and a different allele encodes wrinkled seeds.



Different alleles for a particular gene occupy the same locus on homologous chromosomes.

Simple Mendelian Genetics...a Review

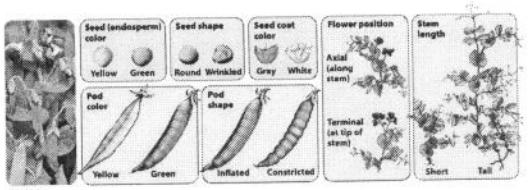
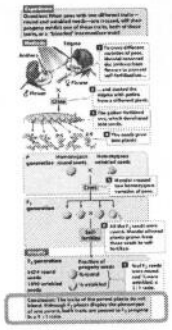
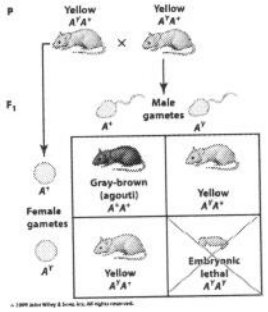


Figure 3-1
Genetics: A Conceptual Approach, Third Edition
© 2008 W.H. Freeman and Company

Simple Mendelian Genetics...a Review

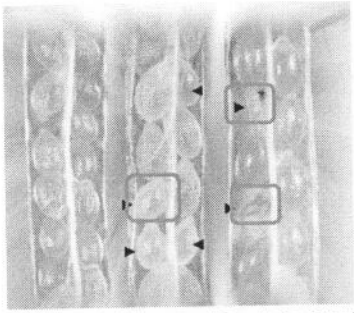


What Happens if the KO Results in a Lethal Phenotype?



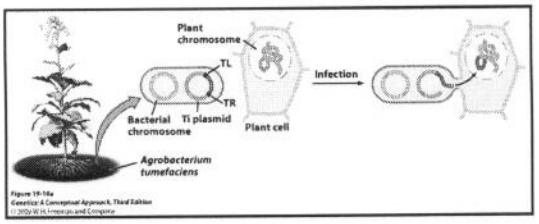
Embryo/Seed Lethality

Note Segregation of Wt and Mutant Seeds



Arabidopsis Siliques and Developing Seeds

Using Agrobacterium T-DNA as a Mutagen



T-DNA Inserts Randomly Into Plant Genome

Transforming Plants With T-DNA

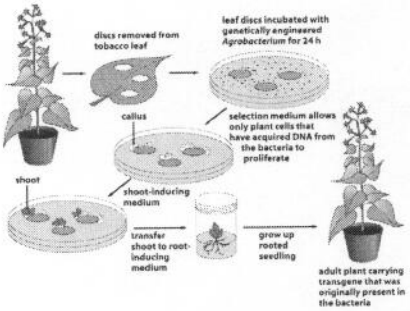
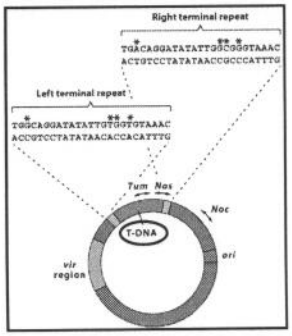
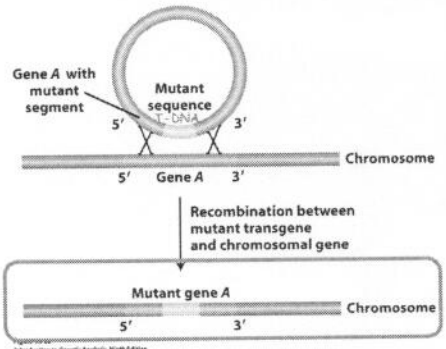


Figure 5-67a *Molecular Biology of the Cell* (© Garland Science 2008)

Agrobacterium Ti Plasmid



Using Agrobacterium T-DNA as a Mutagen



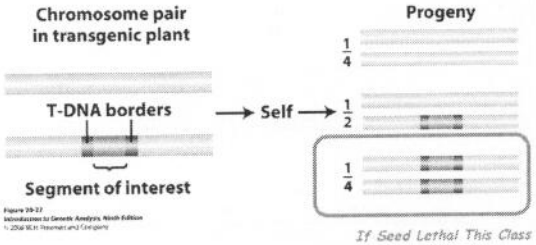
Segregation of T-DNA Inserts in Knock-Out Lines

Male Gametes

Female Gametes	T-DNA Allele	Wt Allele
T-DNA Allele	T-DNA/TDNA	Wt/T-DNA
Wt Allele	T-DNA/Wt	Wt/Wt

If Gene Is Critical For Controlling Seed Development
The T-DNA/T-DNA Class Does Not Appear!

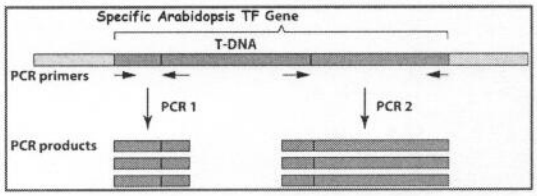
Inheritance of the T-DNA Inserts

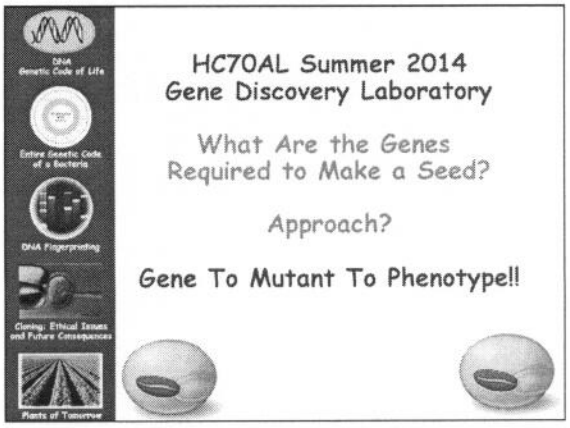


If Seed Lethal This Class Does Not Appear

Arabidopsis Plants Have Been Generated With T-DNA Insertions in Every Gene!

Using Reverse Genetics To Identify T-DNA Mutations in Specific *Arabidopsis* TF Genes



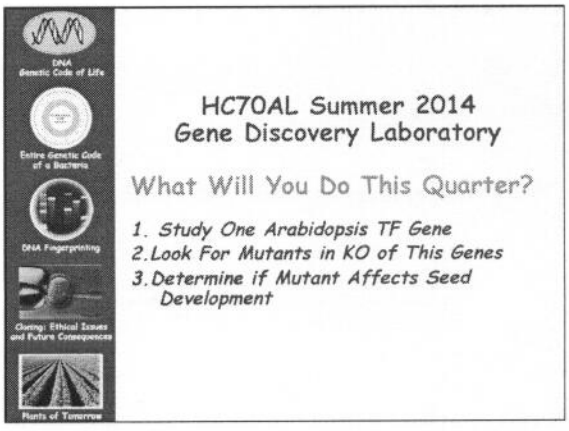


HC70AL Summer 2014
Gene Discovery Laboratory

What Are the Genes Required to Make a Seed?

Approach?

Gene To Mutant To Phenotype!!



HC70AL Summer 2014
Gene Discovery Laboratory

What Will You Do This Quarter?

1. *Study One Arabidopsis TF Gene*
2. *Look For Mutants in KO of This Genes*
3. *Determine if Mutant Affects Seed Development*