

Evolutionary Science of Gut Structures, Microbes, Food, and Cellular Energy



Presentation Outline

How All Living Organisms Evolved From a Primitive Cell

From Free-living Bacteria to Essential Human Partners

Complex Conversation Between Your Food, Microbiome,
and Cellular Energy Systems

Core Dietary Principles for Optimal Energy

Strategies for Building Nutrient-Dense Meals

Sources of Information



Earth Formed 4.5 Billion Years Ago





4 Billion Years Ago

**Oceans Dominated
Surface of Earth**

Earliest Signs of Life

Hydrothermal Vents

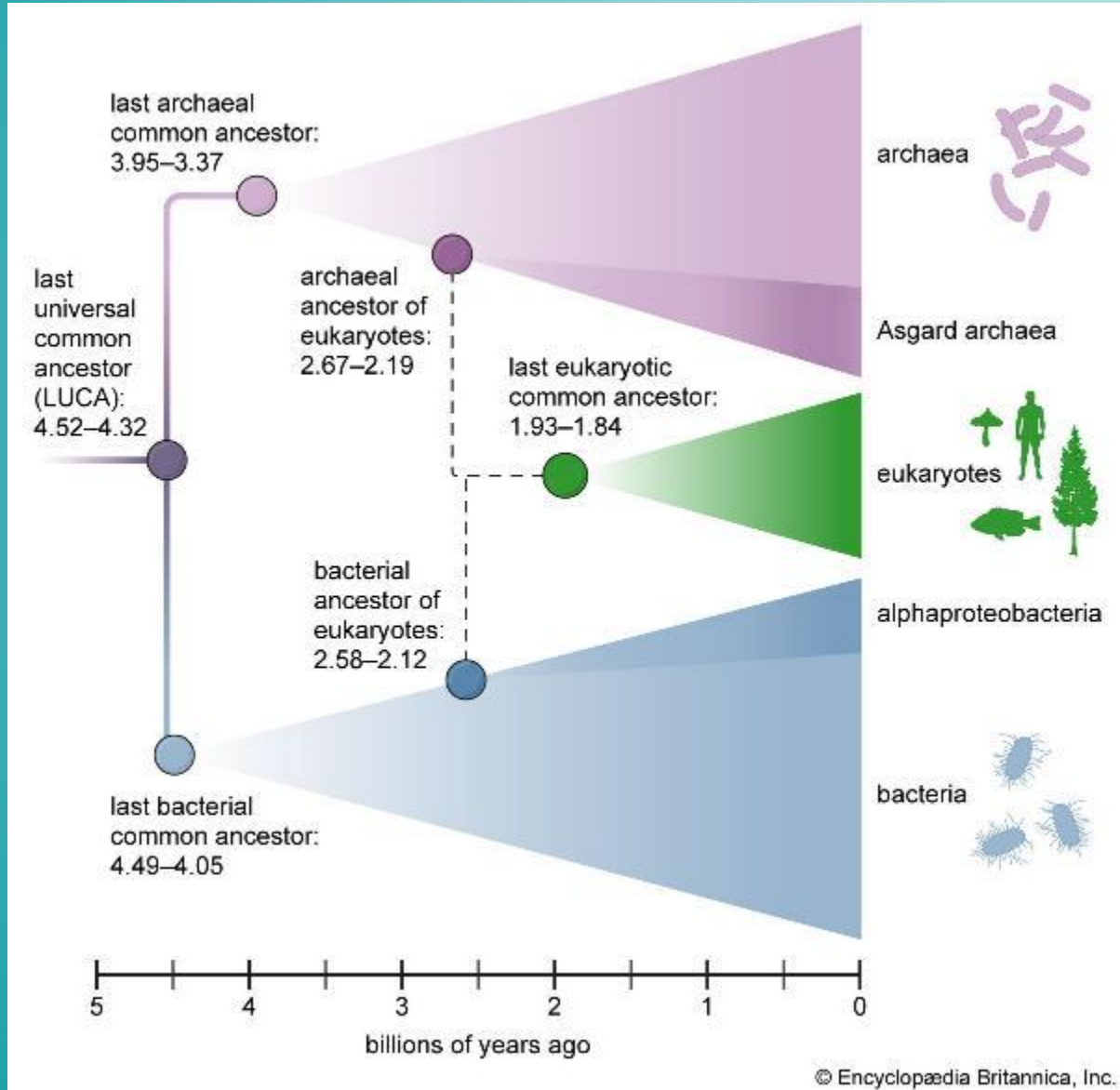
**Pre-cellular Life Uses
Chemical Energy to
Copy Themselves**

**3.8 Billion Years Ago
Last Universal Common
Ancestor Appears**

LUCA



LUCA: The most recent population from which all current life inherited its essential genes



“The nature of the last universal common ancestor and its impact on the early Earth system”

Nature Ecology and Evolution, Volume 8 issue 9, September 2024

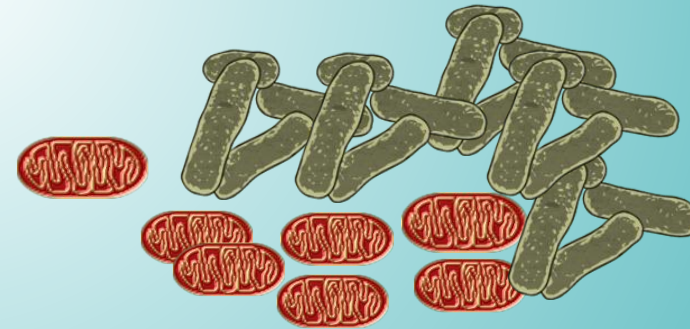
2.7 Billion Years Ago Photosynthetic Bacteria Began Producing Oxygen



1.8-2.0 Billion Years Ago Primary Endosymbiosis Event



Ancient Archea

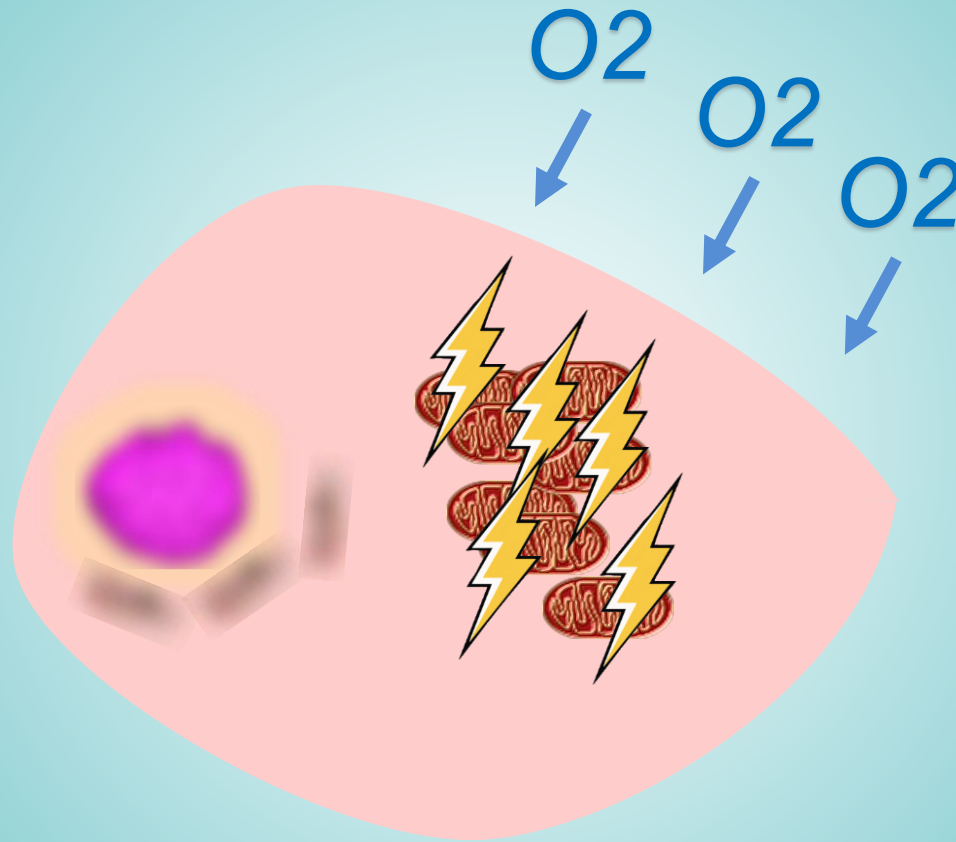


Aerobic Bacteria

Bacteria Use Oxygen to Make Energy for the Cell

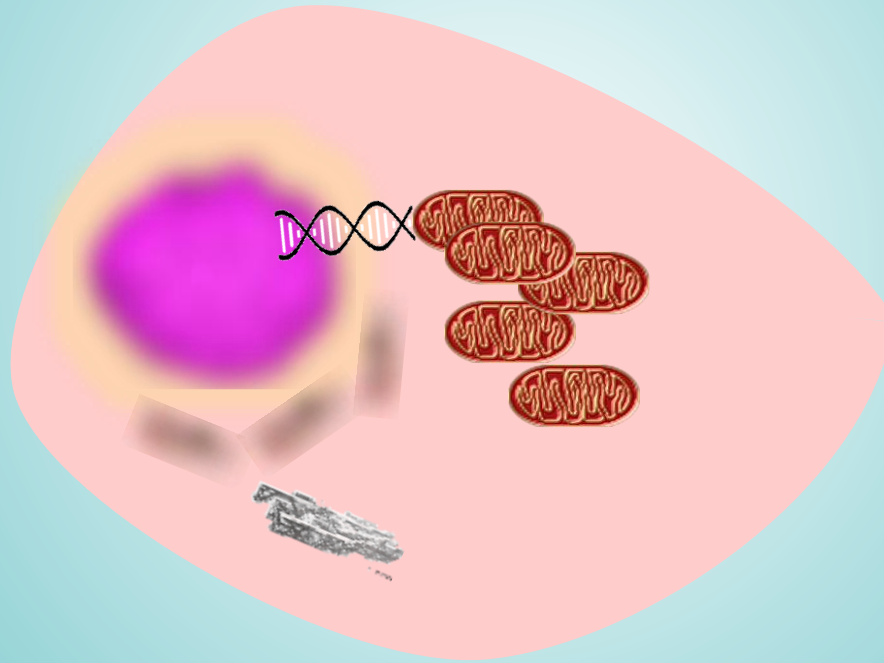


Bacteria Multiply → More Energy

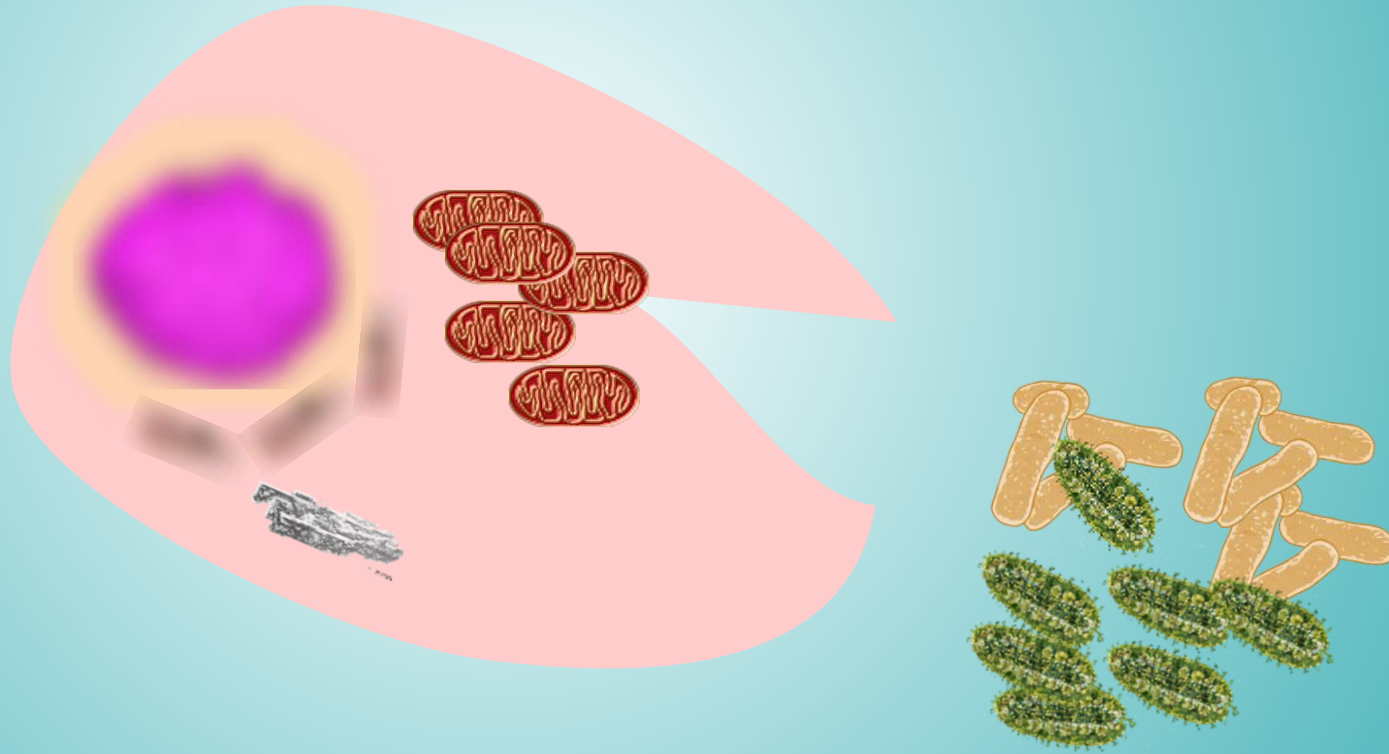


Gene Transfer and Symbiotic Relationship

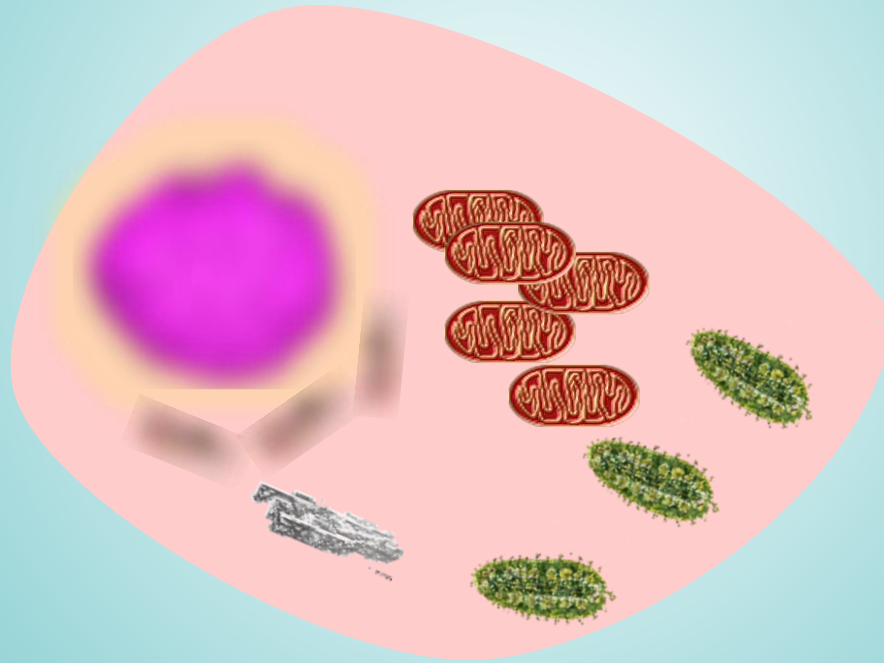
Aerobic Bacteria Became Mitochondria



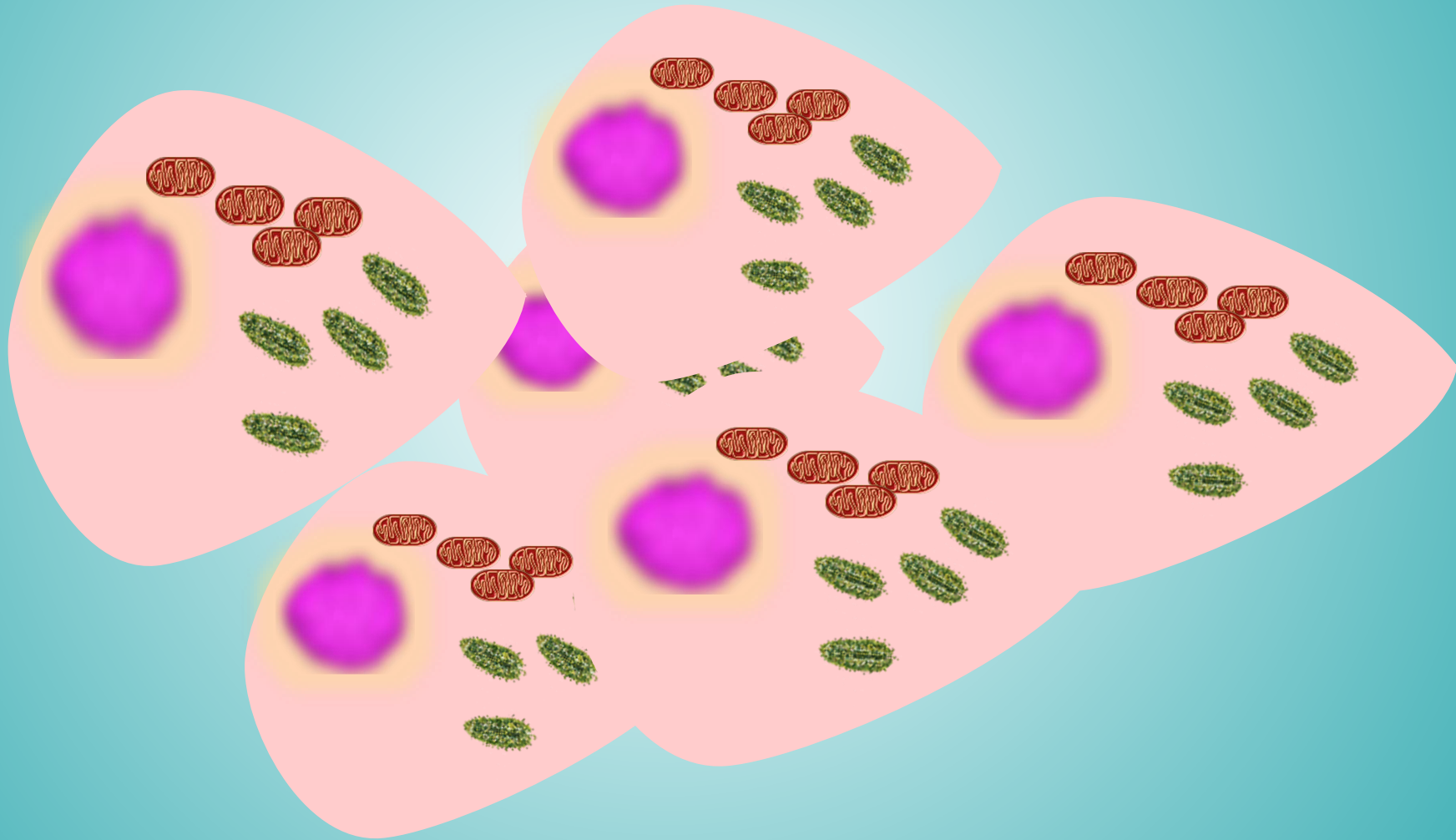
1.5 Billion Years Ago Secondary Endosymbiotic Event



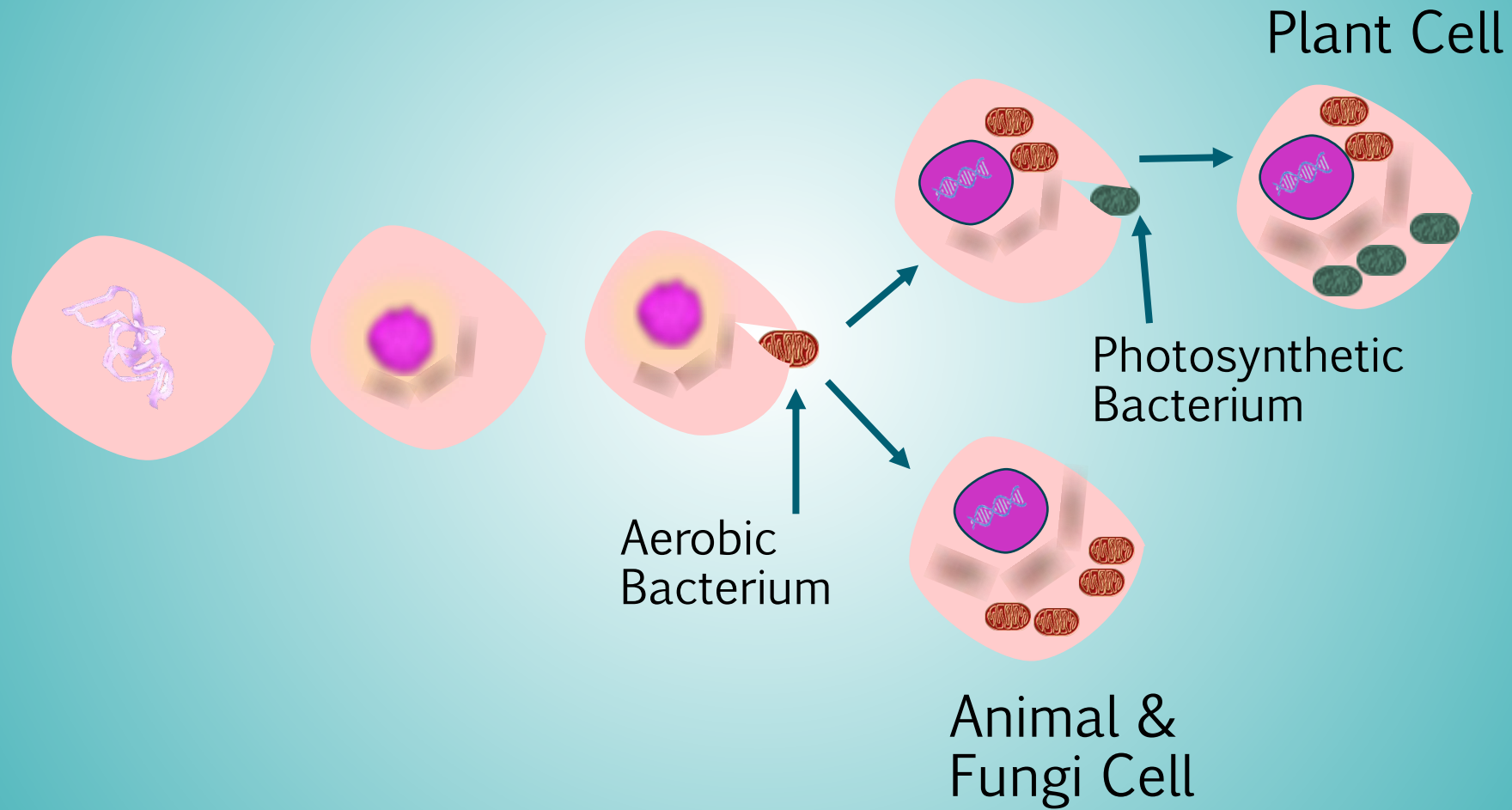
Photosynthetic Bacteria Become Chloroplasts



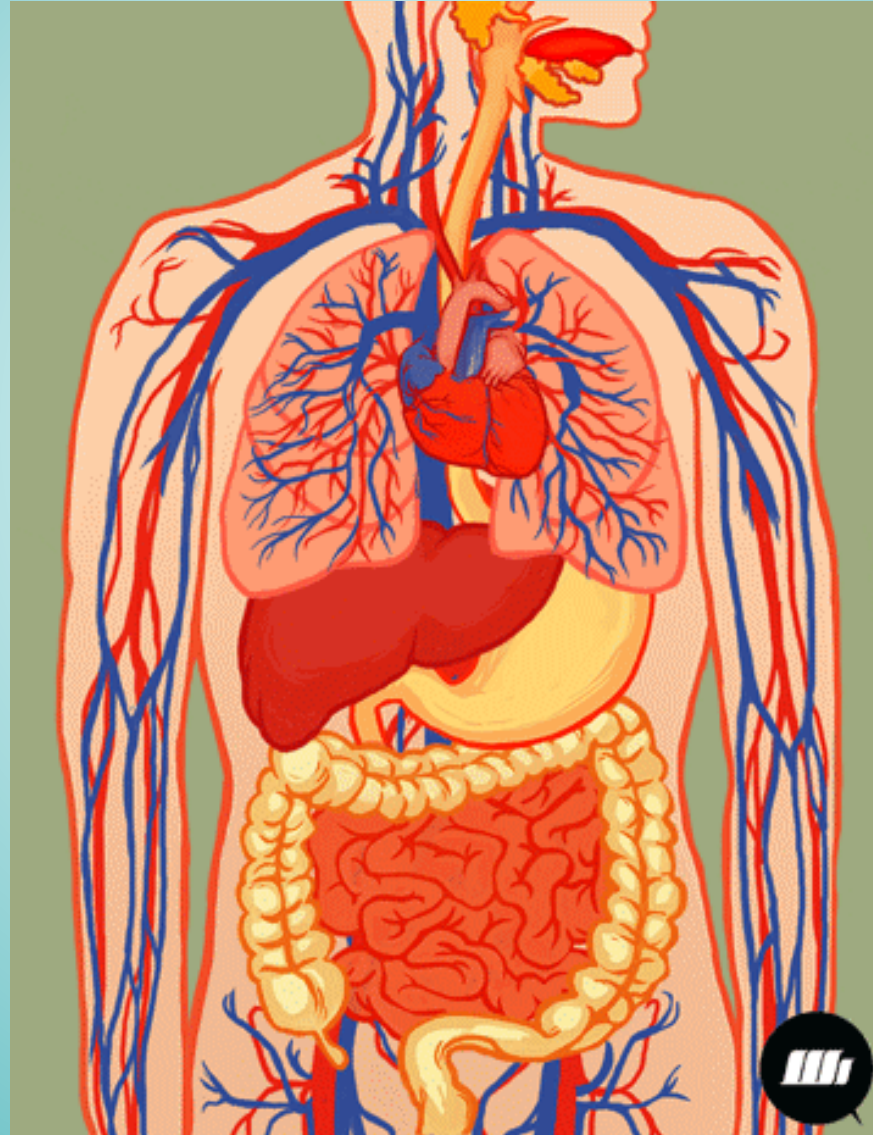
Endosymbiotic Events Allowed Single-Cell Organisms to Grow and Multiply



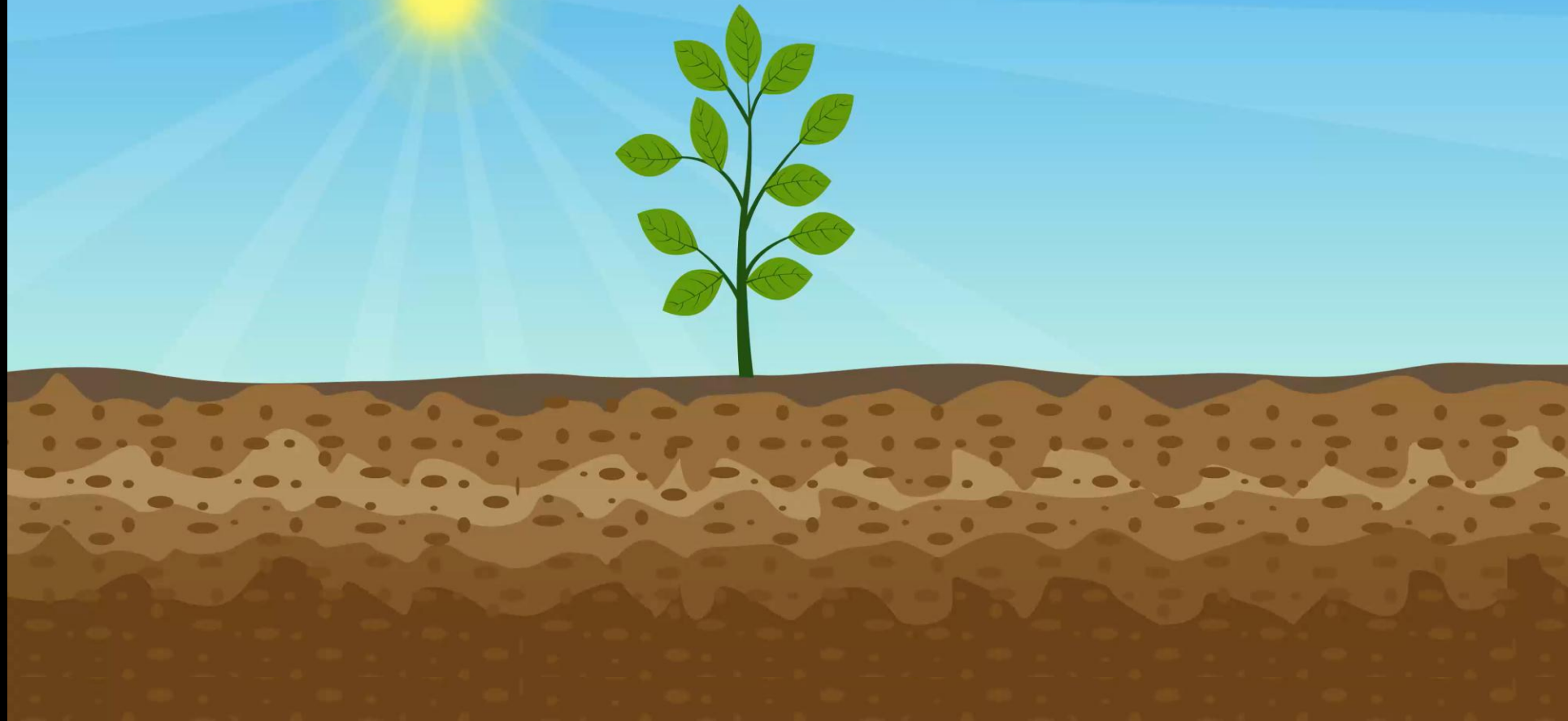
Mitochondria Evolved First Chloroplasts Evolved Later



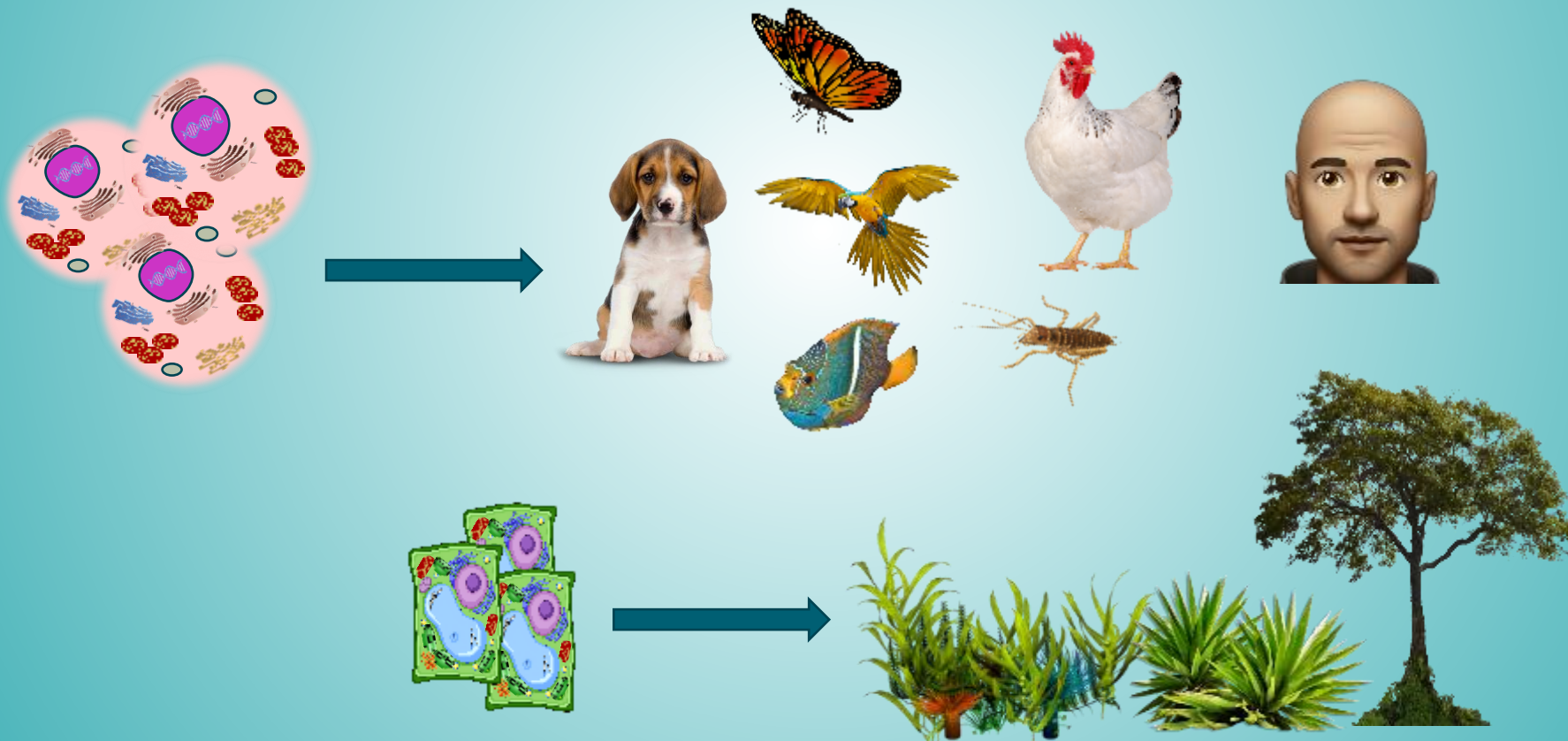
In Humans and Animals Mitochondria Generate 95% of Energy



Plants Use Chloroplasts for 70% of Energy
30% Energy Made by Mitochondria



Merger of Bacteria and Archea Led to Complex Life – Plants and Animals



Key Milestones in Evolution of Life and Energy

4 BYA First Microbes Capture Chemical Energy

3 BYA Photosynthesis Emerges: Energy from Sun

2 BYA Endosymbiosis: Oxygen Enables Hi-efficiency ATP

600 MYA Complex Life: Energy From Food

"All life captures energy—plants from sunlight, animals from food. But we all convert it into the same fuel: ATP. It's the universal gas that powers everything life does."

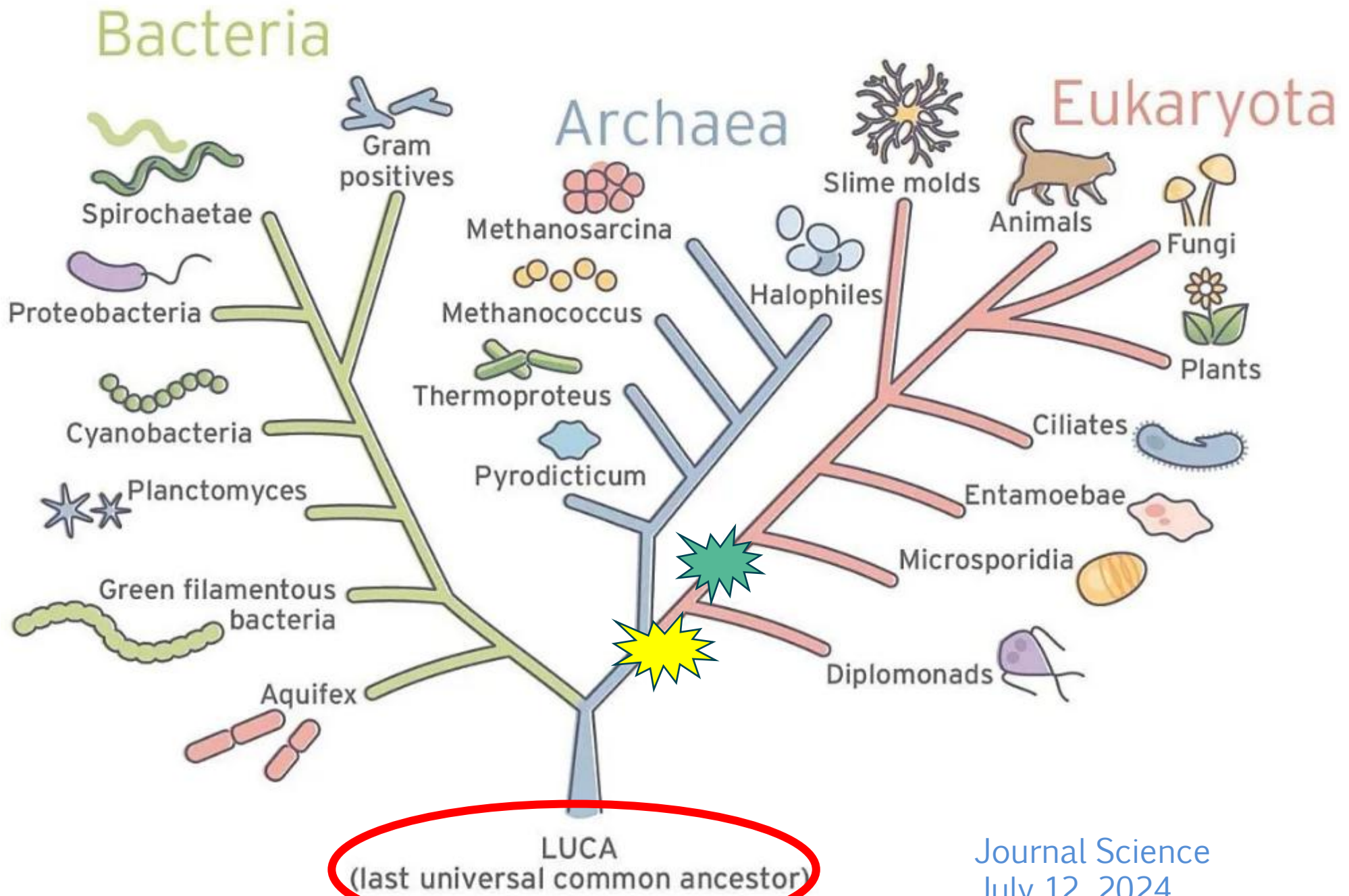
Bacteria are the Architects of Energy for All Life on Earth



They outweigh us by 1000 to 1

99% are beneficial or harmless

“The biomass distribution on earth”
Proceedings of the National Academy of Sciences 5/21/18
Weizmann Institute of Science and Caltech



Every Organism Alive Today Uses:

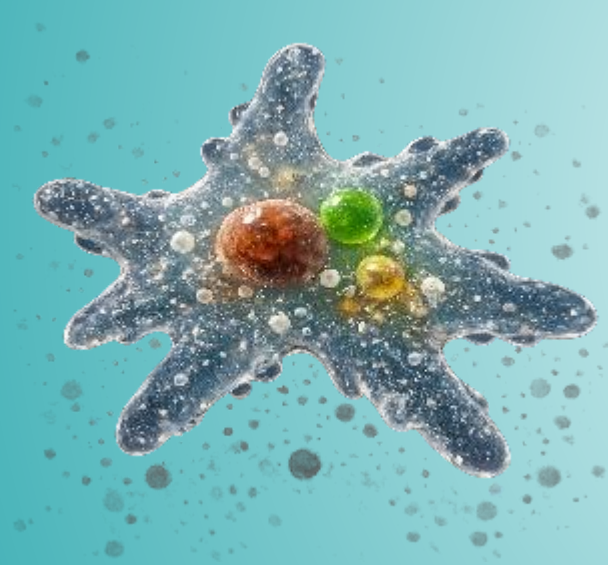
Same genetic code

Same protein-making machinery

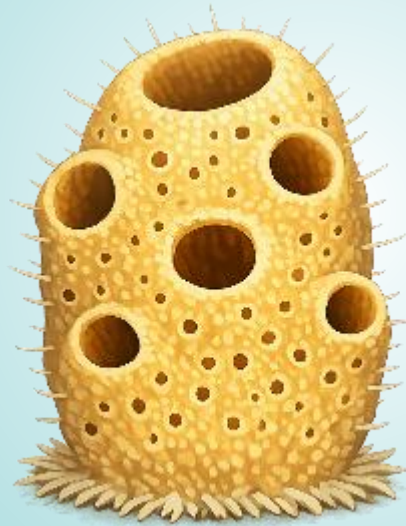
Same 20 amino acids**

Same universal energy molecule - ATP

Single-celled organisms and sponges absorbed nutrients directly through their cell membranes



Amoeba



Sponge

Bacteria absorbed into sponge as food

Some evaded digestion and began living inside sponge tissue

Bacteria living between cells up to 35% of sponge body mass

Jellyfish developed an internal digestive cavity with a single opening

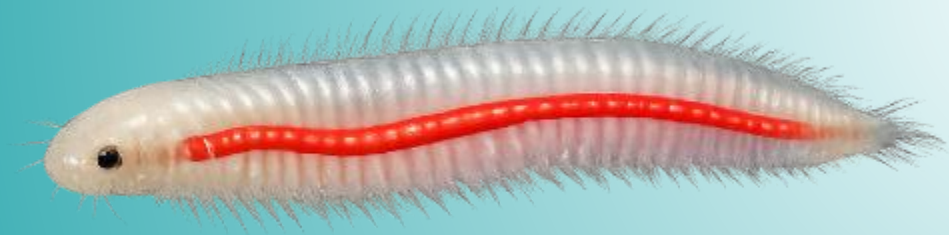


Cells in a cavity secrete digestive enzymes

Bacteria colonize inside cavity as an environment

Stable community of bacteria - microbiome necessary for health

600 MYA Tube open at both ends, beginning of a true gut microbiome

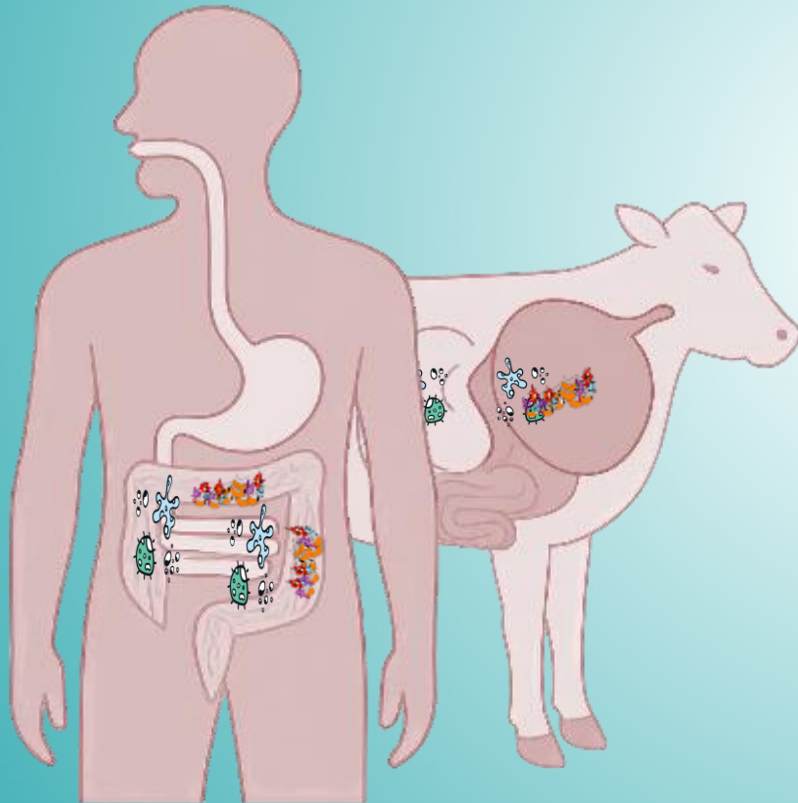


Food moves in a single direction

Regions in digestive tract could become specialized, evolve to digestive organs

Different bacterial species could occupy different niches along its length

~500-100 Million Years Later Digestive Tube Turned into Organs



Efficient nutrient absorption -
develop larger body sizes

New habitats/different microbes:
herbivores, omnivores, carnivores

Microbe-driven dietary diversity
was key to adaptive success

The Grand Design

The gut brings energy in—mitochondria turn it into power—and that's what made complex life possible!

A Successful Partnership

The body provides a protected,
nutrient-rich environment

Gut bacteria transform food into
beneficial compounds we can't
make on our own

This partnership boosts energy
production and strengthens
overall health

Together, we've co-evolved for millions of years.

“We’re not just running on food,
we are manufacturing ourselves
out of food.”

“Food is both our fuel and our
construction material.”

David Katz, MD
Founding director of the Yale-Griffin Prevention Research Center

Core Dietary Principles for Optimal Energy

Build meals around plants + quality protein

Feed your gut microbiome
(high fiber, phytochemicals, fermented foods)

Include healthy fats (especially Omega-3s)

Minimize ultra-processed foods

Limit added sugars

Phytochemicals



Plants



You

Defense

Antioxidants

Attraction

Anti-inflammatory

Communication

Boost Energy

What protects the plants also protects you!

“Phytochemicals and Chronic Disease Prevention”



Nutrients
April 14, 2023

Plant-derived substances show:

Anticancer effects through multiple pathways

Antioxidant activity, anti-inflammatory effects

Inhibiting tumor cell growth and spread and stimulating immune function

“From phytochemicals to recipes: health indications and culinary uses of herbs and spices” Nature (npj science of food), May 29, 2025



Herbs and spices each contain
~3,000 phytochemicals on average

Connections between phytochemicals
and health indications mapped

Predict new relationships between
compounds and potential health
outcomes

Increase Fiber Intake Gradually

USDA and IOM recommend 26-38 grams/day

US average fiber consumption 10-15 grams/day

Start slow, microbes need time to adapt

Sean Paul Spencer, MD, PhD
Instructor, Medicine - Gastroenterology & Hepatology
Stanford University

I'm a superfood!



I'm magic. ✨



Fermentation

Microbes, like bacteria and yeast, break down food, creating new flavors, textures, and beneficial compounds.



Fermented Foods are Unique

Live microbes temporarily join gut community

Microbial byproducts:

- Provide fuel - more efficient ATP production

- Increase mitochondrial number

- Reduce inflammation

- Protect gut barrier

Dead bugs feed healthy gut bugs
and train immune system



Choose Healthy Proteins

Aim for Variety, Rotate

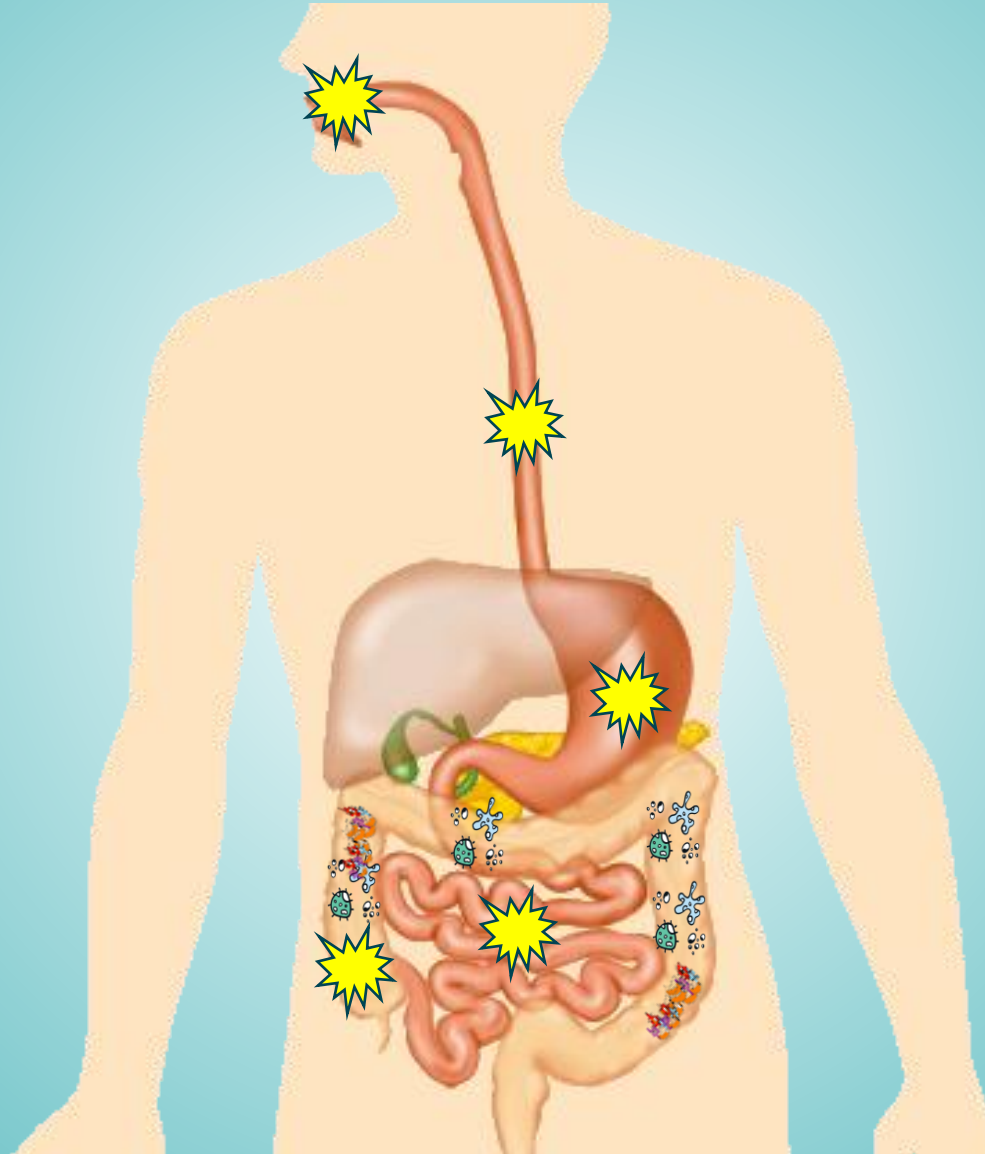


- Fish
- Poultry
- Beans & lentils
- Tempeh & tofu
- Beef

Limit Ultra-Processed Foods



Process of Absorption/Digestion



Ultra Processed Food Effect

Fiber/Phytonutrients Extracted

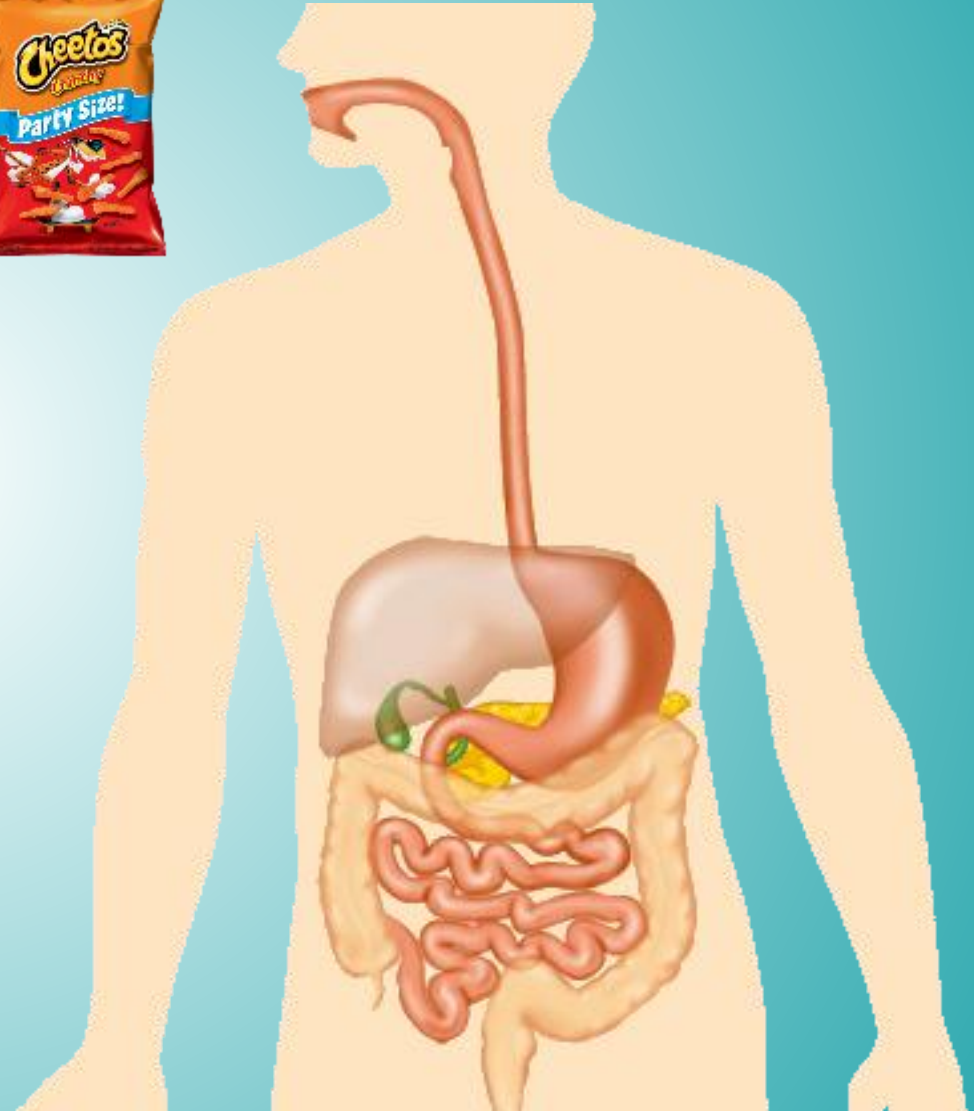
Speeds up Digestion

Absorbed Early in Small Intestine

All Calories Absorbed

Weak Satiety (fullness) Signals

Engineered Cravings



~~100~~

85

160



Case Study: Frito-Lay's "Vanishing Caloric Density"



Frito-Lay used EEG and fMRI studies to engineer their chips to dissolve quickly on the tongue, which **interferes with the brain's natural satiety signals** and triggers continued consumption (Moss, 2013)

Case Study: Kraft's Lunchables Brain-Optimized Packaging



Packaging featuring nutrition claims activated the parental approval centers in the brain, while bright colors and characters activated the children's reward centers

- Kraft redesigns Lunchables packaging
- Dual-targeted approach resulted in a 20% sales increase within 6 months

Early Brand Exposure = Lifelong Consumer Habits



Longitudinal study by Ellis et al., 2018, Journal of Consumer Psychology

Early Brand Exposure = Lifelong Consumer Habits



Longitudinal study by Ellis et al., 2018, Journal of Consumer Psychology

What is the Best Diet for
Your Bacteria...and You?

Mediterranean Dietary Pattern

For the general population, a Mediterranean diet with lots of plants and fiber remains the gold standard.

Ranked Best Overall Diet for 8 Consecutive Years by US News & World Report
Framingham Heart Study, UK Biobank, Baltimore Longitudinal Study on Aging

Shopping Strategies - Diversity Matters



Farmer's Markets

Natural and Organic
Grocery Stores

Organic Section of
Supermarket

Frozen Vegetables
and Fruits

Choosing Produce

Dirty Dozen



Clean 15



2024 Lists from the Environmental Working Group (EWG)

Tucson Village Farm

2201 E Roger Rd, Tucson, AZ



Cooperative Extension



SuppCo

Scan Barcodes of Supplements

Detailed Assessment of Product Quality



Yuka

Scan Barcodes of Food and Cosmetics

Assess Impact on Health

Key Messages

Humans live in partnership with trillions of microbes, especially in the gut.

Dietary fiber, fermented foods, and phytochemicals are the main fuel for your bacterial partners.

Processed foods high in sugar, fat, and additives starve or damage beneficial bacteria.

Aim for 30 Plants/wk → diversity in microbes → resilience and health

Think “feed the bugs first” — if your microbes are healthy, your whole body runs better.



Plant Power

Ignite the
Energy of Life