



SCALE: THE UNIVERSAL LAWS OF LIFE, GROWTH & DEATH IN ORGANISMS, CITIES, & COMPANIES

Professor Geoffrey West, Distinguished Shannan Professor & Former President, Santa Fe Institute

Webinar

Thursday, 02 September 2021, 15:00 BST

A Word From Today's Chairman



Professor Michael Mainelli

Executive Chairman

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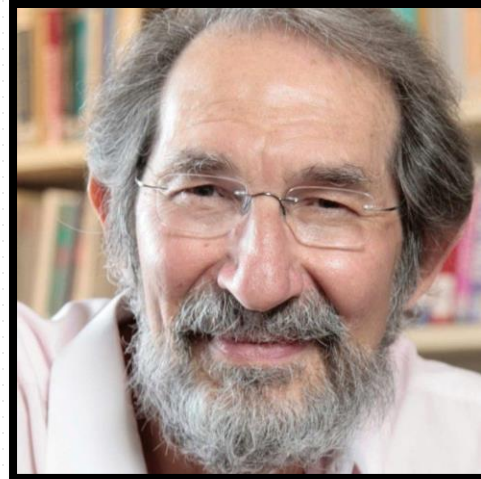
GIBRALTAR STOCK EXCHANGE

Today's Agenda



- 15:00 – 15:05 Chairman's Introduction
- 15:05 – 15:25 Keynote Presentation – Professor Geoffrey West
- 15:25 – 15:45 Question & Answer

Today's Speaker



Professor Geoffrey West

Distinguished Shannan Professor & Former President

Santa Fe Institute

SCALE

***THE UNIVERSAL LAWS OF GROWTH, LIFE AND
DEATH IN ORGANISMS, CITIES AND
COMPANIES***

GEOFFREY WEST

SANTA FE INSTITUTE

GREEN-TEMPLETON COLLEGE, OXFORD UNIVERSITY





***AVERAGED FROM FROM NOW TILL
2050 WE ARE URBANISING OVER ONE
MILLION PEOPLE EVERY WEEK***

***AVERAGED FROM FROM NOW TILL
2050 WE ARE URBANISING OVER ONE
MILLION PEOPLE EVERY WEEK***

***EQUIVALENT TO ADDING A METROPOLITAN
LONDON EVERY COUPLE OF MONTHS***

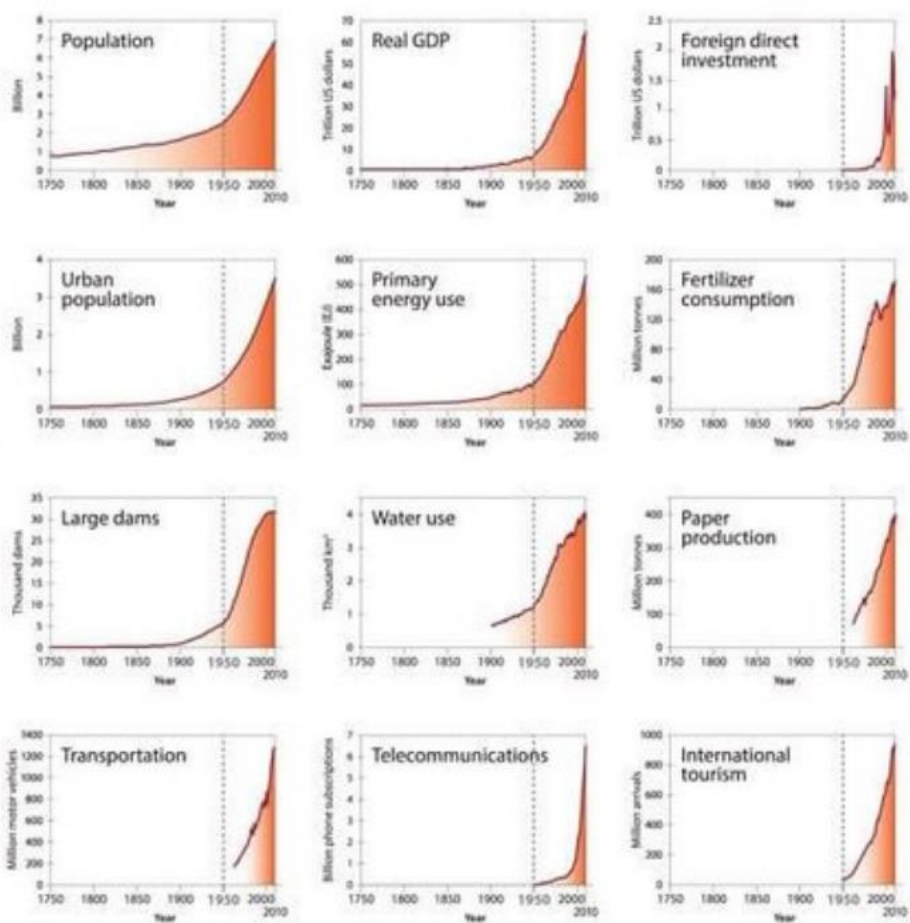
***AVERAGED FROM FROM NOW TILL
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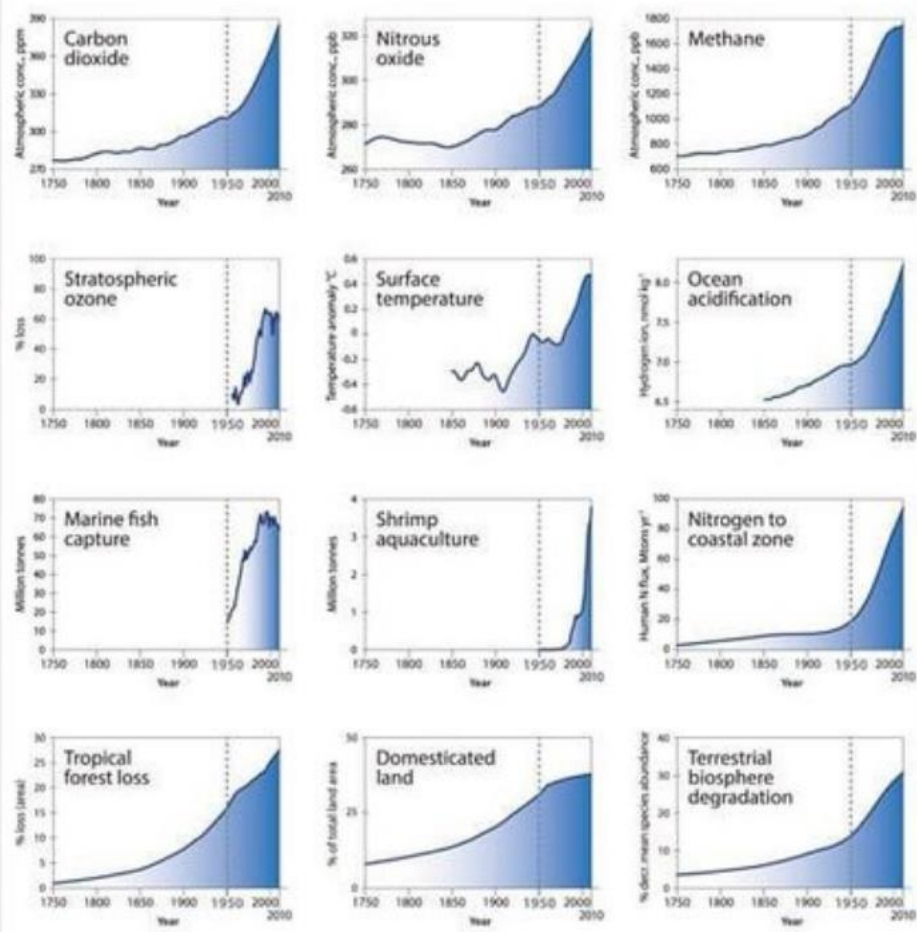
OR.....A TAUNTON OR OXFORD EVERY DAY

THE GREAT ACCELERATION

Socio-economic trends



Earth system trends



Updated Great Acceleration Graphs

Source: Will Steffen et al. "The trajectory of the Anthropocene: The Great Acceleration." *The Anthropocene Review*, March 2015

A night cityscape featuring a complex highway interchange in the foreground and a dense skyline of illuminated skyscrapers in the background. The scene is framed by a large, light-colored diamond shape with a circular cutout in the center. The background is a dark, textured blue.

FATE OF OUR PLANET IS
the fate of our cities









**THE CITY IS THE MARVELLOUS MACHINE WE
DEVELOPED FOR FACILITATING THE
CREATION OF**

**THE CITY IS THE MARVELLOUS MACHINE WE
DEVELOPED FOR FACILITATING THE
CREATION OF**

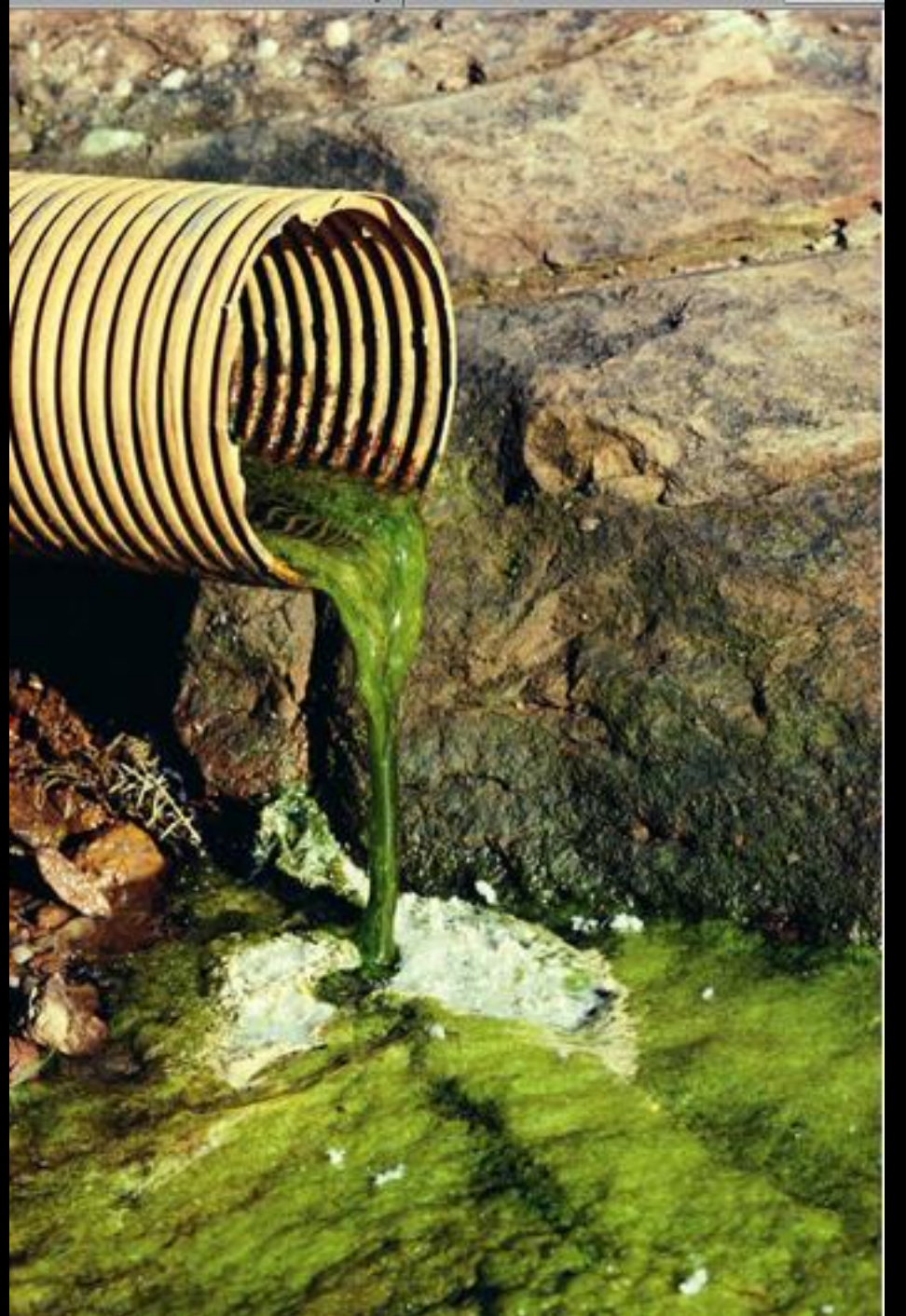
- ***WEALTH***
- ***KNOWLEDGE, INNOVATION AND IDEAS***
- ***INCREASED STANDARDS & QUALITY OF LIFE***

**BUT UNINTENTIONALLY (AND INEVITABLY!) IT
ALSO CREATES**

SOCIAL ENTROPY:









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Classified



FRIDAY

**MASSIVE
INCREASE
IN KNIFE
CRIME
SURVEYS**

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www.thisisweston.com



DISEASE AND PANDEMICS!



AND SOCIAL UNREST!



London After Climate Change?



FIRST QUESTIONS:

I. IS THIS SUSTAINABLE?

YES

NO

II. IF YES, FOR HOW LONG?

10 YEARS

100 YEARS

INDEFINTELY

***CITIES ARE QUINTESSENTIAL COMPLEX
ADAPTIVE SYSTEMS***

***ENERGY & RESOURCES
(METABOLISM, INFRASTRUCTURE)***

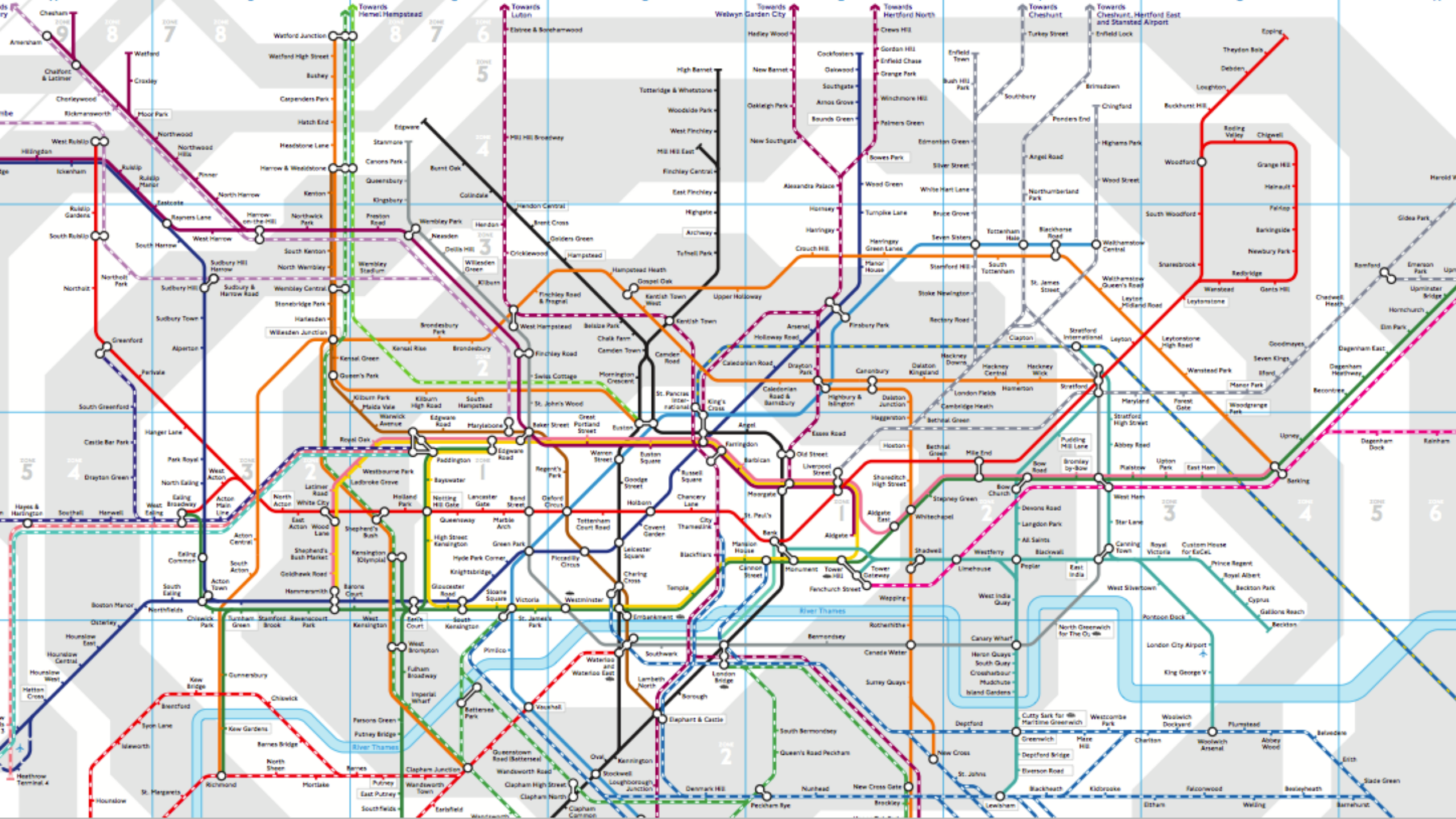


***INFORMATION
(GENOMICS, INNOVATION)***

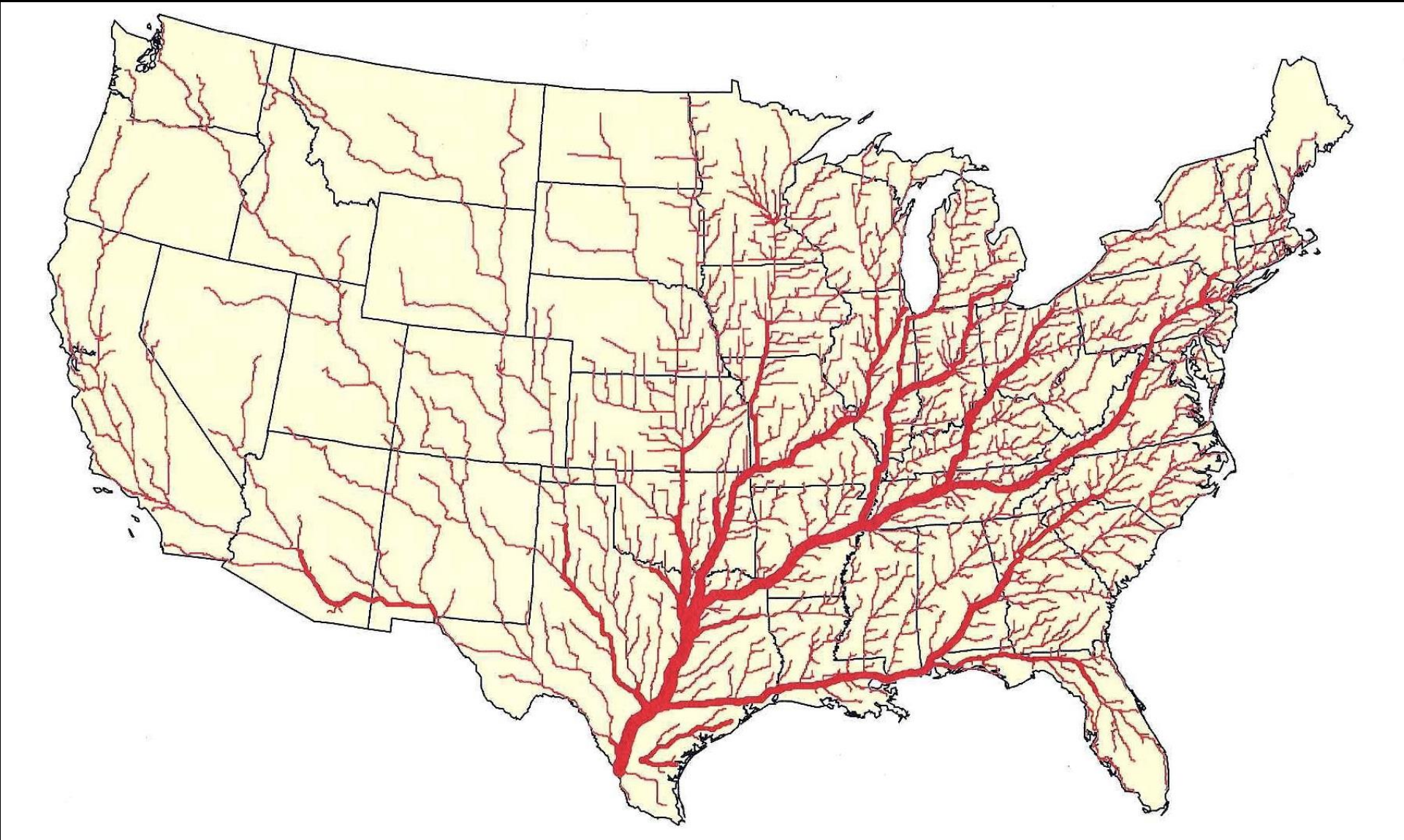


NETWORKS









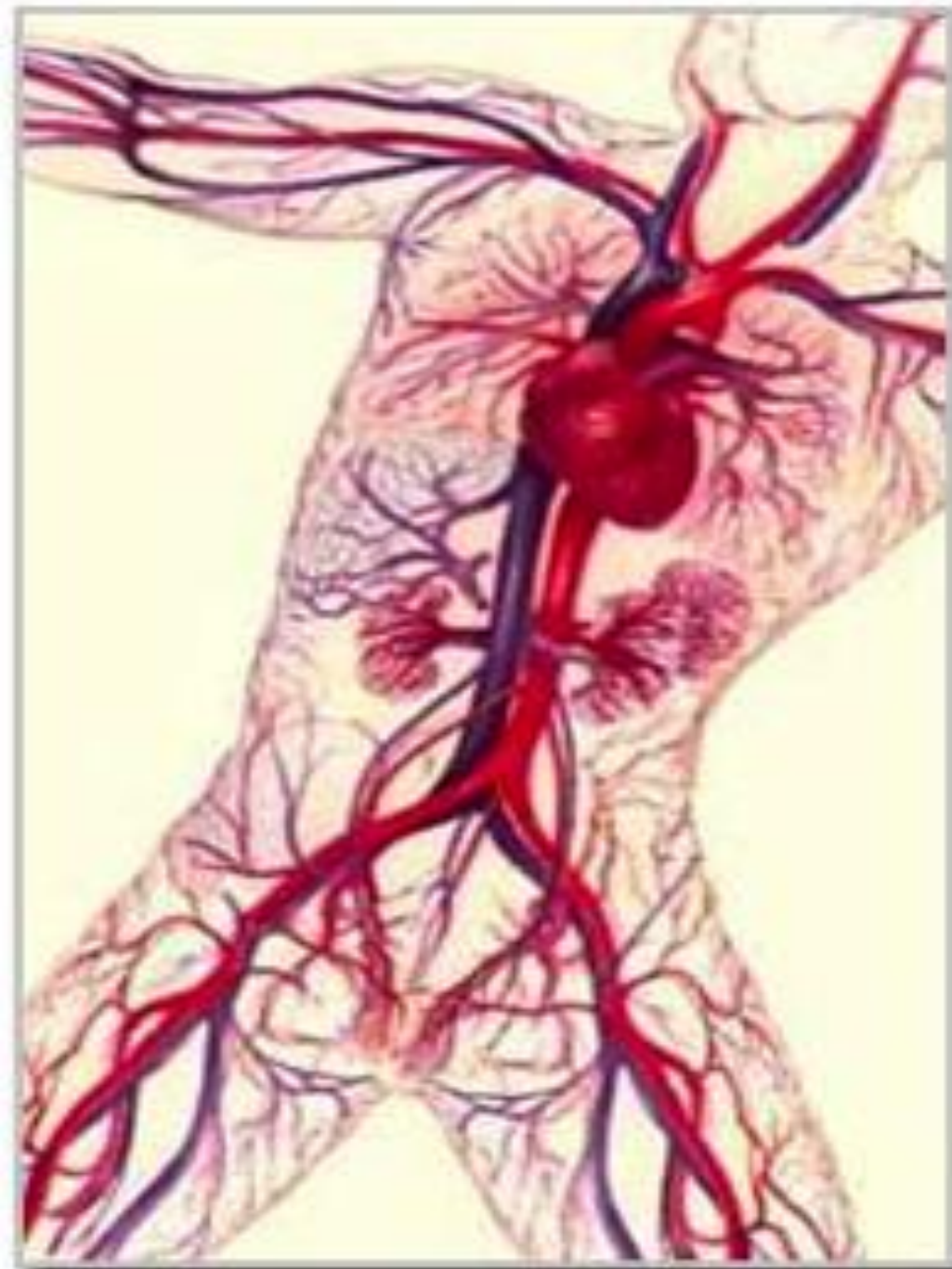
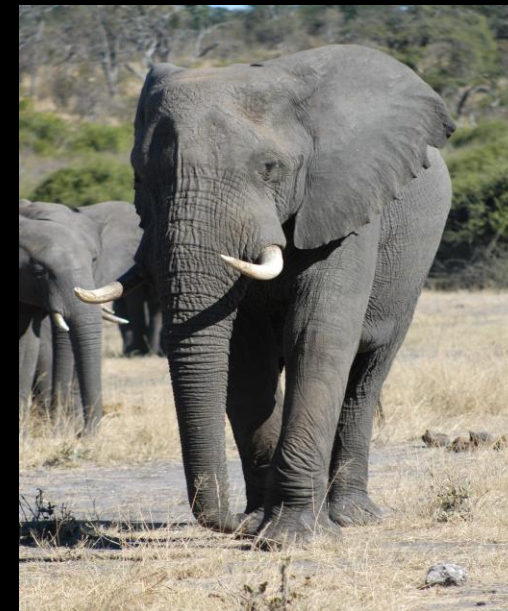
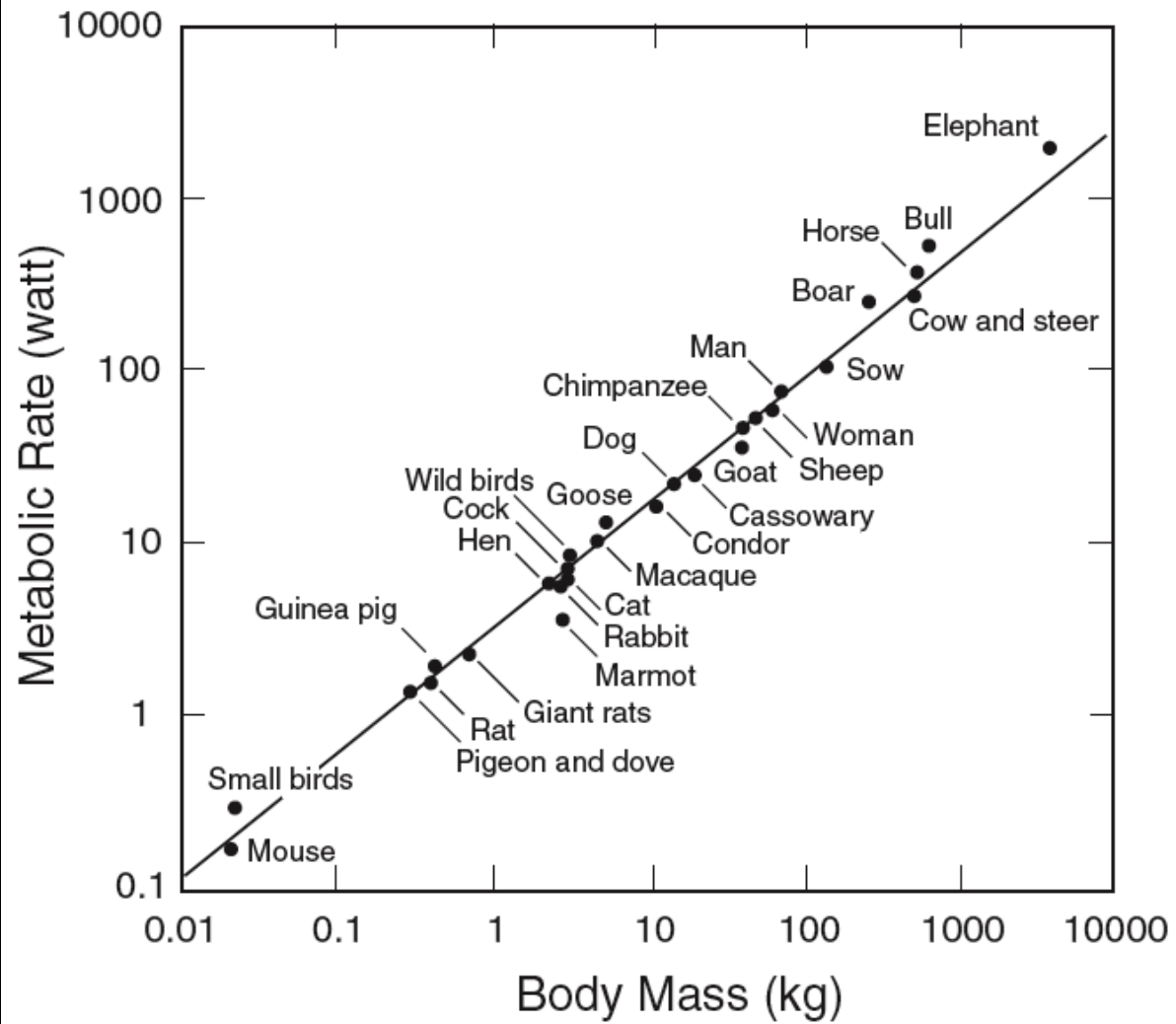




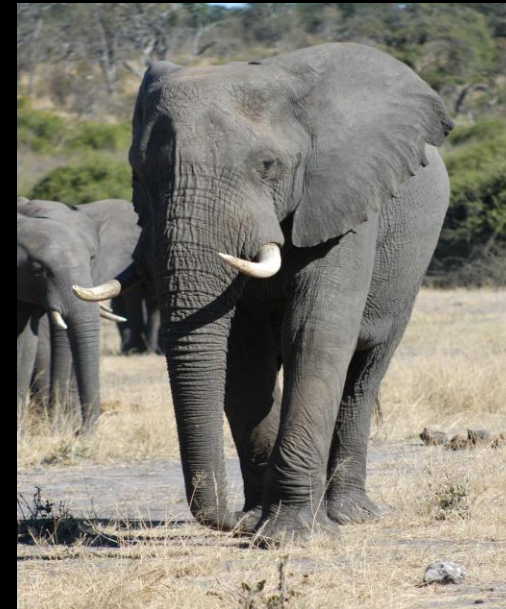
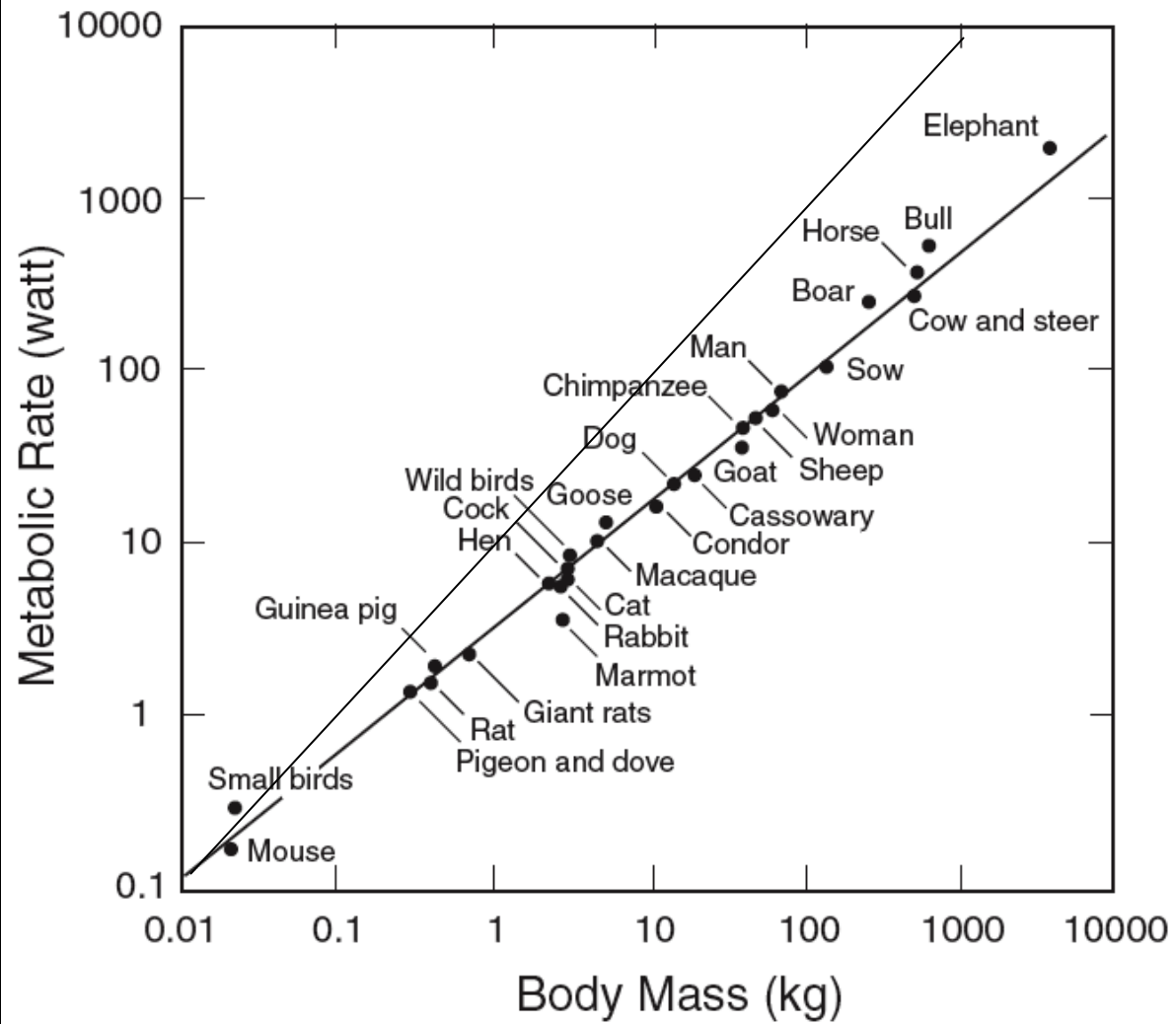
Figure 5: A slice through the cerebellum showing the progressive branching structure of white matter is distributed throughout the cerebellar volume. The geometric complexity of these structures provides for rapid dissemination of information (or nutrients) via a large surface area in a compact space. This feature is a hallmark of structures which maximize the surface area within a finite volume.

Relation between number and size of branches within a tree





SLOPE = $\frac{3}{4} < 1$ SUB-LINEAR ECONOMY OF SCALE

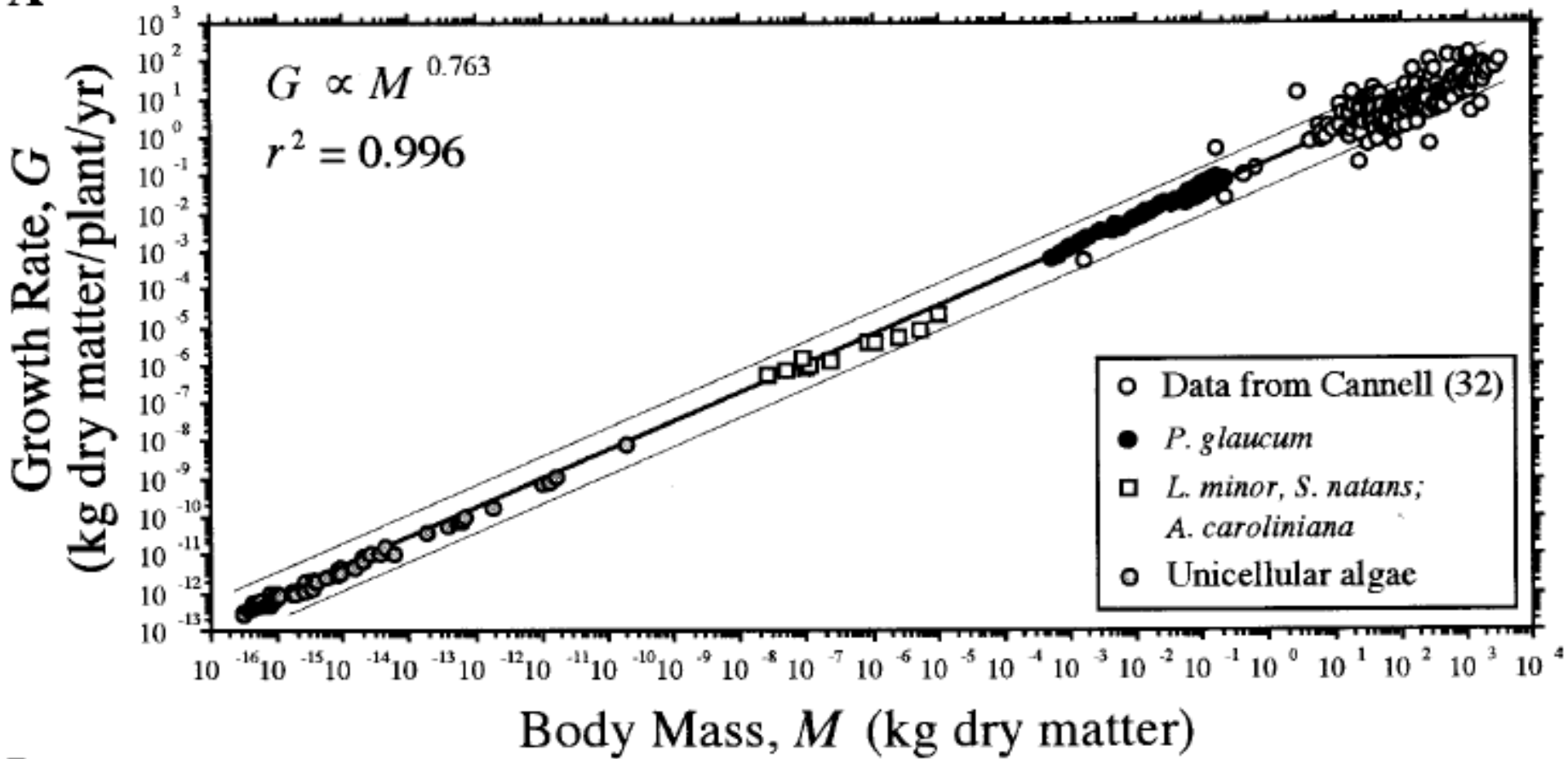


SLOPE = $\frac{3}{4}$ < 1 SUB-LINEAR ECONOMY OF SCALE

***SURPRISINGLY SYSTEMATIC
ECONOMY OF SCALE (THE BIGGER
YOU ARE, THE LESS NEEDED PER
“CAPITA”)***

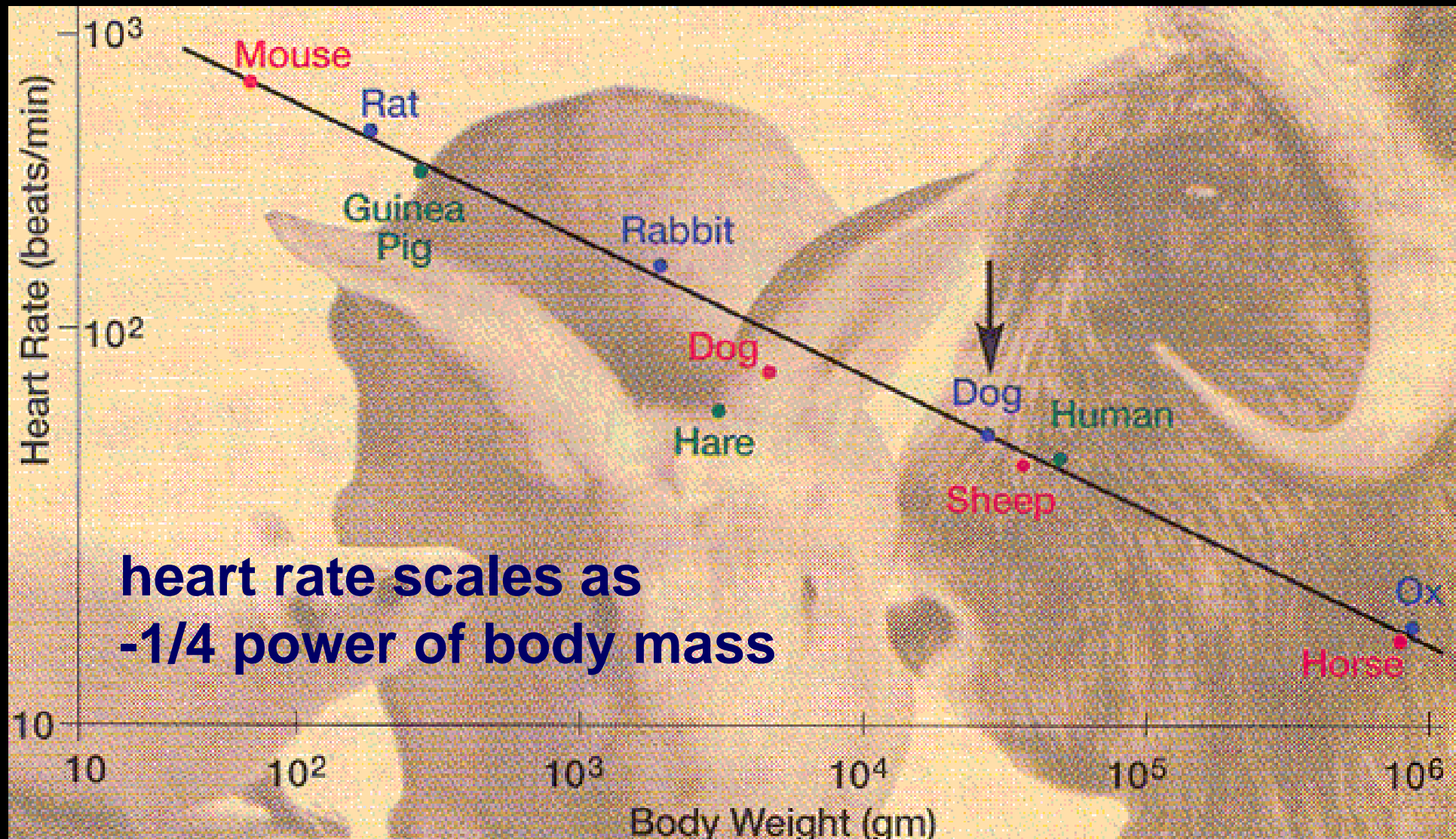
***SIMILAR SCALING HOLDS TRUE
FOR ALL PHYSIOLOGICAL
PROCESSES AND LIFE HISTORY
EVENTS OVER THE ENTIRE
SPECTRUM OF LIFE***

A

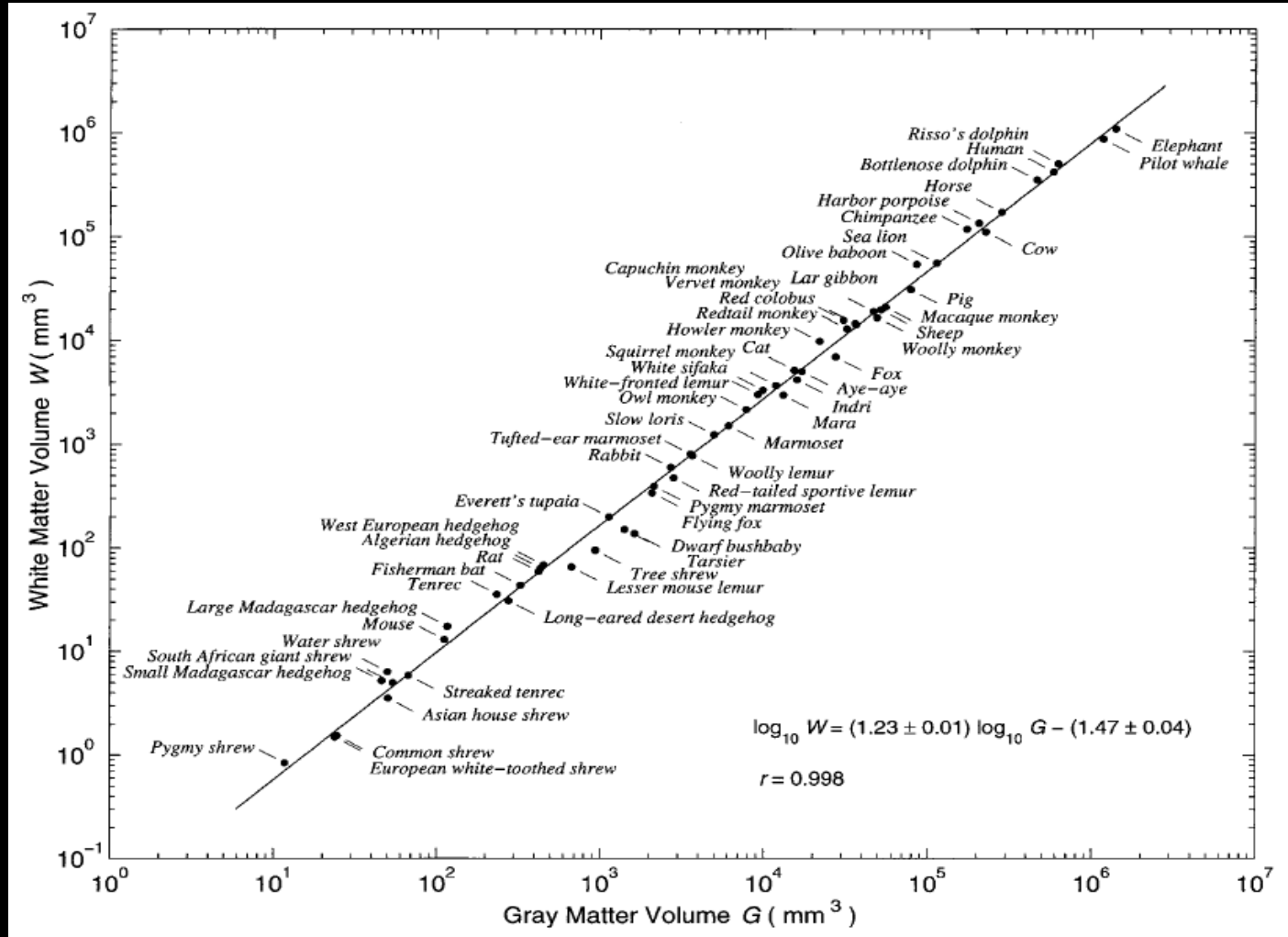


Metabolic rate sets the pace of life

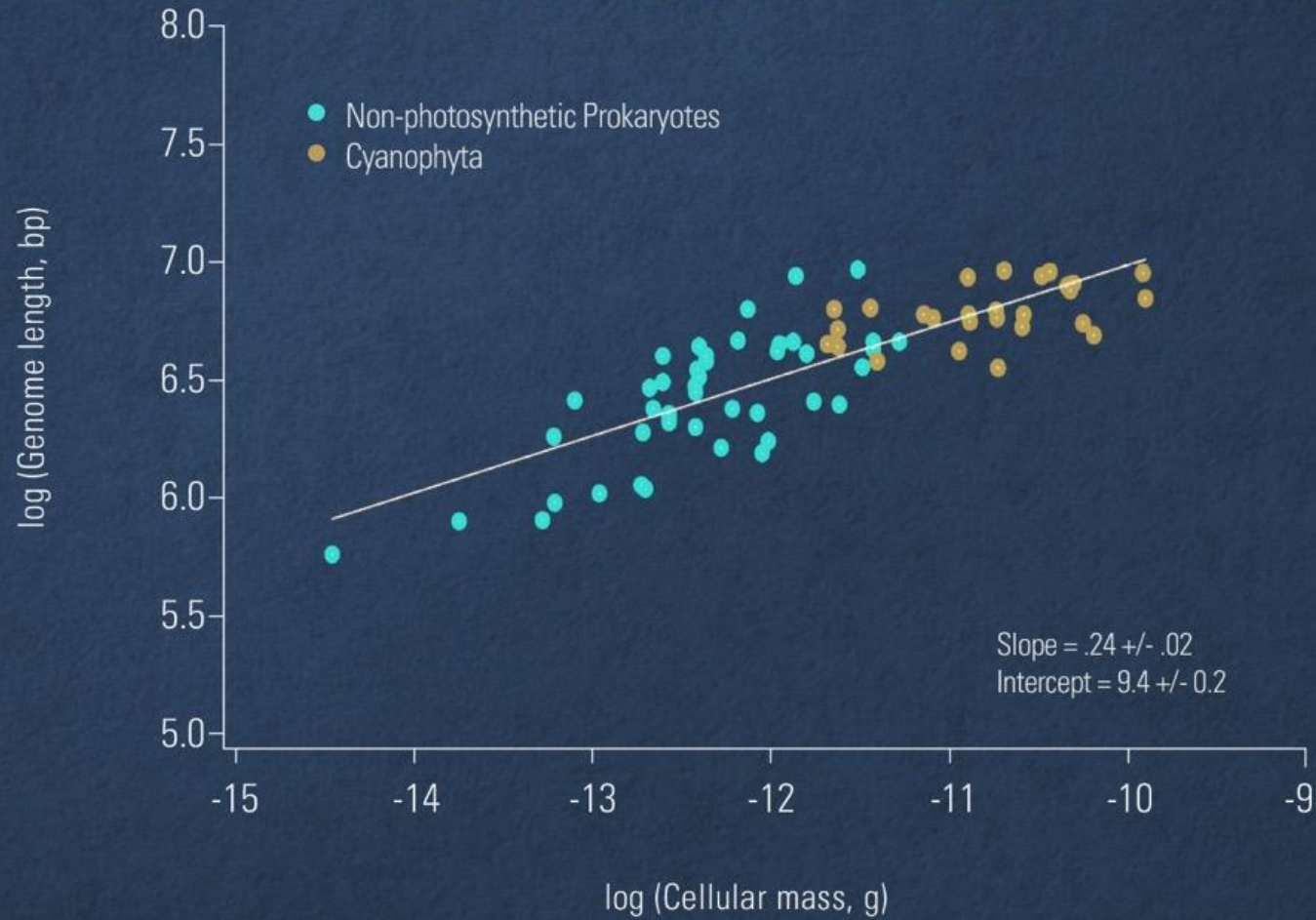
Small animals live fast and die young



WHITE & GREY MATTER IN BRAINS

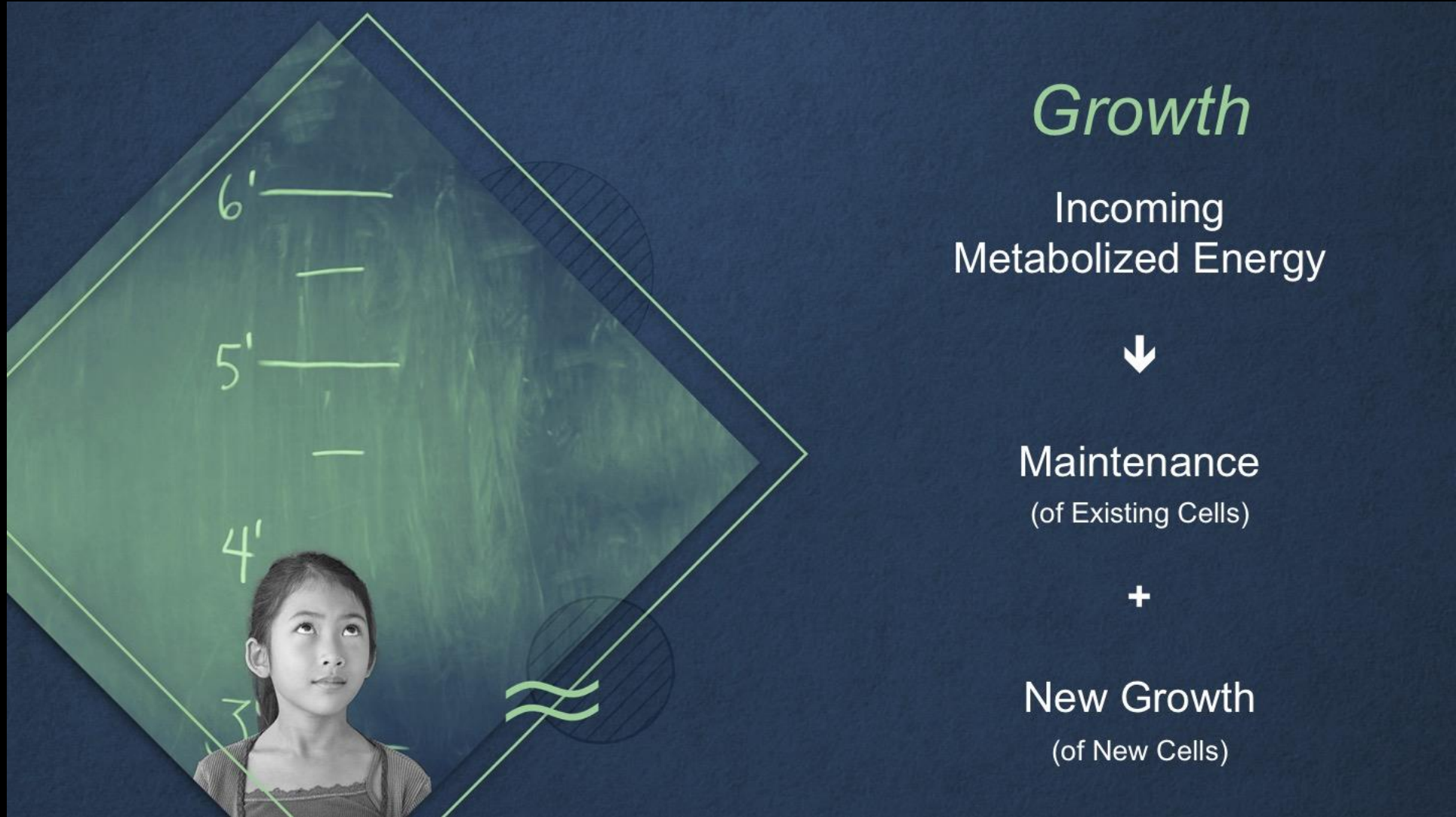


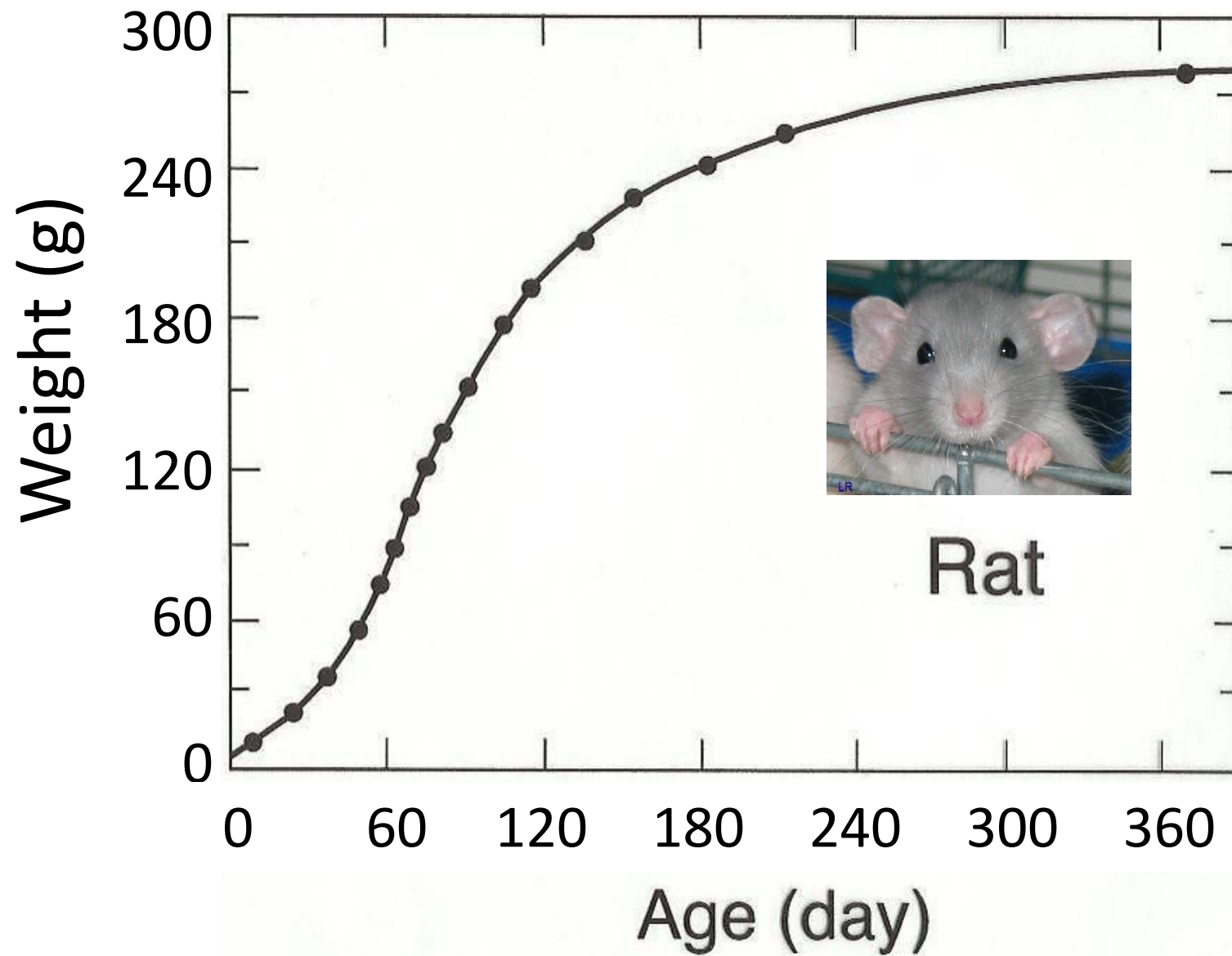
DEPENDENCE OF GENOME LENGTH ON CELLULAR MASS



Slopes (exponents) are typically
sub-linear and simple multiples of $\frac{1}{4}$

“quarter-power scaling”

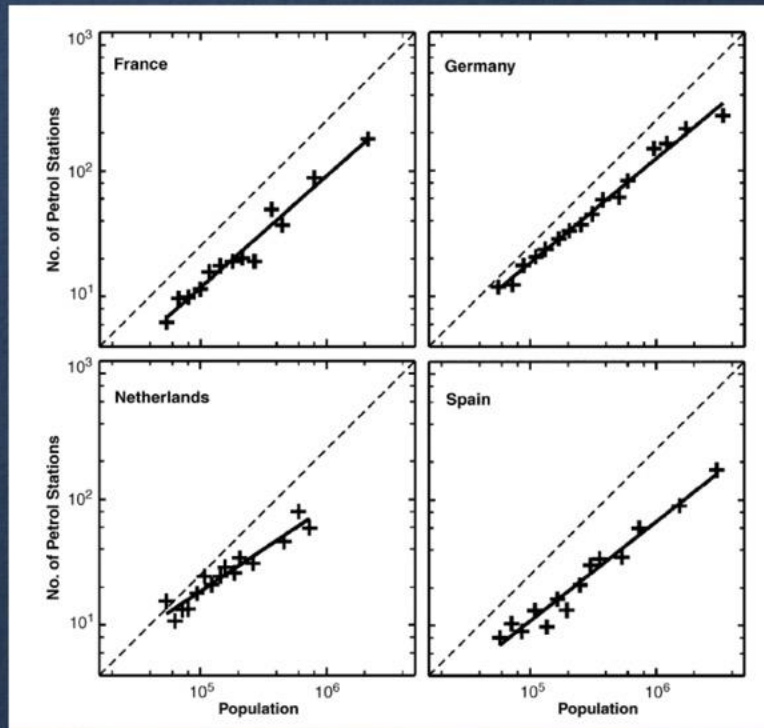




**SUB-LINEAR SCALING
LEADS TO BOUNDED GROWTH**

HIDDEN LAWS OF BIOLOGY \longrightarrow HIDDEN LAWS OF CITIES

NUMBER OF PETROL STATIONS VS. POPULATION

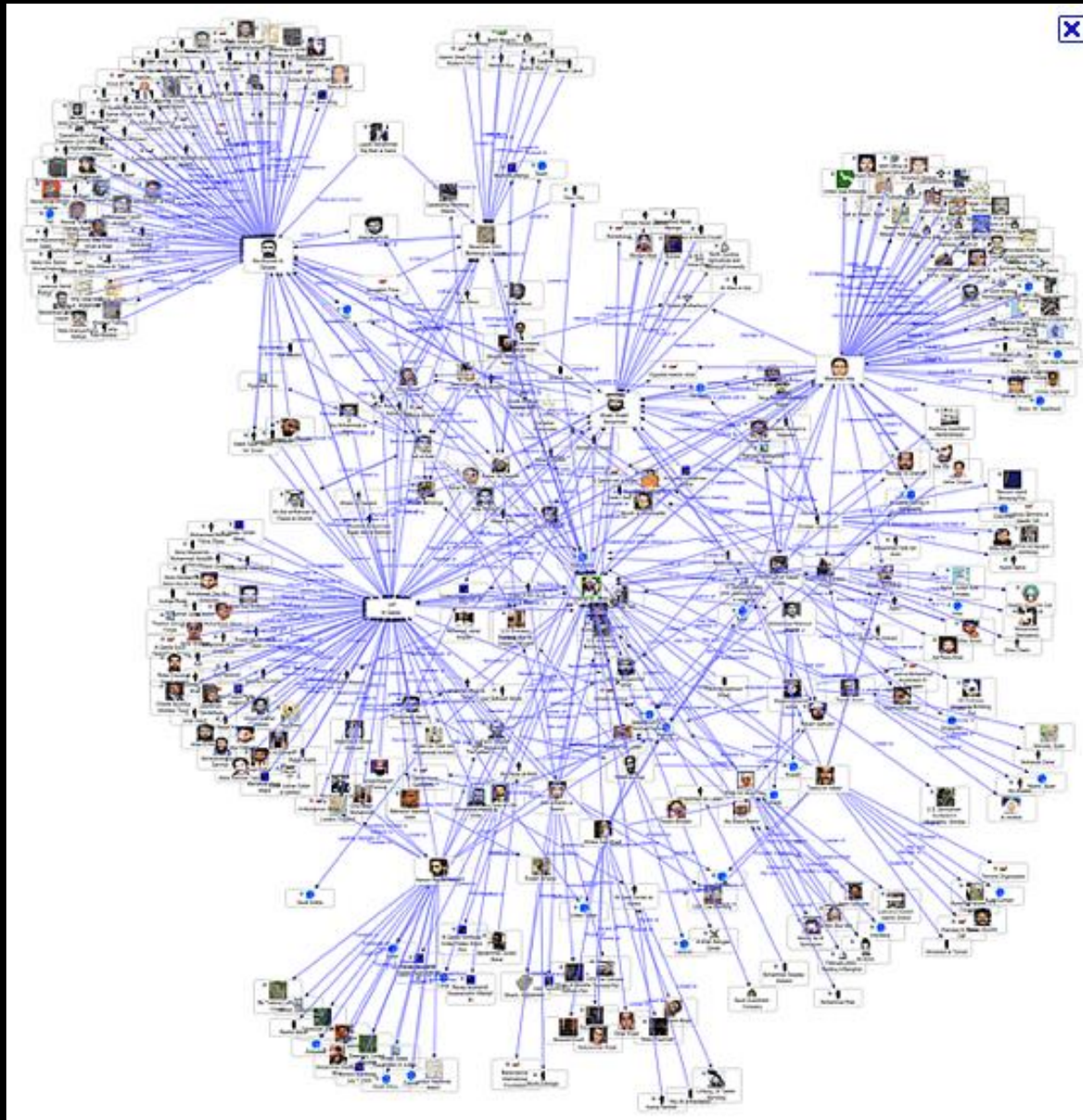


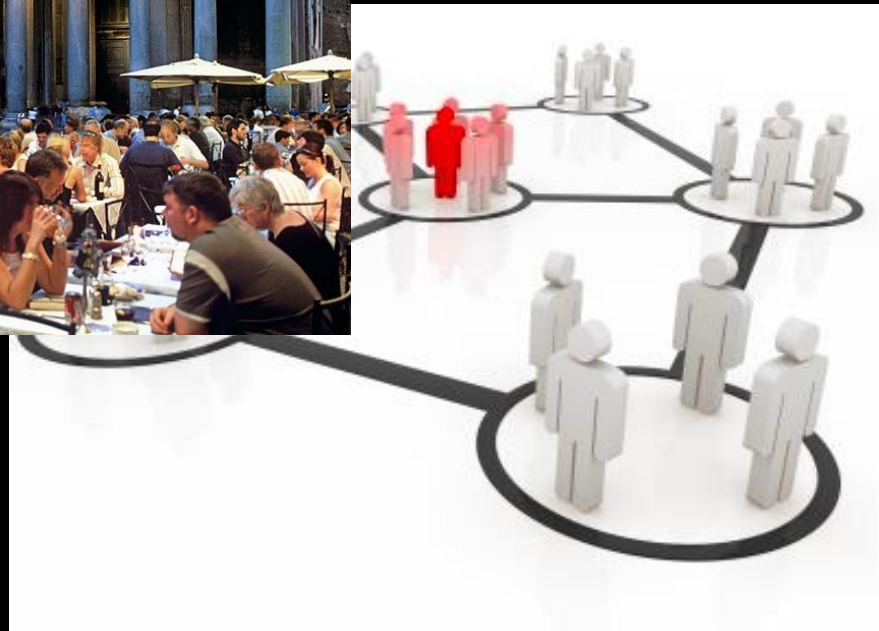
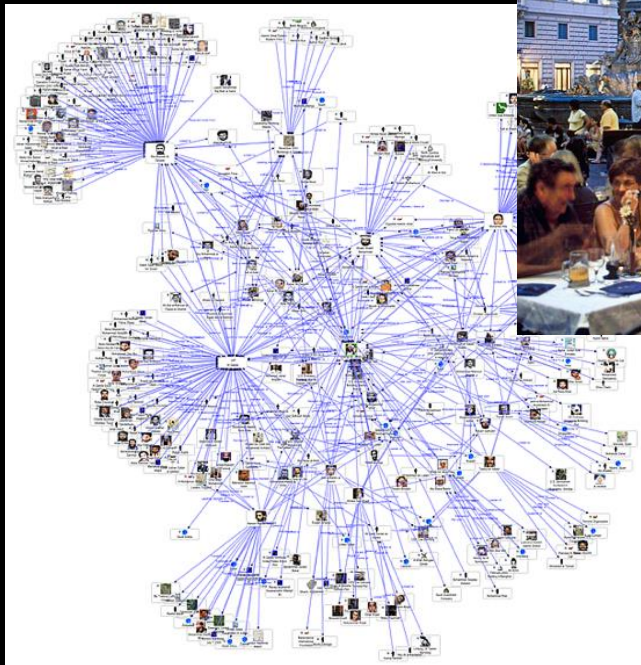
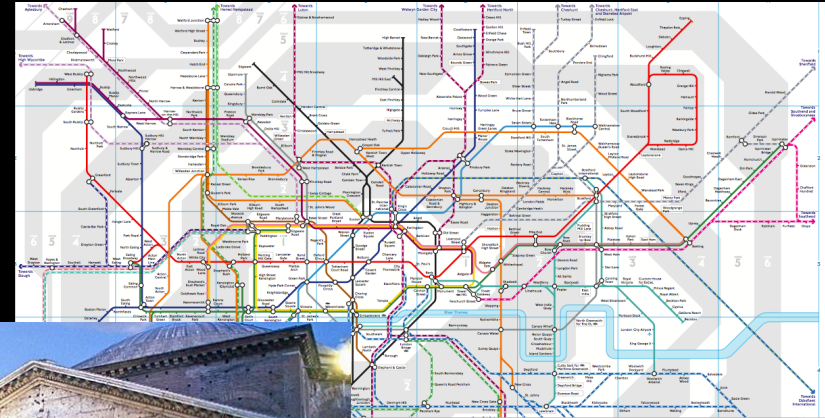
INFRASTRUCTURE

SUB-LINEAR SCALING

ECONOMY OF SCALE

SOCIAL NETWORKS



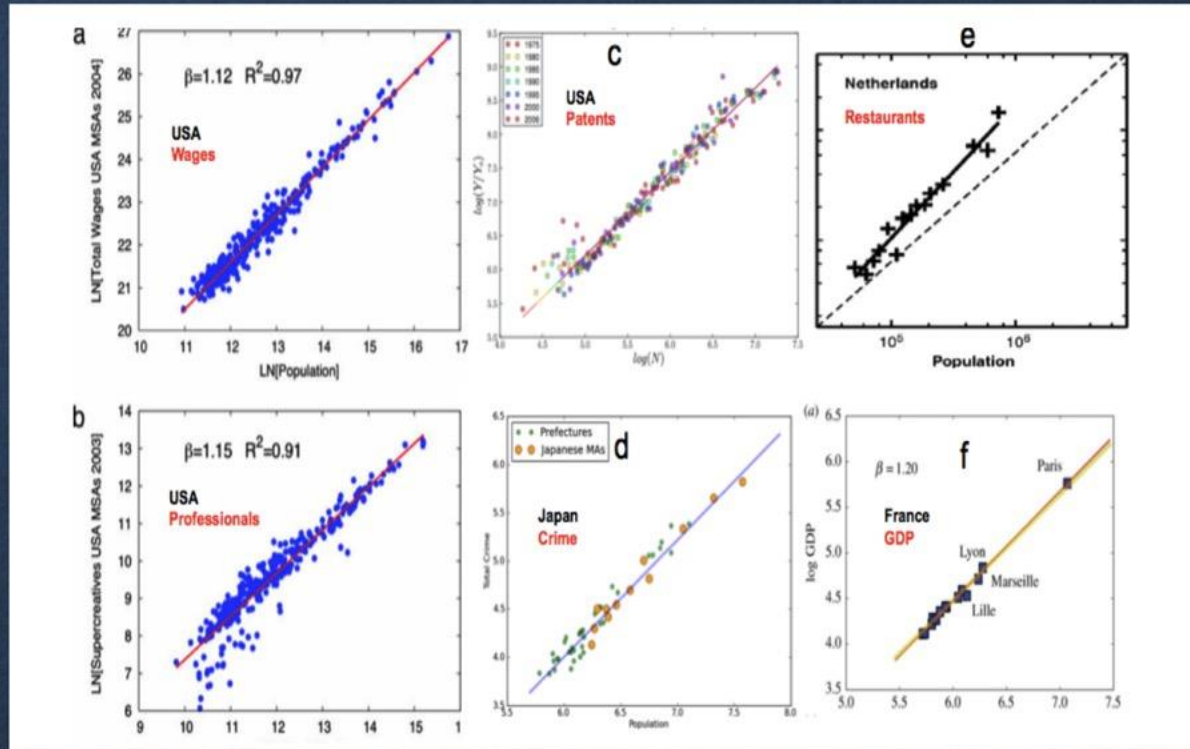


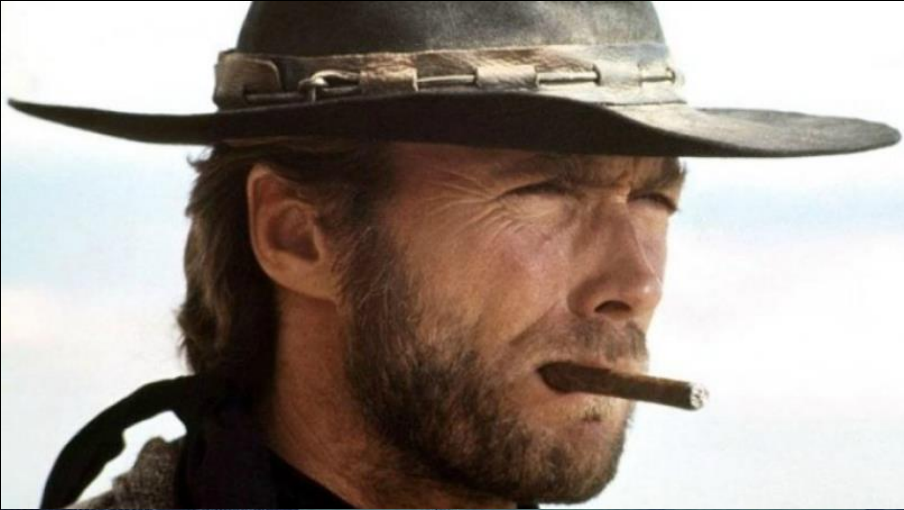
**POSITIVE FEEDBACK MECHANISM IN
SOCIAL NETWORKS**



**SUPERLINEAR SCALING & INCREASING
PACE OF LIFE**

UNIVERSALITY OF URBAN SCALING





**THE GOOD,
THE BAD,
THE UGLY**

**ON AVERAGE DOUBLING THE SIZE OF
A CITY SYSTEMATICALLY**

**ON AVERAGE DOUBLING THE SIZE OF
A CITY SYSTEMATICALLY**

***SAVES APPROXIMATELY 15% ON ALL
INFRASTRUCTURE***

***(ROADS, ELECTRICAL LINES, GAS
STATIONS,.....)***

**ON AVERAGE DOUBLING THE SIZE OF
A CITY SYSTEMATICALLY**

***SAVES APPROXIMATELY 15% ON ALL
INFRASTRUCTURE***

***(ROADS, ELECTRICAL LINES, GAS
STATIONS,.....)***

AND

INCREASES

**INCOME, WEALTH, PATENTS,
COLLEGES, CREATIVE PEOPLE,
POLICE, CRIME, SOCIAL
INTERACTIONS, AIDS, FLU,
AND**

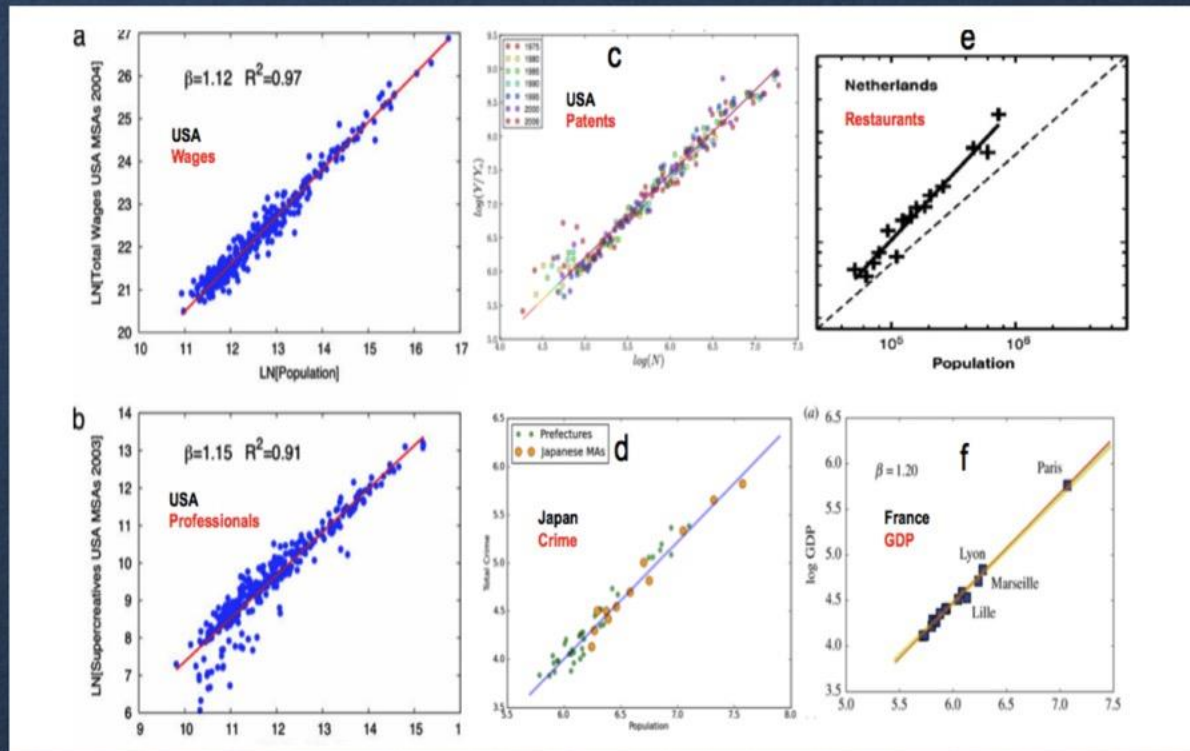
INCREASES

**INCOME, WEALTH, PATENTS,
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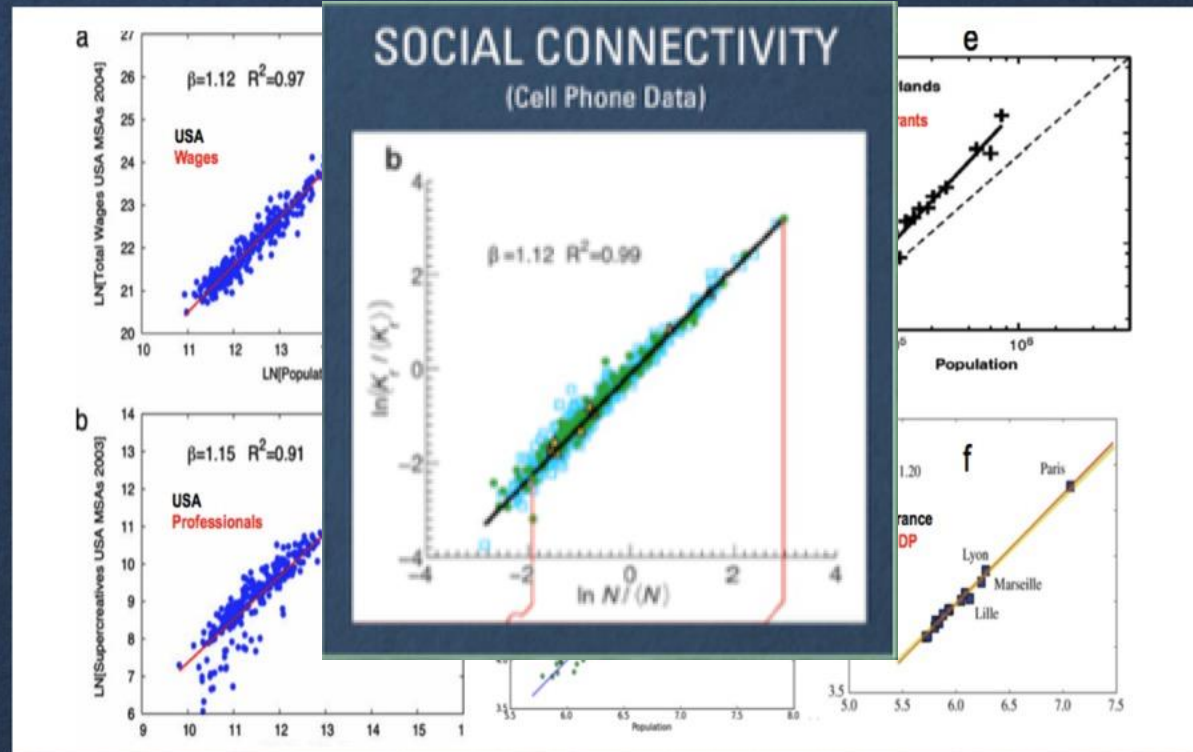
COVID-19

ALL BY ABOUT 15%

UNIVERSALITY OF URBAN SCALING



UNIVERSALITY OF URBAN SCALING



?

Turn on Original Sound

Total zoom video participants: 1

20:00:29 Speaker View

Carak Fando	Waylon Eitz	Jessica Hestager	Josh With Zoo	Shawn Corbett	Jay Jackson	Anna Vasiliadis
Charles Smith	Felix Thelen	Katrina Tye	Adam Strong	Christy Pitt	Charles Bryant	Ed Meritt
Melissa Dorick	zoom Deliver... Success	Kathleen Ambica	James Lisk	Katrina Galdieri	Art Jobbovhan	Jeffrey Faulner
Julie O'Brien	zoom Chilling HZ	Jeremiah Fanciarosa		Kathleen Gibreath	Carrey Quinoy	Youni Mohammed
Mike Grawick	Jed Columbus	Zak Peira	Ryan Blake	Shella Feng	Scott Hurd	Scott Jordan
Brian Engberg	Jeffrey Suddarth	James Burton	Britney Deason	Mark Pickett	Walker Dalley	Brian McIntyre
Tom Wilmers	Brandon Evansome	Alicia Ramirez	Joshua Jones	Travis Stone	Norman Vaughan	Kerry Martinez

1/2

1/2

Mute Stop Video

Profile Participants Stop Screen Chat Poll

Leave Meeting

SECOND QUESTION:

WILL WE BE “SAVED” BY:

- **IT AND THE INTERNET**
- **BIG DATA**
- **AI AND MACHINE LEARNING**
- **CULTURAL/SOCIAL REVOLUTION**
- **DIVINE INTERVENTION**
- **NONE OF THE ABOVE**

Growth

Incoming “Social Metabolic Rate”

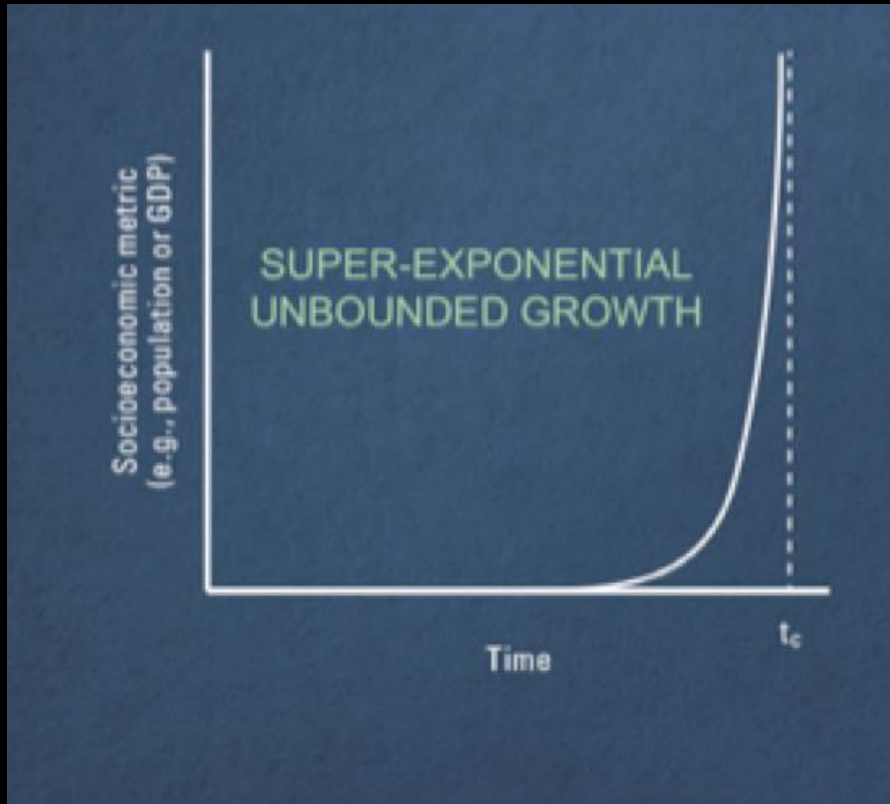
(Resources, Products, Patents,... .. “Energy” or
“Dollar” equivalent)

≈ **Maintenance** (Repair, Replacement,
Sustenance of Infrastructure, People, Institutions,
Companies ...)

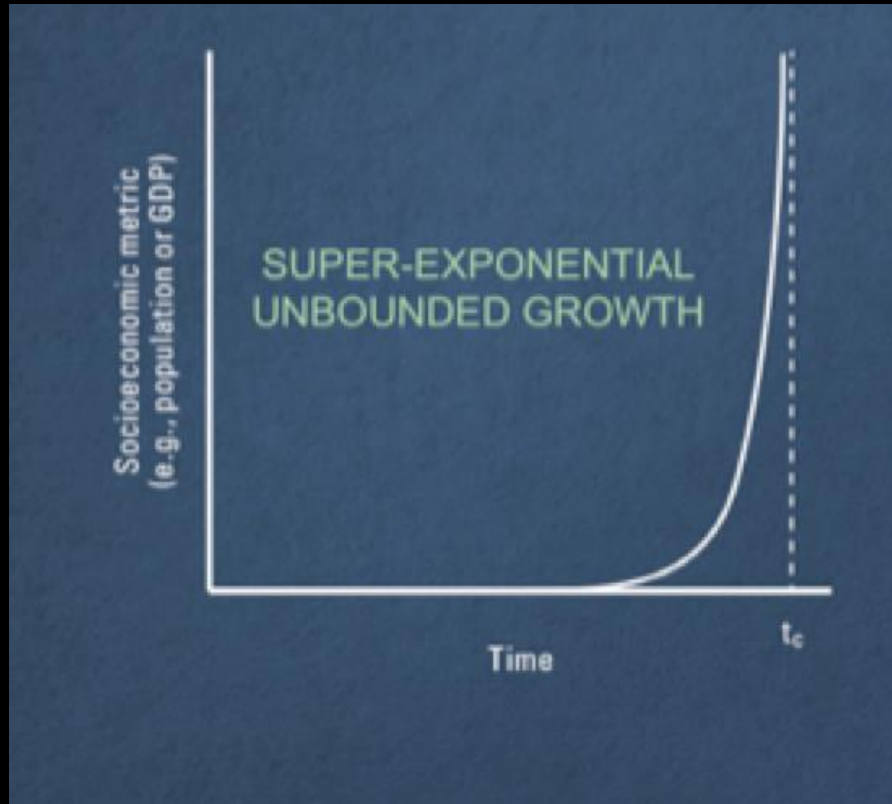
+

New Growth (of Infrastructure, People,
Institutions, Companies ...)

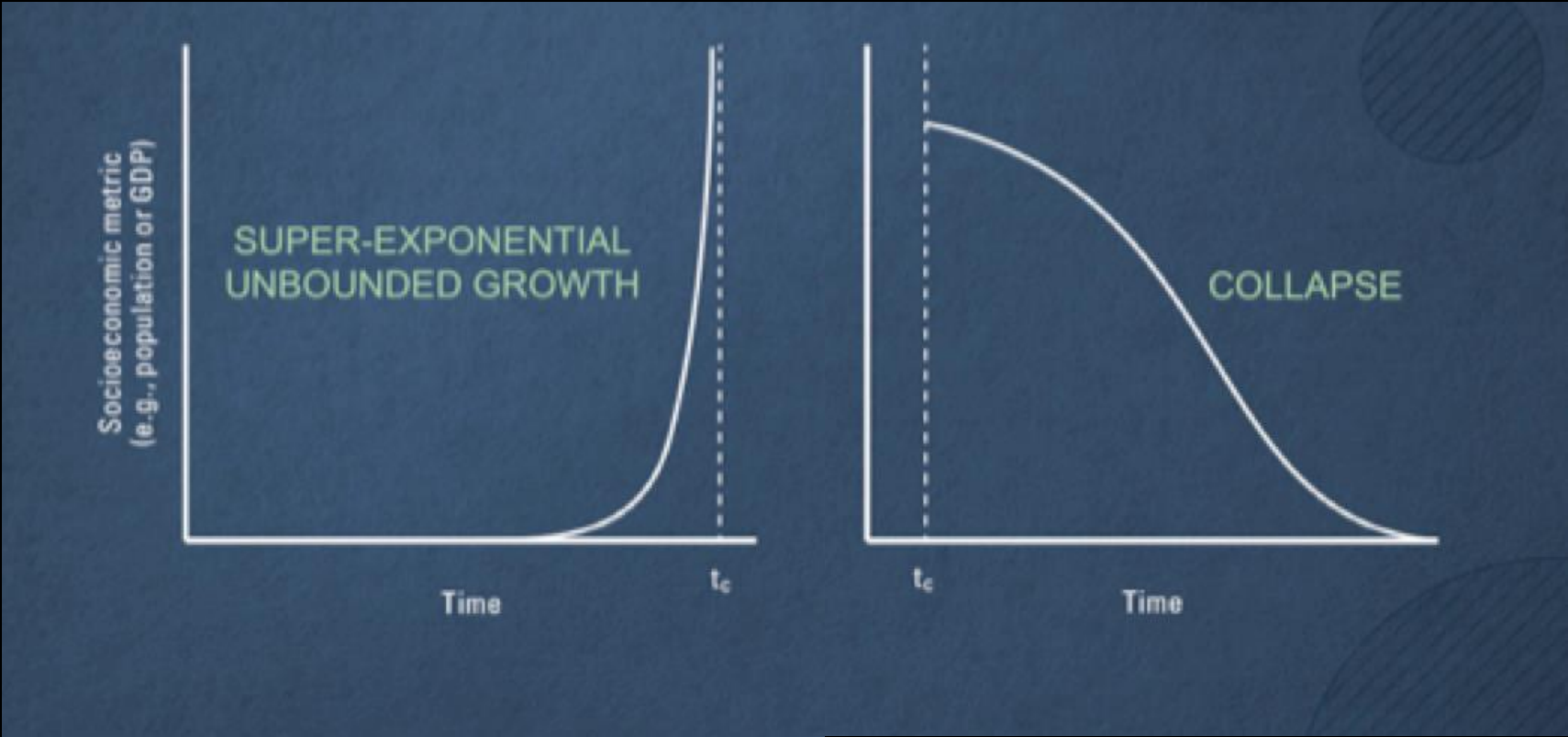
SUPERLINEAR SCALING LEADS TO UNBOUNDED GROWTH

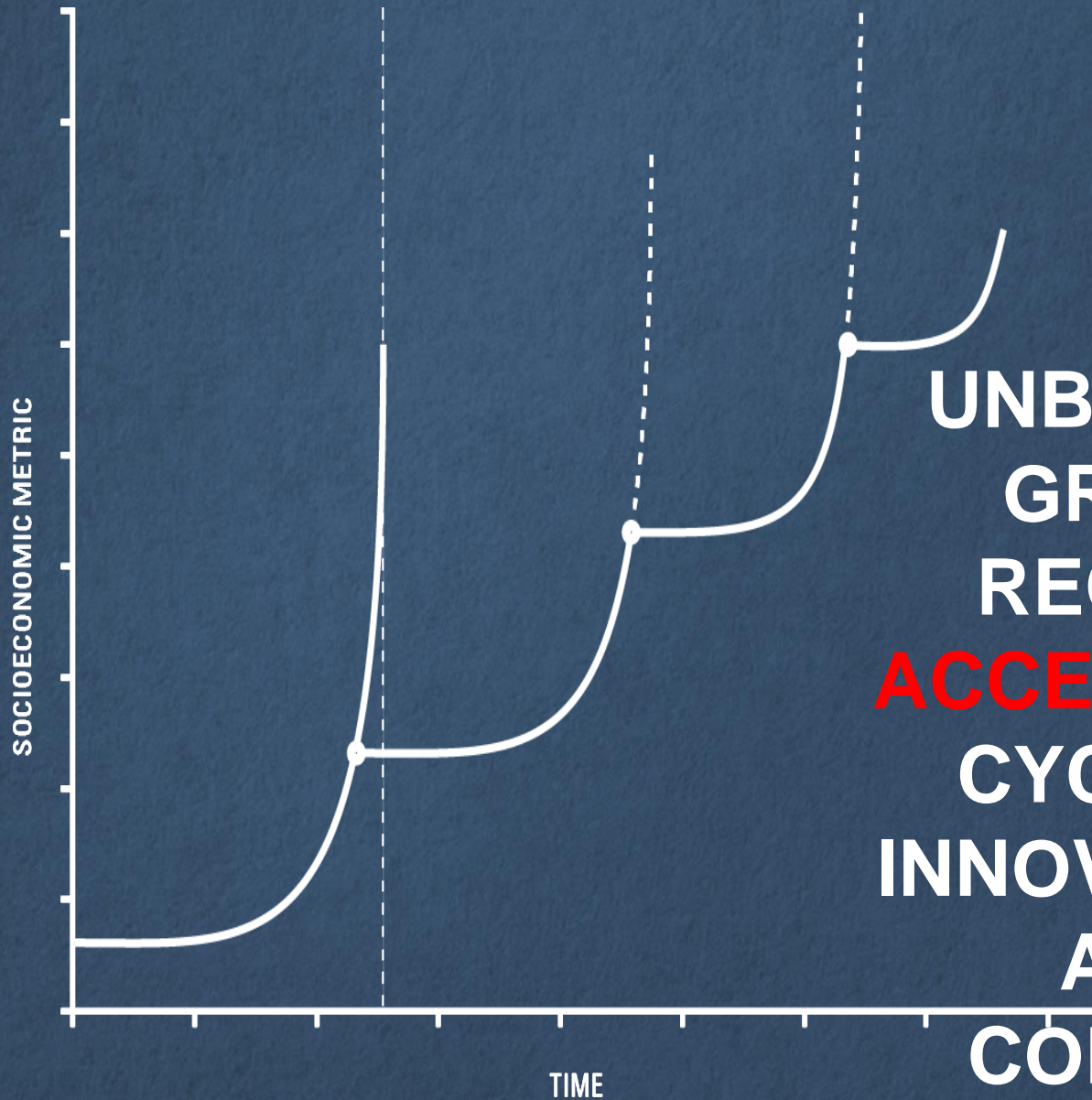


BUT ALSO TO A FINITE TIME SINGULARITY



FINITE TIME SINGULARITY



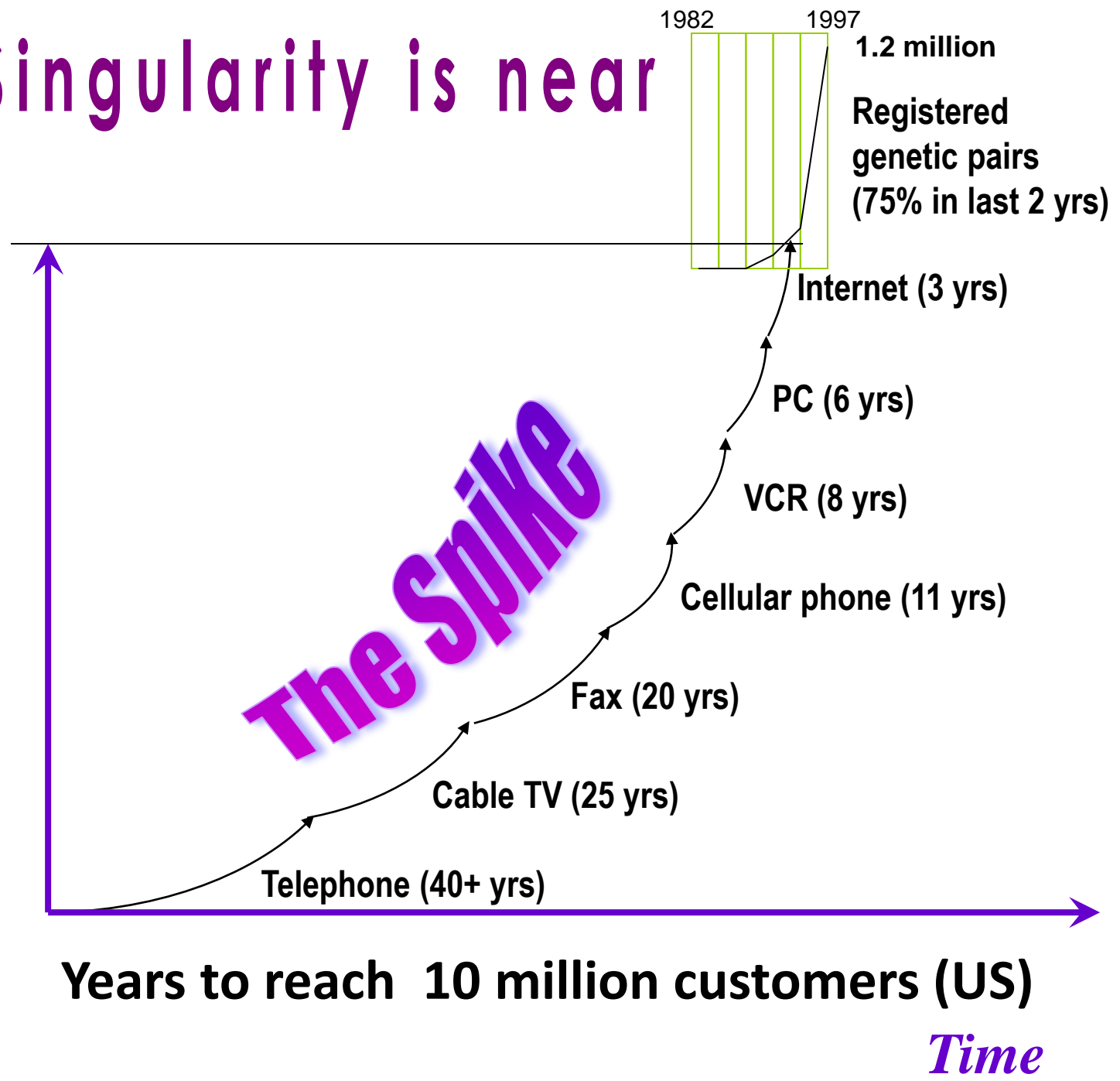


**UNBOUNDED
GROWTH
REQUIRES
ACCELERATING
CYCLES OF
INNOVATION TO
AVOID
COLLAPSE**



Damien Broderick

Singularity is near

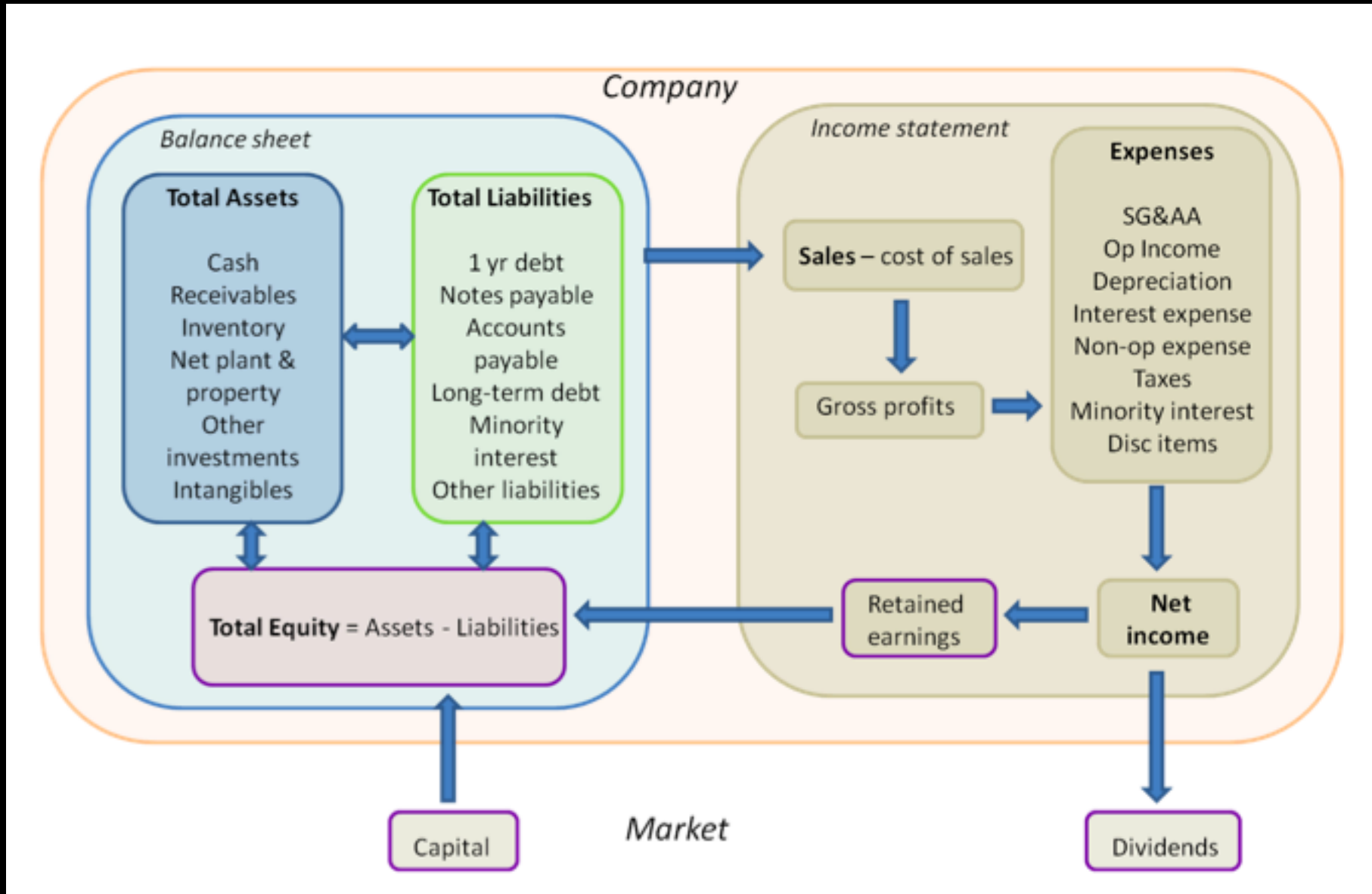


- **UNBOUNDED GROWTH LEADS TO “FINITE-TIME SINGULARITY” & COLLAPSE**
- **UNLESS INNOVATIONS OCCUR (SYSTEMATICALLY) FASTER AND FASTER**

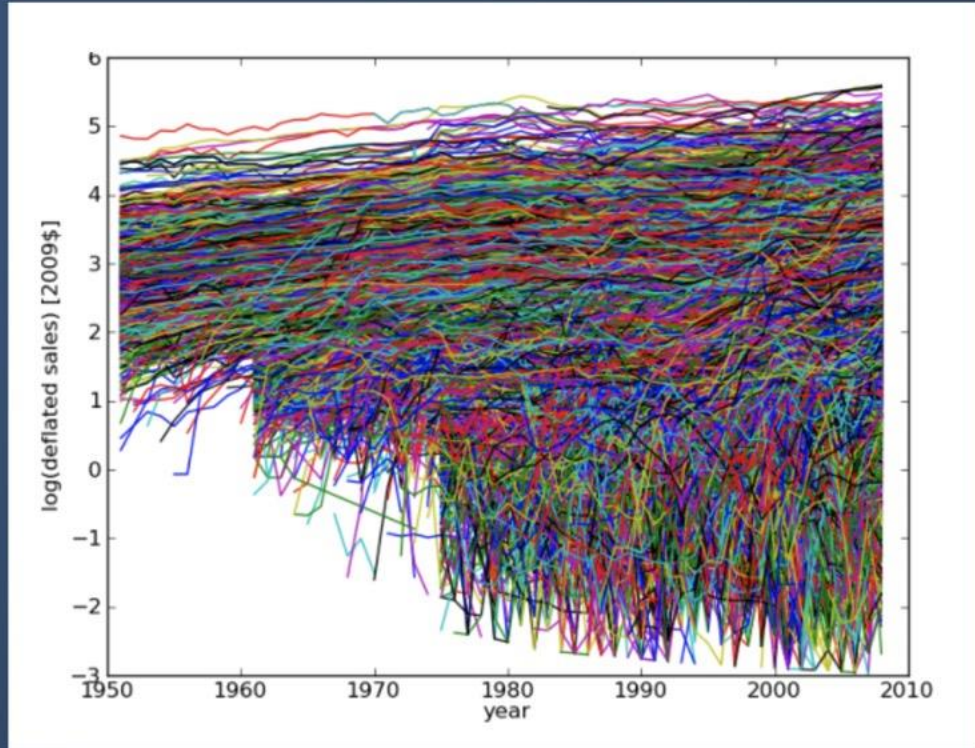
- **UNBOUNDED GROWTH LEADS TO “FINITE-TIME SINGULARITY” & COLLAPSE**
- **UNLESS INNOVATIONS OCCUR (SYSTEMATICALLY) FASTER AND FASTER**
- **EXAMPLE OF THE ACCELERATING PACE OF ALL SOCIO-ECONOMIC LIFE!!**
- **NEED TO ADAPT FASTER AND FASTER USING THE SAME BRAIN AND BIOLOGY WE’VE ALWAYS HAD!**

SUSTAINABLE????

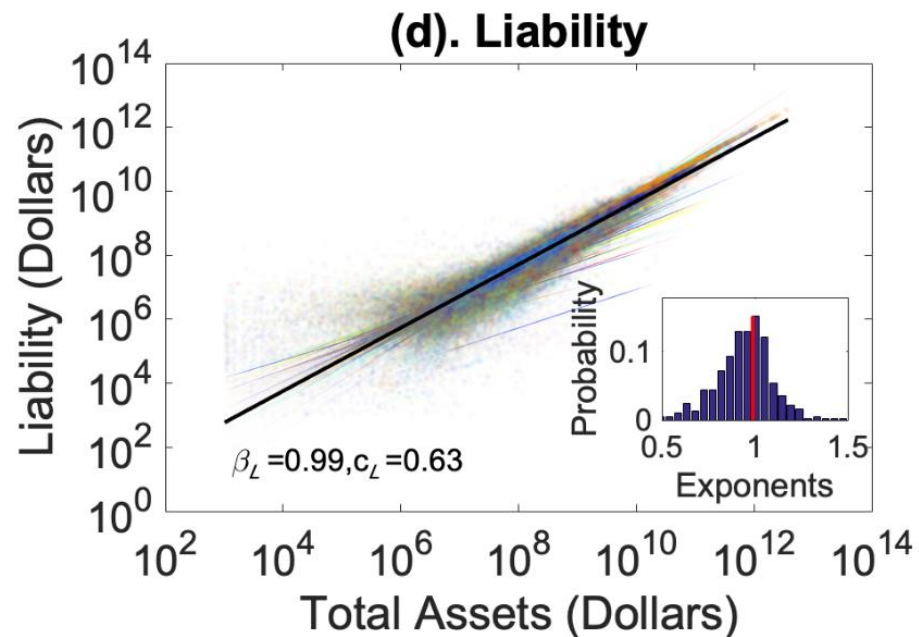
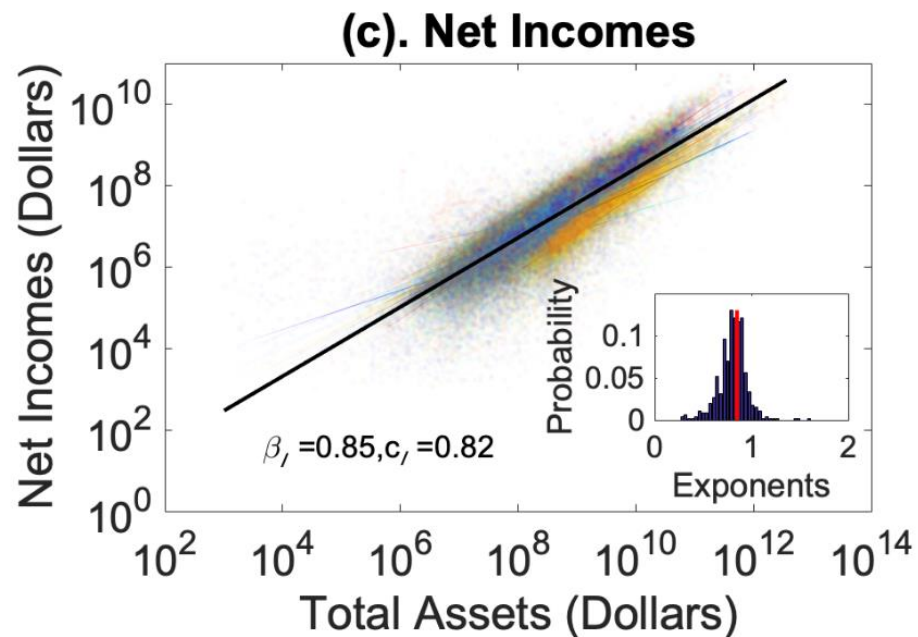
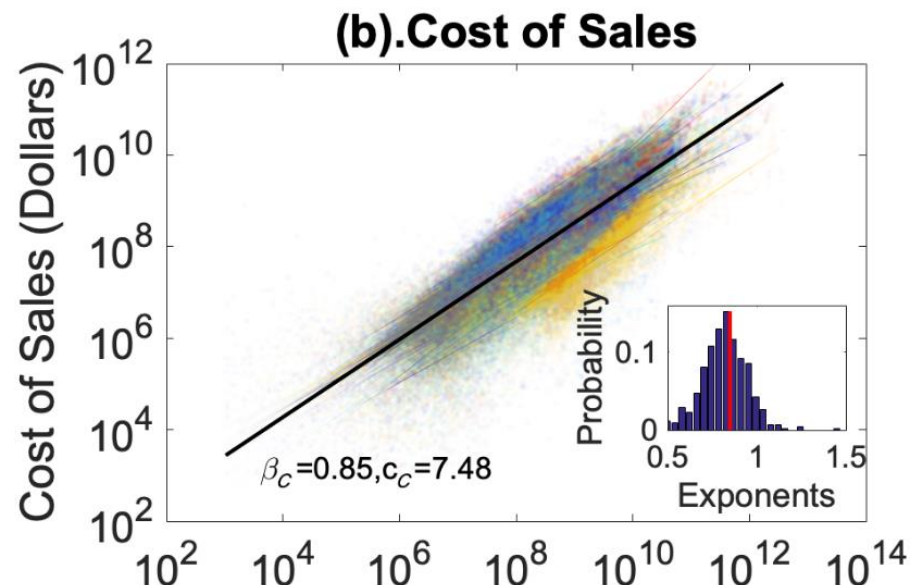
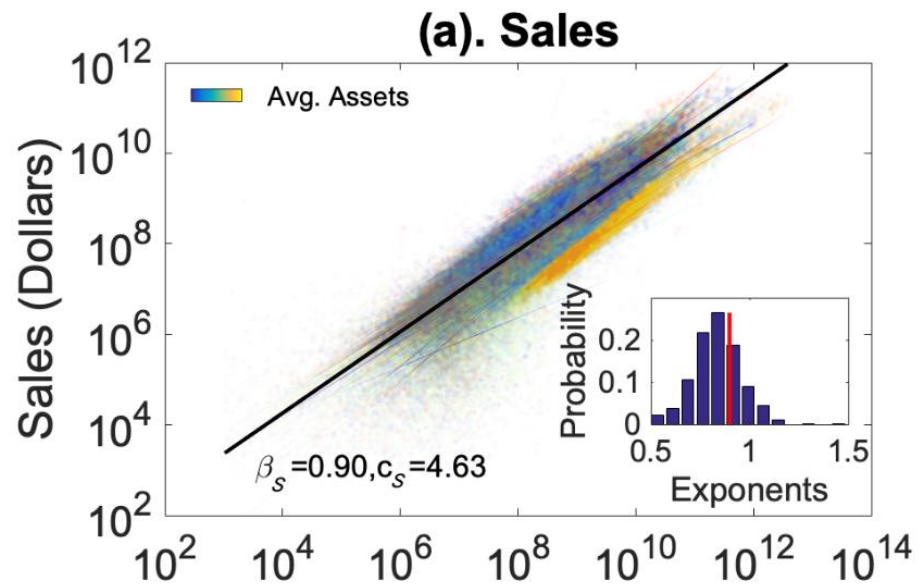
THE SCALING, GROWTH & MORTALITY OF COMPANIES



GROWTH OF FIRMS



COMPANIES SCALE SUB-LINEARLY LIKE ORGANISMS



THE GROWTH OF COMPANIES

COMPANY METABOLIC RATE

=

MAINTENANCE

+

GROWTH

GROWTH OF FIRMS

***COMPANY METABOLIC RATE
(SALES)***

=

MAINTENANCE

+

GROWTH

GROWTH OF FIRMS

***COMPANY METABOLIC RATE
(SALES + FINANCING)***

=

MAINTENANCE

+

GROWTH

GROWTH OF FIRMS

***COMPANY METABOLIC RATE
(SALES + FINANCING)***

=

***MAINTENANCE
(EXPENSES)***

+

GROWTH

GROWTH OF FIRMS

***COMPANY METABOLIC RATE
(SALES + FINANCING)***

=

***MAINTENANCE
(EXPENSES)***

+

***GROWTH
(INCREASE IN ASSETS)***

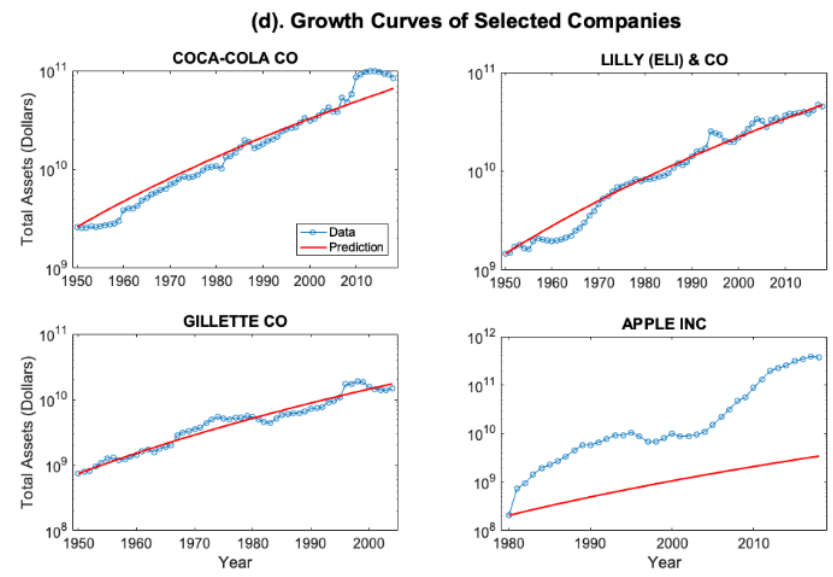
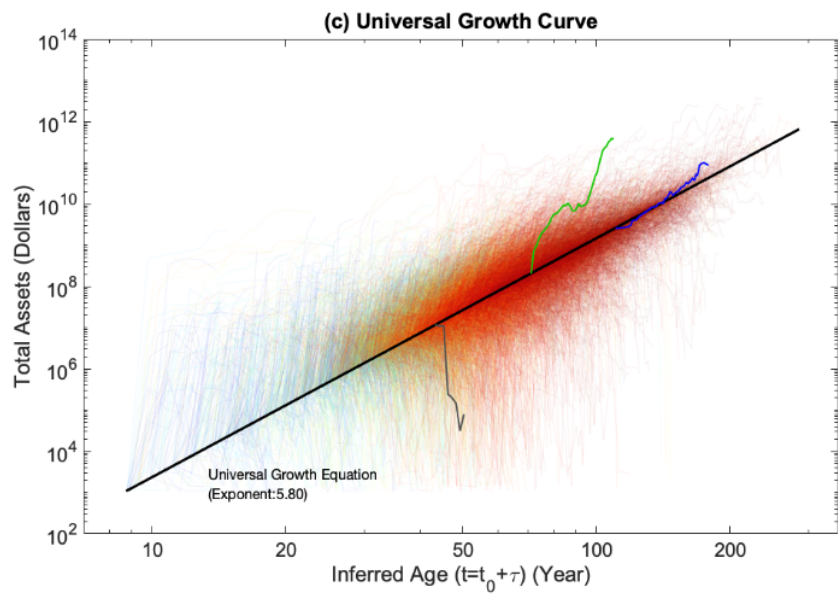
**GROWTH EQUATION PREDICTS THAT
COMPANIES GROW FOLLOWING A POWER
LAW IN TIME WITH A LARGE EXPONENT**

**RATHER THAN
EXPONENTIALLY**

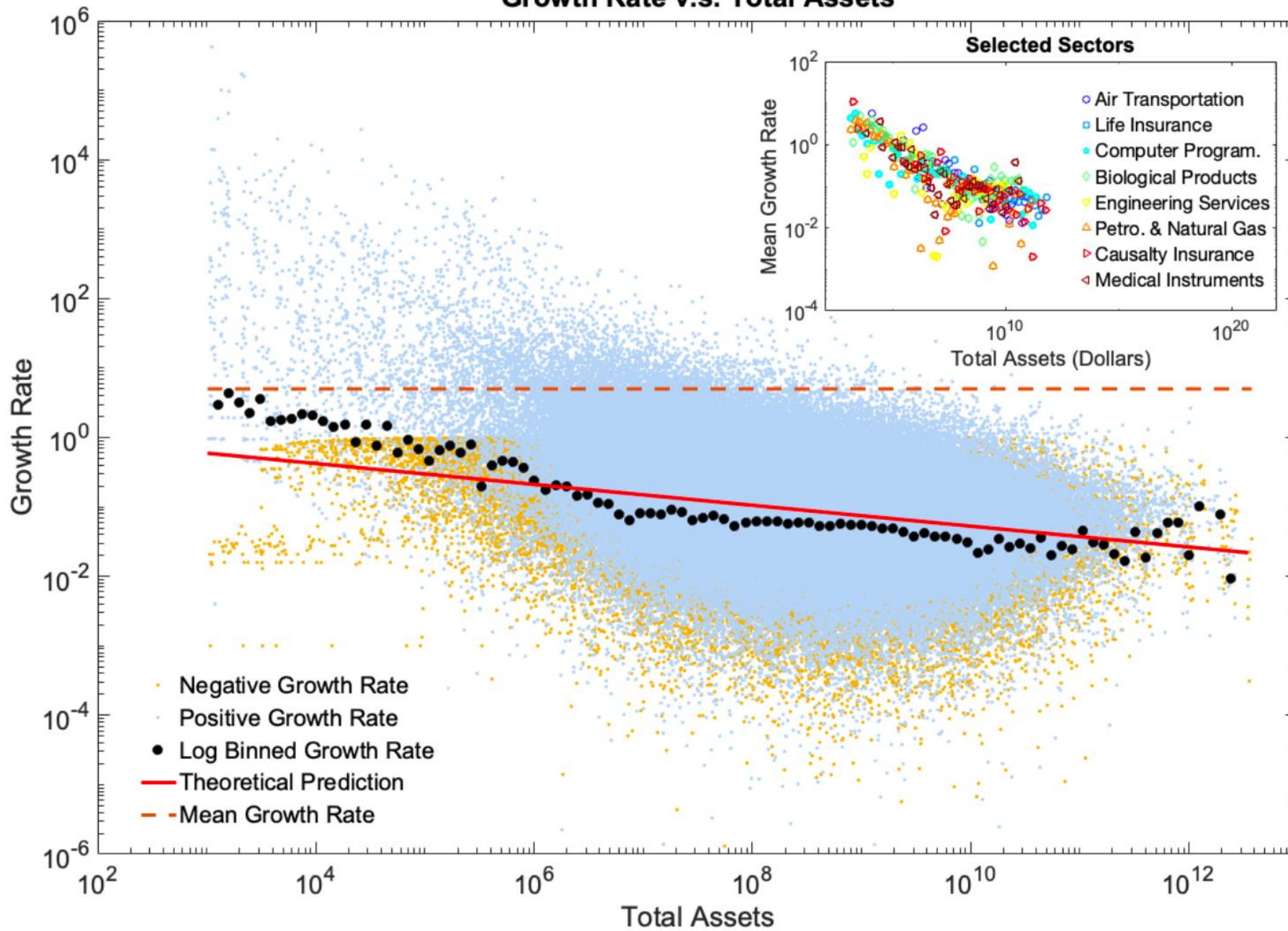
$$A(t) \approx ct^\gamma$$

$$\gamma = 1/(1 - \beta_I)$$

~ 6



Growth Rate v.s. Total Assets



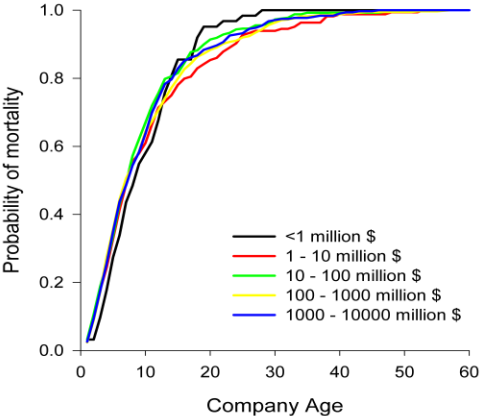
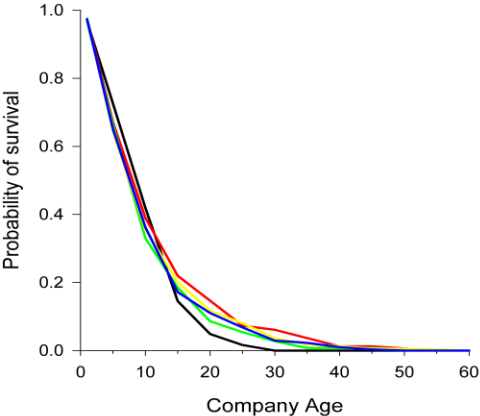
THIRD QUESTION:

**HOW LONG DO YOU EXPECT YOUR COMPANY OR
INSTITUTION TO LAST?**

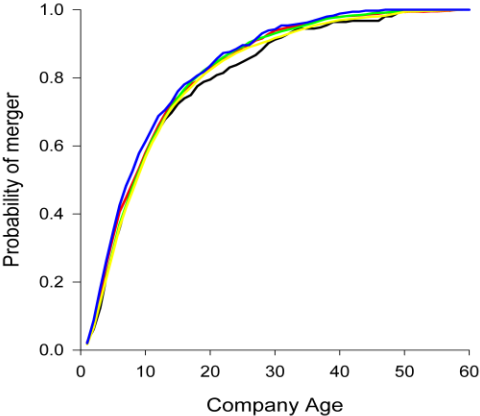
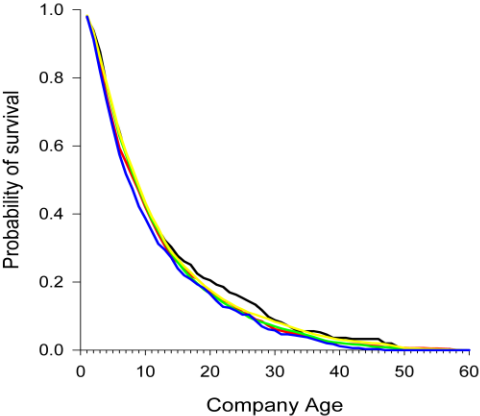
- **5 YEARS**
- **10 YEARS**
- **50 YEARS**
- **100 YEARS**
- **INDEFINITELY**

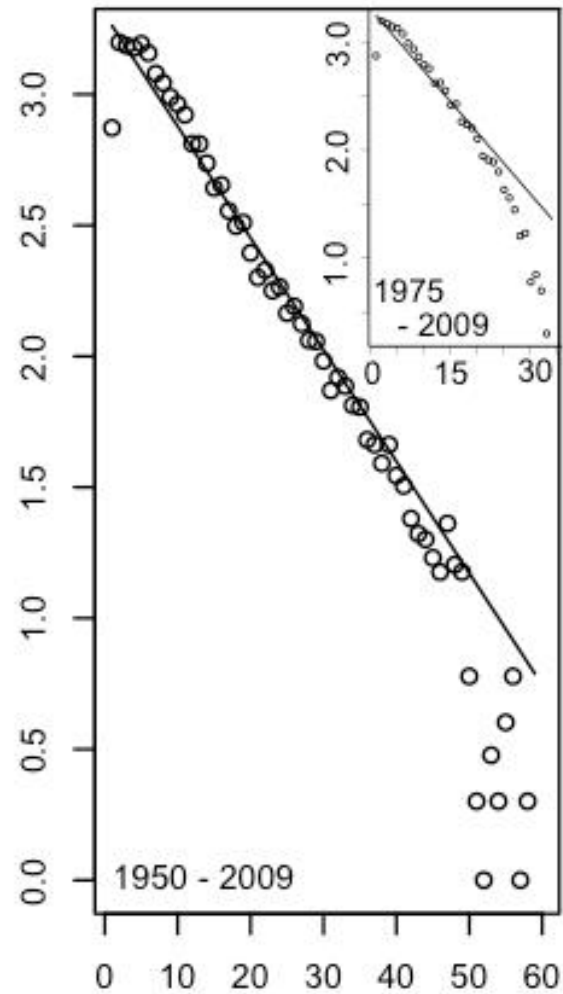
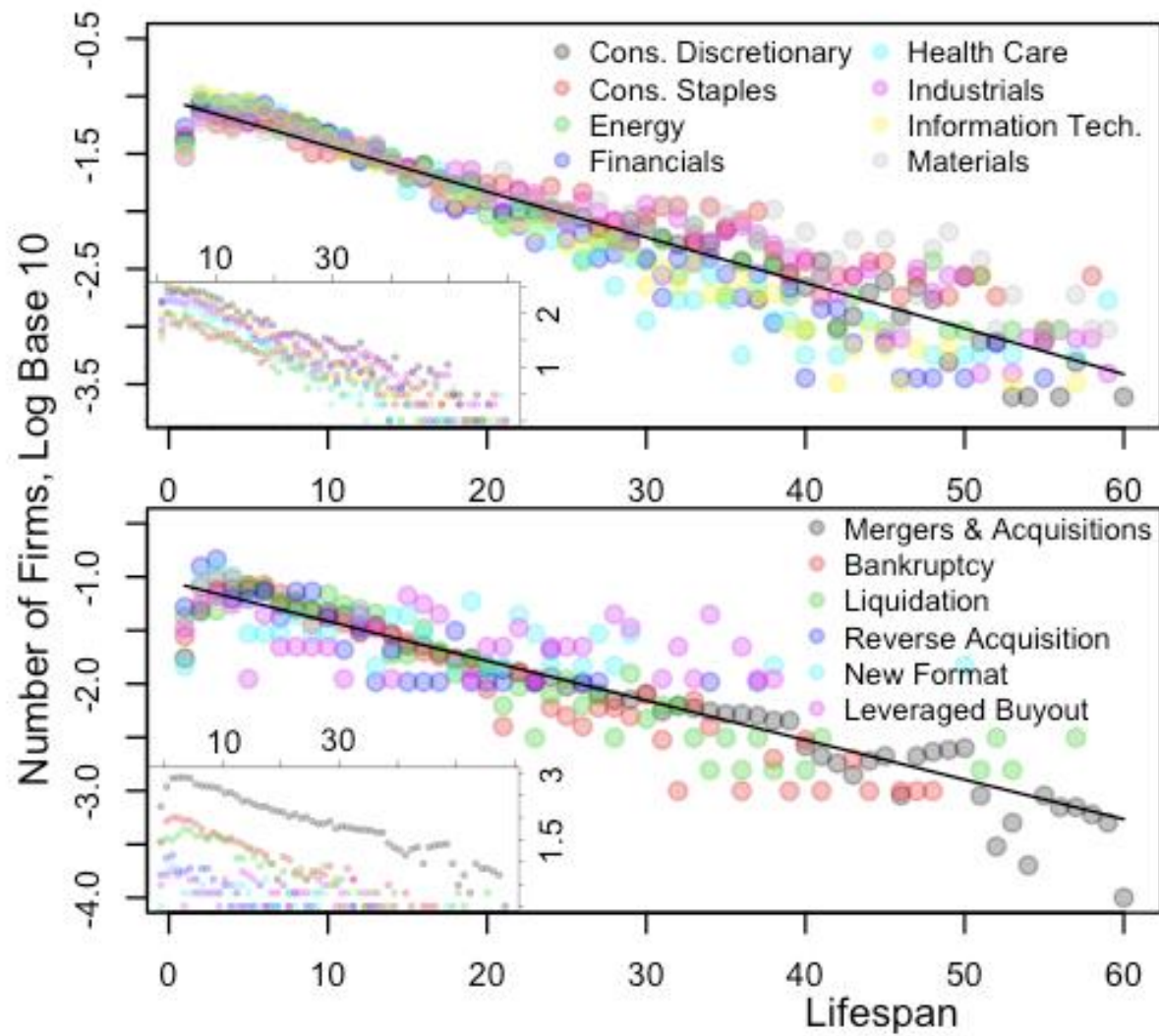
MORTALITY OF COMPANIES

Bankrupt or liquidation



Acquisition or merger





Our “natural” metabolic rate ~90 *watts*

Our social metabolic rate ~11,000
watts

We are equivalent to a
30,000 kg Gorilla





12 Elephants



THE SINGULARITY IS NEAR!

The ever accelerating progress of technology....gives the appearance of approaching some essential singularity in the history of the race beyond which human affairs, as we know them, could not continue.



John von
Neumann
(1903 - 1957)







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Thank You For Listening



Forthcoming Events

- Tue, 07 Sep (10:00-10:45) Assessing Extraordinary Claims: Actuarial Science And The Search For Truth
- Wed, 08 Sep (15:00-15:45) The Code Of Capital: How The Law Creates Wealth And Inequality
- Tue, 14 Sep (15:00-15:45) Share Schemes For Non-Employees & The Gig Economy
- Wed, 15 Sep (15:00-15:45) Deforestation-Linked Sovereign Bonds – A Nature-Based Solution?
- Thu, 16 Sep (09:00-09:45) All Party Parliamentary Groups: What Purpose Do They Serve?

Visit <https://fsclub.zyen.com/events/forthcoming-events/>