

# ORIGINS: THE UNIVERSE, AND EARTH, AND LIFE

## 13.7 Billion Years – the summary

what have we learned about the natural universe, and why do we trust it

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*“Dare to Know”  
Immanuel Kant, 1789*

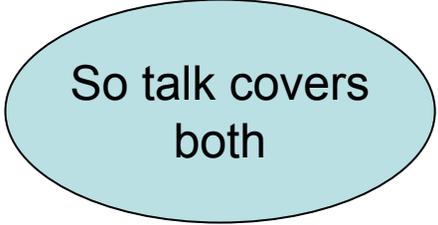
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# OUTLINE

- HOW SCIENCE WORKS, WHAT IS A “THEORY”
- “EFFECTIVE THEORIES” – FROM THE SMALLEST TO THE LARGEST SCALES
- WHAT HAVE WE LEARNED, WHAT SHOULD EVERYONE KNOW?
- SOME PERSPECTIVES:  
Big Questions – Myths and science and meaning – Next time



- When Shakespeare wrote, *nothing* was understood about how the natural world works
- Many conjectures and ideas – but no way to decide what was right
- Then modern science – both a way, a method, to try to understand the natural world, *and* the cumulative results
- Today we have, or are *addressing scientifically*, essentially a complete comprehension of the natural universe and all that is in it!!!



So talk covers both

*full description of **physical universe**, from beginning to end to smallest constituents to forces – don't know what the dark matter or the inflaton is, but testing several candidates, etc – know “how” but not yet “why”*

*for **biological universe** Darwin taught us “why”, and research focuses on “how” – have several ways life could originate from chemical molecules but don't yet know which actually happened – don't yet know how much of evolution is via changes in genes vs. by changing which genes are turned on at a given stage of development – active research areas*

## ➤ A little more about how science works...

- o Science is a human activity -- examine natural world, guess explanation for how something works, or why, figure out some consequences if indeed it works that way, test with observations and measurements, repeat until get it right
  - observations fine, always relics (don't have to be at the Big Bang or origin of life or see evolution to test it)
- o Every development in science has to be consistent with all we have learned, all established theories
  - e.g. age of universe, sun, earth must be old enough for evolution to have occurred
- o What is a “theory”?
  - basically a big idea that explains several or lots of observations and questions (Big Bang theory, quantum theory, theory of evolution, ...) – never “just a theory” – has passed many tests – may still be undergoing tests, but accepted by most relevant scientists

*NO BELIEFS, NOTHING EVER PROVED – but science has built up a great body of knowledge and understanding about the world*

## ➤ “Effective theories”

(name from “effectively you can ...”)

(based on building blocks known not to be elementary but can be treated as if they were)

Elementary  
constituents  
of matter

- o If we had to understand whole physical universe to understand any part, would never have made progress
- o Astronomers or geneticists don't need to know about quarks
- o Suppose properties of an atom depended on its history, or on whether it were in a person or a rock – wouldn't understand them yet  
(that's why physics is the easiest science)
- o Particle physics deduces, explains proton and its properties (from quarks and their properties) – but proton is input into nuclear physics, astrophysics, chemistry
- o Once we understand the individual effective theories, we can unify – today unification far along
  - Darwin and his ideas unified living and non-living, human and non-human, physical and mental
  - Probably only one force in nature, not four – only a few particles

universe

galaxies

solar systems

planets

molecules

atoms

nuclei

protons

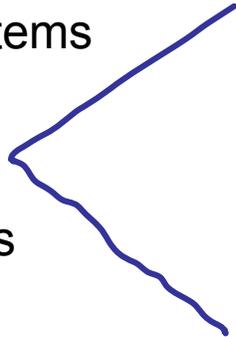
electrons

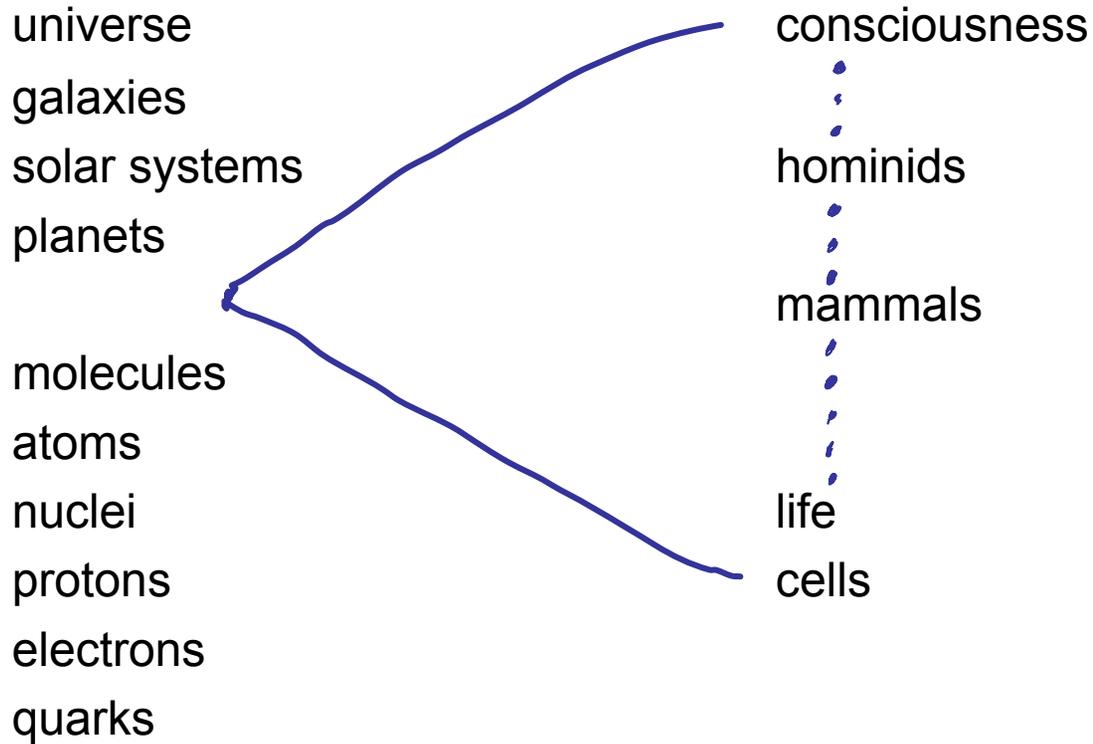
quarks

“Standard Model” theory of particle physics

Supersymmetry theory?

String theory?

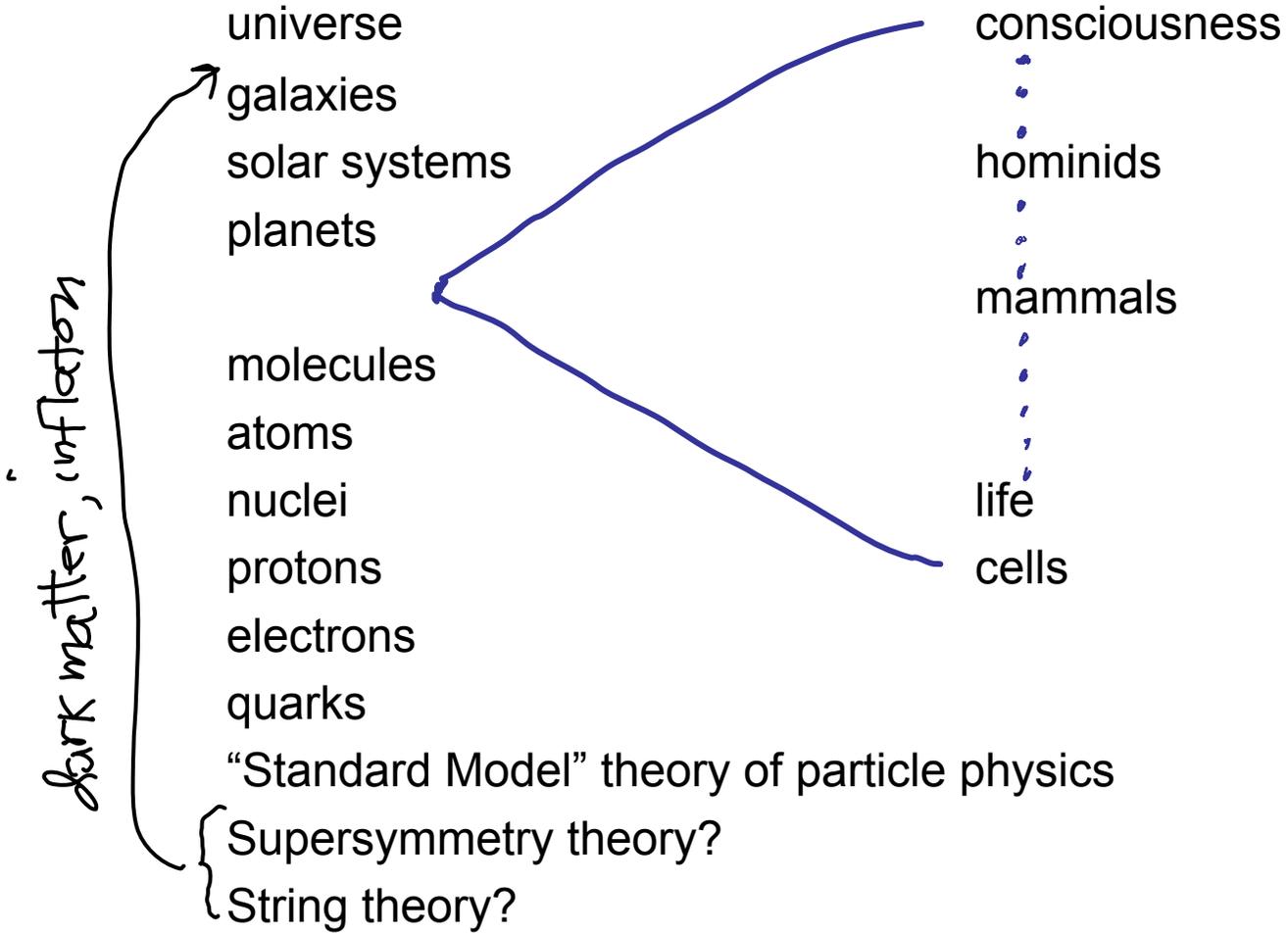




“Standard Model” theory of particle physics

Supersymmetry theory?

String theory?



dark matter, inflation

universe

galaxies

solar systems

planets

molecules

atoms

nuclei

protons

electrons

quarks

“Standard Model” theory of particle physics

Supersymmetry theory?

String theory?

consciousness

⋮

hominids

⋮

mammals

⋮

life

cells

emergence ↑  
↓ reductionism

## ➤ WHAT HAVE WE LEARNED ABOUT THE NATURAL UNIVERSE?

...and every educated person should know...

(there is very good evidence for the whole list...not metaphors,  
quantitative theories...)

- The universe is governed by a few (or maybe even one) irreducible universal natural laws that describe all there is and all that happens in the natural world – people can discover and understand them (it)

- The universe formed as a tiny region of energy density, then expanded very rapidly (“inflation”) – energy density unstable, turned into matter (elementary particles) – universe expanded and cooled – matter clumped, formed galaxies, stars and planets – carbon, oxygen, and other elements necessary for the chemistry of life on earth were made in stars that exploded before our earth formed

➤ All we see in the universe *is* made of just three fundamental particles (electrons, up quarks, down quarks), interacting via a few forces

(quarks combine to make protons and neutrons, which combine to make nuclei, nuclei and electrons to make atoms, atoms bind to molecules, which combine to make organisms... nuclei make planets and stars...)

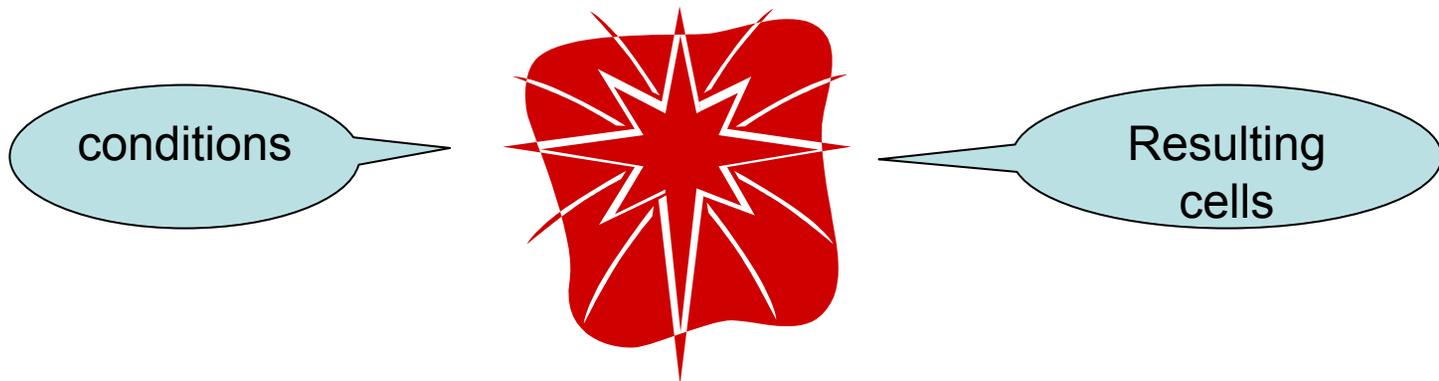
- The quarks and electrons in us are essentially all from the Big Bang, and many have been in every person who ever lived 😊

➤ The universe and the earth and life have histories – each began and developed – we mostly know and understand these histories

(began to be known for earth few centuries ago, for life maybe two centuries ago, for universe less than a century ago))

- The earth's history – oceans, atmosphere, continents, etc, the transition from chemicals to organisms -- is being understood

- Much is known and being learned about conditions when life began – much is known and being learned about the resulting cells – have a few plausible scenarios where can see how each step could have occurred – one actual mechanism may become convincing



- All life on earth is descended from a simple cell that developed nearly 4 Billion years ago (as Darwin said, now clear evidence) – living things share the same genetic code (and same biochemistry, RNA, left handed amino acids, right handed sugars, etc) 😊

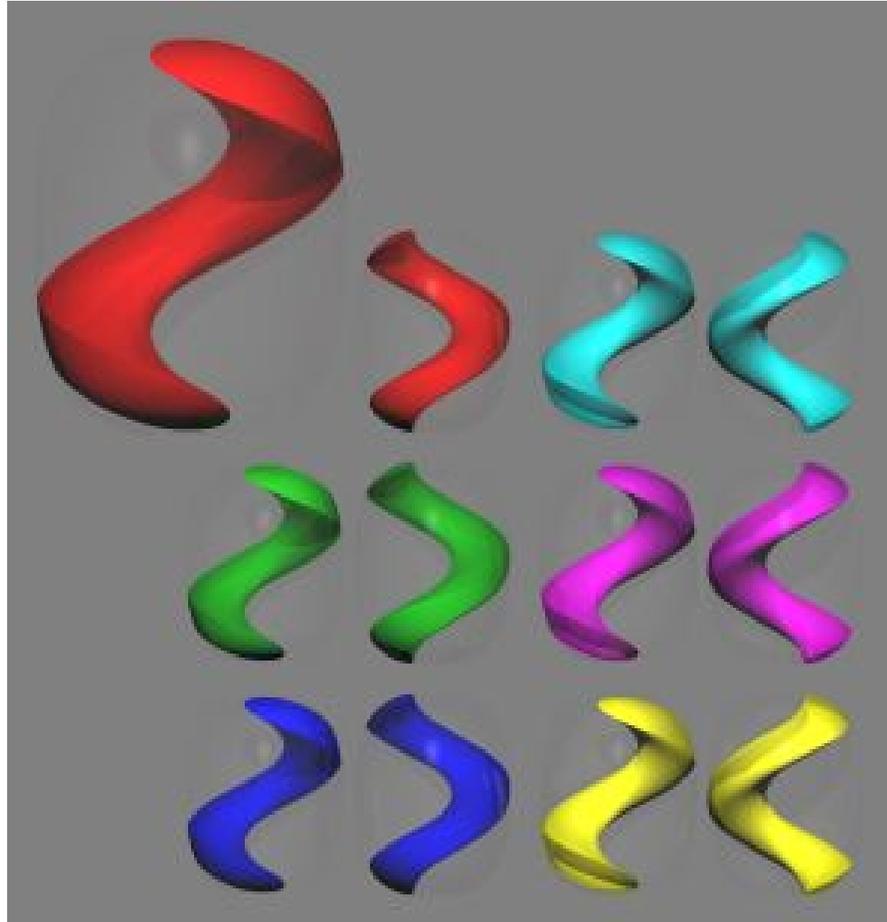
- Every human and organism is a fossil, with DNA that carries a record of the evolutionary past

- Once life began, natural selection can account for the evolution of today's diverse forms of life on earth, and of intelligent, conscious humans

All humans are interconnected through the history of their quarks and the history of their genes

# UP QUARKS

Jan Henrik Andersen



WOULD BE GREAT TO HAVE ONE UNDERGRAD  
COURSE PRESENTING AND EXPLAINING THESE  
(and more)

--AND WHY WE ARE CONFIDENT THEY ARE  
CORRECT

-- AND HOW WE LEARNED THEM

-- NO PREREQUISITES, HIGH SCHOOL MATH

some perspectives

For thousands of years people have been asking “big questions”

- Where did our universe come from, how did it begin?
- What are we made of?
- What is life, how did it begin?
- How are people different from animals?
- What is consciousness?

Beginning in Ionian Greece about 2600 years ago  
questions asked more systematically, answers debated  
– Greeks argued that people could answer them – but  
little progress until about 1600 in Western Europe

*Science started slowly* – crucial and major step was to ask  
small questions (define velocity, acceleration...study  
finch's beaks for years) – another was to formulate  
problems mathematically to deduce and predict testable  
consequences – modern science *methods* and *results*  
evolved steadily over 4 centuries

Scientists mostly study particles, finches to learn the  
underlying laws, not for their intrinsic interest -- always  
really aiming at Big Questions

TODAY SOME BIG QUESTIONS ARE ANSWERED, THE REST ARE BEING *ADDRESSED* SCIENTIFICALLY

-- first time in history

-- usually when topics become subjects of scientific research they become understood within decades

-- while developing, an area changes, then eventually settles down (e.g., everything around us is made of atoms, age of universe, genetic code), becomes textbook science

-- while it's changing there are lots of ideas, and data that needs confirmation:

## Research In Progress

Distinguish “Research In Progress” from textbook science

Origin of universe? Why is there something rather than nothing? *Being addressed now...*

ALL WE KNOW IS CONSISTENT WITH SPONTANEOUS CREATION OF UNIVERSES

- **IS THE UNIVERSE A VACUUM FLUCTUATION.** E.P. Tryon, 1973. *2pp.*
- **IS IT POSSIBLE TO CREATE A UNIVERSE IN THE LABORATORY BY QUANTUM TUNNELING?** E. Farhi, A. Guth, J. Guven 1989, *67pp*
- **CREATION OF A COMPACT TOPOLOGICALLY NONTRIVIAL INFLATIONARY UNIVERSE.** By A. Linde 2004

For example – quantum fluctuations create particle-antiparticle pairs and fields temporarily from nothing – events without causes standard in quantum theory – by uncertainty principle can do that for finite time – creation of pairs may occur in varying gravitational field so particles move, can't find each other to annihilate – energy density – inflates – energy released in big bang, etc

From time to time universes begin, all the time – total energy zero since gravitational field energy can be negative, so no time limit – only truly free thing – *lots* of universes

**R.I.P.**

All cultures addressed big questions – for thousands of years invented myths – no myth considered idea the universe or life could arise in an extremely simple form and evolve over a long time into a beautiful and complex system

Myths are satisfying, science right or wrong (and satisfying too – understanding why there is there)

-- universe is old and cold and dark – but now we understand that life only possible if universe is old and cold and dark

-- humans evolved to need to understand – so understanding the world can be a source of confidence and dignity

-- color arises from colorless molecules, and one can laugh without being composed of laughing particles, so morals can arise from genes that have none (paraphrase of Lucretious)

We shall not cease from exploration  
And the end of all our exploring  
Will be to arrive where we started  
And know the place for the first time

T.S.Eliot, *Four Quartets*

- Next time “Origins” (and course) could add some frontier topics:
  - o Ecology and complex systems
  - o Origins of language and of languages
  - o Consciousness (in past decade more books on consciousness by scientists than by philosophers!)
  - o Origins of music, art, mathematics
  - o Evolutionary medicine
  - o Depression
  - o Religion
  - o Extra space dimensions, hidden – for supersymmetry and strings
  - o Long term future of earth and life and universe

➤ Levels of explanation...proximate ... ultimate

Mom, where do people come from?

-- from mom's tummys

No, before that

-- Africa

No, before that

-- ancestors like apes

\* \* \* \* \*

No, before that

-- chemical elements

No, before that

-- the Big Bang

No, before that

Right answer for an exam?

- For Shakespeare: people, earth the center of the universe  
– since then we have moved from the center in many ways

Earth only one planet of many, orbits one sun, same laws of nature on earth and in heavens, sun in one galaxy, many galaxies, atoms in us were made in earlier stars, universe expanding, observable universe just part of universe, probably many universes, probably more dimensions

Life evolved, humans are animals and have same ancestors as animals, probably consciousness understandable as an emergent property of brains, much goes on in our minds and affects our behavior that is unconscious

Stars, lightning, earthquakes, hurricanes, strokes not punishment for behavior and are not predicting future

➤ *HOW DO YOU KNOW THAT?* -- frequent question

- *How do you know what it was like when the universe started?*
- *How do you know how the sun works?*
- *How do you know what it was like when life began?*
- *How do you know my genetics and biochemistry is the same as a pumpkin's?*
- *This is really all speculation, right?*
- *If you know all that why can't you help me lose weight or tell me when to carry an umbrella?*

Universities develop, disseminate knowledge – courses, books