PINE BROOK

The Carbon Problem: A New Perspective

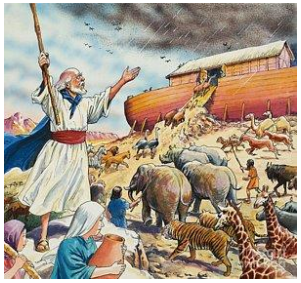
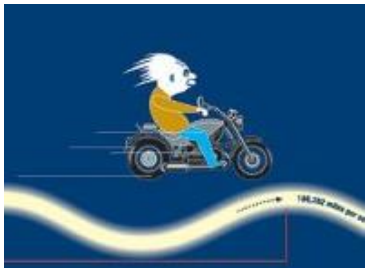
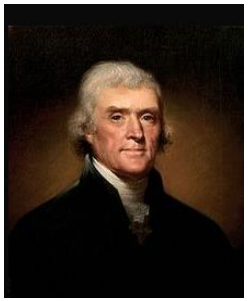
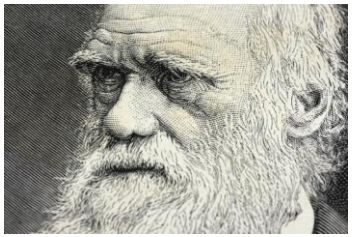
Howard H. Newman, Chairman and Chief Executive Officer

October 30, 2018

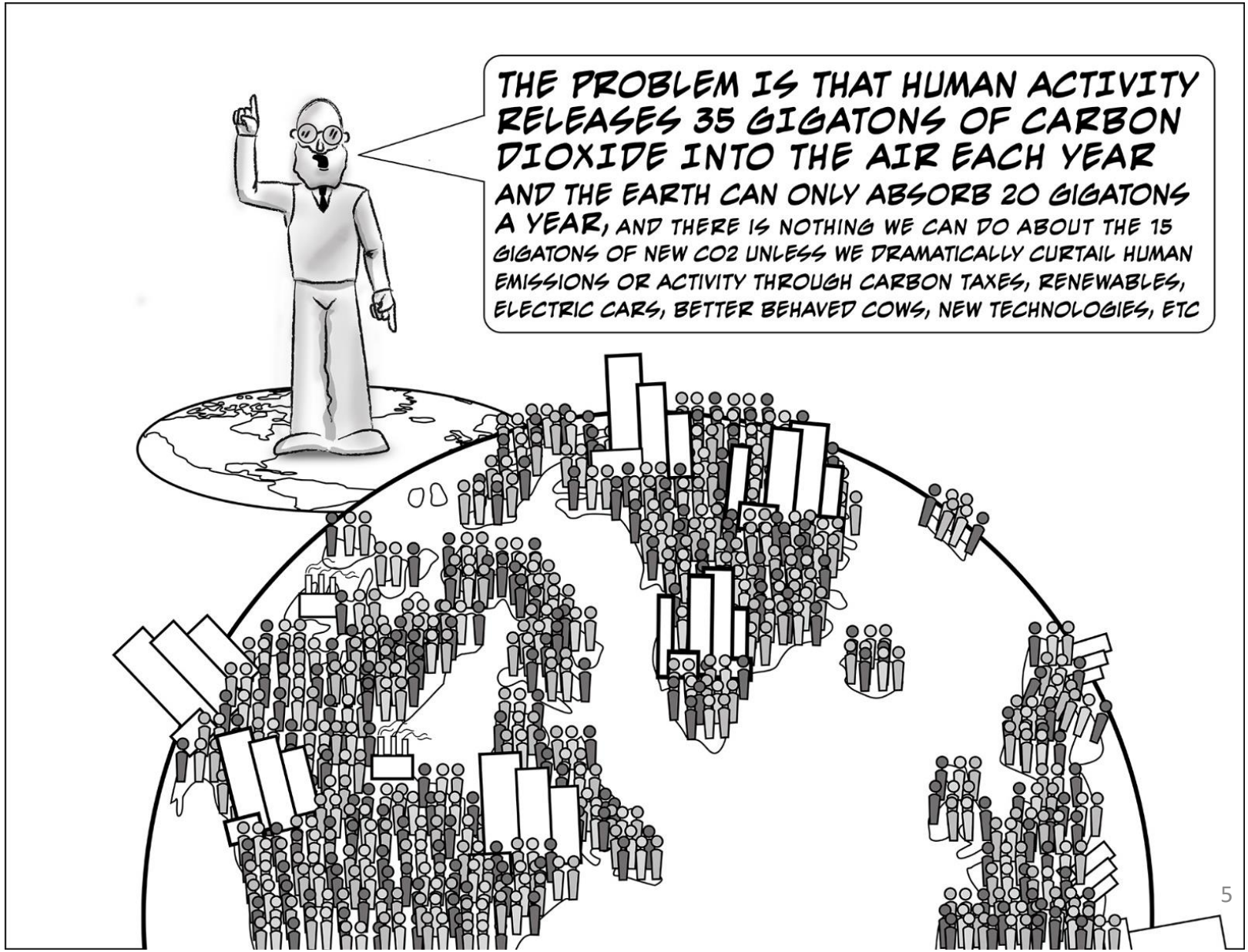

HARNESSING
PLANTS
To Fight
Climate
Change

Sometimes, It Depends on How You Look at Something

For Example…

Gravity	Rights of Man	Speciation	Computing
			
Newton	***The Divine Right of Kings***	***Noah's Ark***	***Bill Gates***
			
Einstein	***Certain Unalienable Rights***	***Darwin***	***Steve Jobs***

The Problem as We See it Today



The Math of Old Thinking

(in $GtCO_2$)	
Human Emissions	37
Natural Absorption	(19)
Net Increase	**18**

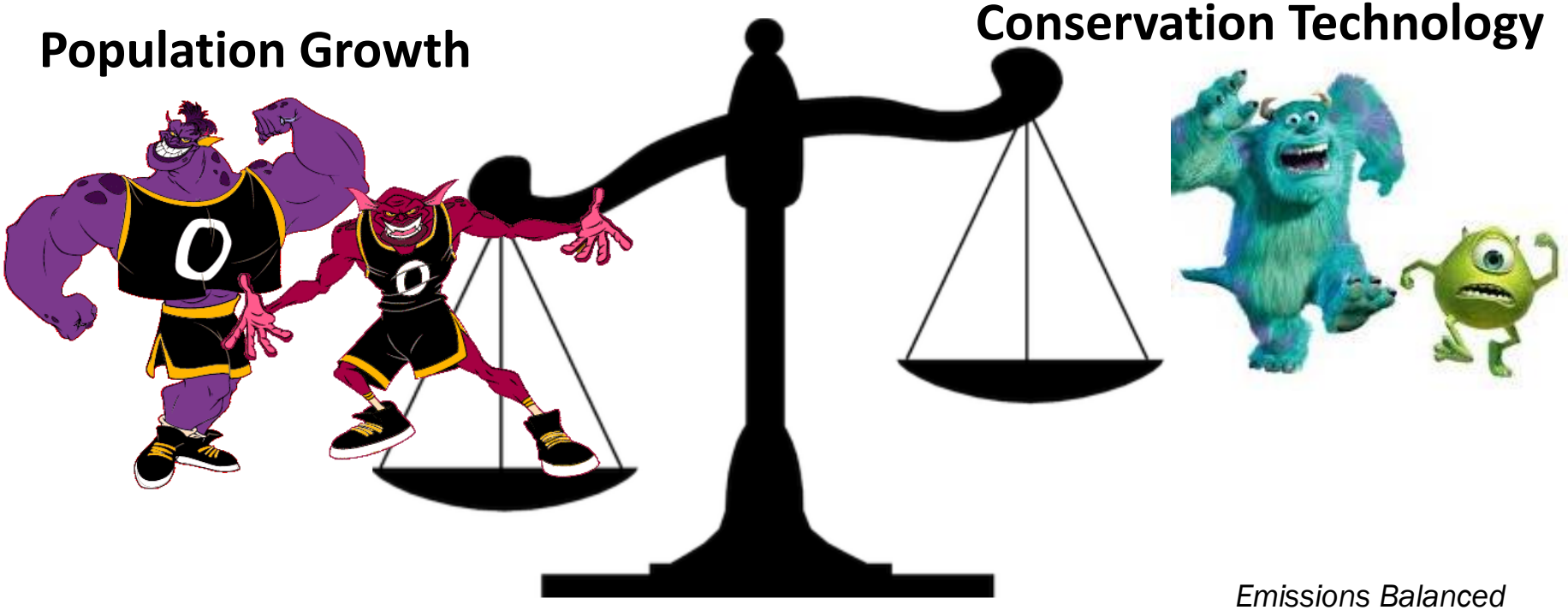
Difficult Imbalance to Overcome

Income Growth

Population Growth

Behavioral Change

Conservation Technology

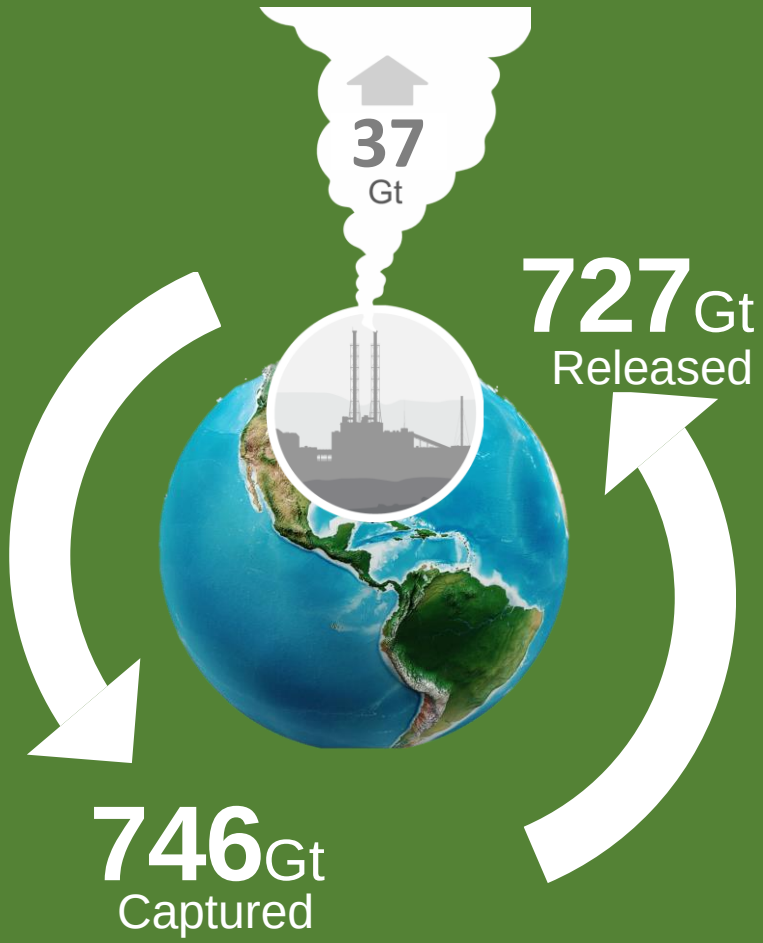


($ in millions)	1988 (IPCC 1)	2017 (IPCC 5)	*Emissions Balanced* 2040 (estimated)
Global Data			
GDP (Current US$ trillions)	$19.2	$80.7	$207.0
Population (billions)	5.1	7.5	9.2
Annual CO2 Emissions (GtCO2)	21.8	36.8	20.0
Emissions / Person	4.3	4.9	2.2

Sources: GDP: St. Louis FRED, PwC. Population: The World Bank, United Nations Population Division, Census reports from national statistical offices, Eurostat, U.S. Census Bureau, Secretariat of the Pacific Community. Emissions: Global Carbon Project, National Oceanic and Atmospheric Administration.
Note: GDP reflects market exchange rates in current US $.

We Need to Reframe the Problem

The Math of New Thinking



(in $GtCO_2$)	
Natural Absorption	(746)
Natural Release	727
Human Emissions	37
Net Increase	**18**

18 Gt of CO_2 more per year than the earth can handle

It's impractical to believe that changes in human behavior will reduce emissions by almost 50%

Consider:

- Population will grow by 25% over the next 25 years
- Middle class population may double
- Global economy will more than double


Salk scientists believe:
Increasing plant efficiency by 2% is more viable than a 50% reduction in human CO_2 contribution

Biological Sequestration – The 2% Solution

- Plants are quite good at pulling CO2 from the air. In fact, they pull more and more each year.
- In North America, the CO2 concentration varies seasonally by 64-100 gigatons (8-12ppm)
- Nearly all of the CO2 captured by crops is quickly returned to the atmosphere. Unless it is buried somewhere.
- The challenge is to breed plants with large, long-lived roots that are also protected by forms of carbon that bacteria and fungi – microbes – don't eat when the plant dies

Step One: Increase Root Mass

- Recent Salk research has shown how a single gene can alter root architecture in a model plant by changing how the plant responds to gravity, and in the process, grow deeper and more extensive roots without noticeably affecting the plant above ground.
- Other research groups have found a second gene that works in a similar manner in many different plants.
- But simple burying is not enough. Rapid decomposition must be avoided.

Step Two: Add Suberin

- Suberin is the cork that seals most fine wines.
- Suberin is common. It is the netting on cantaloupe rinds, the peel of avocados, the thick bark on certain trees, and the skin on potatoes. It even exists in short-lived annuals where suberin-rich cork cells exist in their roots
- Bury each of these in a compost bin, return months and even years later, and the cork, the netting, the bark, and the peels remain!
- **Suberin is highly resistant to decomposition and can maintain its molecular form for hundreds, or perhaps thousands, of years**

Step Three: Add Water and Stir

- Seagrass and other coastal marine plants are naturally high in suberin
- The evolutionary key to seagrass survival in the oceans is their ability to make large amounts of suberin in their roots
- 50% of all seagrass habitat has been lost since 1990
- Researchers can select seagrass varieties that flourish in harsh environments by enhancing their already substantial suberin levels.

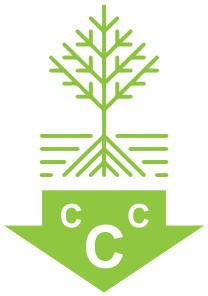
More Powerful than a Locomotive…

- Recent research has shown that a gene for deeper rooting can almost triple the size of some root systems without affecting plant height.
- Other studies have shown it is possible to increase suberin levels by more than 1,900 percent in leaves
- By increasing root depth and biomass and increasing the suberin content, carbon sequestration per acre can be increased by 20 times
- And coastal marine plants can be 30x more efficient at carbon sequestration than terrestrial plants

A better way to get to 50%

Approach One
TERRESTRIAL

1.



Store more carbon to sequester 25% + of human emitted CO2 per year

Approach Two
MARINE

2.

Select from existing species to restore sea beds and sequester 25%+ human emitted CO2

Why Now?

- Biology has evolved in the last 10 years to make it possible:
  - Joanne Chory has discovered multiple pathways that regulate plant form and size in response to the environment
  - Joe Ecker has led sequencing of the first plant genome and mapped the first plant epigenome
  - Joe Noel has uncovered the blueprints used by plants to produce chemical compounds
  - Wolfgang Busch has identified multiple key genes for regulating root growth
  - Julie Law has identified mechanisms for epigenetic regulation

You Can’t Make Bricks Without Straw

What's the Plan?

10-Year Plan

2018

- Complete build-out of Salk climate simulation lab
- Hire key personnel
- Identify genes that give model plants long roots
- Begin collecting seagrasses with collaborators
- Analyze public genome sequences of seagrass
- Survey germ cell genomes from model plants for natural variations in suberin
- Model the optimal suberin- enhanced root system

2020

- Determine the regulatory mechanisms that govern suberin accumulation in model plants
- Model future terrestrial and marine environments to predict defining survival features and test models in climate simulation lab
- Begin testing seagrass adaptations climate simulation lab
- Begin talks with stakeholders and policymakers

2023

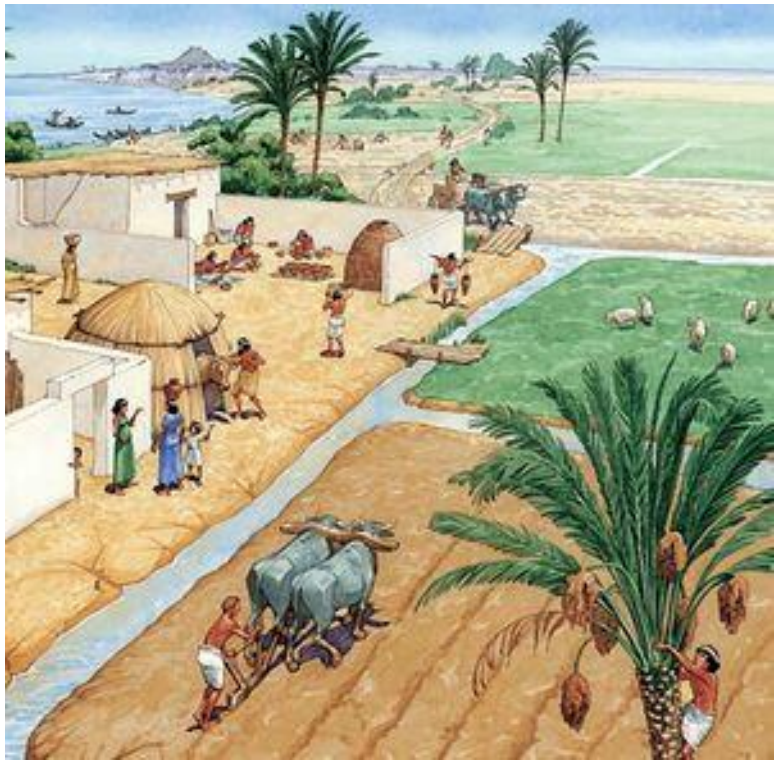
- Produce prototypes of carbon-sequestering Lotus and seagrass varieties
- Identify sites for field trials
- Identify food legumes for the next generation of Salk® Ideal Plants™
- Identify food crops for enhanced suberin production
- Begin seagrass repopulation

2028

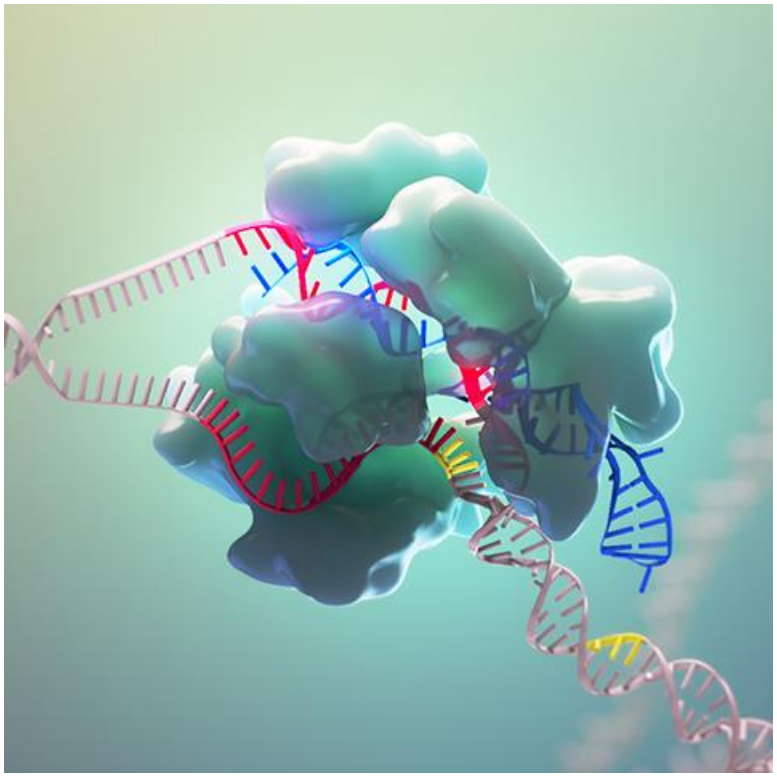
- Produce seeds for first Salk® Ideal Plants™ (Lotus japonicus) for global planting
- Complete seagrass distribution and repopulation in depleted sites
- Begin seed production for carbon-sequestering food crops

Let 1,000 Plants Bloom

Neolithic



Modern Biology



Resistance Movement

- It's too good to be true
- Doesn't require:
  - Big carbon tax
  - Behavioral change
  - Reduced fossil fuels
- Competes with existing initiatives
- Market, not fiat, driven


HARNESSING
PLANTS
The
Natural
Solution

“Our greatest responsibility is to be good ancestors.”

Jonas Salk