The Future of Cacao Research: Systems Science in Support of Cacao Farmers

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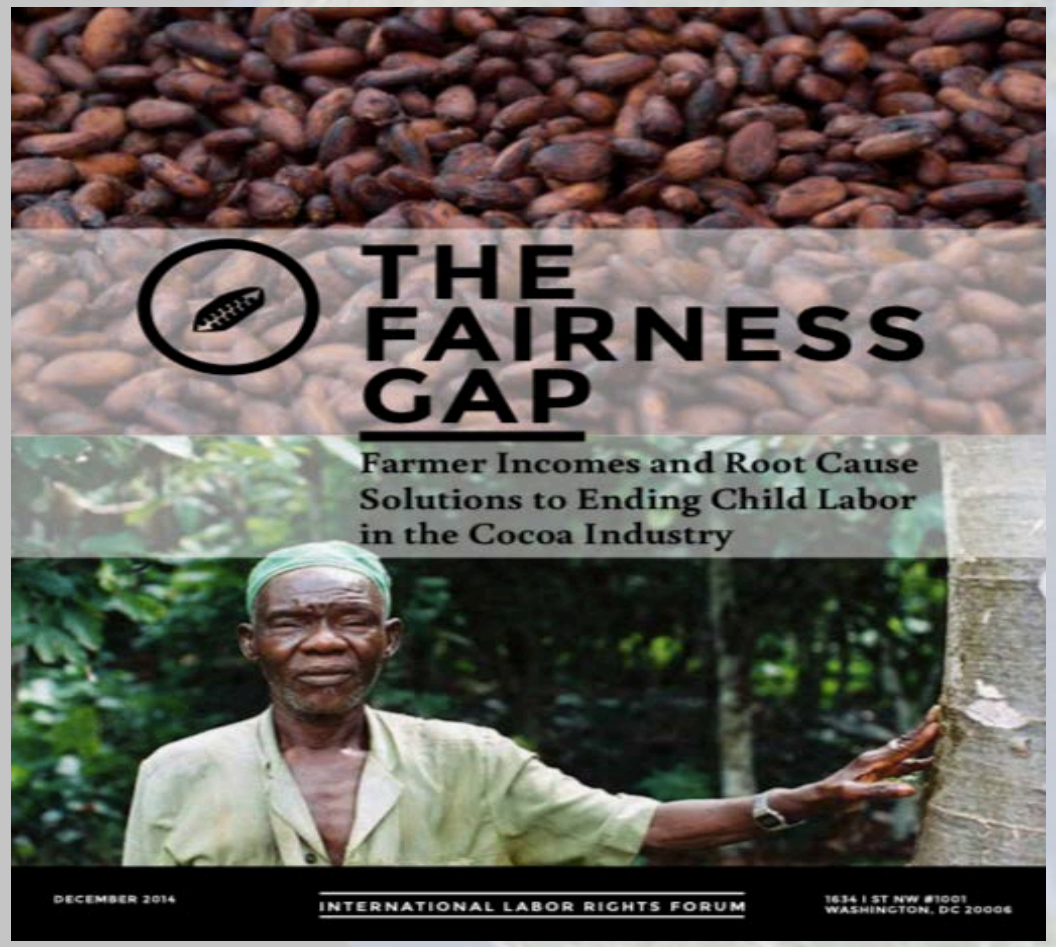
Penn State University
ISCR – November 13-17, 2017 – Lima, Peru

What is a Sustainable Cocoa Value Chain?

- ***Economic sustainability***: All participants earn a reasonable standard of living, retail chocolate prices remain affordable and quality is sustained and improved over time.
- ***Social sustainability:*** Basic human rights of all individuals involved in the production of cacao are respected.
- ***Environmental sustainability:*** No degradation of natural resources necessary for production and no significant negative impacts on the environment or biodiversity.

Have We Reached Our Goal of a Sustainable Cocoa Supply?



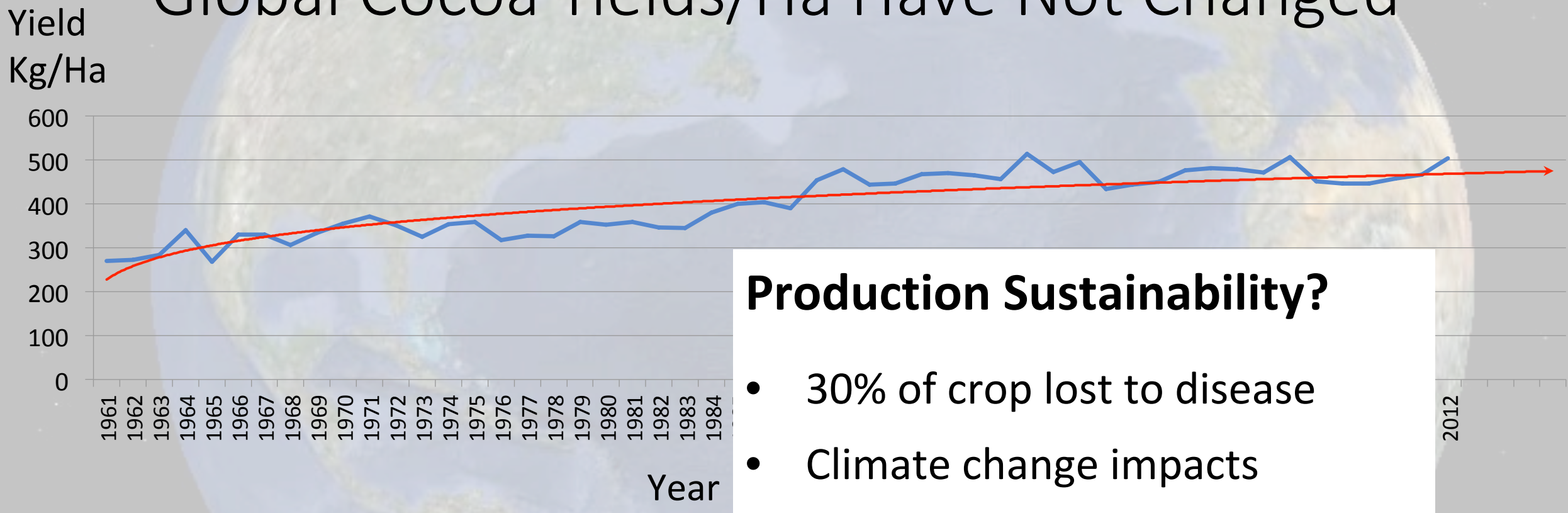
Economic Sustainability?

- Cocoa price volatility: today price is 33% lower than recent high
- Average Farmer income $1- $2/day
- Farm gate price in specific countries only 1/4 of a year ago

Source: International Labor Rights Forum, 2014

Have We Reached Our Goal of a Sustainable Cocoa Supply?

Global Cocoa Yields/Ha Have Not Changed



Production Sustainability?

- 30% of crop lost to disease
- Climate change impacts
- Aging Trees
- Estimated deficits in the future?

Source FAOSTAT http://faostat.fao.org

Have We Reached Our Goal of a Sustainable Cocoa Supply?

Social Sustainability?

- Overall the number of children working on cocoa farms increased approx. significantly between 2008-2014
- In West Africa alone, an estimated 11 million children participating in hazardous work

Source: http://www.childlaborcocoa.org/index.php/2013-14-final-report

Have We Reached Our Goal of a Sustainable Cocoa Supply?

Environmental Sustainability?

- Cacao growing regions hold some of the worlds highest biodiversity
- Overall since 1990 there has been an increase in rate of forest and biodiversity loss
- A part of this is driven by cacao cultivation

Source: https://www.damemagazine.com/2017/10/27/how-our-chocolate-addiction-killing-environment

Have We Reached Our Goal of a Sustainable Cocoa Supply?

We have made some great progress on all fronts but….

…… **We must do better…..**

Why is it so difficult?...

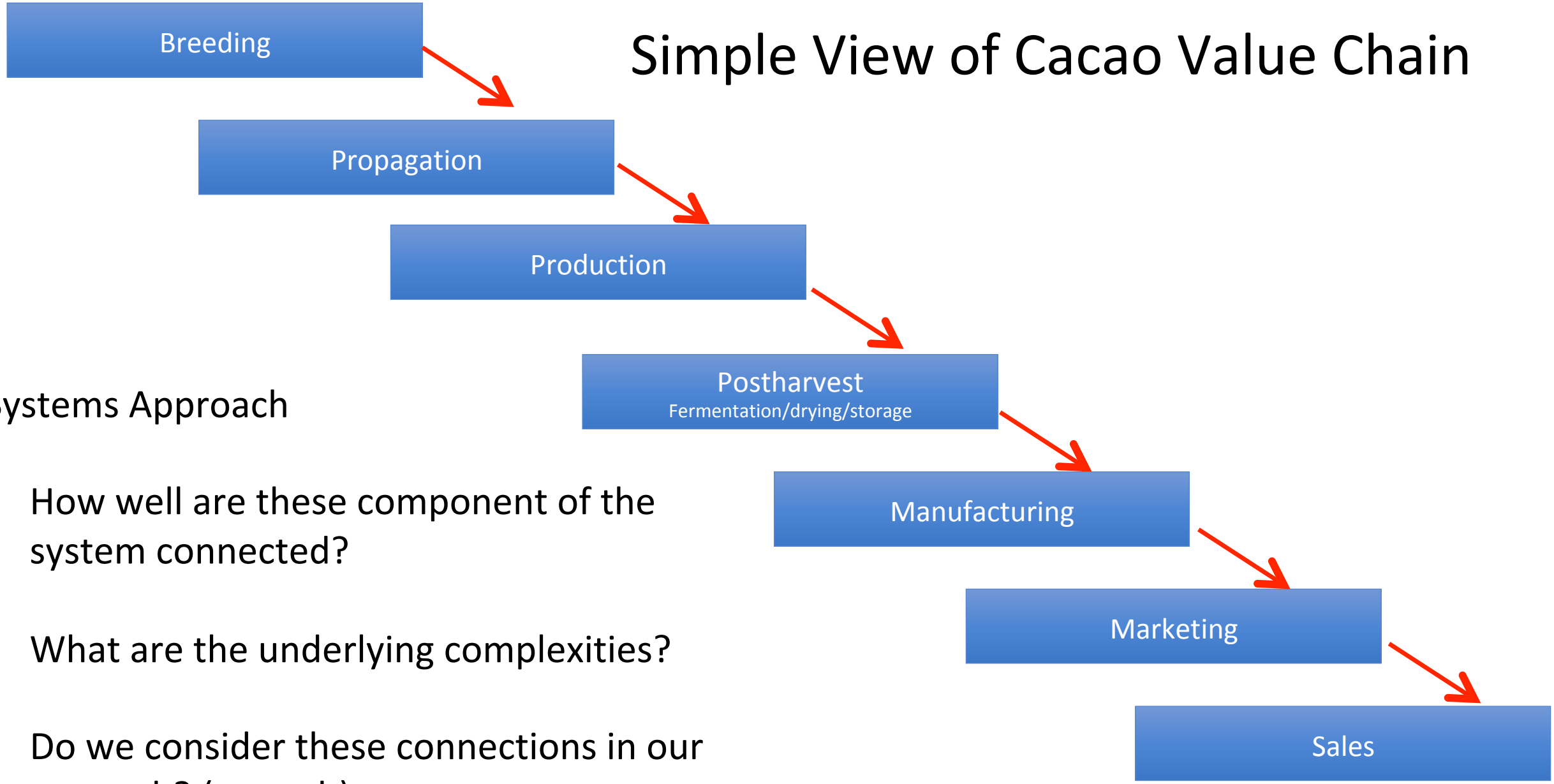
- A highly complex system spanning many disciplines, countries, work sectors, geopolitical and economic boundaries.

- Will become more complex is future as globalization and interconnectedness continues to increase at rapid pace. Increased communication: accelerated and amplified economic feedback loops.

How to improve such a complex system?

Systems based research and development approaches.

Simple View of Cacao Value Chain



Systems Approach

- How well are these component of the system connected?
- What are the underlying complexities?
- Do we consider these connections in our research? (enough)

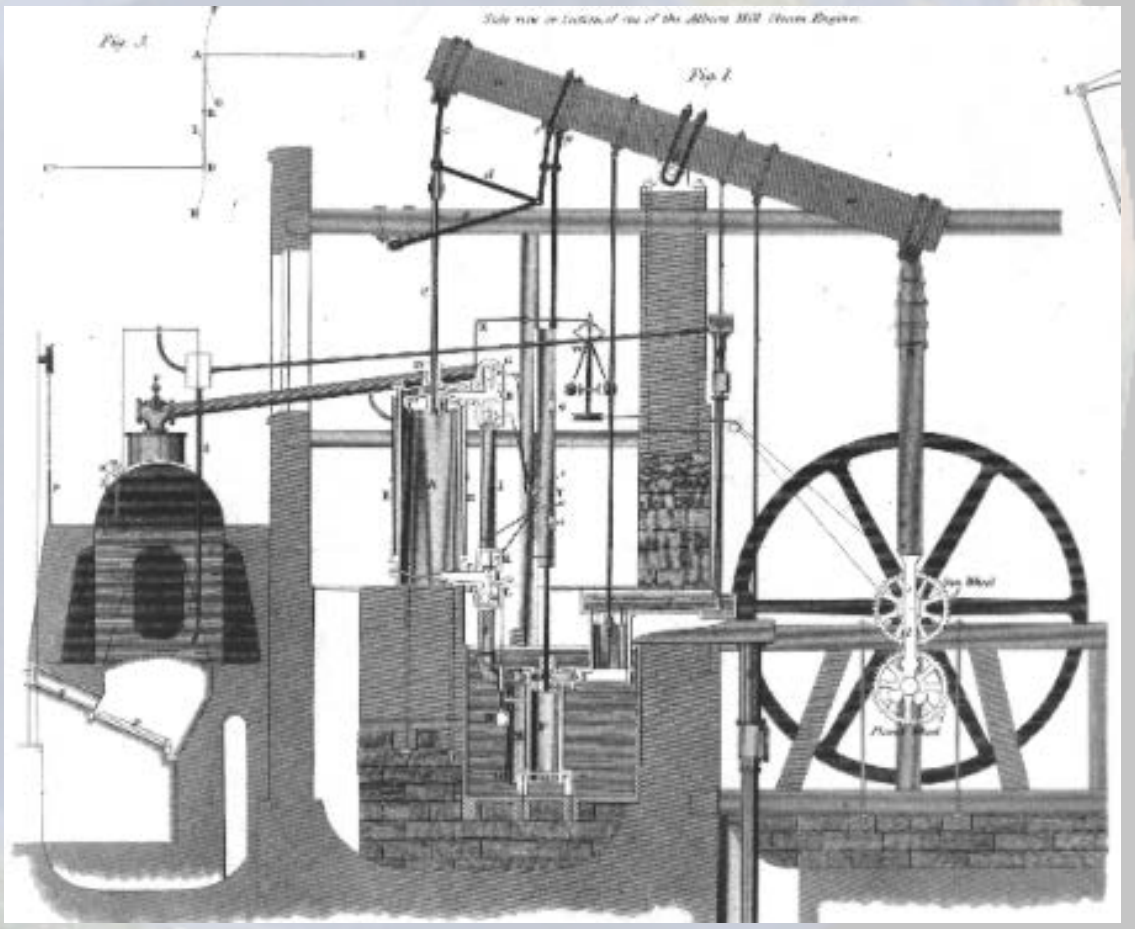
What is a System?

Merriam-Webster Dictionary: A system is defined as a regularly interacting or interdependent group of items forming a unified whole.

Something more than the sum of its parts.

Consists of three kinds of things:

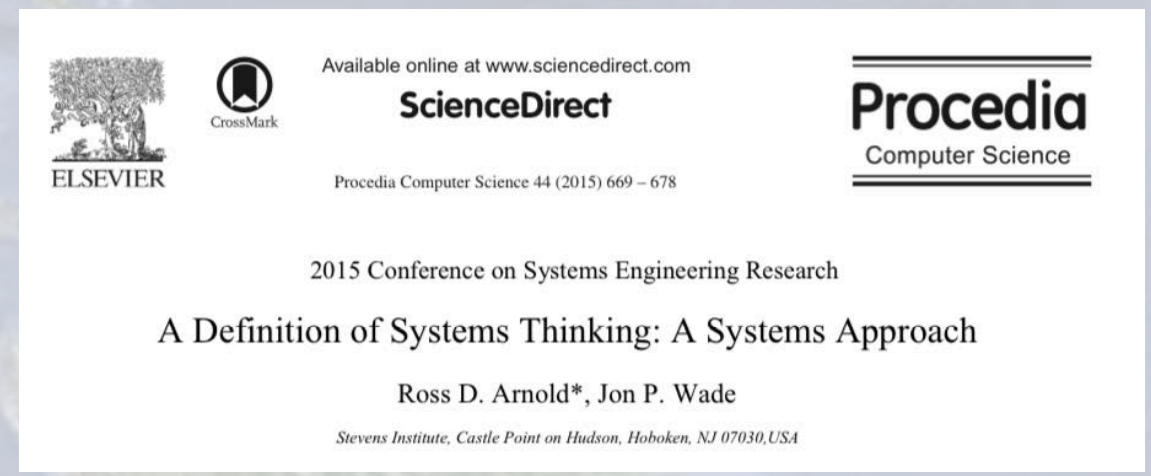
- elements
- interconnections
- function or purpose



What is Systems Thinking?

System Thinking first defined in 1987: Barry Richmond

"As interdependency increases, we must learn to learn in a new way. It's not good enough simply to get smarter and smarter about our particular "piece of the rock." We must have a common language and framework for sharing our specialized knowledge, expertise and experience with "local experts" from other parts of the web."



What is System Thinking?

- The art and science of making reliable inferences about behavior by developing an increasingly deep understanding of underlying structure of a system.
- Takes into account dynamic complexity: change over time and feedback loops (positive and negative).
- Can consider a system a different scales: From farms to molecules

What is System Thinking?

I cannot see the forest for the trees!

A Swedish Proverb

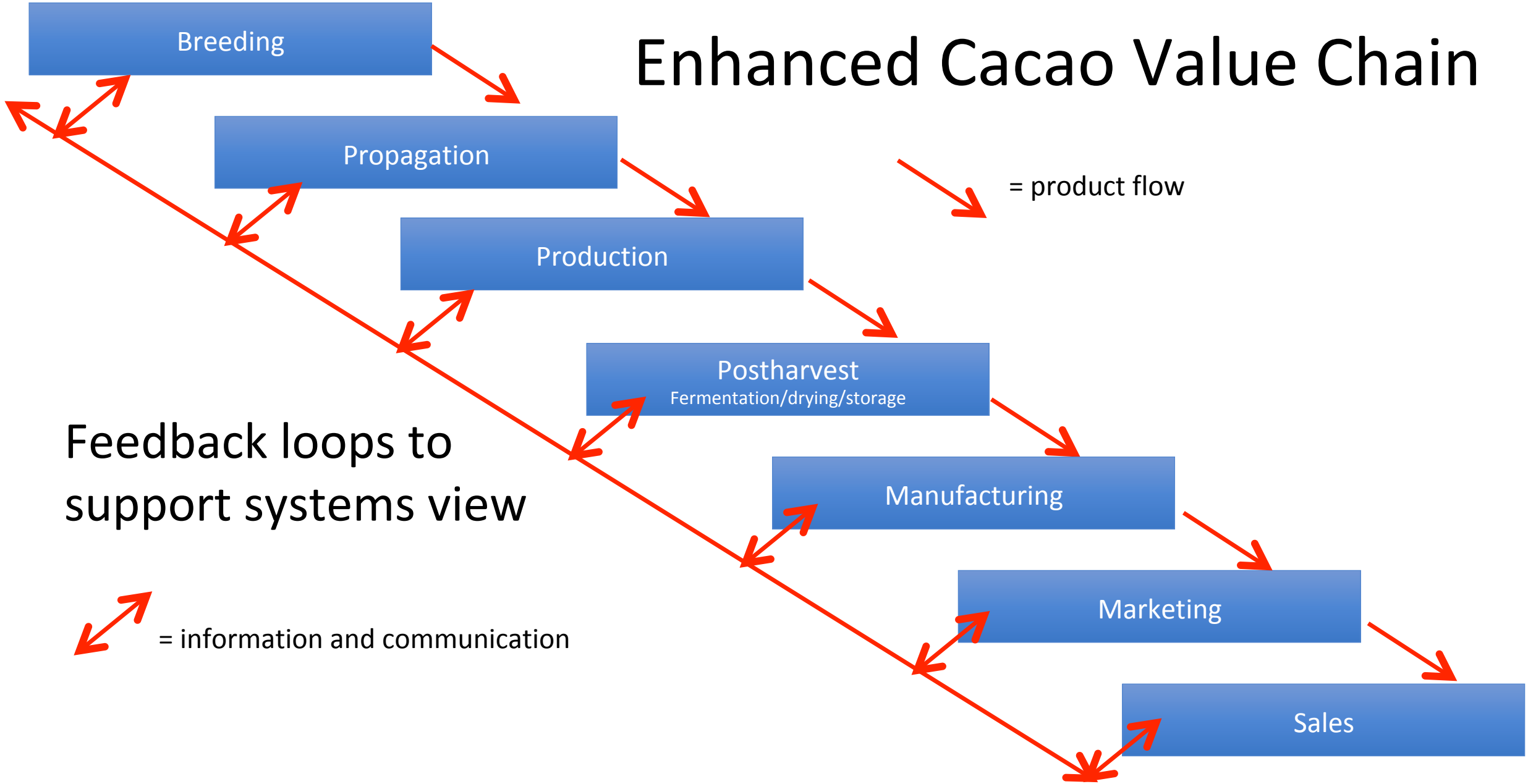
Systems Thinking

I can see the forest AND the trees!

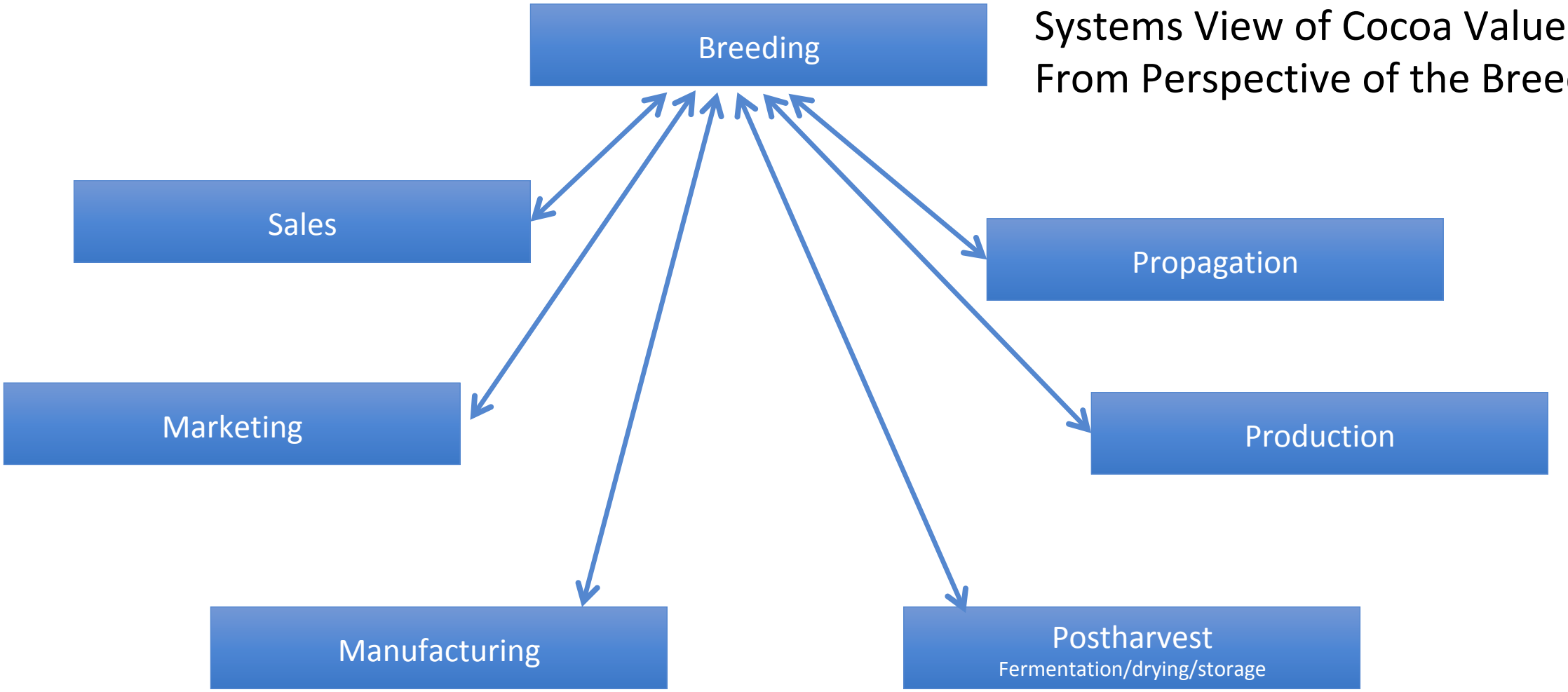
Support the Full Range of Farmers Needs
A Comprehensive Approach: From Seed to Sale

Source: Bill and Melinda Gates Foundation, 2009

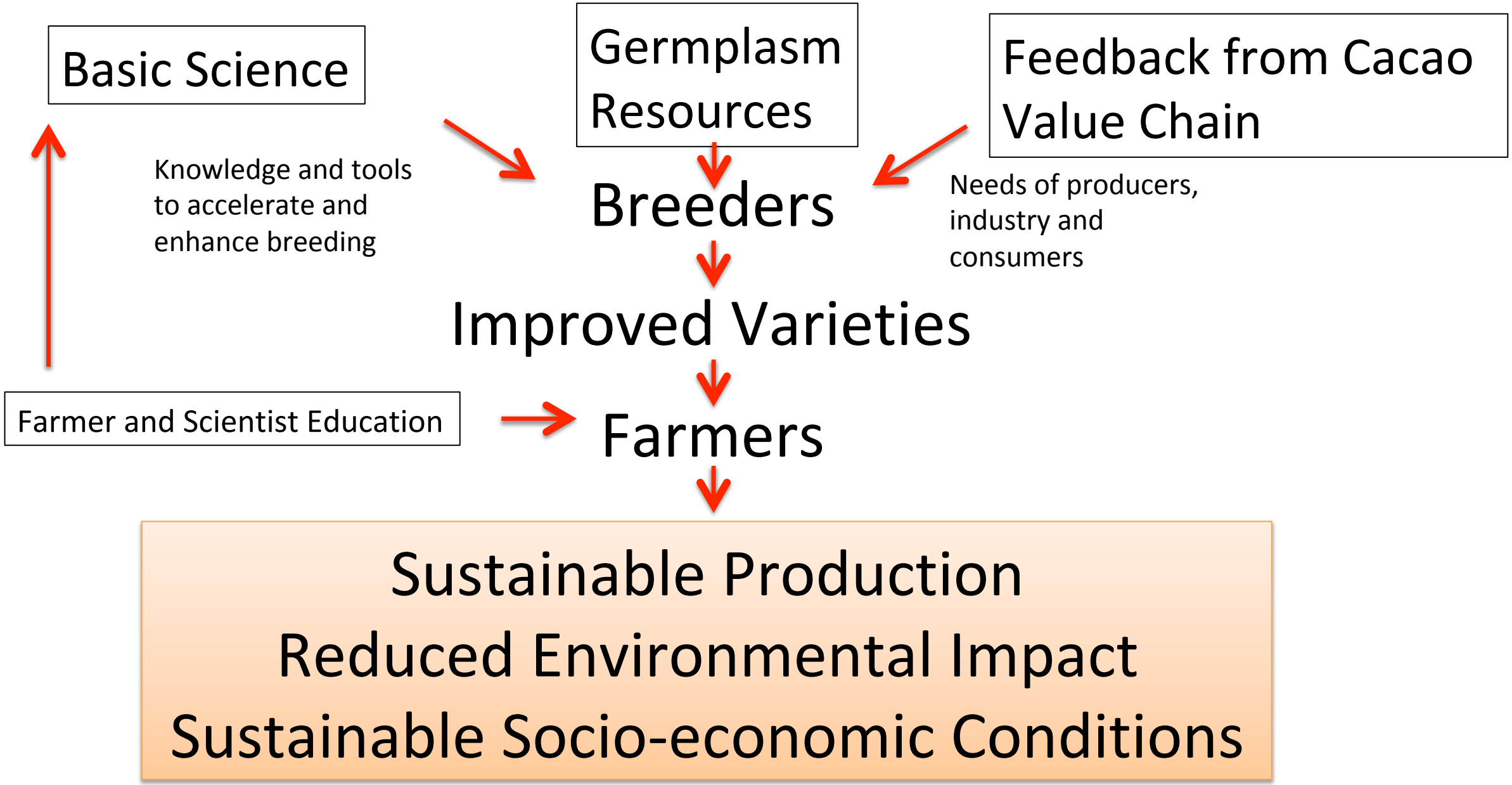
Enhanced Cacao Value Chain



Systems View of Cocoa Value Chain From Perspective of the Breeder



Cacao Genetics and Breeding System View



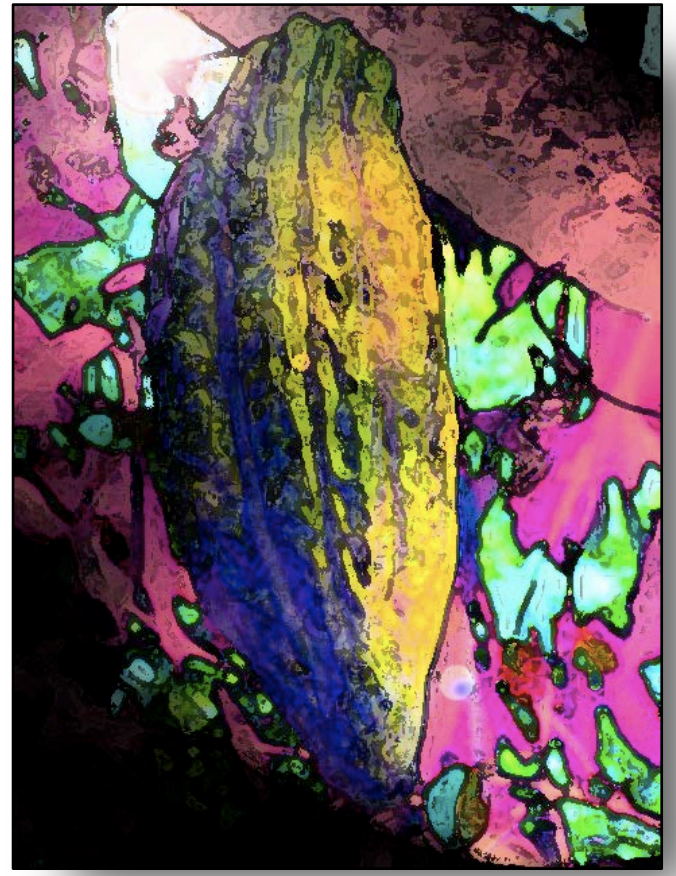
Role of Basic Science in the Cocoa Value Chain

Basic Science

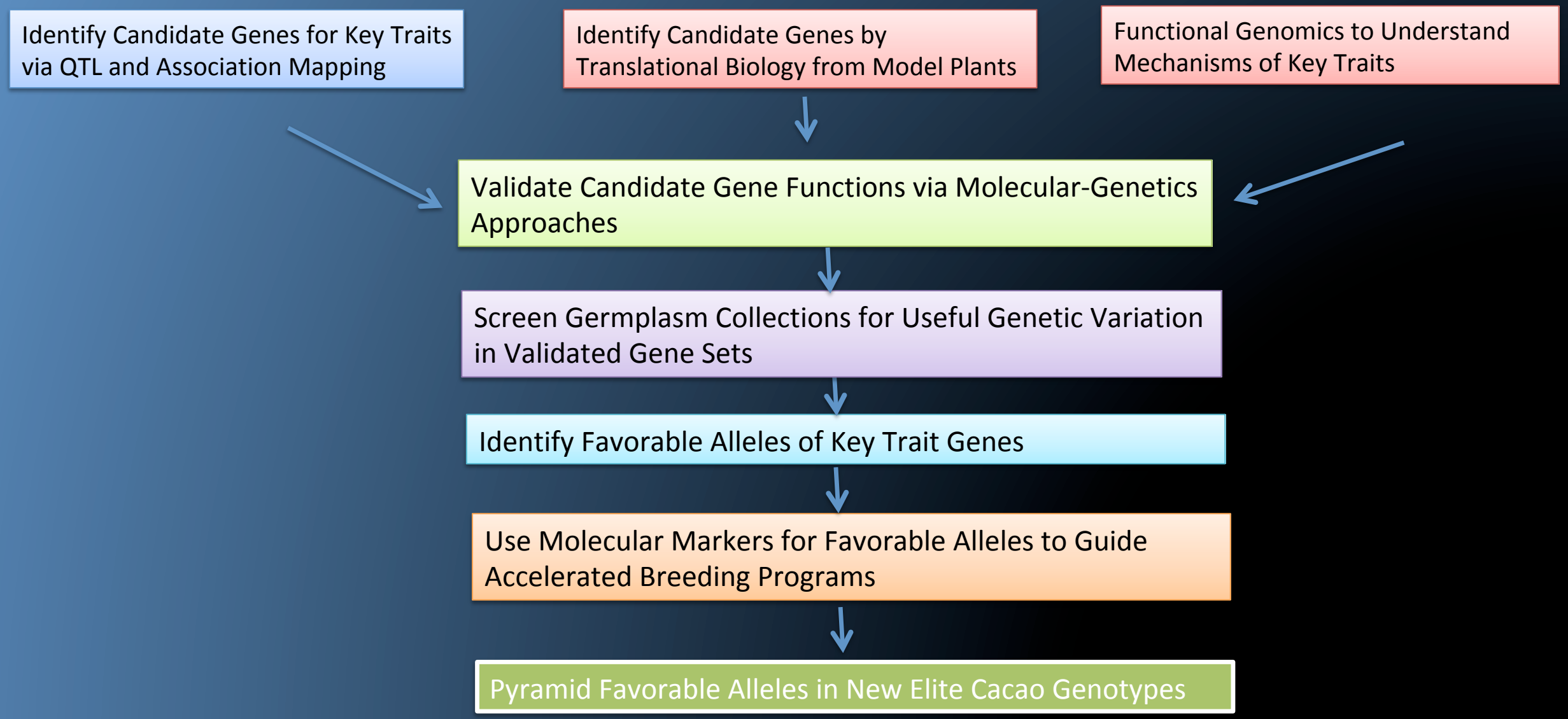
Knowledge and tools to accelerate and enhance breeding

Breeders

Improved Varieties

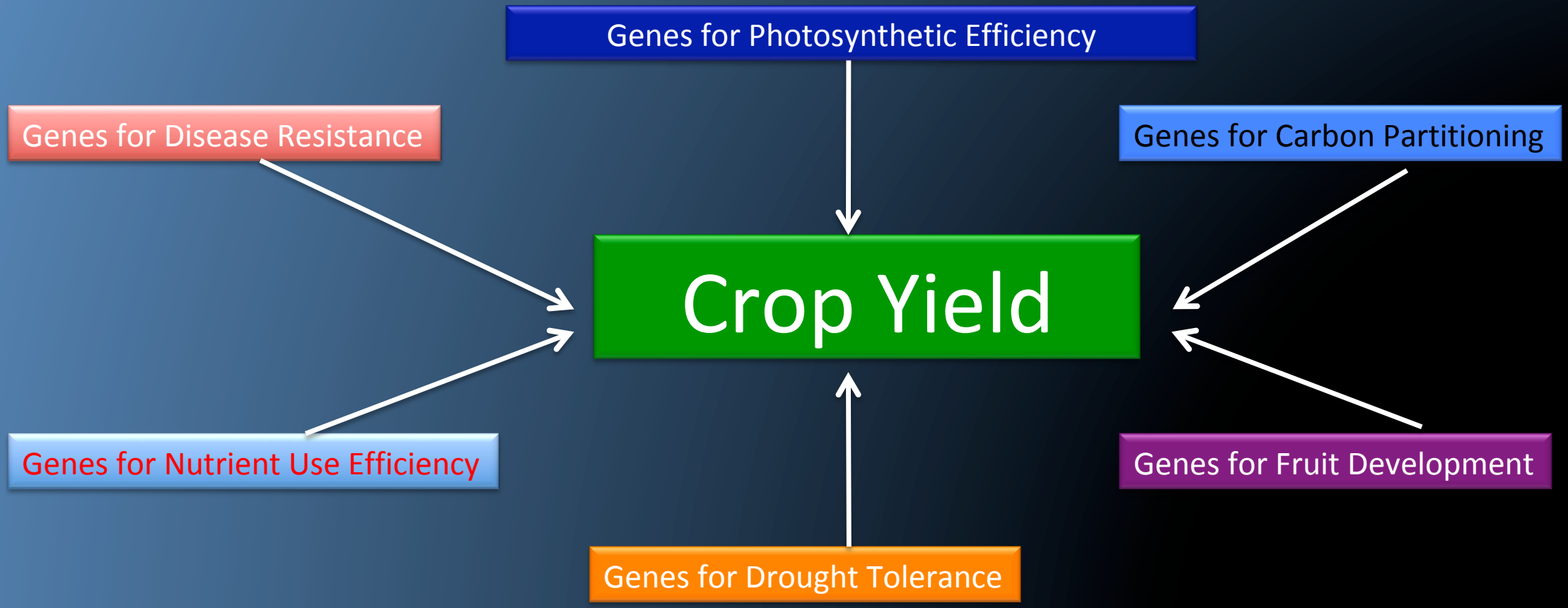


Accelerating Breeding With Basic Science



Gene Discovery

Most Traits are Controlled by Multiple Genes (Multigenic Traits)



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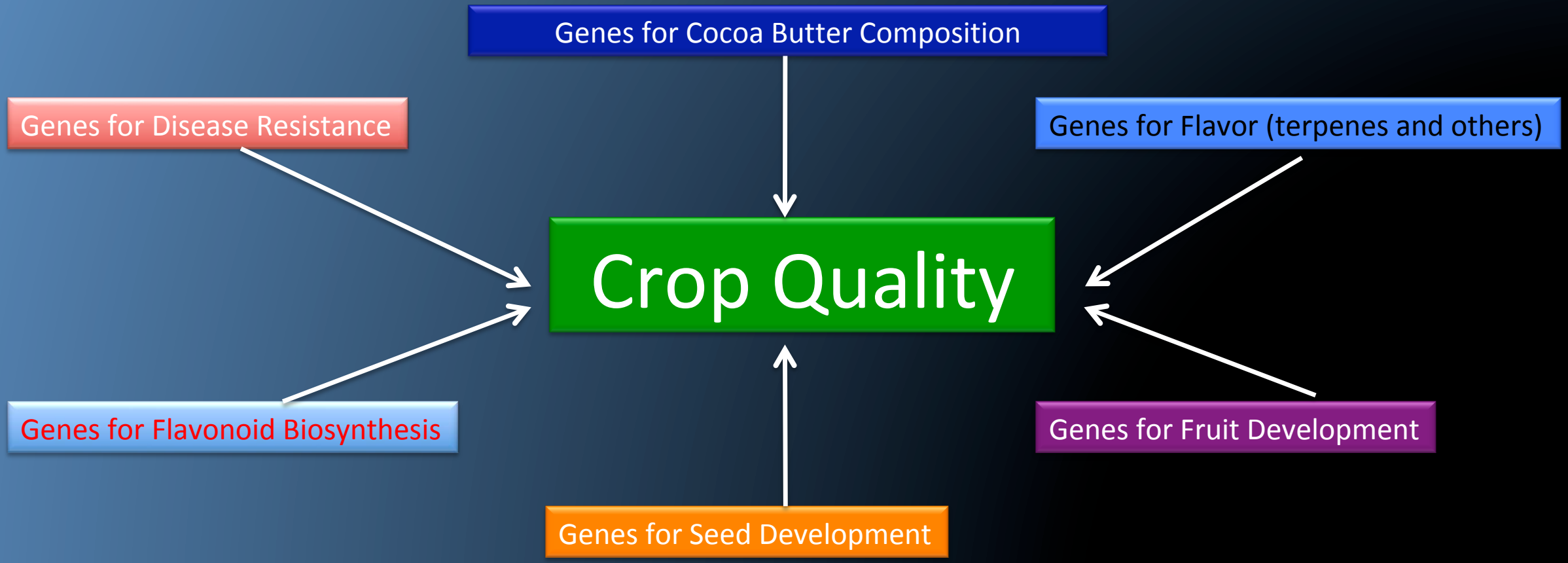
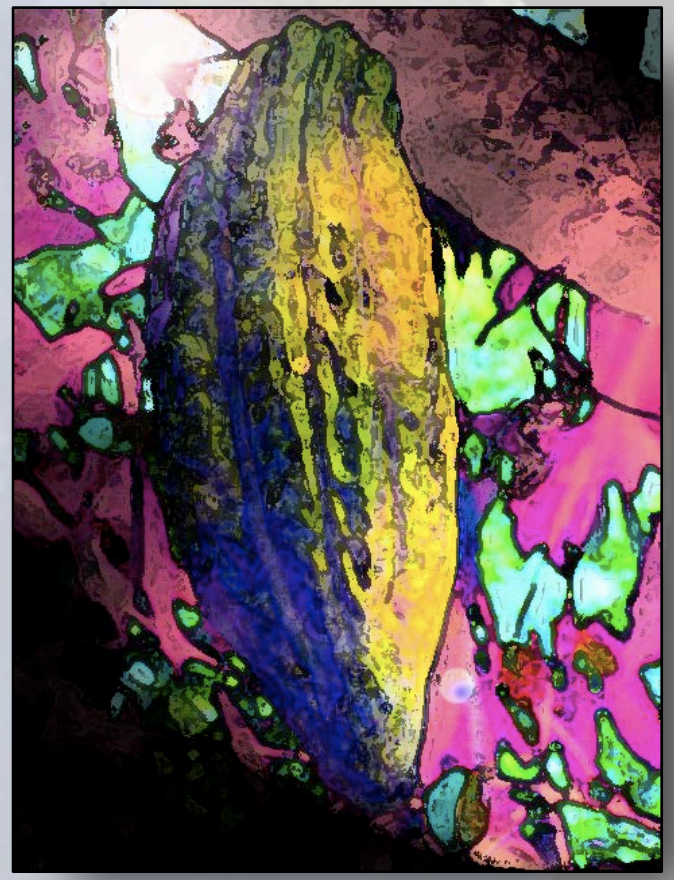


Examples of Molecular Systems View

Traits of Importance to Cacao Improvement

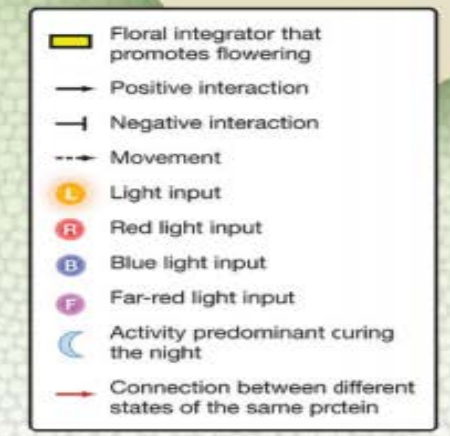


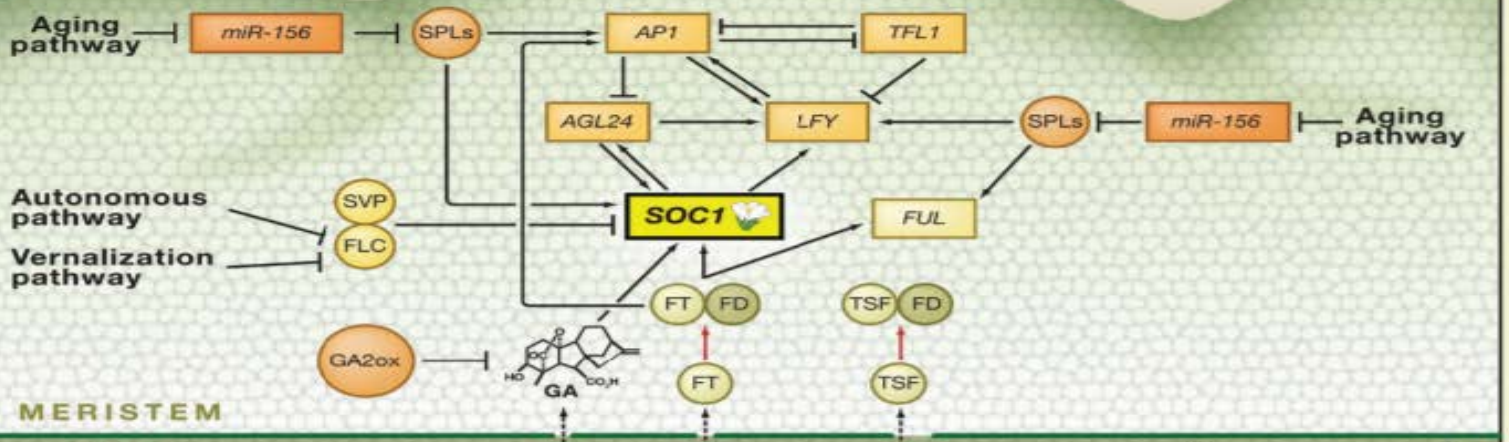
550 Cell 141, April 3, 2010 ©2010 Elsevier Inc. DOI 10.1016/j.cell.2010.04.024

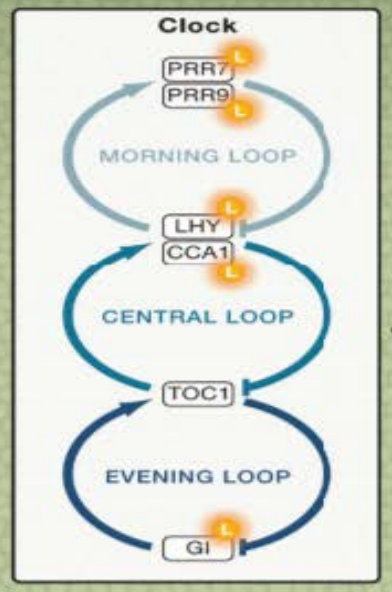
SnapShot: Control of Flowering in *Arabidopsis*

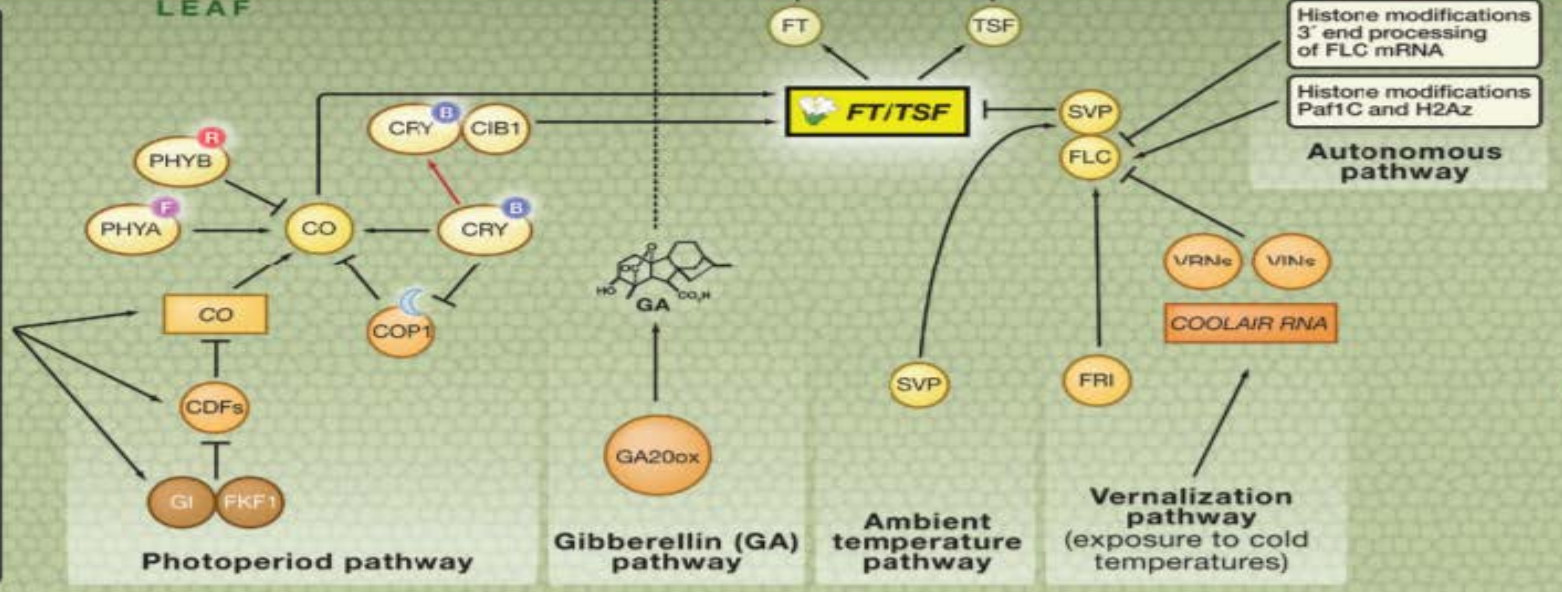
Fabio Fornara, Amaury de Montaigu, and George Coupland
Max Planck Institute for Plant Breeding Research, Köln 50829, Germany

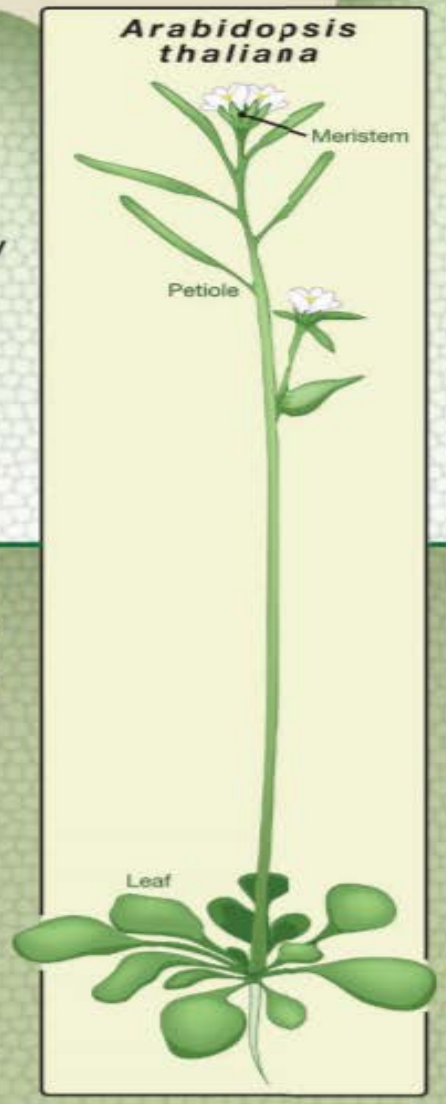
Cell



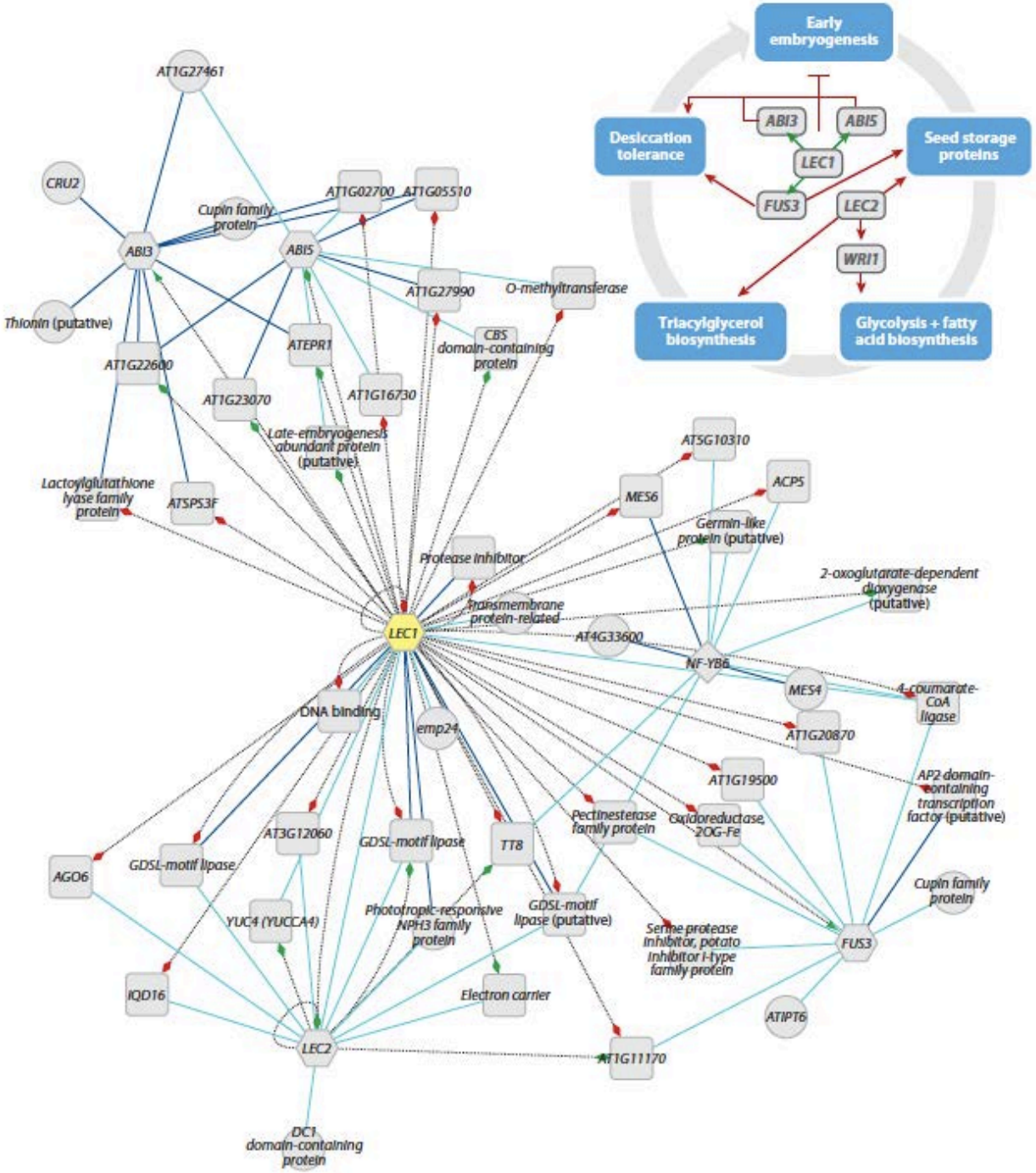






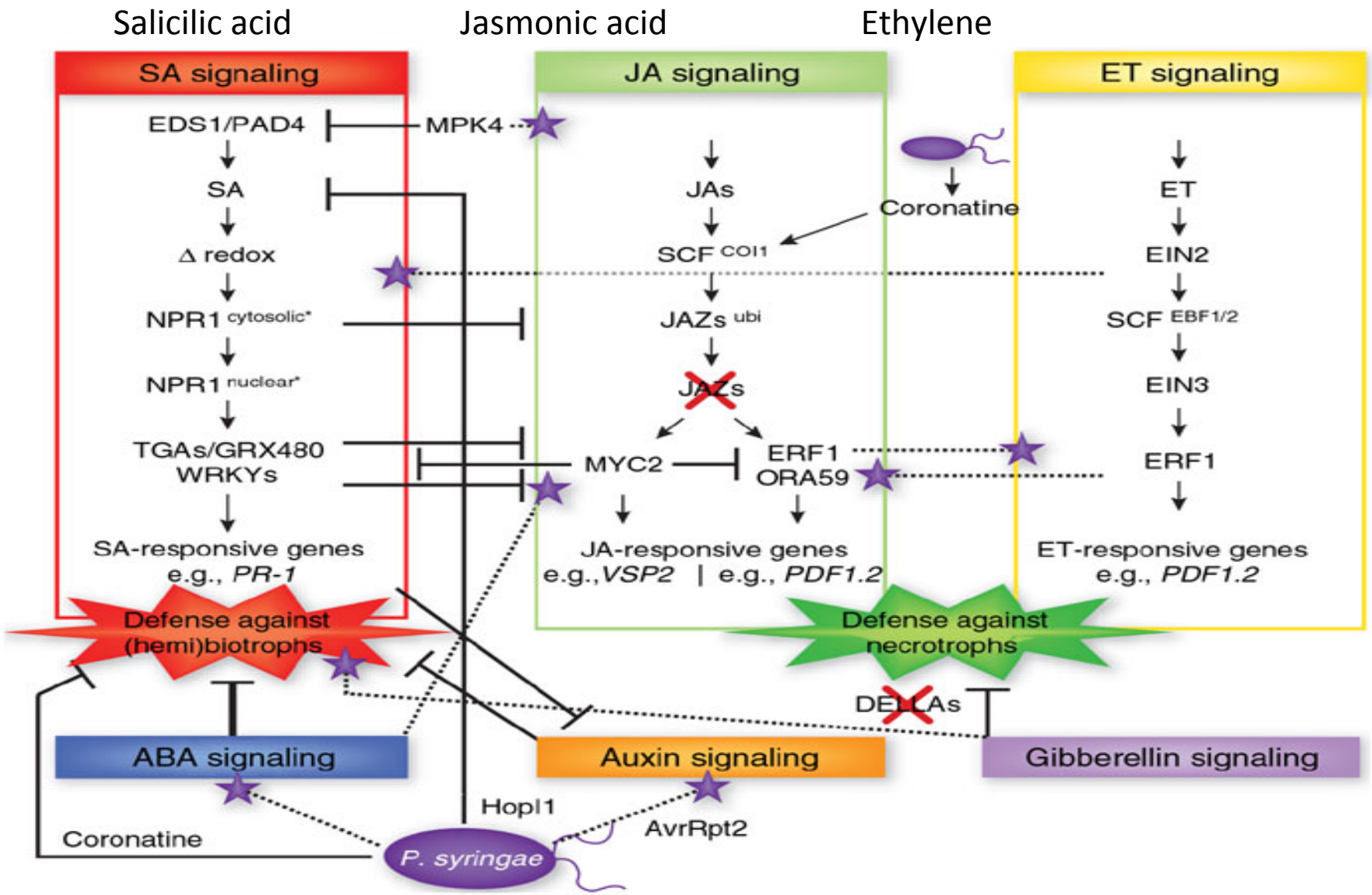


See online version for legend and references.



Systems Model of Seed Development Regulatory Network

The Principles of Plant Immunity
Signal Transduction

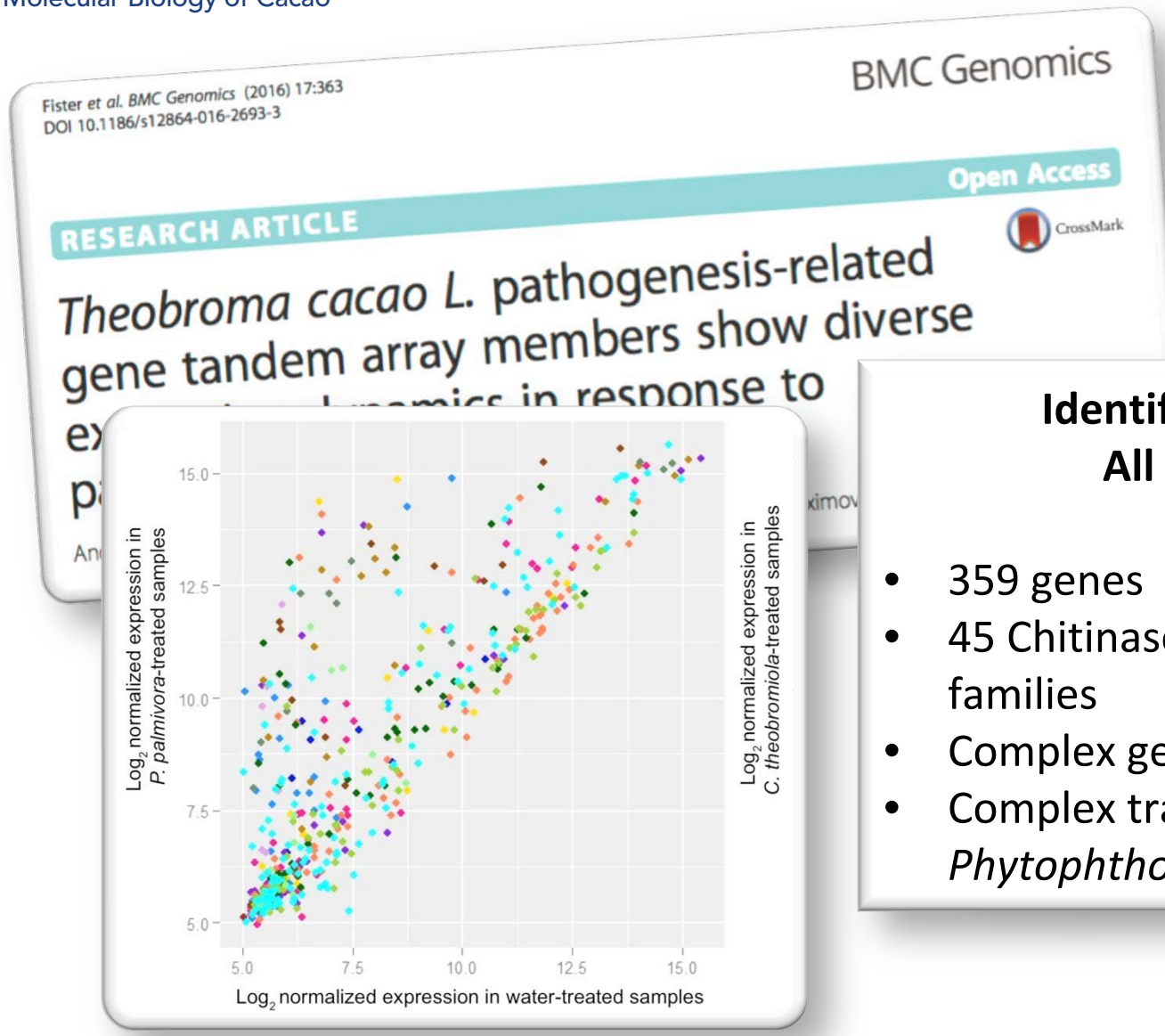


Pieterse et al. 2009 Nature Chemical Biology **5**, 308 – 316.

PennState
College of Agricultural Sciences

Program in the Molecular Biology of Cacao

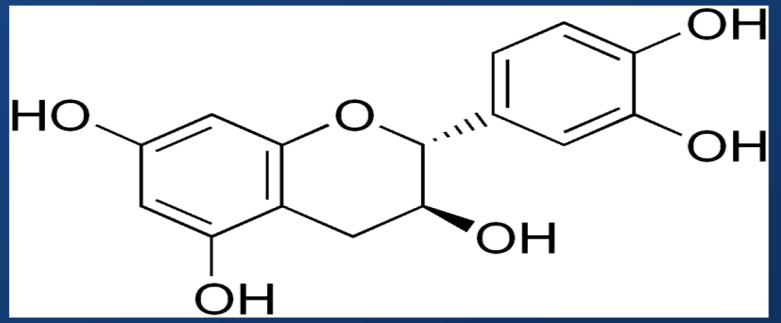
Andrew Fister

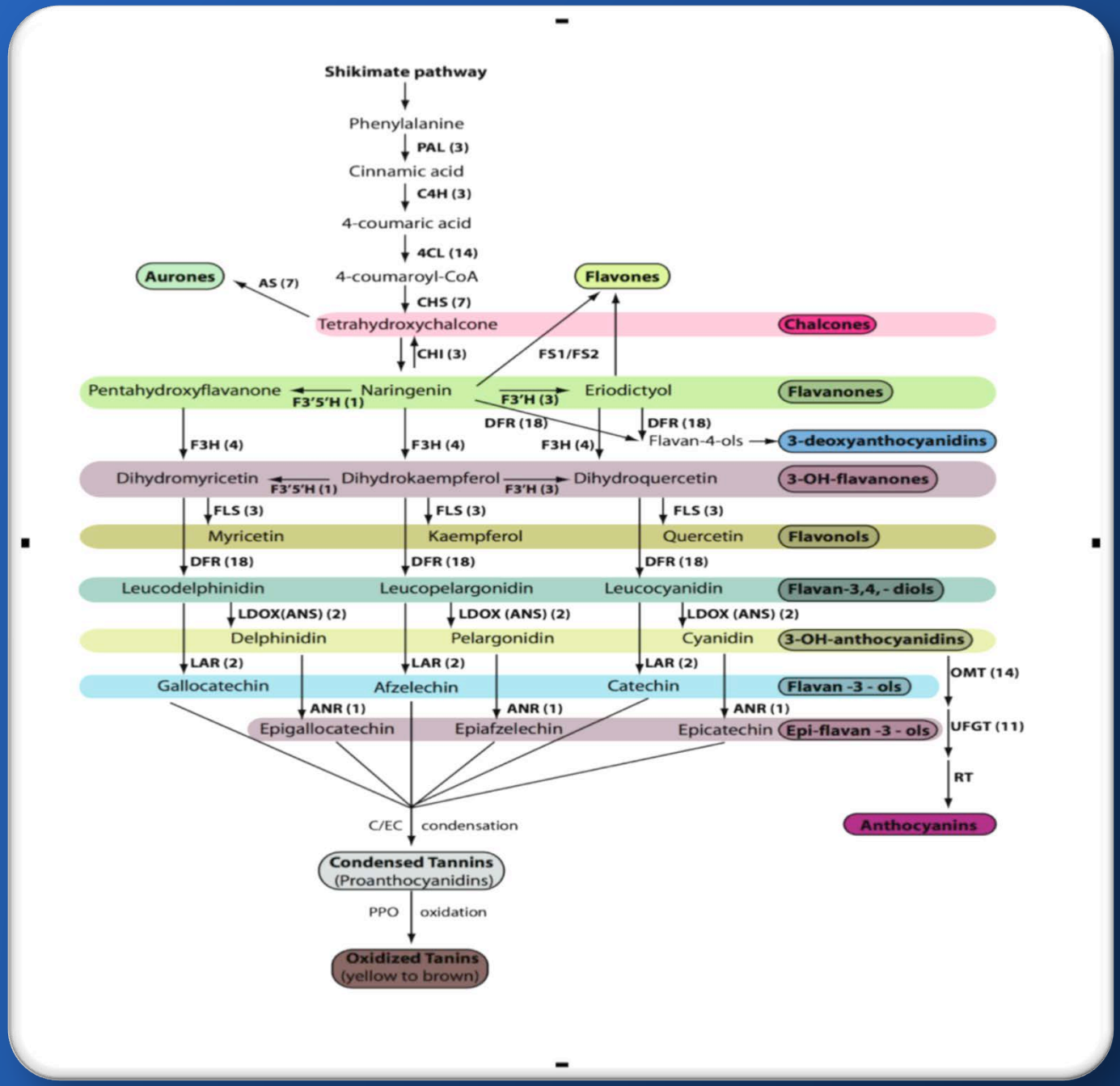


Identified and Annotated
All Cacao PR Genes

- 359 genes
- 45 Chitinases genes in 4 Multi-gene families
- Complex gene expression profiles
- Complex transcriptional response to *Phytophthora* infection

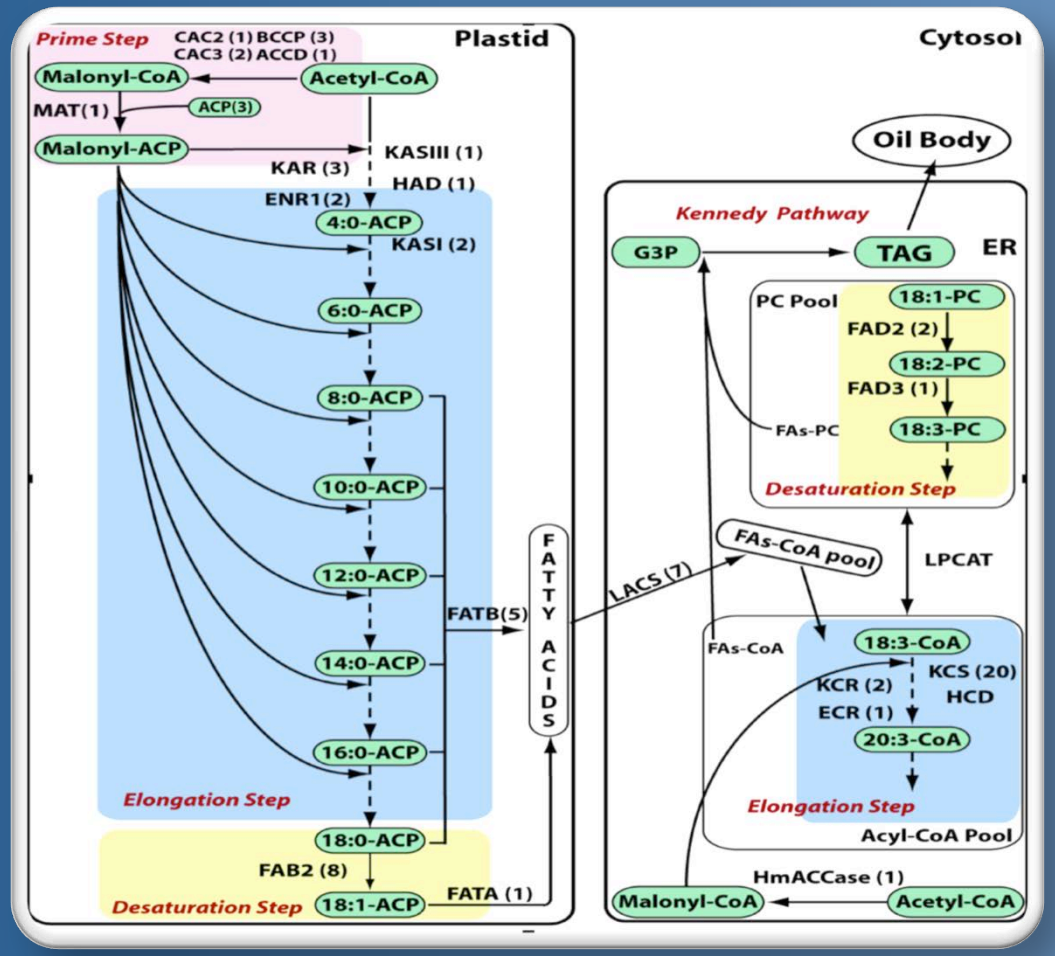
Flavonoid Biosynthesis

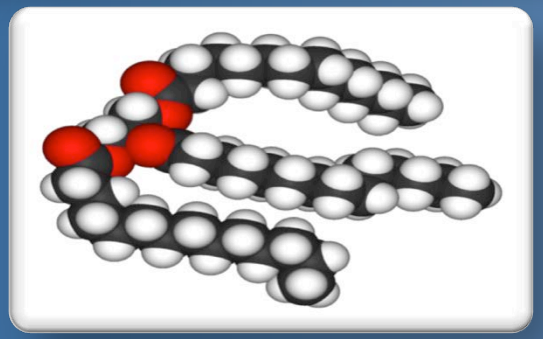




- 32 Genes
- No Expansion of Cacao Gene Copy Numbers
- Myb Box Transcription Factor Regulators

Cocoa Butter Biosynthesis





27 Enzymes
75 Genes
13 single copy genes
Family sizes up to 20

Plant Science

Accelerated Breeding

Improved Crop Varieties

Increased Farm Productivity and Income

Sustainable Cocoa Supply

Reduced Environmental Impact

How Will *Systems Approaches* Lead to Helping Farmers and a Sustainable Cocoa Supply?

How to Incorporate Systems Thinking Into Your Work

- Design interdisciplinary research into your projects and work with collaborators out of your field
- Read literature out of your field
- Learn about Systems Thinking and the Science of Team Science
- Teach Systems Thinking to your students

Thanks for your Attention

Questions?

CCN51, Ecuador Photo: M. Guiltinan