

THE LESSONS OF SCIENCE

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Kavli Institute
for
Theoretical
Physics



B R I D G E S T O P E A C E

THE LESSONS OF SCIENCE

THE SCIENTIFIC METHOD

THE KNOWLEDGE OF NATURE

THE CONTROL OF NATURE

INTERNATIONALISM

QUESTIONS & PREDICTIONS

B R I D G E S T O P E A C E

THE SCIENTIFIC METHOD

- ★ Understanding is obtained by subjecting our ideas to **OBSERVATION** and **EXPERIMENT**.
- ★ The only authority for truth is agreement with Nature, through **OBSERVATION** and **EXPERIMENT**.
NOT Political Power or Religious Faith
- ★ All of our theories are **provisional** and are subject to continual quantitative test and improvement.
- ★ Scientific findings must be made **available to all** .

A healthy scientific culture
requires an open society.

Science promotes tolerance.

Science promotes democracy.

B R I D G E S T O P E A C E

KNOWLEDGE OF NATURE

PHYSICS

ASTROPHYSICS-
COSMOLOGY

BIOLOGY

B R I D G E S T O P E A C E

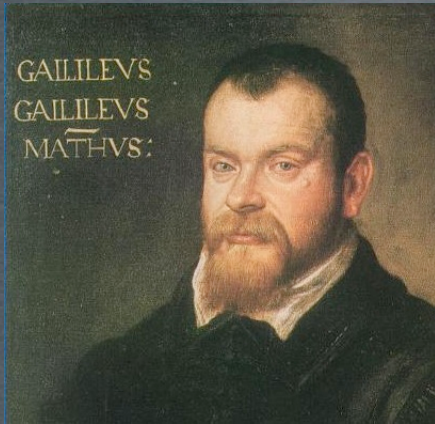
PHYSICS

Over the last 400 years we have discovered the basic laws of motion and the symmetries that govern all physical phenomena.

We have unveiled the underlying atomic structure of matter and discovered the quantum nature of reality.

We have constructed a comprehensive theory of the atomic and nuclear forces, identified the basic constituents of matter and are striving to unite all the forces of nature.

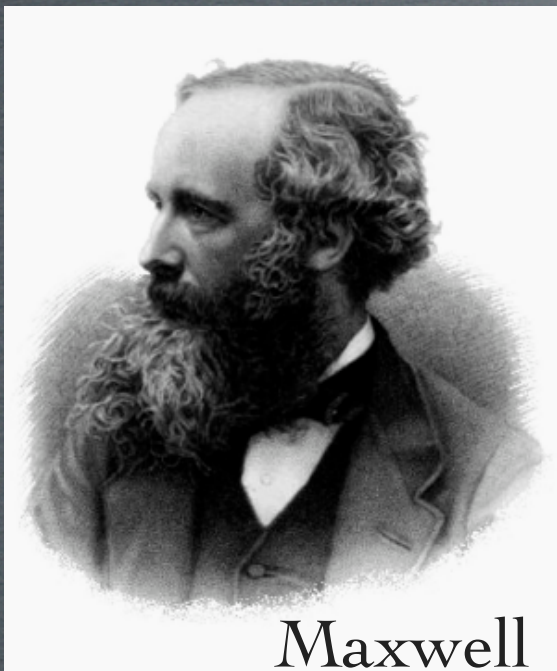
The language of physics
is mathematics.



The laws of physics
govern the motion of
planets and apples.



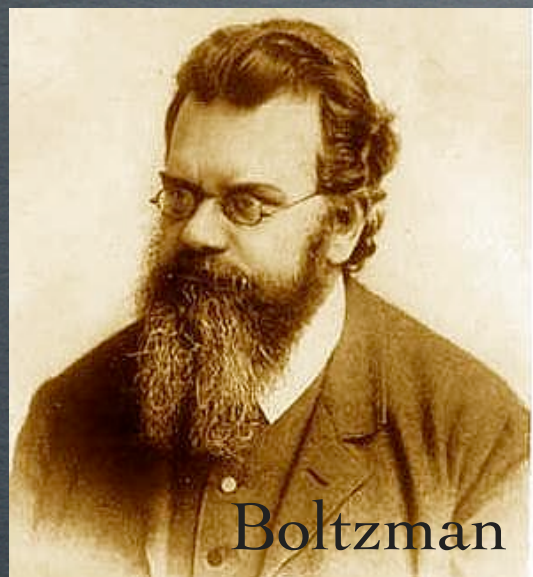
BRIDGES TO PEACE



Maxwell



THE LAWS OF ELECTRICITY MAGNETISM & LIGHT



Boltzman

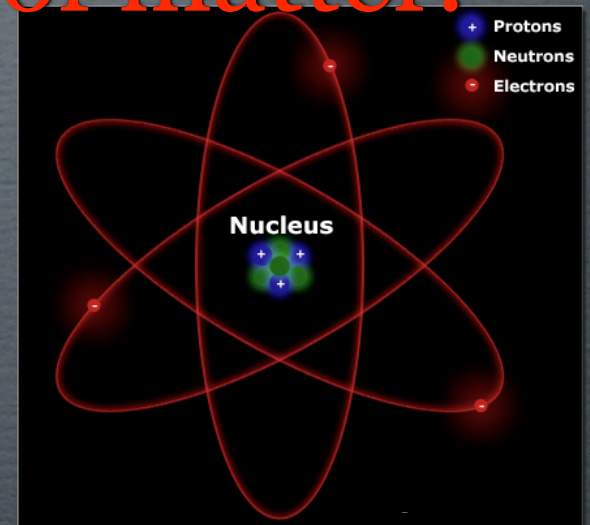
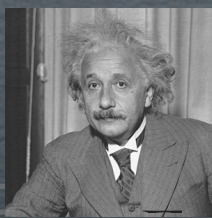
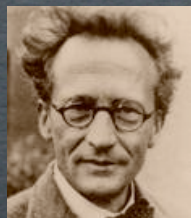
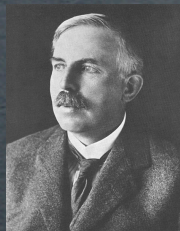
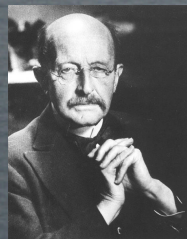
$$S = k \ln W$$

HEAT ENERGY & ENTROPY

B R I D G E S T O P E A C E

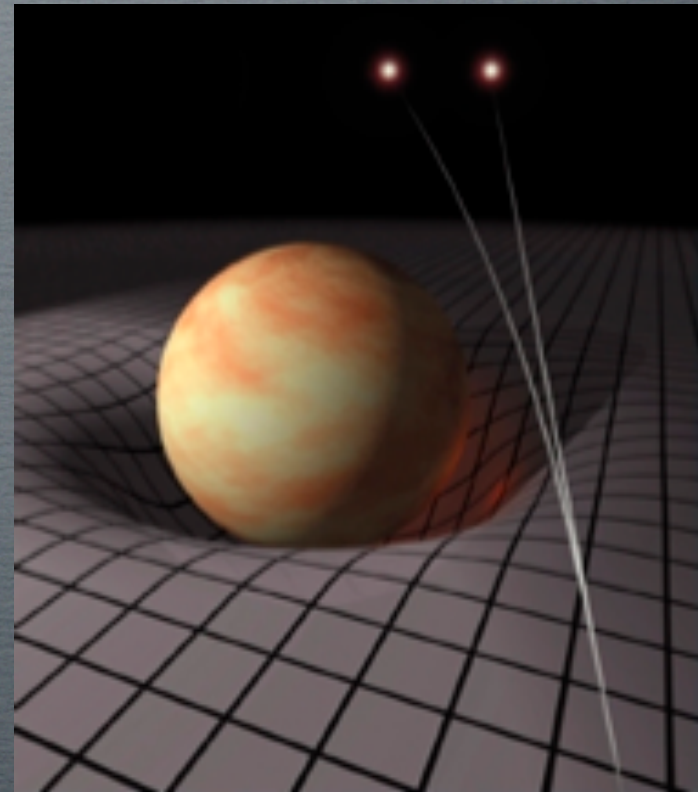
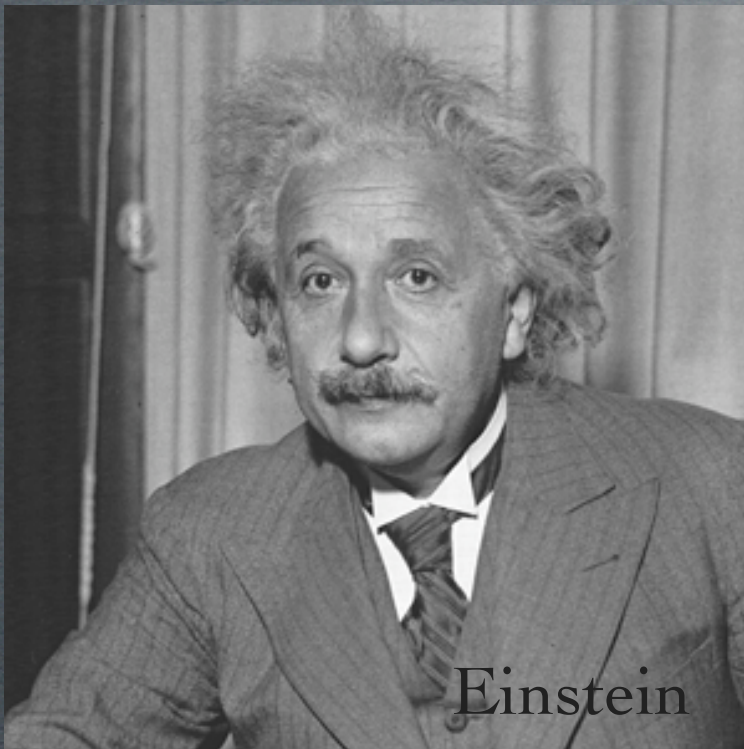
ATOMIC THEORY

All ordinary matter is made of atoms,
electrons revolving around nuclei-
governed by the probabilistic laws of
quantum mechanics.
The collective behavior of atoms is
responsible for all the
properties and phases of matter.



TO PE

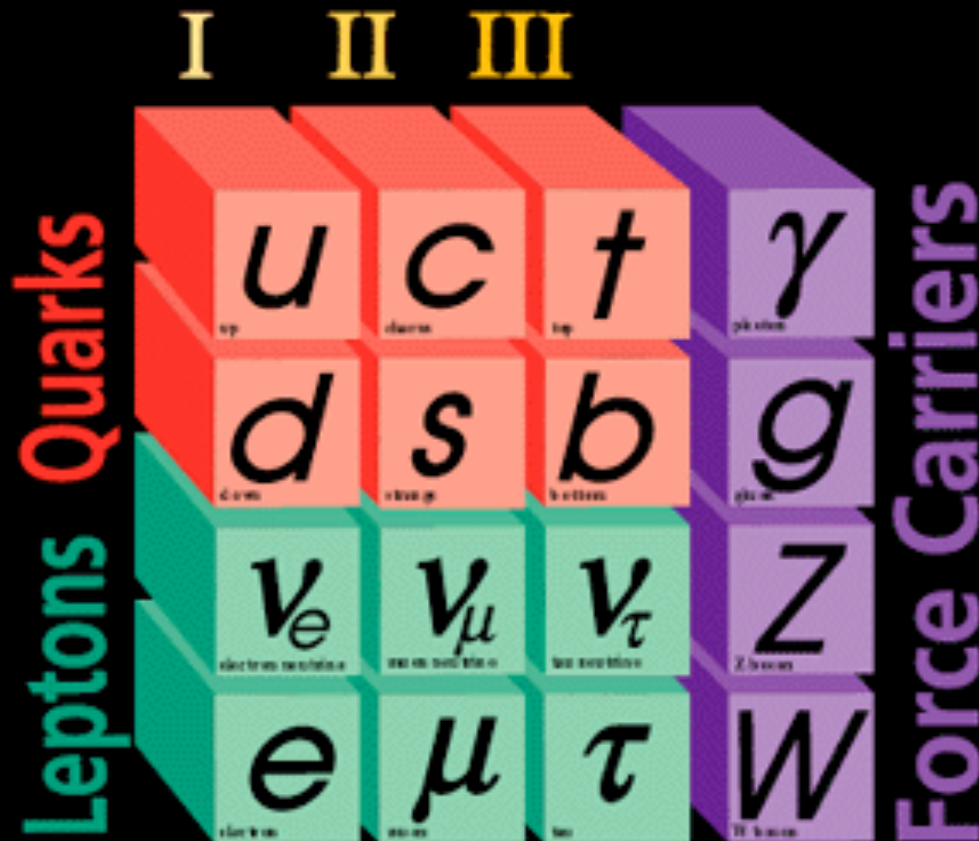
SPACE-TIME IS DYNAMICAL AND ITS CURVATURE GIVES RISE TO GRAVITY



B R I D G E S T O P E A C E

The Standard Model of Particle Interactions

Three Generations of Matter



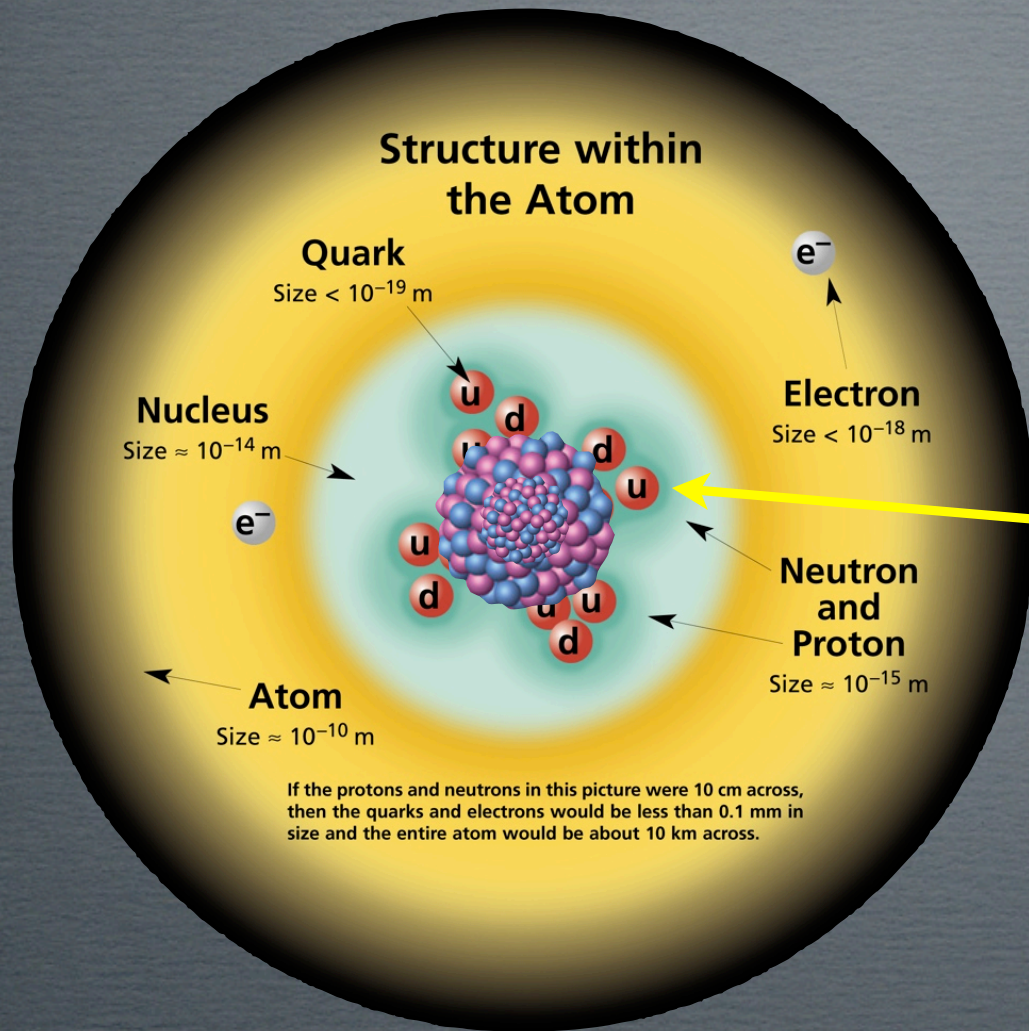
ELECTRO-
MAGNETISM

STRONG
NUCLEAR
FORCE

WEAK
NUCLEAR
FORCE

B R I D G E S T O P E A C E

THE NUCLEAR FORCE



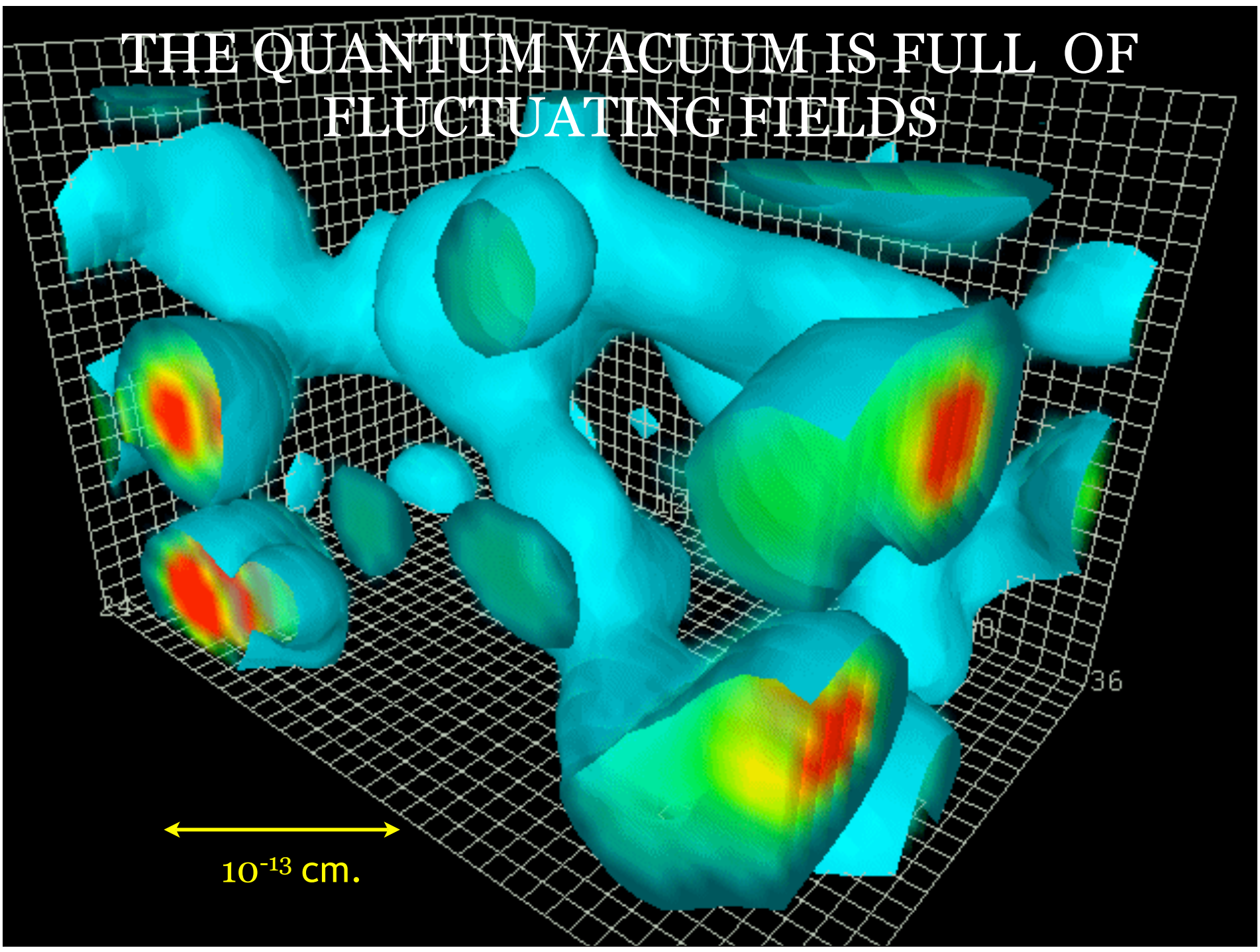
Experiment showed that the proton looked as if it were made of freely moving **quarks** at short distances.

But one could not pull the quarks out of the proton.

THE VACUUM

**THE CLASSICAL
VACUUM IS EMPTY**

THE QUANTUM VACUUM IS FULL OF FLUCTUATING FIELDS

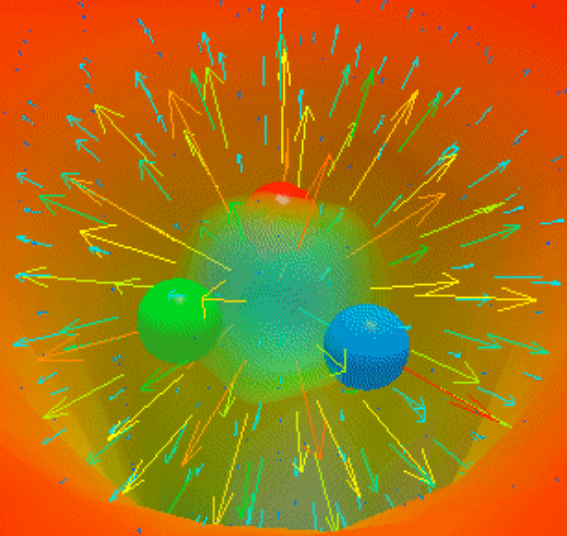


A 3D visualization of quantum vacuum fluctuations. The image shows a complex, interconnected network of blue and cyan structures, resembling a sponge or foam, set against a black background. The structures are composed of many small, rounded, and elongated shapes. Some of these shapes have a color gradient from cyan to red, indicating varying levels of fluctuation. The entire structure is overlaid on a white grid that recedes into the distance, creating a sense of depth. In the bottom left corner, there is a yellow double-headed arrow pointing left and right, with the text 10^{-13} cm. below it. In the bottom right corner, the number 36 is visible.

10^{-13} cm.

Pulling quarks
out of a proton
in QCD

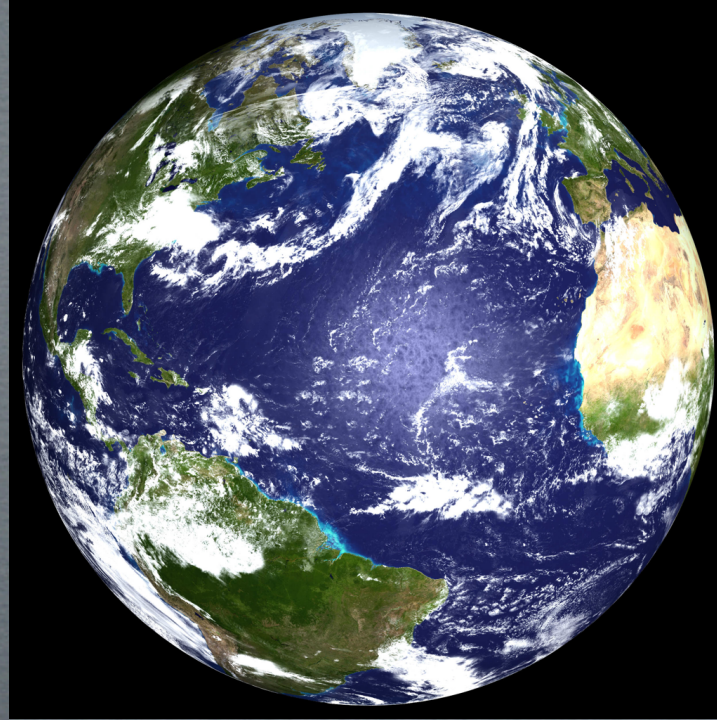
$$\langle r \rangle = 0.15 \text{ fm}$$
$$\langle d \rangle = 0.35 \text{ fm}$$



COSMOLOGY

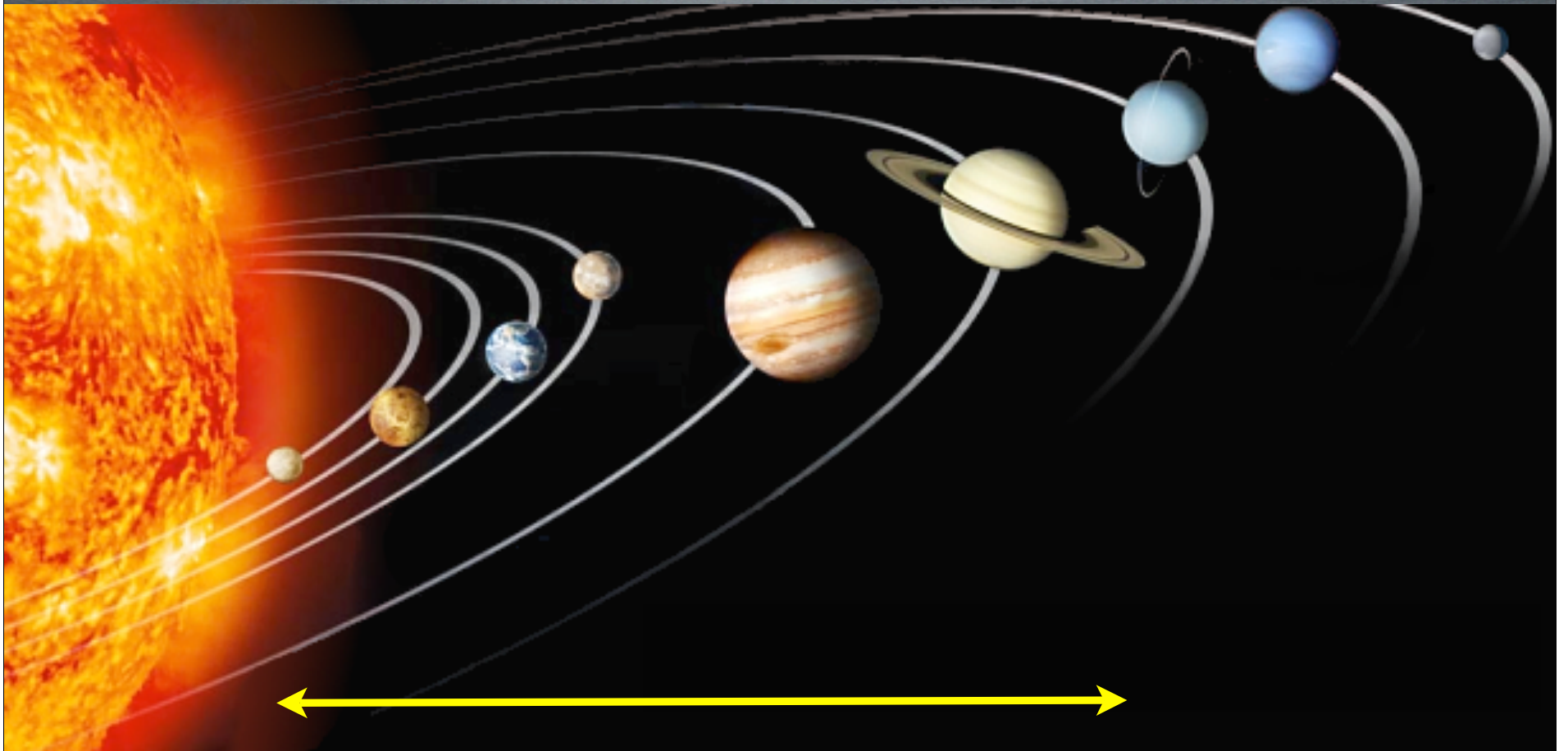
Over the last century we have learned that our sun is only one of 100 billion stars in the galaxy; in an expanding universe that contains ~100 billion galaxies; that emerged from a hot big bang 13.7 billion years ago.

B R I D G E S T O P E A C E



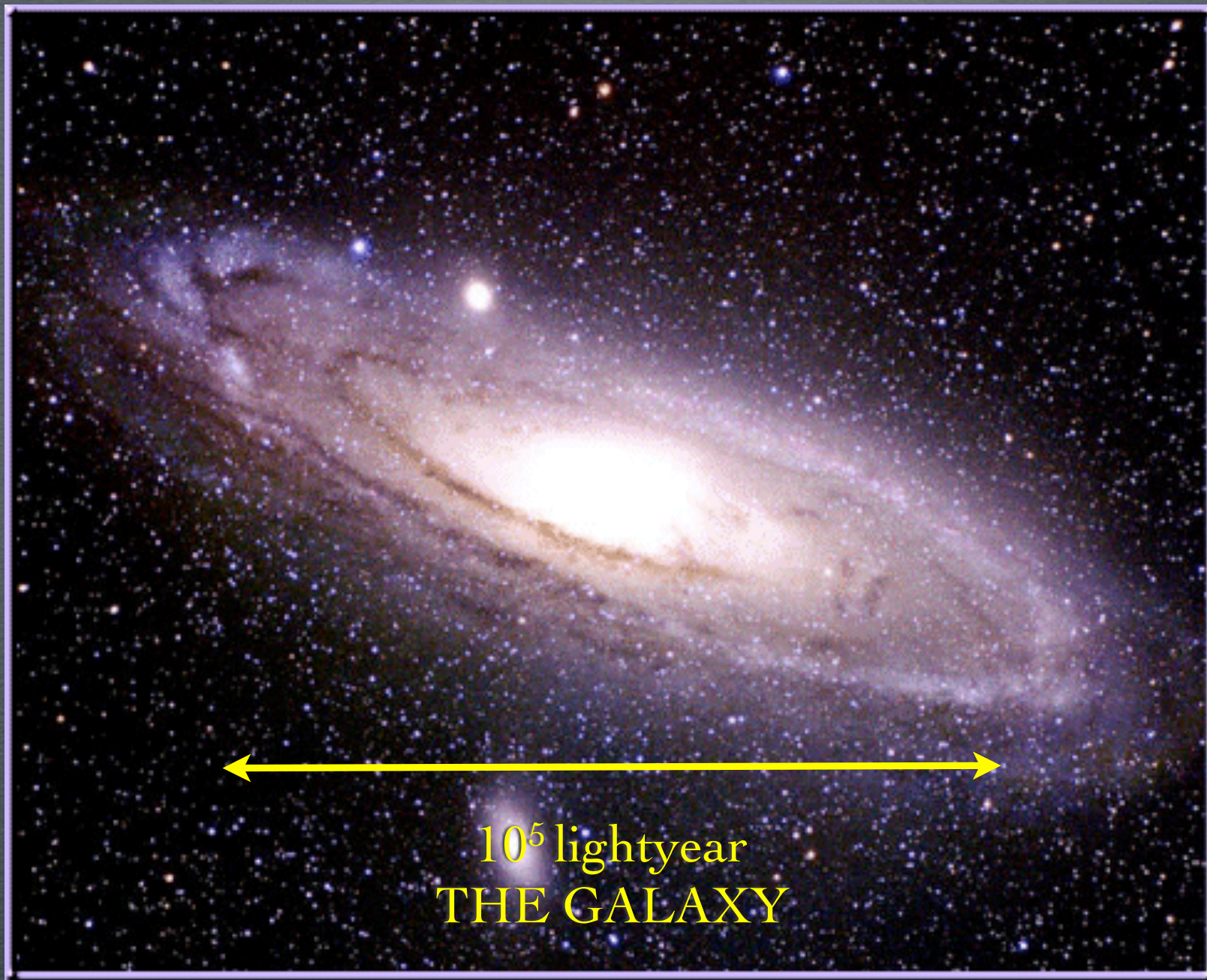
10^3 meter $\sim 10^{-13}$ lightyear
THE EARTH

B R I D G E S T O P E A C E

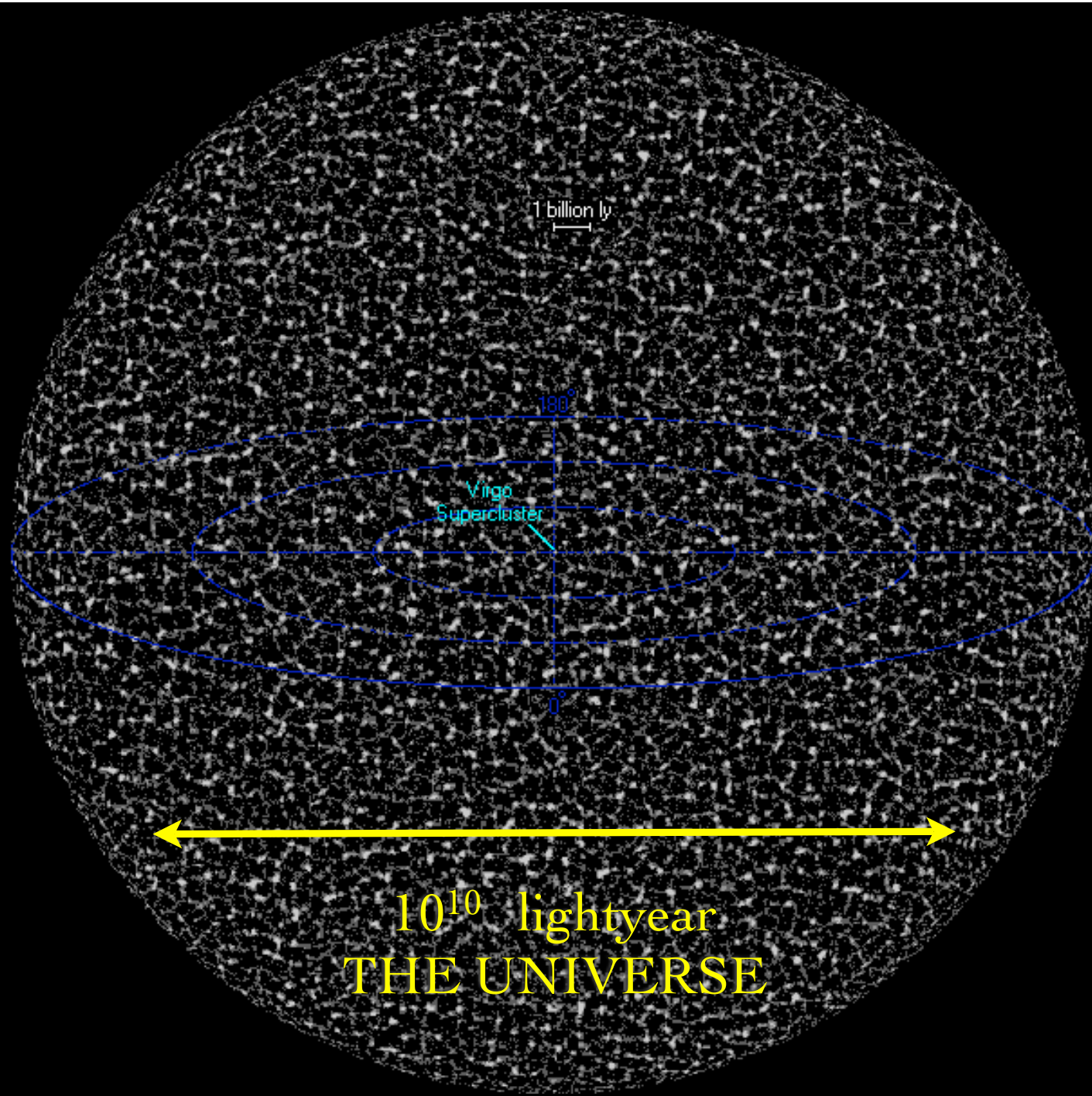


10^{12} meter $\sim 10^{-4}$ lightyear
THE SOLAR SYSTEM

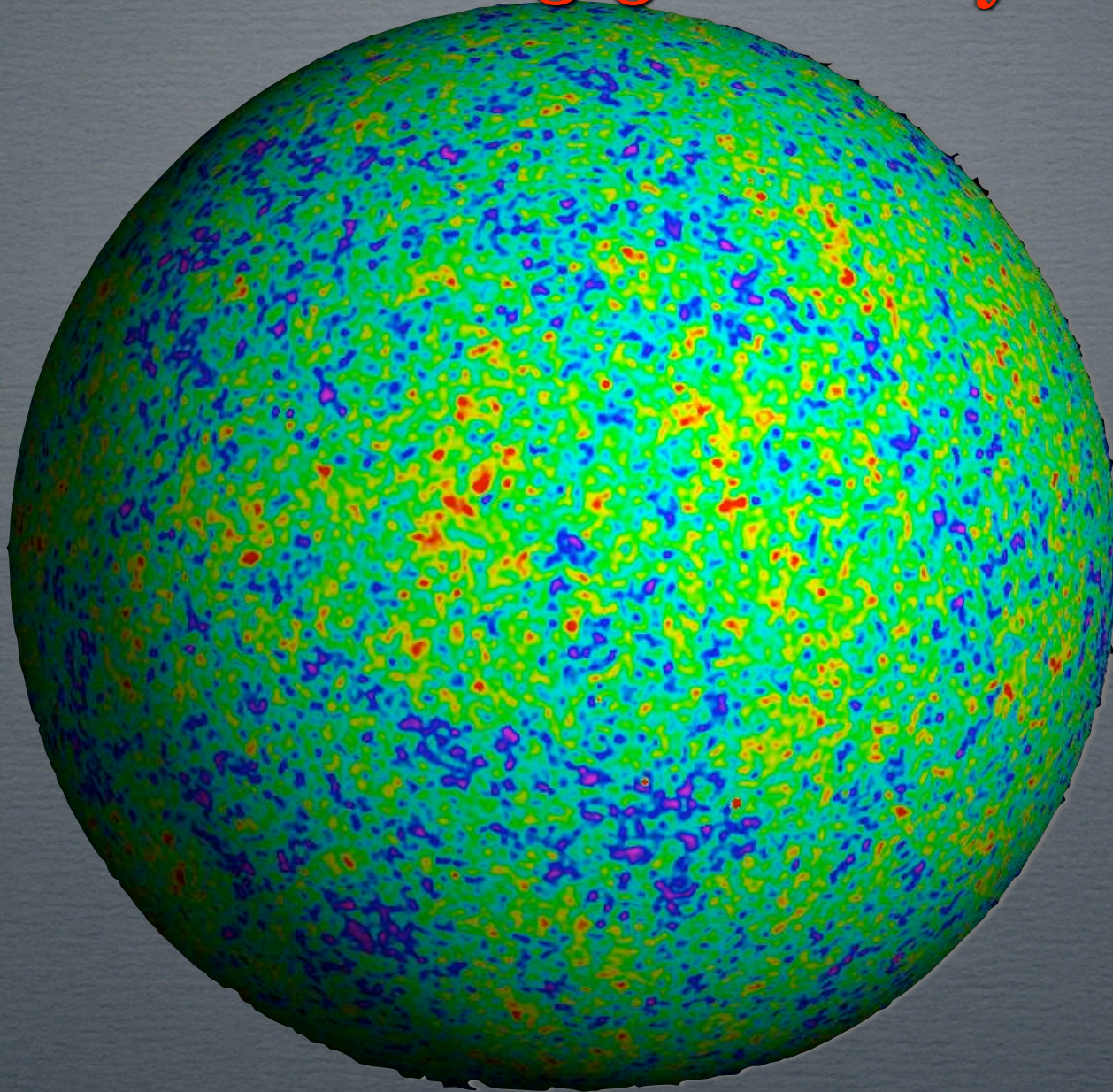
B R I D G E S T O P E A C E



B R I D G E S T O P E A C E

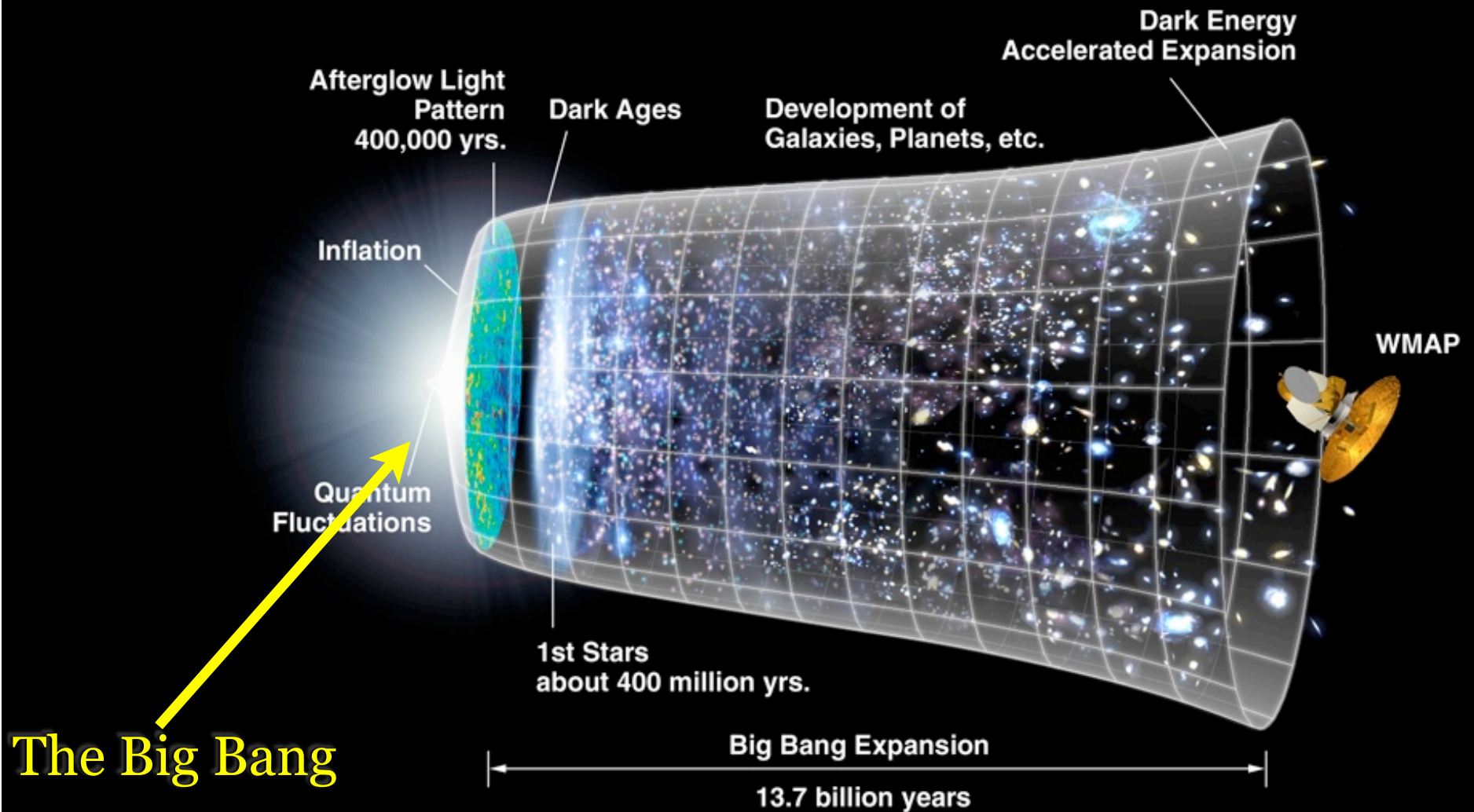


The Universe 13.5 billion years ago



B R I D G E S T O P E A C E

THE HISTORY OF THE UNIVERSE



BIOLOGY

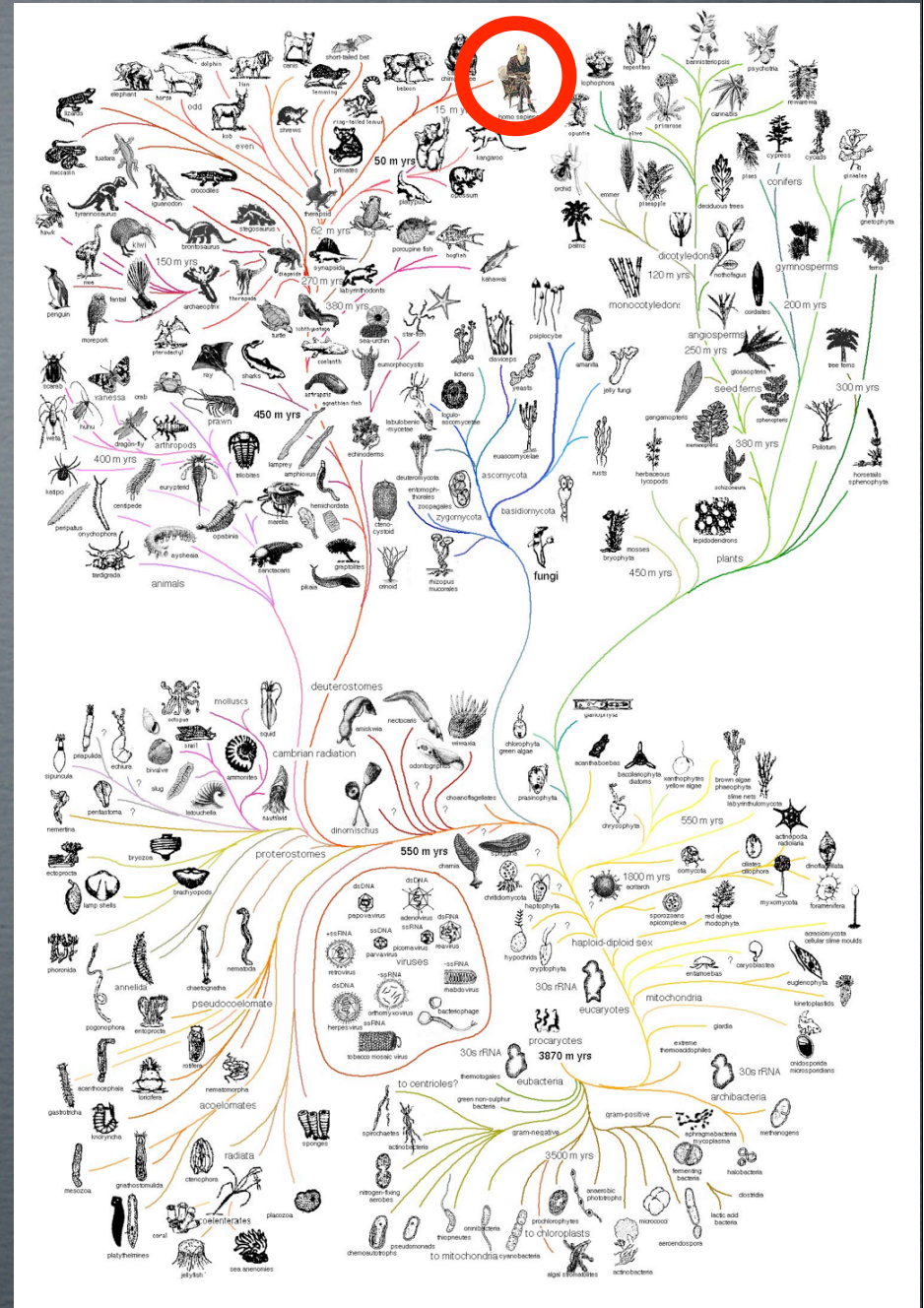
Over the last 150 years we have learned that life emerged over 3 billion years ago and evolved by mutation and natural selection.

We have located and deciphered the genetic code and outlined the basic mechanism of living cells and discovered the cause of disease.

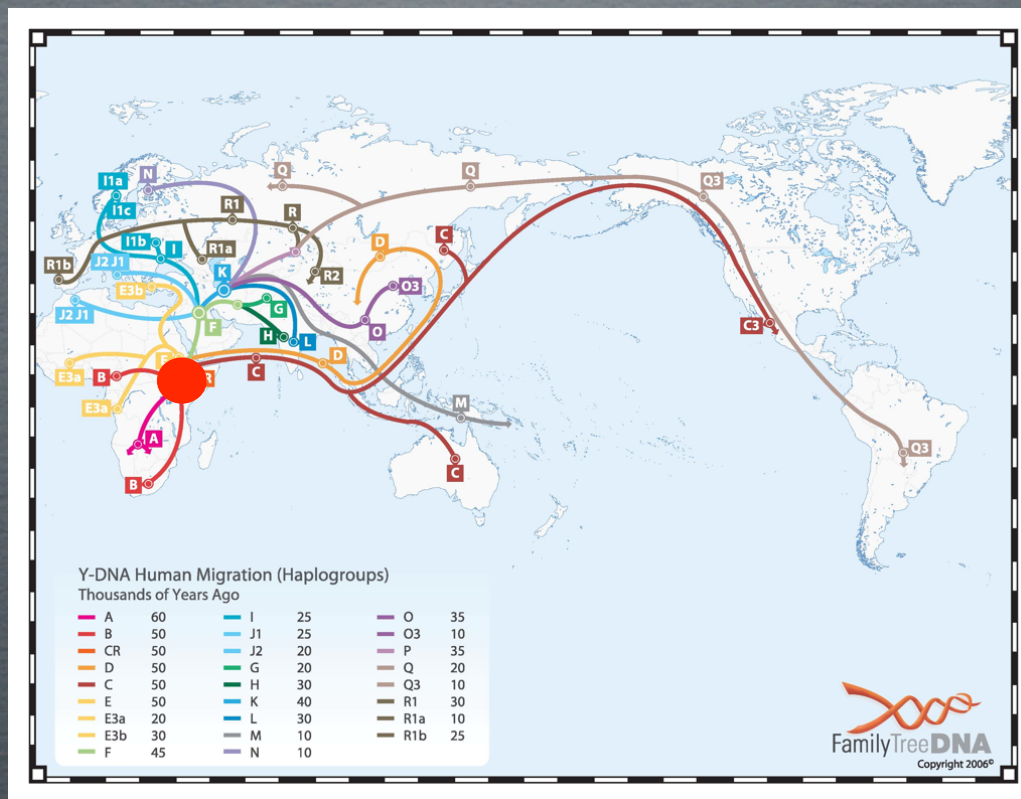
We have located the source of consciousness and emotion in the brain, and have started to explore its mysteries.

B R I D G E S T O P E A C E

Evolution, via natural selection, produces all the variations of living matter.



All humans have a (rather recent)
common ancestor and
a common origin.



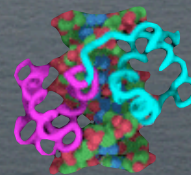
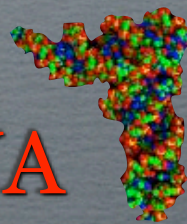
B R I D G E S T O P E A C E

The Microscopic Structure of Life.

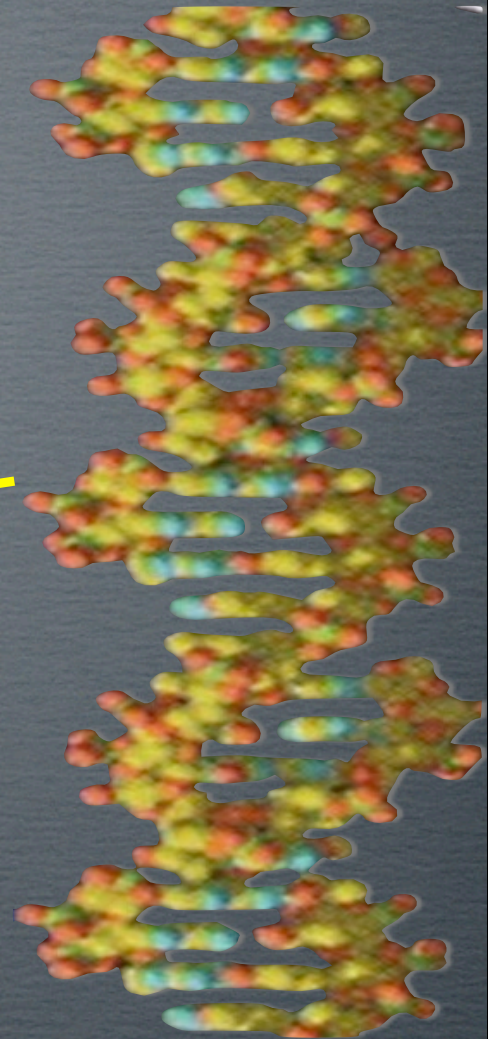


The cell

RNA

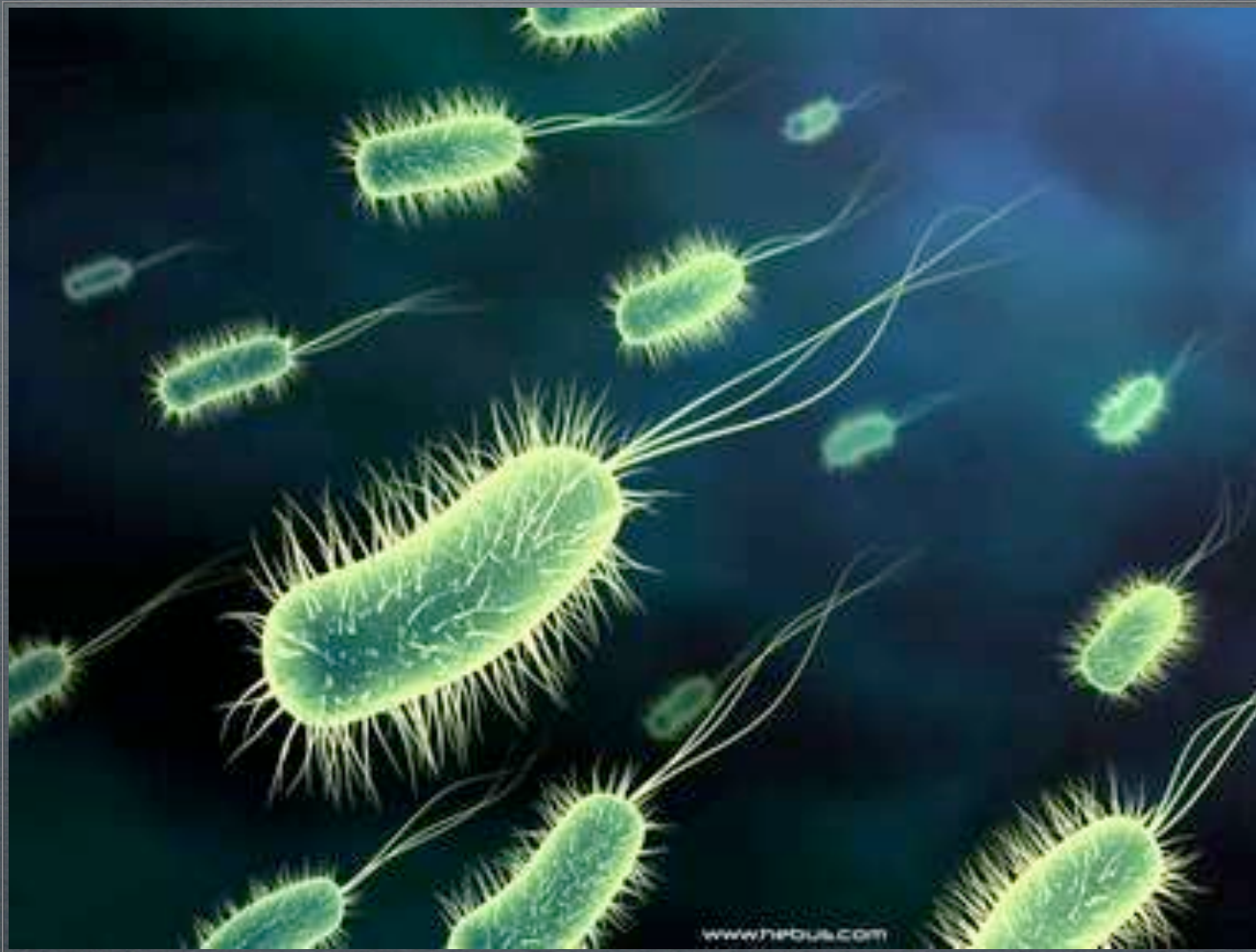


Proteins



DNA

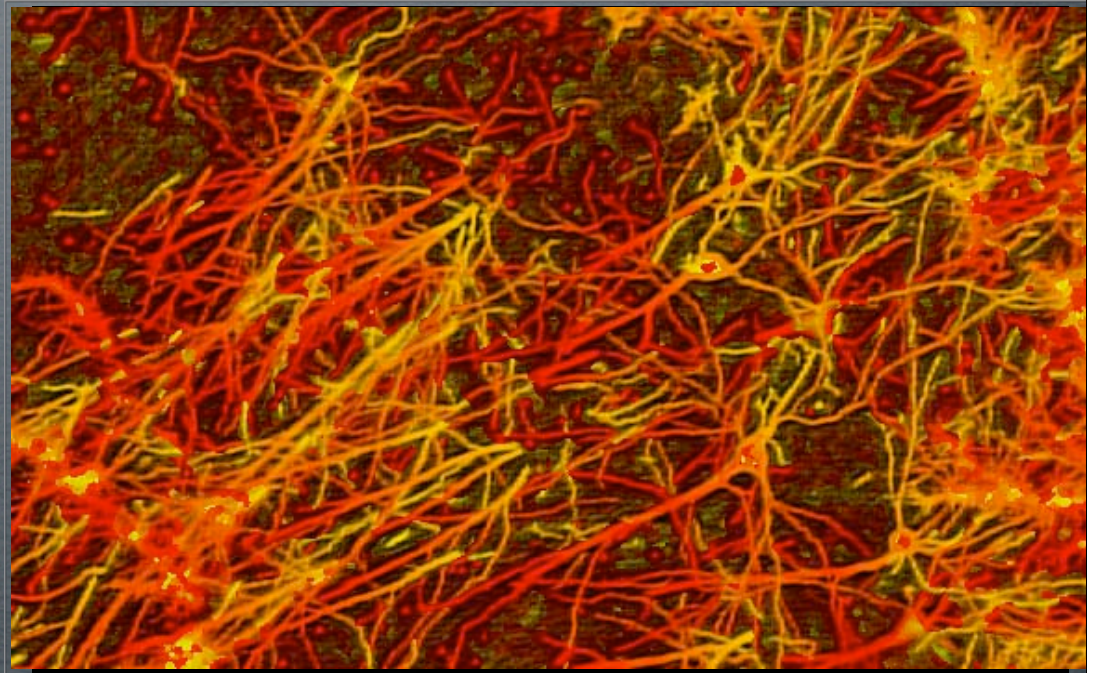
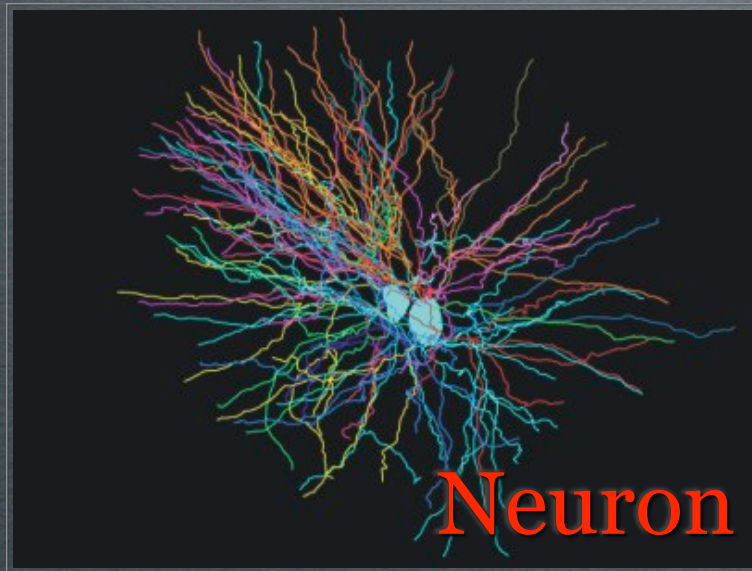
Disease is caused by bacteria, viruses, parasites and genetic mistakes.



B R I D G E S T O P E A C E

The locus of thought and
emotion is the brain.

A vast collection of 100 billion
interconnected neurons



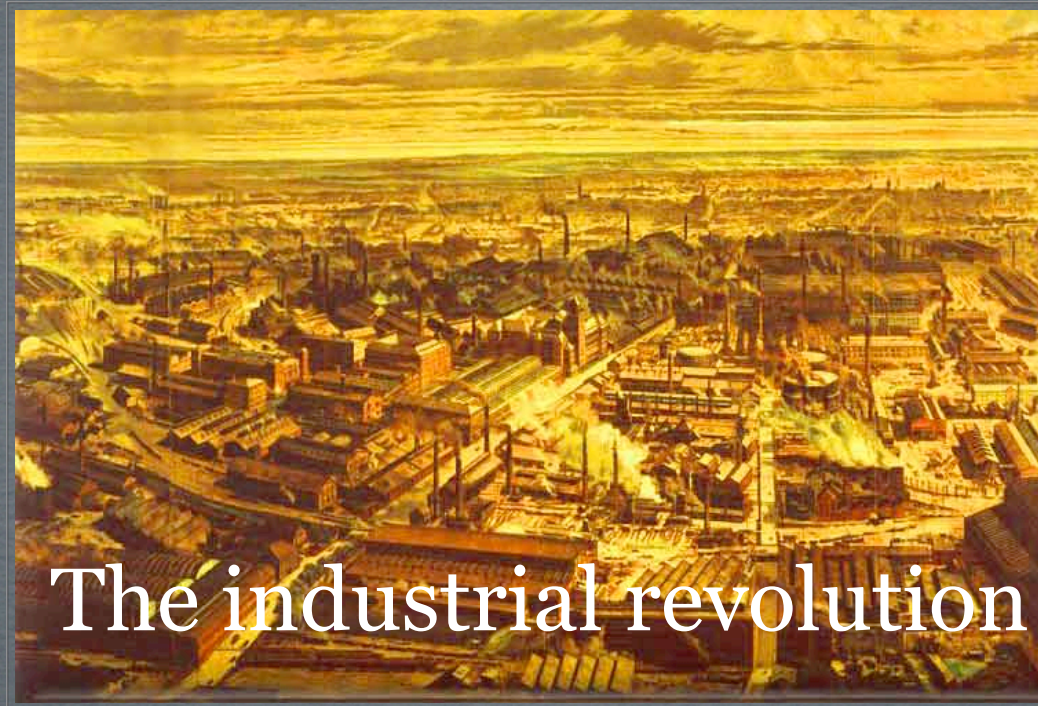
B R I D G E S T O P E A C E

THE CONTROL OF NATURE

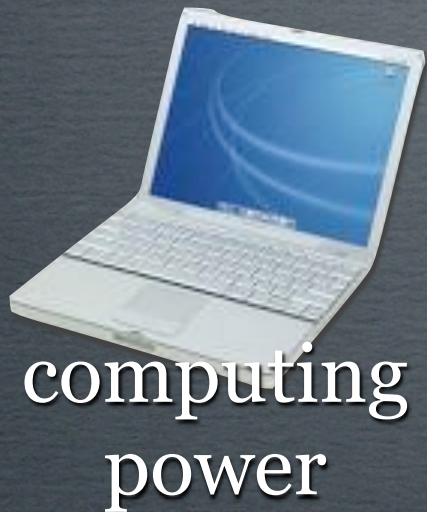
Basic science inevitably leads to
greater control over nature and
unpredictable new tools

The technology that science
has produced is of immense
benefit to humankind-
but also presents grave dangers

B R I D G E S T O P E A C E



The industrial revolution



computing
power



rapid transit



communication

BRIDGES TO PEACE

MEDICINE



DRUGS



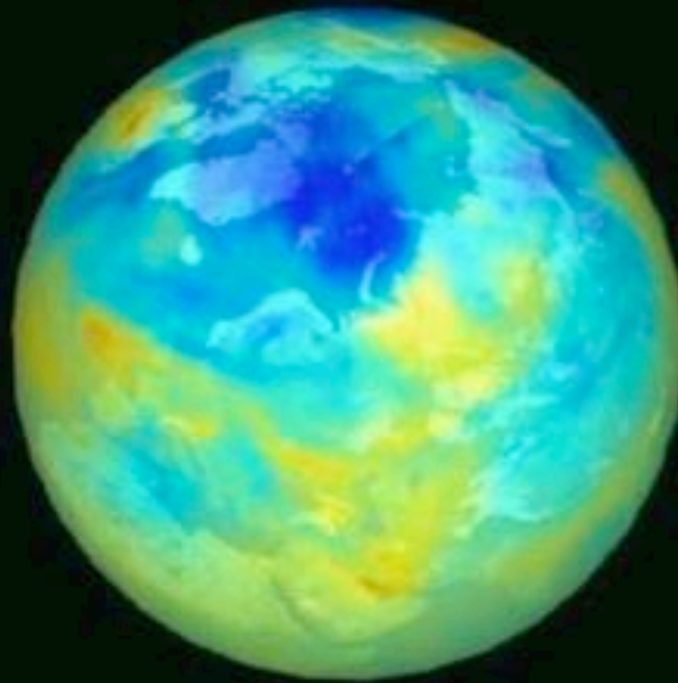
IMAGING

THE HUMAN
LIFESPAN HAS
DOUBLED IN
THE LAST 200
YEARS

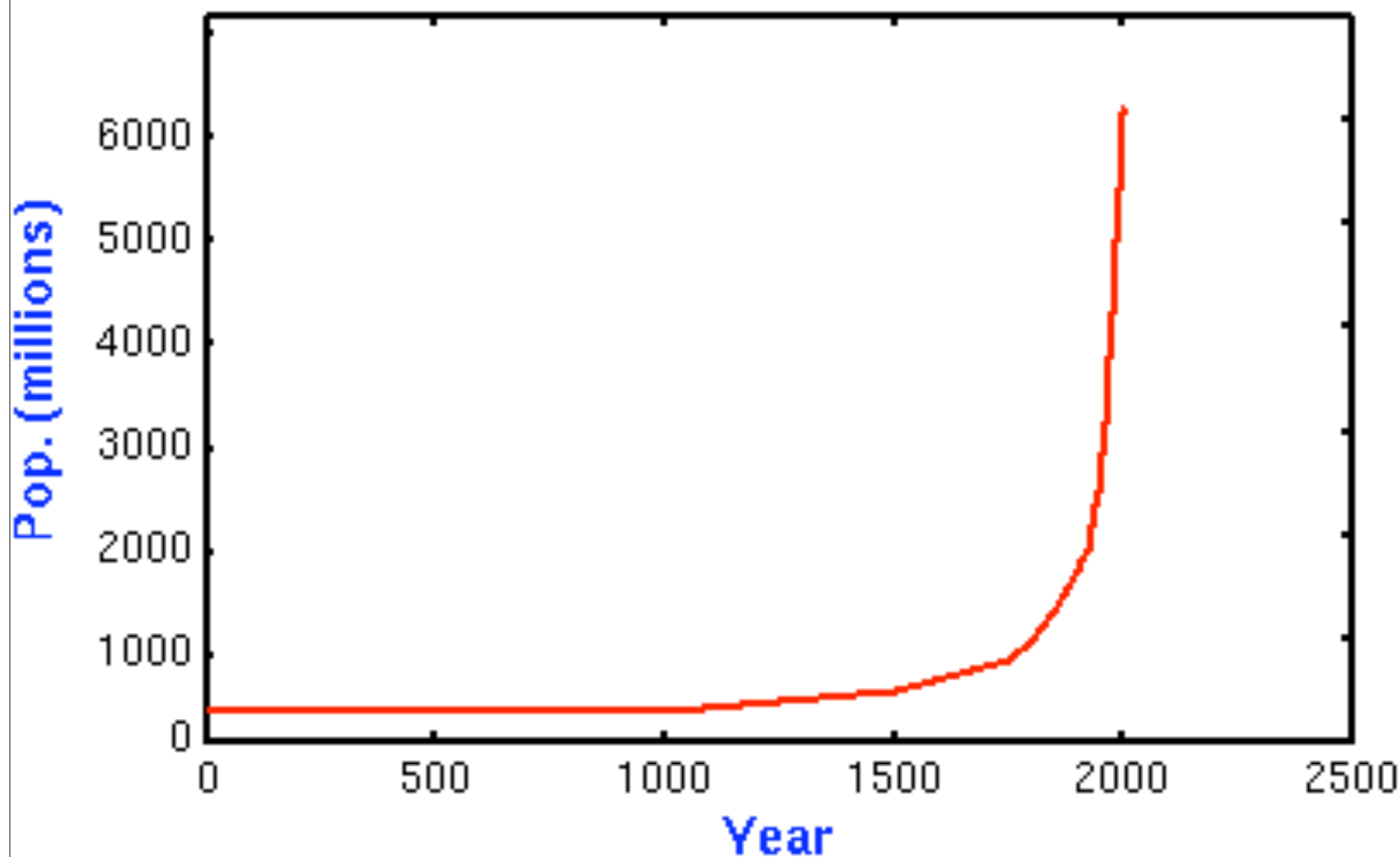
POWERFUL AND AWFUL WEAPONS



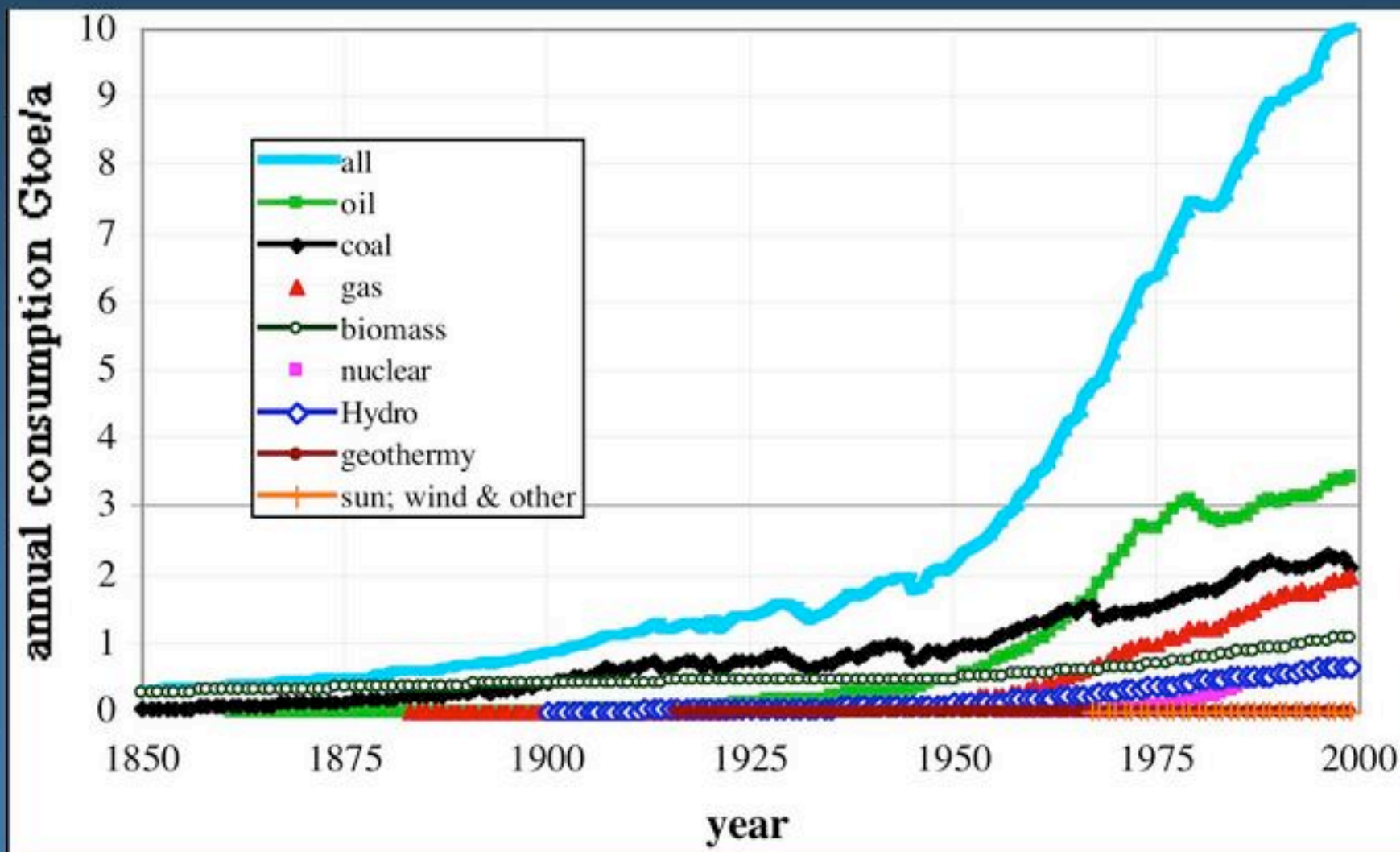
THREATS TO THE HEALTH OF OUR PLANET



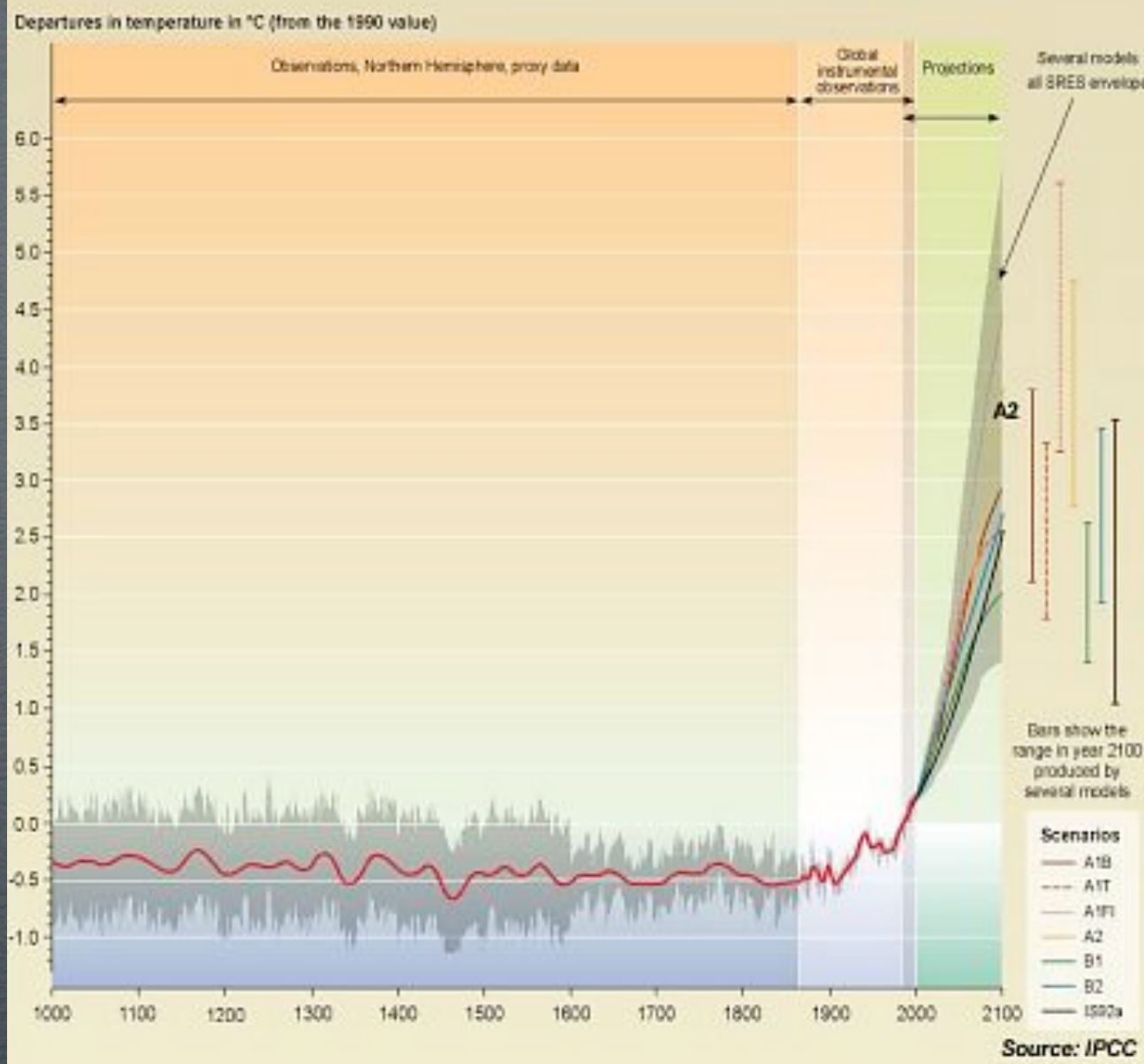
World Population, 1AD-2001



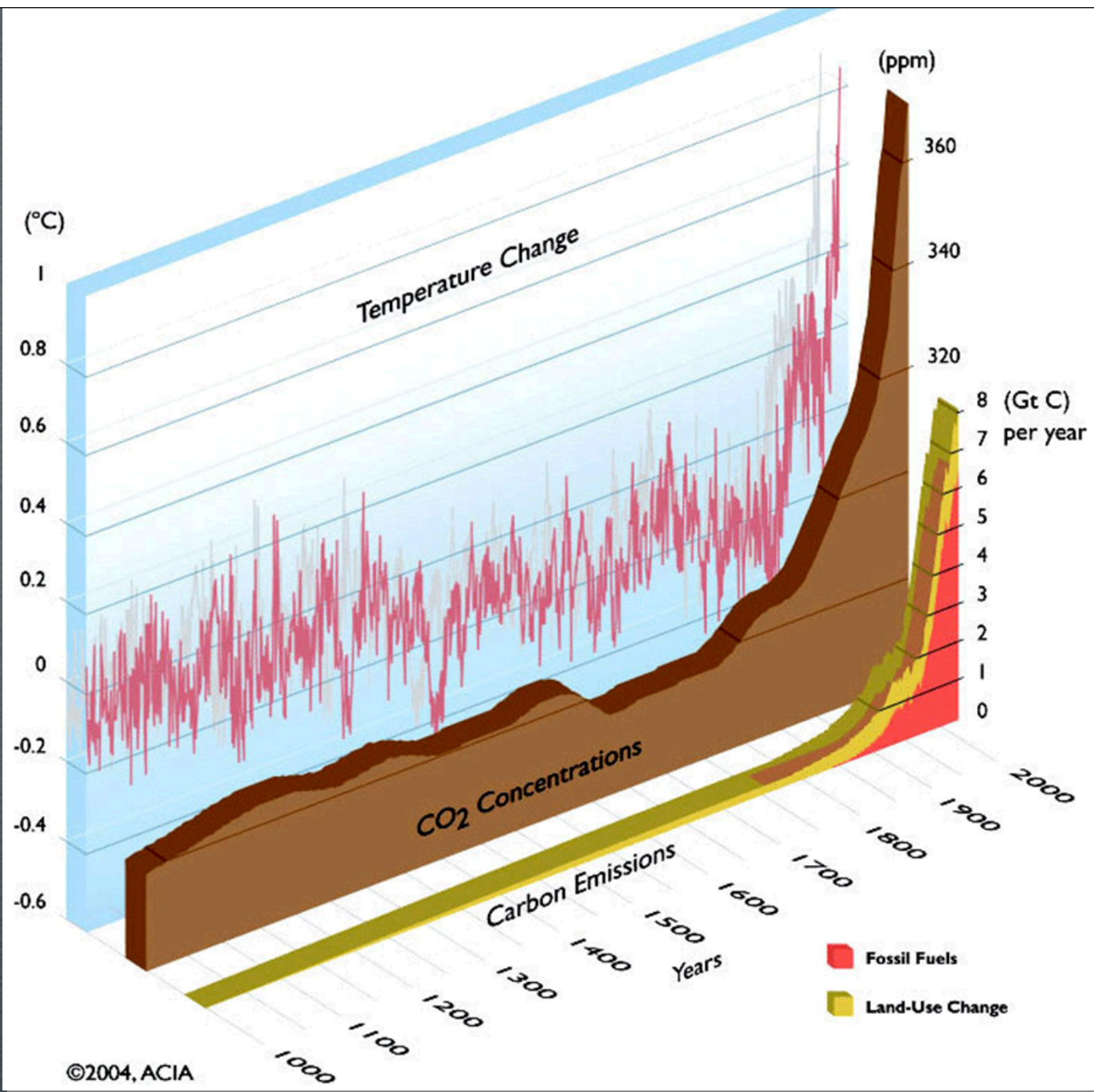
Global Energy Consumption



Variations of the Earth's surface temperature: year 1000 to year 2100

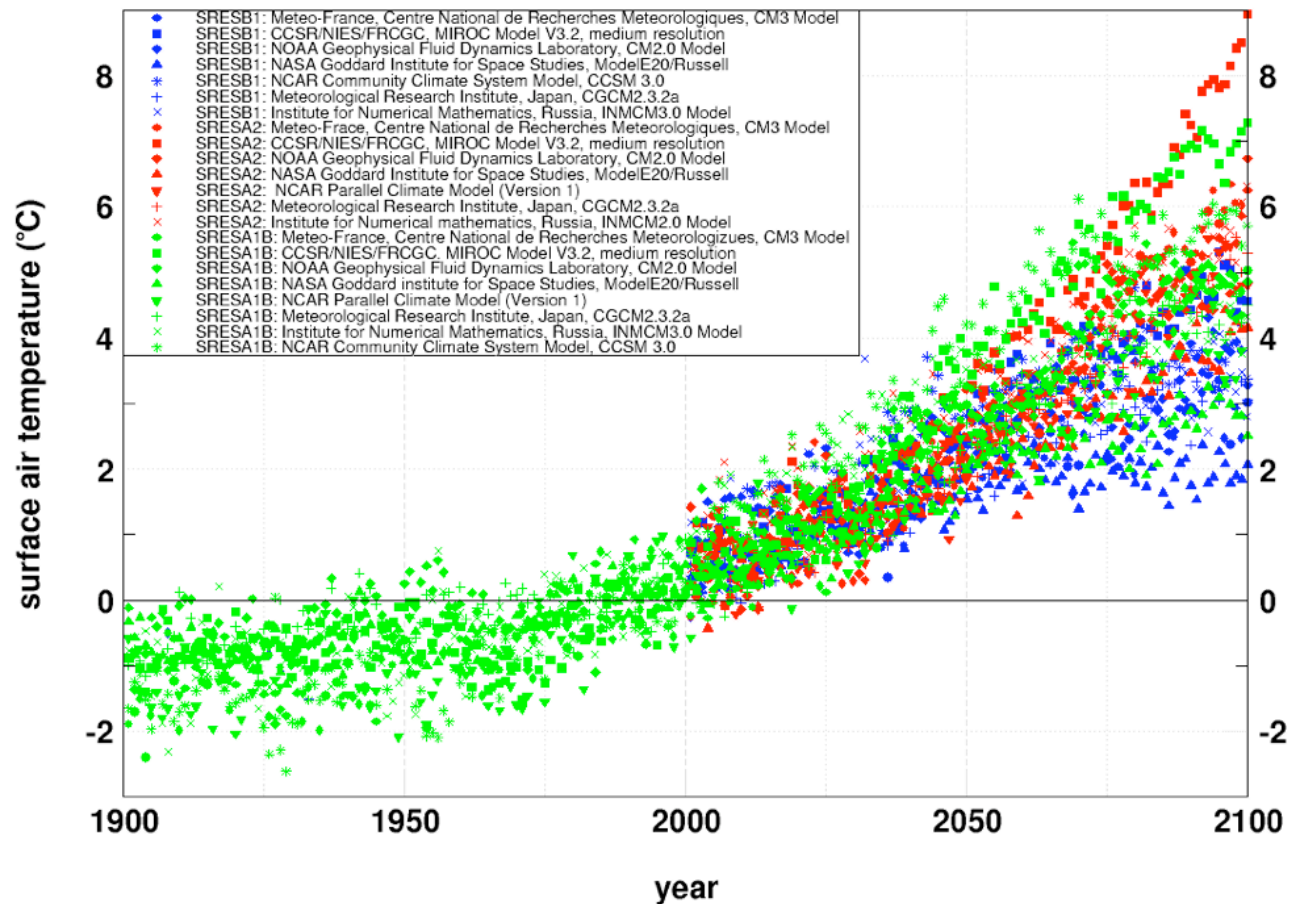


BRIDGES TO PEACE



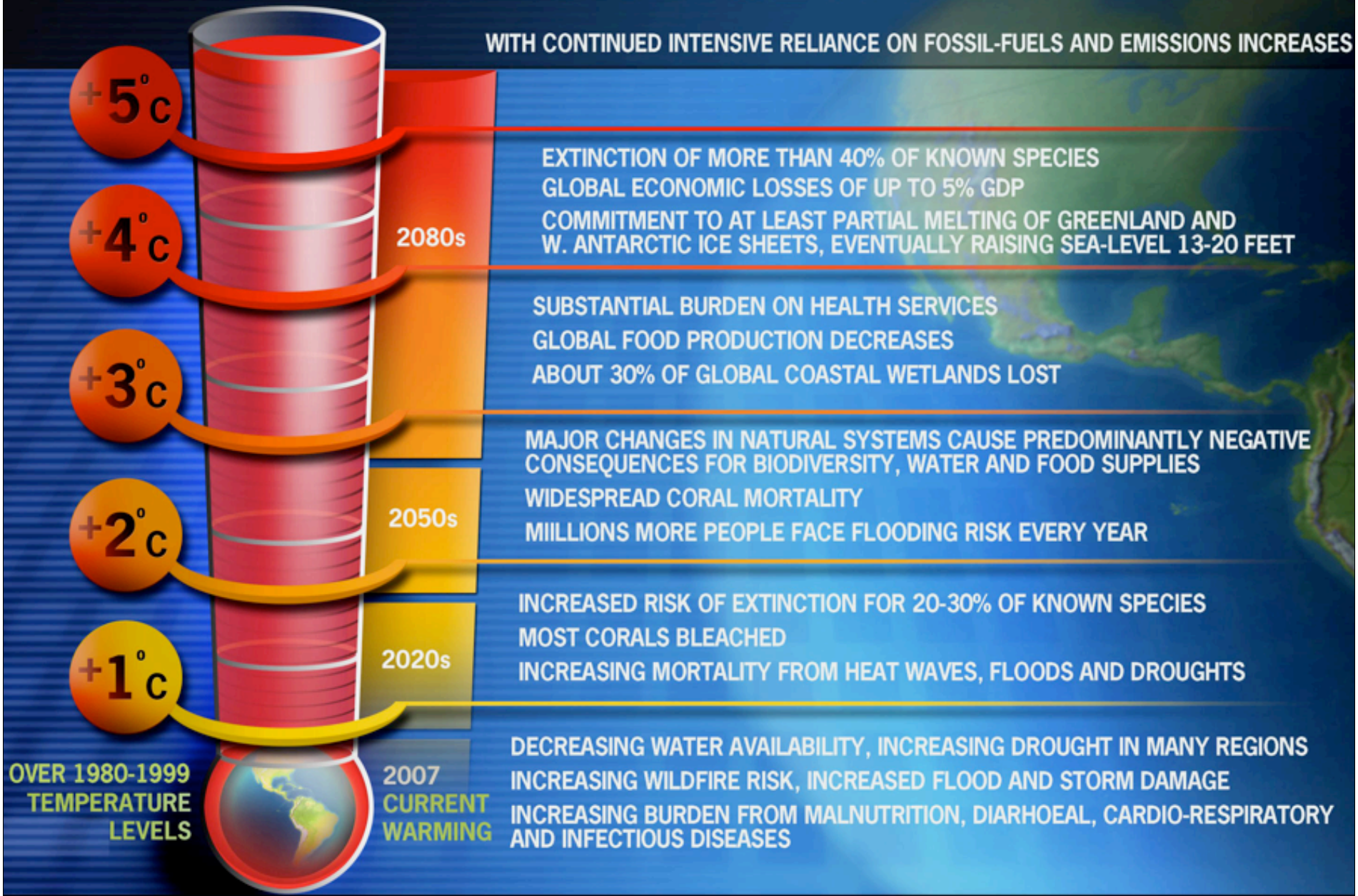
IPCC Projected Arctic Surface Air Temperature

(60°N - pole) : annual : 1900-2100



RISING IMPACTS OF GLOBAL WARMING

WITH CONTINUED INTENSIVE RELIANCE ON FOSSIL-FUELS AND EMISSIONS INCREASES



Greenland Ice Sheet

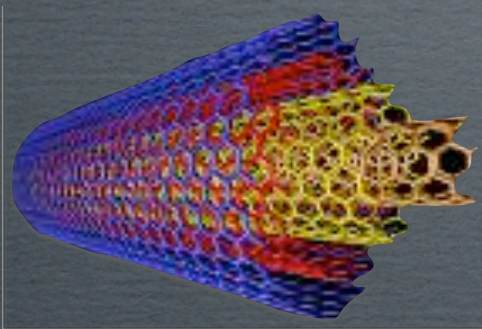
Coral Bleaching



B R I D G E S T O P E A C E

SCIENCE CAN AND MUST HELP

Nanotechnology



Solar Power



BRIDGES TO PEACE

**BUT MORE THAN SCIENCE IS
NEEDED**

**WE MUST BUILD AN ECONOMIC
AND POLITICAL SYSTEM THAT IS
NOT DEPENDENT ON
UNLIMITED CONSUMPTION
AND GROWTH**

**WE MUST MOVE TOWARDS
WORLD GOVERNMENT**

B R I D G E S T O P E A C E

INTERNATIONALISM

THE PROBLEMS EXPLORED BY BASIC
SCIENCE ARE POSED BY NATURE

ALL ARE EQUAL IN SCIENTIFIC RESEARCH

BASIC SCIENCE IS A TRULY
INTERNATIONAL ENDEAVOR
A MODEL OF COOPERATION,
COLLABORATION AND COMPETITION

B R I D G E S T O P E A C E

Thank you. I am grateful for this opportunity to send
greetings to a gathering of persons devoted to the cause of world law.

The growing movement of a
supranational government
seems to me today the major
hope of mankind...only world
law can assure us progress
towards civilization peace and
true humanity.

Albert Einstein

inevitably have a world law--either by way of brute force, or by
peaceful agreement.

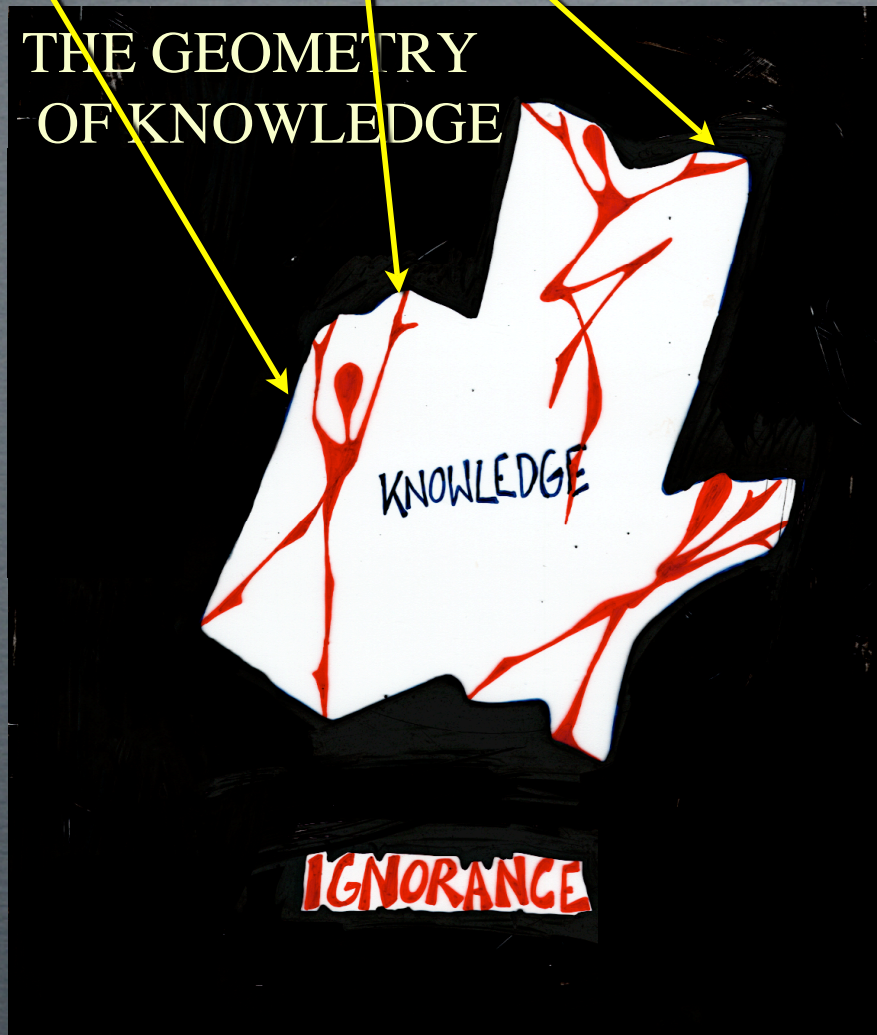
There is no effective defense against our modern methods of
mass destruction. There will be no defense to save civilization if we

QUESTIONS & PREDICTIONS

THE MOST IMPORTANT
PRODUCT OF
KNOWLEDGE IS
IGNORANCE

B R I D G E S T O P E A C E

QUESTIONS & PREDICTIONS



BRIDGES TO PEACE

QUESTIONS

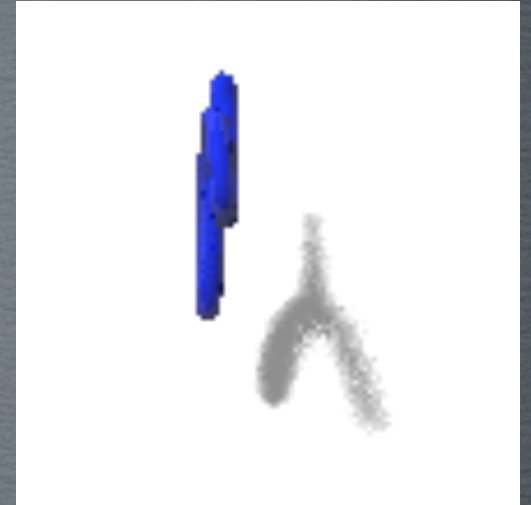
- ★ How did the Universe begin?

What is the nature of the dark

- ★ matter and the dark energy that fill the universe?

- ★ How do the forces of nature unify?

★ Is string theory the answer?



★ What is the nature of space and time ?

★ How does consciousness arise from
the collective behavior of neurons ?

AND MANY MORE

B R I D G E S T O P E A C E

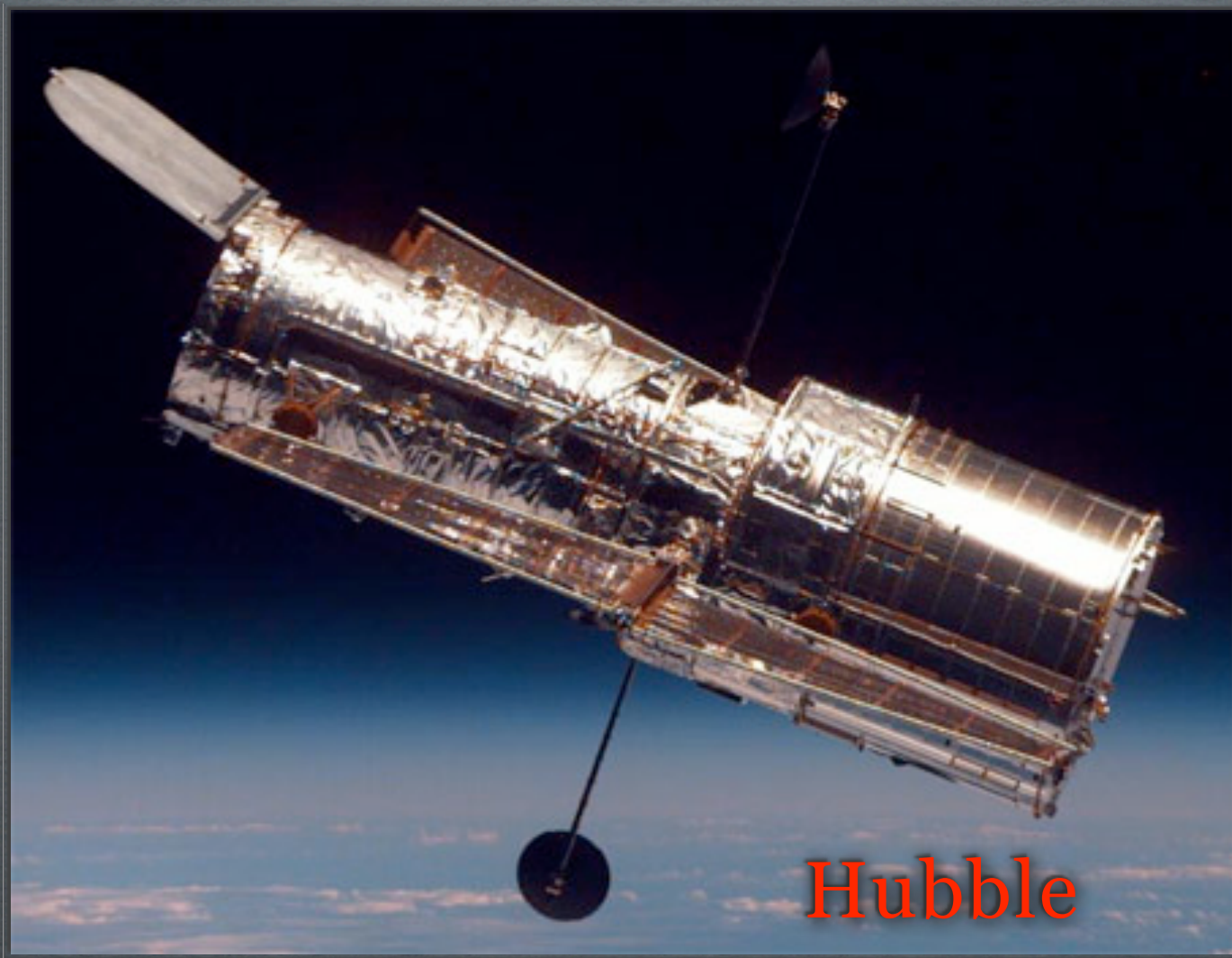
An aerial photograph showing the landscape of the LHC tunnel route. The tunnel is represented by a white line that forms a large circle and a smaller circle, both of which are part of the LHC's circular path. The landscape is a mix of green fields, brown patches, and some buildings. The border between Switzerland and France is visible in the bottom left corner.

SWITZERLAND

The Large Hadron Collider

FRANCE

BRIDGES TO PEACE



B R I D G E S T O P E A C E

PREDICTIONS

50-100 YEARS

Most of the questions of basic science that we ask today will be answered, but we will have new questions to ponder.

As we learn how the human mind works
social science, political science,
economics....will begin to be true sciences .

We will be well on our way towards a
sustainable economic and social
arrangement and a world government.

⋮

100-1000 YEARS

Increased Lifespan

Speciation

The Spread of Life

⋮

B R I D G E S . T O P E A C E

Science will be even more
important in tomorrow's world.

Science will continue to reveal more
of nature's secrets and increase our
control over its forces--
with consequences good and bad.

The culture of Science will inspire us
to exploit the good and avoid the bad.

THE END

BRIDGES TO PEACE