So you want to teach an astrobiology course?

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Teaching Astrobiology
Who is Your Audience?

- Future astrobiology researchers.
- Other future scientists and engineers (not astrobiologists).
- Future “general public.”

Each audience calls for different course goals and pedagogical approaches.
Defining Your Goals

What do you want your students to retain in, say, 10 years?

• What particular content should you teach toward those goals?

• What is the best way to deliver that content?
This won’t work...

Education is not the filling of a pail, but the lighting of a fire.
— William Butler Yeats
Instead, you need to motivate....

- **Education**: Science content.
- **Perspective**: Change student perceptions on ourselves and our planet.
- **Inspiration**: Inspire your students to want to learn more and make the world a better place.

*Human history becomes more and more a race between education and catastrophe.*

— H. G. Wells, 1920
You cannot actually teach anything to anyone, but can only facilitate them learning for themselves.

- Study time is required.

- Your job as a teacher is to help them study sufficiently and efficiently:
  - Class (or online lecture) time ~ 1/4 to 1/3 of total student “time on task” — use it to motivate.
  - Assignments (reading, homework) build understanding.
  - Exams designed to help students consolidate knowledge.
My Goals for an astrobiology course (future "general public")

1. The Nature of Science *(APPROACH)*
   How to evaluate scientific evidence; how to distinguish science from nonscience; …

2. Basic Science Literacy *(FACTS/CONCEPTS)*
   Our physical place in space and time; origin and history of the universe; origin and history of the Earth; the theory of evolution; …

3. Lifelong Science *(LEGACY)*
   Excite students so they’ll want to learn more: additional formal science courses, reading the newspaper and following the web, …
Nature of Science

• Epicurus (c. 300 B.C.):
  “There are infinite worlds both like and unlike this world of ours… we must believe that in all worlds there are living creatures and plants and other things we see in this world.”

• Aristotle:
  “The world must be unique…”

→ 2000 years of debate --- why?
Nature of Science

Because it’s possible to argue endlessly as long as there are no actual facts to get in the way…

Science is:

• a way of distinguishing possibilities from realities.
• a way of helping people come to agreement.
Hallmarks of Science

Seeks explanations for observed phenomena that rely solely on natural causes.

Progresses through creation and testing of models of nature that explain the observations as simply as possible.

Science

Makes testable predictions about natural phenomena. If predictions do not agree with observations, model must be revised or abandoned.
Basic Science Literacy

- Focus on the Big Picture – use the “10-year test.”
- Understand how learning occurs. E.g.:
  \(
  \Rightarrow \text{set context (e.g., scale)}
  \)

...
Beyond UFOs ("what I know about aliens (visiting Earth)"
Basic Science Literacy

• Focus on the Big Picture – use the “10-year test.”
• Understand how learning occurs. E.g.:
  → set context (e.g. scale)
  → extract key ideas (“simplify but don’t lie”)
  → relate to familiar ideas (“concrete to abstract”)
  → avoid jargon as much as possible
  → address misconceptions
  → “translate” scientific usage
<table>
<thead>
<tr>
<th>Term</th>
<th>Everyday Life Meaning</th>
<th>Scientific Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>model</td>
<td>something you build</td>
<td>a representation of nature, sometimes using mathematics or computer simulations, that is intended to explain or predict observed phenomena.</td>
<td>A model of planetary motion can be used to calculate exactly where planets should appear in our sky.</td>
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<tr>
<td>hypothesis</td>
<td>a guess or assumption of almost any type</td>
<td>a model that has been proposed to explain some observations, but which has not yet been rigorously confirmed</td>
<td>Scientists hypothesize that the Moon was formed by a giant impact, but there is not enough evidence to be fully confident in this model.</td>
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<tr>
<td>theory</td>
<td>speculation</td>
<td>a particularly powerful model that has been so extensively tested and verified that we have extremely high confidence in its validity</td>
<td>Einstein’s theory of relativity successfully explains a broad range of natural phenomena and has passed a great many tests of its validity.</td>
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<tr>
<td>bias</td>
<td>distortion, political motive</td>
<td>tendency toward a particular result</td>
<td>Current techniques for detecting extrasolar planets are biased toward detecting large planets.</td>
</tr>
<tr>
<td>critical</td>
<td>really important; giving comments (sometimes taken as negative comments)</td>
<td>right on the edge</td>
<td>A boiling point is a “critical value” because above that temperature, a liquid will boil away.</td>
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<tr>
<td>deviation</td>
<td>strangeness or unacceptable behavior</td>
<td>change or difference</td>
<td>The recent deviation in global temperatures compared to their long-term average implies that something is heating the planet.</td>
</tr>
<tr>
<td>enhance/enrich</td>
<td>improve</td>
<td>increase or add more, but not necessarily making something “better.”</td>
<td>“Enhanced color” means colors that have been brightened. “Enriched with iron” means containing more iron.</td>
</tr>
<tr>
<td>negative feedback</td>
<td>poor response</td>
<td>a self-regulating cycle</td>
<td>The Sun’s fusion rate is steady because if it were to go up, negative feedback would cause it to go back down.</td>
</tr>
<tr>
<td>positive feedback</td>
<td>good response, praise</td>
<td>a self-reinforcing cycle</td>
<td>Gravity can provide positive feedback to a forming planet: Adding mass leads to stronger gravity, which leads to more added mass, and so on.</td>
</tr>
<tr>
<td>state (as a noun)</td>
<td>a place or location</td>
<td>a description of current condition</td>
<td>The Sun is in a state of balance, so that it shines steadily.</td>
</tr>
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<td>trick</td>
<td>deception or prank</td>
<td>clever approach</td>
<td>A mathematical trick solved the problem.</td>
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<td>uncertainty</td>
<td>ignorance</td>
<td>a range of possible values around some central value</td>
<td>The measured age of our solar system is 4.55 billion years with an uncertainty of 0.02 billion years.</td>
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<td>values</td>
<td>ethics, monetary value</td>
<td>numbers or quantities</td>
<td>The speed of light has a measured value of 300,000 km/s.</td>
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Lifelong Science

• Space exploration
• Curiosity about our origins
• ET / SETI

→ astrobiology and “the turning point”
  (in Beyond UFOs, this is the “astonishing implications to our future”).
Course Structure

1. Introduction —
   the basis of the new science of LIU and the nature of science in general

2. Life on Earth —
   its nature and history

3. Life in the Solar System —
   especially Mars, Europa

4. Life Among the Stars —
   issues of habitability, extrasolar planets, and SETI
Detailed Structure 1: Introduction
(2 weeks in a 1-semester course)

- The Astronomical Context
- The Emergence of Astrobiology
- The Nature of Science
Detailed Structure 1: Introduction
(2 weeks in a 1-semester course)

- The Astronomical Context
  - Number of stars and planets (lots of places to look)
  - Scale of the universe (but these places are not easily accessible)
  - History of the universe (why the elements of life are widespread)
  - Formation of stars and planets (why Earth is probably not unique)

- The Emergence of Astrobiology

- The Nature of Science
Detailed Structure 1: Introduction
(2 weeks in a 1-semester course)

- The Astronomical Context
- The Emergence of Astrobiology
  - Mounting evidence that life elsewhere is at least plausible
  - Topics of study in astrobiology
- The Nature of Science
Detailed Structure 1: Introduction
(2 weeks in a 1-semester course)

- The Astronomical Context
- The Emergence of Astrobiology
- The Nature of Science
  - Historical development of science, including Copernican revolution
  - Hallmarks of modern science
  - Theories in science (the “just a theory” misconception)
  - Distinguishing science from nonscience and pseudoscience
Detailed Structure 2: Life on Earth
(3–4 weeks in a 1-semester course)

- The Habitability of Earth (Geological Context of life)
- The Nature of Life on Earth
- The Origin and Evolution of Life on Earth
The Habitability of Earth
- Importance of geology: volcanism, plate tectonics, magnetic field
- How we study the past: rocks and fossils; the geological time scale
- Geological history: origin and early Earth
- Keeping Earth habitable: plate tectonics; climate regulation and the CO$_2$ cycle

The Nature of Life on Earth

The Origin and Evolution of Life on Earth
The Habitability of Earth

The Nature of Life on Earth
- What is life? — Attempts to define life; the critical role of the theory of evolution
- How life works: Cells as basic “units of life”; metabolism as the basic chemistry of life; heredity and the molecular basis of reproduction and evolution
- We are not “typical” of life on Earth. E.g., the 3 domains; extremophiles

The Origin and Evolution of Life on Earth
Detailed Structure 2: Life on Earth
(3–4 weeks in a 1-semester course)

- The Habitability of Earth
- The Nature of Life on Earth
- The Origin and Evolution of Life on Earth
  - Searching for origins: When did life begin? Where did it begin?
  - How did life begin? We may never know, but can construct plausible scenarios…
  - Major steps in the evolution of life on Earth: e.g., rise of oxygen, Cambrian explosion
  - Impacts and extinctions
  - Human evolution
Detailed Structure 3: Life in the Solar System
(3–4 weeks in a 1-semester course)

- The Search for Life in the Solar System
- Prospects for Finding Life on Mars
- Prospects for Finding Life on Jovian Moons
- The Evolution of Habitability
The Search for Life in the Solar System
- Environmental requirements for life — and where we might find life in the solar system.
- Methods of exploring the solar system

Prospects for Finding Life on Mars

Prospects for Finding Life on Jovian Moons

The Evolution of Habitability
Detailed Structure 3: Life in the Solar System
(3–4 weeks in a 1-semester course)

- The Search for Life in the Solar System
- Prospects for Finding Life on Mars
  - A little history: Percival Lowell and myths of Martians
  - Martian conditions today, including possible underground liquid water
  - The climate history of Mars
  - Searching for life
  - Future Mars exploration plans
- Prospects for Finding Life on Jovian Moons
- The Evolution of Habitability
The Search for Life in the Solar System

Prospects for Finding Life on Mars

Prospects for Finding Life on Jovian Moons
  - The nature of jovian moons, and why some are geologically active
  - Evidence concerning a subsurface ocean on Europa
  - Energetics of potential life on Europa — is there enough chemical energy available to support widespread life?
  - Possible subsurface oceans on Ganymede and Callisto
  - Organic chemistry on Titan; Enceladus and beyond

The Evolution of Habitability
Detailed Structure 3: Life in the Solar System
(3–4 weeks in a 1-semester course)

- The Search for Life in the Solar System
- Prospects for Finding Life on Mars
- Prospects for Finding Life on Jovian Moons
- The Evolution of Habitability
  - Nature of the habitable zone and how it evolves with time
  - Why Earth has remained habitable for 4 billion years, while Venus did not.
  - Future habitability of the Earth.
Detailed Structure 4: Life Among the Stars
(3–4 weeks in a 1-semester course)

- The Search for Habitable Worlds
- SETI
- Interstellar Travel
- What Do Other Civilizations – Or Lack Thereof – Mean to Us?
Detailed Structure 4: Life Among the Stars
(3–4 weeks in a 1-semester course)

- **The Search for Habitable Worlds**
  - What kinds of stars could support habitable planets?
  - Detecting extrasolar planets
  - Detecting life on extrasolar planets — spectral signatures, etc.
  - Are Earth-like planets rare or common?

- **SETI**

- **Interstellar Travel**

- **What Do Other Civilizations – Or Lack Thereof – Mean to Us?**
The Search for Habitable Worlds

SETI
- What is SETI searching for? — Drake equation etc
- The evolution of intelligence — if life is common, should intelligence be common as well?
- SETI strategies

Interstellar Travel

What Do Other Civilizations – Or Lack Thereof – Mean to Us?
Detailed Structure 4: Life Among the Stars
(3–4 weeks in a 1-semester course)

- The Search for Habitable Worlds
- SETI
- Interstellar Travel
  - Could we travel to the stars? The challenge and possibilities of interstellar travel.
  - Reconsidering UFOs in light of the realities of interstellar travel.
- What Do Other Civilizations – Or Lack Thereof – Mean to Us?
The Search for Habitable Worlds
SETI
Interstellar Travel
What Do Other Civilizations – Or Lack Thereof – Mean to Us?
- The Fermi paradox (where is everybody?) and its possible solutions
- Implications of finding microbial life elsewhere
- Implications of contact with ET.
# UFOs, Creationism

These topics WILL come up, so best to be prepared!

A few guidelines:

- Never belittle these ideas. Some students hold them dearly, and any hint of condescension will backfire.
- Carefully distinguish between science and nonscience, showing students why beliefs in UFOs and creationism don’t rate as science…
- …while pointing out that everyone is free to believe what they wish, and that being nonscience doesn’t make it wrong (just not something we can evaluate scientifically)
- Do all the above early to break down “us against them” barriers, then use the rest of the semester to help students understand, e.g.,
  - why evolution is not “just” a theory
  - the extensive evidence for a long history for the universe, the Earth, and life
  - the difficulty of interstellar travel and why UFO claims generally just don’t add up.

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Always a challenge, but a few ideas . . .

- Quizzes: EOC Quick Quiz; NEW: online Reading and Concept Quizzes.
- Homework: EOC selection.
- Projects: EOC Web Projects; many others possible.
- Testing: NEW Test Bank for instructors
Resources

- Reading: Books, web
- Assignments, exams: books, web site
- Poster on Scale: Contact me if you want to reproduce.

- “How to Succeed” handout: download from my web site.
- Mini-book on teaching science: reviewers wanted.
E-mail: jeff@bigkidscience.com
personal web site: www.jeffreybennett.com
Beyond UFOs web site: www.BeyondUFOs.com
Children’s web site: www.BigKidScience.com