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

and remember:

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…"

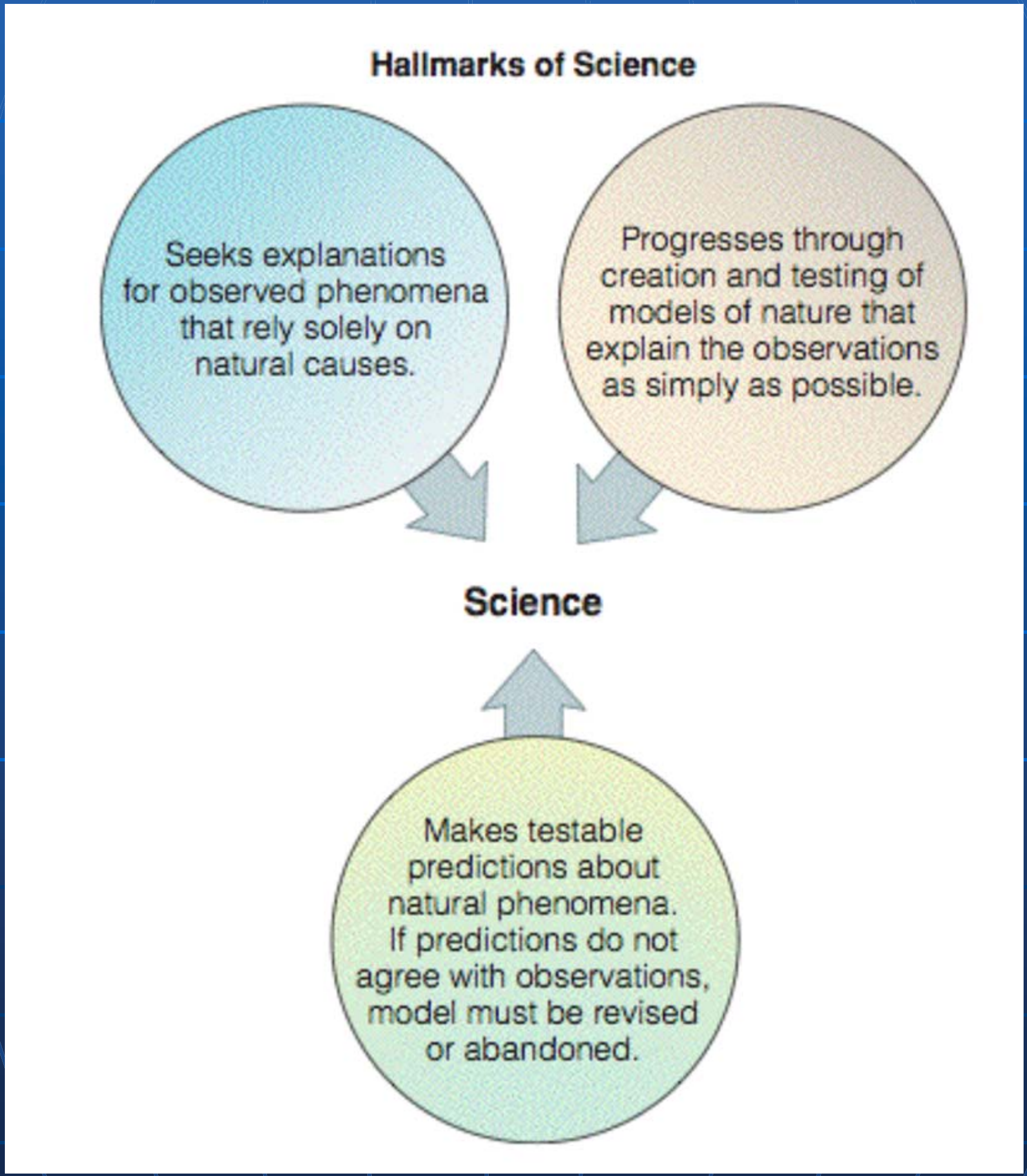
  → *2000 years of debate --- why?*

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.:
  → ***set context (e.g., scale)***
  . . .

Voyage Scale Model Solar System
(1 to 10 billion)

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 3.2 Scientific Terminology

This table lists some words you will encounter in this book that have a different meaning in science than in everyday life. (Adapted from a table published by Richard Somerville and Susan Joy Hassol in Physics Today, Oct. 2011.)

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

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

Detailed Structure 2: Life on Earth
(3–4 weeks in a 1-semester course)

- 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

Detailed Structure 2: Life on Earth
(3–4 weeks in a 1-semester course)

- 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

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

- 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

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 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.

Example

Detailed Structure 4: Life Among the Stars
(3–4 weeks in a 1-semester course)

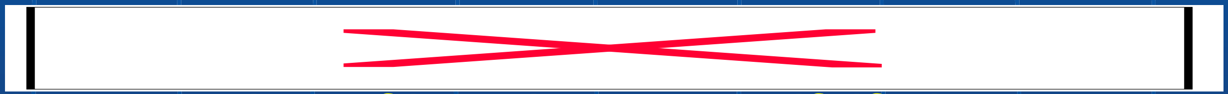
- The Search for Habitable Worlds
- SETI
- Interstellar Travel
- What Do Other Civilizations – Or Lack Thereof – Mean to Us?

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?

Detailed Structure 4: Life Among the Stars
(3–4 weeks in a 1-semester course)

- 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?

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?
  - 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.

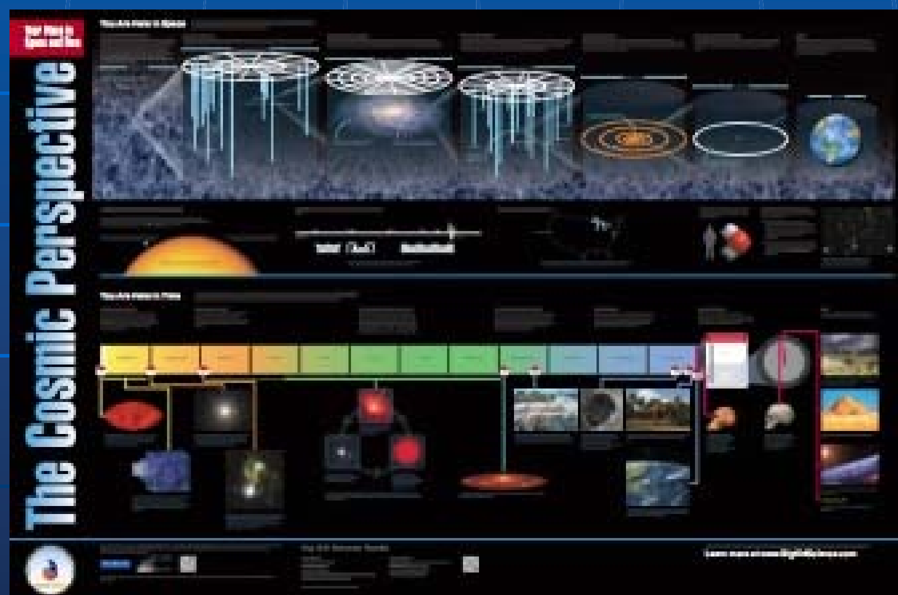
Assessment

Always a challenge, but a few ideas . . .

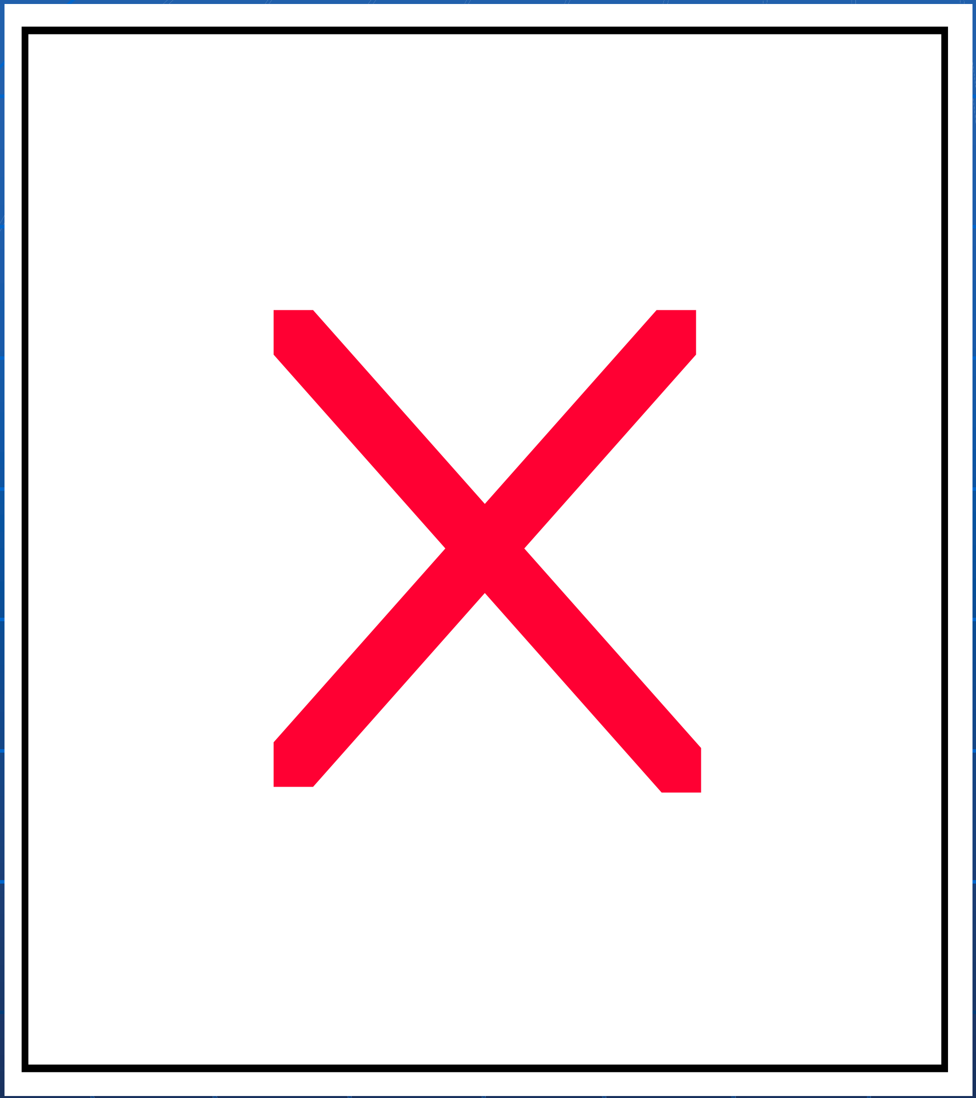
- Quizzes: EOC Quick Quiz; NEW: online Reading and Concept Quizzes.
- Homework: EOC selection.
- Projects: EOC Web Projects; many others possible.
- Testing: NEW Test Bank for instructors

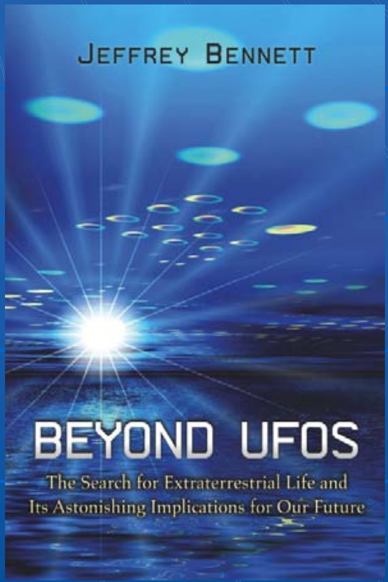
Resources

- 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.





Text
Jeffrey Bennett, Beyond UFO's
Dave Eggers , What Is the What
Micahel Goldfarb, Ahmad's War, Ahmad's Peace
Lucy Grealy, Autobiography of a Face, Ann Patchett, Truth and Beauty
Caryl Phillips, Crossing the River
Barbara Ehrenreich, Nickel and Dimed
Tim O'Brien, The Things They Carried
Sister Helen Prejean, C.S.J., Dead Man Walking
Shackleton, The Endurance: Shackleton's Legendary Antarctic Expedition
LeAlan Jones, Lloyde Newman, David Isay Our America
Sherman Alexie, The Lone Ranger and Tonto Fistfight in Heaven
Abraham Verghese, My Own Country
Julia Alvarez, How the Garcia Girls Lost Their Accents
Studs Terkel, The Good War
Cornel West, Race Matters
Scott Russell Sanders, Paradise of Bombs
Richard Rodriguez, Hunger of Memory
Jayne Anne Phillips, Machine Dreams
Tim O'Brien, Going After Cacciato
Toni Morrison, Song of Solomon
Elie Wiesel, Night
Margaret Atwood, The Handmaid's Tale
Robert Persig, Zen and the Art of Motorcycle Maintenance
Lewis Thomas, Late Night Thoughts on Listening to Mahler's 9th
Kurt Vonnegut, Slaughterhouse Five
George Orwell, 1984
Alan Toffler, The Third Wave

Life in the Universe
Bennett | Shostak
COSMIC PERSPECTIVE
the essential cosmic perspective
BENNETT DONAHUE SCHNEIDER VOIT
The Cosmic Perspective Fundamentals
Bennett Donahue Schneider Voit
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USING & UNDERSTANDING MATHEMATICS
Jeffrey Bennett
BEYOND UFOS
The Search for Extraterrestrial Life and Its Astonishing Implications for Our Future
Math for Life
Crucial Ideas You Didn't Learn in School
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WHAT IS RELATIVITY?
JEFFREY BENNETT
early 2014
Max Goes to the Moon
A Science Adventure with Max the Dog
Max Goes to Mars
A Science Adventure with Max the Dog
Max Goes to Jupiter
A Science Adventure with Max the Dog
The Wizard Who Saved the World
Jeffrey Bennett
Max Goes to the Space Station
A Science Adventure with Max the Dog
Jeffrey Bennett
Nov. 2013

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