

NATIONAL GEOGRAPHIC PRESENTS

C O S M O S

POSSIBLE WORLDS



Discussion Guide written by Nick Sagan. Based on COSMOS: POSSIBLE WORLDS, a 13-part television series written by Ann Druyan and Brannon Braga.

TABLE OF CONTENTS

A LETTER FROM ANN DRUYAN AND NICK SAGAN	3
ABOUT COSMOS: POSSIBLE WORLDS	4
 EPISODE DISCUSSION GUIDES	
EPISODE 1: LADDER TO THE STARS.....	5
EPISODE 2: THE FLEETING GRACE OF THE HABITABLE ZONE.....	11
EPISODE 3: LOST CITY OF LIFE.....	14
EPISODE 4: VAVILOV.....	19
EPISODE 5: THE COSMIC CONNECTOME	22
EPISODE 6: THE MAN OF A TRILLION WORLDS	27
EPISODE 7: THE SEARCH FOR INTELLIGENT LIFE ON EARTH.....	30
EPISODE 8: THE SACRIFICE OF CASSINI.....	34
EPISODE 9: MAGIC WITHOUT LIES.....	38
EPISODE 10: A TALE OF TWO ATOMS	41
EPISODE 11: SHADOWS OF FORGOTTEN ANCESTORS	44
EPISODE 12: COMING OF AGE IN THE ANTHROPOCENE	49
EPISODE 13: SEVEN WONDERS OF THE NEW WORLD.....	53
 ACKNOWLEDGMENTS AND CREDITS.....	 57

A LETTER FROM ANN DRUYAN AND NICK SAGAN

Dear Teacher,

In the more than 40-year span of the three seasons of COSMOS and their companion books, by far the greatest source of gratification to us has been how many people have been inspired by COSMOS to study and teach science and to actually join the generations of scientific searchers. In a society utterly dependent on science and high technology, how can we aspire to be a democracy without a citizenry of informed decision-makers? You have committed your lives to this imperative, which is arguably more urgent now than at any other time in our history.

Our fondest hope for this study guide is that it will lead to still more questions and attract your students to a life informed by the awesome power of the scientific perspective. The history of science has been a more permanent revolution than any other human endeavor. You are the keepers of that flame, inspiring the young to test themselves against the new questions that are inevitably raised by the little we know. In that spirit, we hope that this guide will be useful to you in your critically important work.

Ann Druyan

Nick Sagan

ABOUT

COSMOS: POSSIBLE WORLDS

In the vastness of time and the immensity of space, the number of worlds to explore and stories to tell are infinite. As with the first two award-winning seasons of **COSMOS**, these 13 episodes of **COSMOS: POSSIBLE WORLDS** employ cinematic production values to bring lost worlds and worlds to come into vibrant reality, to make you an eyewitness to the sweep of cosmic evolution, and to glimpse a possible distant future. Along these adventures, we will meet an all-new pantheon of heroes from the generations of searchers whose courage rivals any hero of myth. And we will travel through the hole in the matrix that is quantum reality.

COSMOS: POSSIBLE WORLDS focuses on extra-solar planet discovery, as well as the ancient realms of the human journey and wonderlands that hide beneath the wavelength limit of light. It transports the viewer to the hidden place where life may have begun on Earth and decrypts the mysteries of consciousness — our own and that of others. Our quest to make contact with intelligent beings will take us across the vast ocean of spacetime and into a global subterranean network that we had no idea existed — until science showed us the way.

EPISODE 1: LADDER TO THE STARS

Skepticism and Wonder

COSMOS: POSSIBLE WORLDS explores our universe with the Ship of the Imagination “propelled by twin engines of skepticism and wonder.” Let’s take a closer look at these engines.

How does skepticism protect scientific inquiry against mysticism, superstition and falsehoods?

Why are curiosity and wonder valuable qualities in a scientist? How do they drive us toward new ideas?

“Science invites us to let the facts in, even when they don’t conform to our preconceptions. It counsels us to carry alternative hypotheses in our heads and see what best fit the facts. It urges on us a delicate balance between no-holds barred openness to new ideas, however heretical, and the most rigorous skeptical scrutiny of everything — new ideas and established wisdom.”

— Carl Sagan



Driven by twin engines of skepticism and wonder, the Ship of the Imagination will carry you anywhere you can think to go.
(© Cosmos Studios Inc.)

Scientific Rules

The “simple set of rules” that define science:

- Test ideas by experiment and observation.
- Build on those ideas that pass the test.
- Reject the ones that fail.
- Follow the evidence wherever it leads.
- **Question everything.**

Why is each of these rules so important? Can you give examples of how you’ve followed them in science classes? Do they have applications in other areas of your life?

When exploring that final rule – “Question everything” – consider how one of the four fundamental forces of nature remains wildly mysterious. Despite all the years since Isaac Newton developed his Theory of Universal Gravitation, how gravity actually works is a riddle we have yet to solve. We don’t yet understand why it’s weaker than electromagnetism and the other two fundamental forces. (It’s not just a little weaker – it’s more than a trillion trillion trillion times weaker than we’d expect it to be!)

Why is humility essential to the scientific method?

“We are aware that revered scientists have been wrong. We understand human imperfection. We insist on independent and – to the extent possible – quantitative verification of proposed tenets of belief. We are constantly prodding, challenging, seeking contradictions or small, persistent residual errors, proposing alternative explanations, encouraging heresy. We give our highest rewards to those who convincingly disprove established beliefs.”

– Carl Sagan

Black Holes and Gravitational Waves

What are black holes?

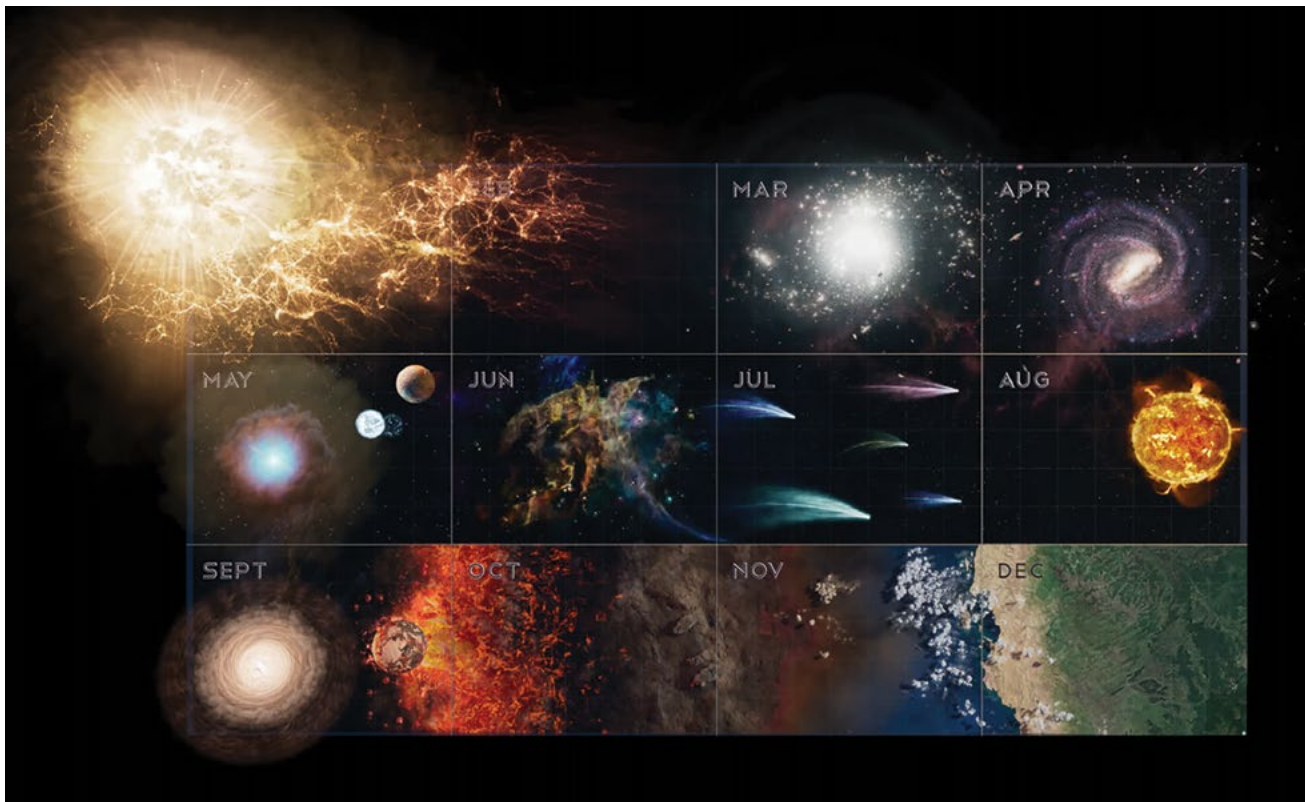
What are gravitational waves and what makes them so difficult to measure? Consider how the Laser Interferometer Gravitational-Wave Observatory (LIGO) required a laser, two airless tunnels (each just over a mile long) and the smoothest mirrors we’ve ever constructed – all to detect the most minuscule spacetime fluctuations.

The Cosmic Calendar

Given the relative brevity of a human lifespan, how can we best wrap our minds around the fact that we live on a 4.5-billion-year-old planet in a 13.8-billion-year-old universe?

By compressing all of time into a single year, does the Cosmic Calendar make these vast expanses more readily understood? Why or why not?

December 26 on the Cosmic Calendar marks when mammals evolved. What are the other significant “days” in the history of our universe? What does your actual birthday represent on the Cosmic Calendar? When did those nearly 40 million years take place? What was happening in our universe?



The Cosmic Calendar takes nearly 14 billion years since the birth of the universe and compresses all that time down to a single calendar year. (© Cosmos Studios Inc.)

Early Ancestors

Why was the evolution of the neocortex so crucial to our ancestors' success? How did that expanded brainpower allow them to not only survive but flourish and slowly but surely dominate the planet?

“You know, when people just shrug and say, ‘Chalk it up to human nature,’ it puzzles me. They’re usually talking about our greed, our arrogance, our violence. But we’ve been human for at least a couple hundred thousand years. For most of that time we weren’t that way at all.”

– Ann Druyan

How did early hunter-gatherers differ from modern humans? Imagine if you had lived as a hunter-gatherer in the Middle Paleolithic Age. Imagine a typical day in your life. What were your hopes, fears and dreams? How did you make sense of the world?

Had you come of age in Blombos Cave, what would you have scrawled on the walls in ochre? What would you have left behind for future generations to discover?

Çatalhöyük

The ancient proto-city, Çatalhöyük, stands out as an example of egalitarian civilization – citizens ate the same foods, lived in similar homes, enjoyed comparable social status, etc. Yet the overwhelming majority of communities since have diminished the idea of social equality as a common good. Why did this happen? Specifically, how did the Agricultural Revolution help transform us into a more class-based, hierarchical civilization?

Antonie Van Leeuwenhoek and Christiaan Huygens

With advances in lenses, Antonie Van Leeuwenhoek and Christiaan Huygens revealed such fascinating new worlds – Leeuwenhoek bringing to light the hidden microbial realm, and Huygens discovering Saturn’s moon Titan, which with its probable underground ocean of liquid water, today’s astronomers deem a leading candidate for extraterrestrial life. How much of the cosmos have we yet to unveil? Consider exoplanets, which were confirmed to exist only as recently as the 1990s – before then, we could not prove that our solar system wasn’t the only one with planets.

Baruch Spinoza

Why was Baruch Spinoza’s belief system so threatening to the religious leaders of his day?

Does our curiosity – our soaring sense of wonder – stem from indoctrination? Or is it innate – part of being human?

How does modern society treat scientific inquiry when the results are inconvenient for an established political or societal construct?

Why does democracy require a separation of church and state?

The Halls of Extinction

Considering our dependence upon the plant and animal kingdoms, how can we minimize the damage human activity does to biodiversity?

How can we best avoid human extinction? What are the most significant dangers we face, and what precautions might we take to overcome them?



The Halls of Extinction memorialize the countless Earthlings lost in our planet's six mass die-offs: from anaerobic life swept away in the Great Oxygenation Event to the numerous species annihilated by human activity here in the Anthropocene. (© Cosmos Studios Inc.)

Sailing to Alpha Centauri

"There were no witnesses when the first life left the water for the land. There was nobody to file a report when the first birds took to the skies. But this is one great leap that will be documented in every conceivable way. The whole world is watching."

— Ann Druyan

How does light sail technology work?

Right now, Project Starshot is set to launch a fleet of interstellar nanocraft around 2036. If it hits its launch date, these tiny light-sailing starships will reach Alpha Centauri by 2056. That means by 2060, we'll have our very first up-close look at another solar system – including an exoplanet in Proxima Centauri's habitable zone. What will that mean for humanity, to know we can reach the stars?

What will life on Earth be like in 2060? Best-case and worst-case scenarios?

How do we strike a balance between protecting this world and exploring others? Can we do both at the same time?

FOR ADDITIONAL READING AND STUDY

The Milky Way: <https://imagine.gsfc.nasa.gov/science/objects/milkyway1.html>

Black Holes: <https://science.nasa.gov/astrophysics/focus-areas/black-holes>

Gravitational Waves: <https://www.ligo.caltech.edu/page/what-are-gw>

The Cosmic Calendar: http://palaeos.com/time/cosmic_calendar.html

Çatalhöyük: <http://www.catalhoyuk.com/site/life>

Blombos Cave:

- <https://news.nationalgeographic.com/2018/02/acoustic-caves-rock-art-language-origin-spd/>
- <https://www.nationalgeographic.com/science/2018/09/news-ancient-humans-art-hashtag-ochre-south-africa-archaeology/>

Starshot Nanocraft:

- <https://www.youtube.com/watch?v=cjNa2NufiGA>
- <https://www.youtube.com/watch?v=hNnuCP-BFKY>

Historical Figures:

- Antonie van Leeuwenhoek: http://www.bbc.co.uk/history/historic_figures/van_leeuwenhoek_antonie.shtml
- Christiaan Huygens: <http://www-groups.dcs.st-and.ac.uk/history/Biographies/Huygens.html>
- Baruch Spinoza: <https://www.iep.utm.edu/spinoza/>

EPISODE 2: THE FLEETING GRACE OF THE HABITABLE ZONE

Habitability and Our Ticking Clock

What are the major existential risks for human civilization? Consider nuclear war, asteroid collision, climate change, runaway biotechnology or nanotechnology, etc.

If we're careful and lucky enough to survive those potential extinction events, why do we still need an eventual "exit strategy" for life on planet Earth?

As our sun expands from a yellow dwarf to a red giant and then contracts to a white dwarf, what fate awaits the various planets of our solar system?

Migrating Out of Our Solar System

"Where will we go when the sun's grace leaves us behind for other worlds and Earth is no longer a garden for life? Will our species have set sail for distant islands in the vast ocean of the Milky Way?"

— Ann Druyan and Brannon Braga

What are the challenges involved with finding another solar system for us to inhabit? What are the challenges involved with actually going there?



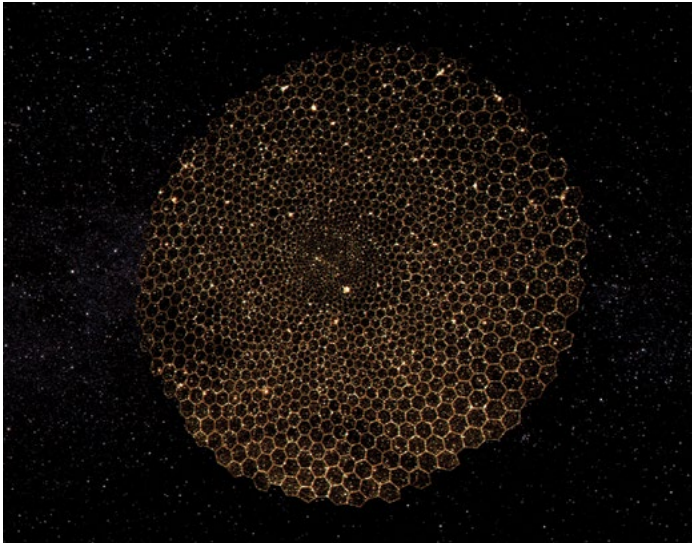
Having risked everything on a voyage through uncharted seas, the Lapita people set foot on land, exploring their new home.
(© Cosmos Studios Inc.)

The Lapita People

"We've passed this way before. Once, there was a people who chose the unknown. They risked everything to go forth on uncharted seas and their courage was rewarded."

— Ann Druyan and Brannon Braga

How does the story of the Lapita exemplify the human need for travel and exploration? Are we driven to find new land?



A cosmic telescope uses a star as its lens, allowing unparalleled magnification when spying distant worlds. (© Cosmos Studios Inc.)

Cosmic Telescopes

How can the spacetime-warping gravity of our sun be used as a lens for a cosmic telescope?

What could such a telescope reveal? Why are cosmic telescopes such an exciting opportunity for exoplanet exploration?

Why haven't we built a cosmic telescope yet? As a society, what should we prioritize? What's the proper balance between looking ahead to the future and focusing on the needs of the here and now?

Light Sailing

How does a tiny push from a photon allow a light-sailing spacecraft to increase velocity? Why is the thinness of the sail so important?

Why is light sail technology potentially so much more practical than conventional rocket propulsion? When "sailing on sunbeams," how much faster and farther can we go? Why is it particularly useful for traversing the vast distances of interstellar space?

Proxima B

Why is Proxima b such an exciting destination for interstellar travel? What conditions there make that world "a possible campsite for our descendants"?

Warp Drive

Could the "warp drive" technology of *Star Trek* actually work someday? How is the Alcubierre drive conceived? What allows it, in theory, to travel faster than light without breaking any rules of science?



Powered by photons, a fleet of light ships speeds its way to Alpha Centauri. (© Cosmos Studios Inc.)

What other *Star Trek* technologies are scientists hoping to actualize? How do science and science fiction interrelate to one another, each inspiring the other?

Carl Sagan's Vision of the Future

"By the time we're ready to settle even the nearest other planetary systems, we will have changed. A simple passage of so many generations will have changed us. The different circumstances we will be living under will have changed us. We're an adaptable species. It will not be we who reach Alpha Centauri and the other nearby stars. It will be a species very like us, but with more of our strengths and fewer of our weaknesses."

— Carl Sagan

In speaking about our "dreams of the future," what dangers does Carl Sagan identify? What must we overcome to truly venture into space? What does he mean by how it won't necessarily be "we" who make the journey?

FOR ADDITIONAL READING AND STUDY

Death of the Sun: <https://www.livescience.com/32879-what-happens-to-earth-when-sun-dies.html>

Lapita Migrations: <https://www.sciencemag.org/news/2016/10/game-changing-study-suggests-first-polynesians-voyaged-all-way-east-asia>

Cosmic Telescope: <https://blogs.scientificamerican.com/observations/using-the-sun-as-a-cosmic-telescope/>

Light Sailing: <https://news.nationalgeographic.com/2016/02/160202-solar-sail-space-nasa-exploration/>

Habitability of Proxima b:

- <https://www.nasa.gov/feature/goddard/2017/an-earth-like-atmosphere-may-not-survive-proxima-b-s-orbit>
- <https://www.livescience.com/63546-proxima-b-nearest-exoplanet-habitable.html>

Alcubierre Warp Drive: <https://phys.org/news/2017-01-alcubierre-warp.html>

Carl Sagan's Vision for the Future: *Pale Blue Dot: A Vision of the Human Future in Space* by Carl Sagan

EPISODE 3: LOST CITY OF LIFE

How It All Began

What would it mean for humankind to know the precise origin of life? Why do so many of us yearn to know how our earliest ancestors came into being?

“The nitrogen in our DNA, the calcium in our teeth, the iron in our blood, the carbon in our apple pies were made in the interiors of collapsing stars. We are made of starstuff.”

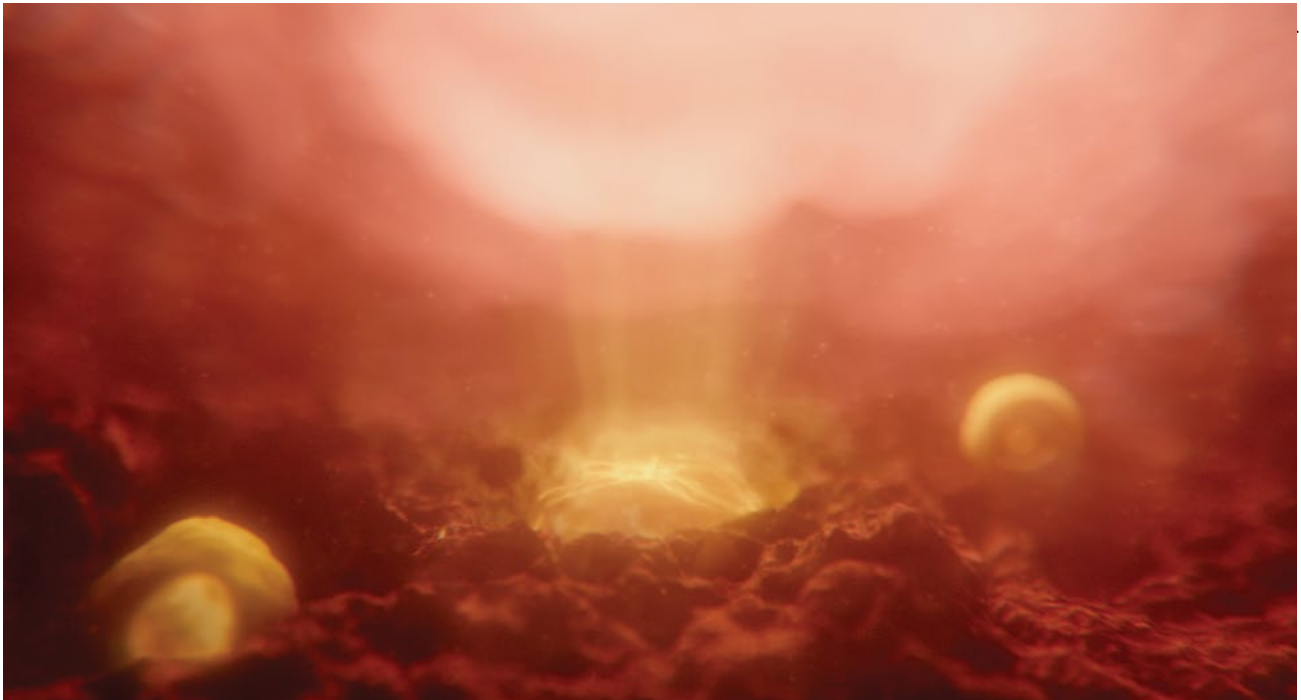
— Carl Sagan

Consider how the very elements that comprise us were born in stars, and then consider how our early solar system was teeming with organic molecules. Does it seem likely that the cosmos might “give rise to life as naturally as it makes stars and worlds,” as the episode suggests?

The Lost City

Discuss the forces at work — deep underwater, billions of years ago — that provided ideal conditions for the formation of life.

How do hydrothermal vents work? How does expelling heated fluid and minerals into the pores of carbonate rocks allow organic molecules to incubate?



Scientists hypothesize that a chemical reaction sparked the building blocks of life into actual living organisms.
(© Cosmos Studios Inc.)

Why does alkaline colliding with acidic seawater produce an energy reaction?

How does the release of this chemical energy create a fluctuating environment? How does environmental flux play a part in natural selection?

Expertise in a single field is clearly valuable but scientists also benefit from a broad scientific base. Consider how the search for life's origin combines biology, chemistry, physics and geology. Can you think of other scientific mysteries where the solution will require work from more than one field?

Compare and contrast our current scientific understanding of how life began with the creation stories of various cultures: Greek, Norse, Egyptian, Cherokee, etc. Which questions about our origin do these stories seek to answer? Which questions do they avoid? Are they more emotionally satisfying? Is the truth stranger than fiction?

How Life Transformed Our World

“We’ve only recently begun to appreciate how powerfully life has shaped the planet. When we think about the ways life has changed Earth, the first things that come to mind are the green expanses of forests and the sprawling cities. But life began transforming the planet long before there were any such things.”

— Ann Druyan and Brannon Braga

What did cyanobacteria contribute to planet Earth? Certainly, our blue sky — that’s the “cyan” root of cyanobacteria — and the very air we breathe today are in large part thanks to these tiny creatures taking in carbon dioxide and giving back oxygen. If you could travel back to a time before cyanobacteria, you would not be able to breathe Earth’s atmosphere.

Although anaerobic life flourished in the early methane-heavy atmosphere, it essentially lost a war to cyanobacteria, dying in great number as oxygen became more prevalent. Had the cyanobacteria been less successful — had creatures that thrive in a methane-rich environment fared better — how different a path might evolution have taken? What would life on Earth be like today?

For that matter, how profoundly different might Earth itself be? Consider the extent of the transformation: Oxygen-producing life brought about some 70% of the minerals on our planet and triggered a global ice age — the longest in Earth’s history.

Explore the science behind this ice age. How did the Great Oxidation Event reduce our greenhouse effect? How did glaciation begin? What caused it to end?



As a consequence of the Great Oxygenation Event, temperatures plummet across Earth, leading to our very first ice age.
(© Cosmos Studios Inc.)

The Cambrian Explosion

Explore the leading theories behind the 541-million-year-old massive increase in evolutionary diversity. Why did the Cambrian Explosion take place?

How did increased oxygen levels create opportunities for more complex lifeforms to evolve? How did increased calcium minerals in the water let marine creatures develop skeletons? To what extent can we credit the newly-formed ozone layer for allowing our early ancestors enough ultraviolet protection to emerge from the water onto the land?

Retracing Life's Odyssey: Christian Friedrich Schönbein and Victor Goldschmidt

Christian Friedrich Schönbein discovered ozone and developed the fuel cell, and he predicted the science of geochemistry. Schönbein also accidentally invented guncotton, a highly flammable explosive that would escalate the lethality of the wars of the late 19th and early 20th centuries. While Schönbein had no ethical problem with his creation, many scientists and inventors have been alarmed by how their discoveries might be turned into weapons of war. Leonardo da Vinci, for example, famously concealed details for a number of his inventions, stating concerns about "the evil nature of Man." What precautions can one take to keep potentially dangerous technology from being used unethically?

How impressive was Victor Goldschmidt? He defies, outwits and escapes the Third Reich while walking around with a cyanide capsule and making gallows humor jokes! That's on top of all his scientific contributions! Popular culture often depicts scientists as wimpy or nerdy. Sometimes, the truth is far from that.

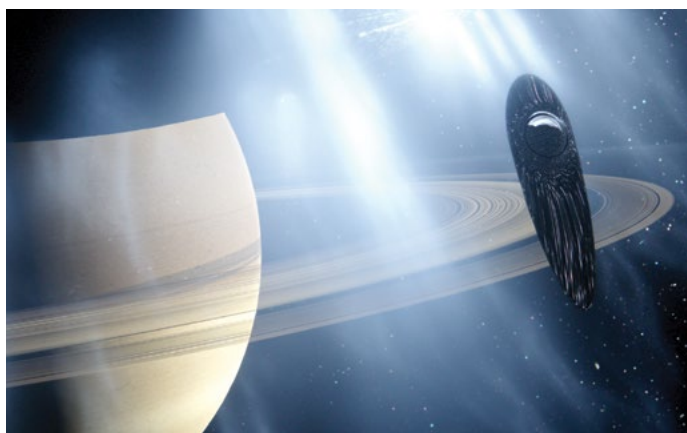
"Before the mystery of the genesis of our planets and their inorganic matter can be revealed," wrote Schönbein, "a comparative science of geochemistry must be launched." How did Goldschmidt realize Schönbein's dream?

How does Goldschmidt's geochemical classification of the elements differ from the standard periodic table? Compare and contrast.

How does matter evolve from one form to another? How can basic elements turn into more complex minerals? How do we get cliffs, canyons and other major geological features?

How does Goldschmidt's science of geochemistry help trace the origin of life? Why was he so fascinated by olivine? With its ability to withstand even the highest temperatures, what role did olivine play in setting the stage for life?

What can geochemistry's related science, cosmochemistry, tell us about other worlds?



The Ship of the Imagination approaches Saturn's moon Enceladus, searching for signs of extraterrestrial life. (© Cosmos Studios Inc.)

Life on Other Worlds

Discuss NASA's planetary protection classifications. What's the difference between a Restricted Category-4 and a Restricted Category-5 world? Why does each require exceptional caution from us if we are to visit and explore? What are the risks we might pose to potential extraterrestrial life? What are the risks it might pose to us?

What makes Europa such an intriguing candidate for extraterrestrial life? How about Enceladus? What hidden features of this moon make it so promising? How significant are the hydrothermal vents the Cassini mission detected?

"You know, it's a funny thing about us. We think we're the story. We're the end-all be-all of the cosmos. And yet, for all we know, we're just the byproduct of geochemical forces — ones that are unfolding throughout the universe. Galaxies make stars, stars make worlds, and for all we know, planets and moons make life. Does that make life less wondrous?

Or more?"

— Ann Druyan and Brannon Braga

Are we “the end-all be-all of the cosmos”? What do you see as the likelihood of life on other worlds?

If the universe is overflowing with life and we’re not alone, what does that mean for us?

What if we **are** alone?

FOR ADDITIONAL READING AND STUDY

The Lost City Hydrothermal Field: <https://oceanexplorer.noaa.gov/explorations/05lostcity/>

Snowball Earth: <http://www.snowballearth.org/>

Cambrian Explosion:

- <https://www.nationalgeographic.com/magazine/2018/03/brief-history-life-evolution-fossils-biology/>
- https://www.pbs.org/wgbh/evolution/library/03/4/1_034_02.html

Cassini Mission and Enceladus:

<https://www.nasa.gov/press-release/nasa-missions-provide-new-insights-into-ocean-worlds-in-our-solar-system>

EPISODE 4: VAVILOV

The Agricultural Revolution

What gave rise to the Agricultural Revolution?

This was a massive societal change. Why go from a hunter-gatherer society to one that settles down and grows its own food? What were the perceived benefits? What were the risks?

“Think of those geniuses who were the first to realize that inside the plants they foraged was a means to make another plant. A seed. That discovery led to the single most fateful choice our species ever made.”

— Ann Druyan and Brannon Braga



The Tower of Jericho is the world's oldest stairway, one of the first monuments humans ever created. (© Cosmos Studios Inc.)

Thinking beyond one season — planning further ahead — how did that change the way we interact with the natural world? How did this shift lead to lengthy construction projects like the Tower of Jericho? What's the appeal of constructing something of apparent permanence, some monument that may exist long after we're dead?

How did the Agricultural Revolution alter our social hierarchies? Where did the power shift?

How did the invention of agriculture change our relationship with the rest of the animal world?

While wandering hunter-gatherers would sometimes experience scarcity, hunger and even starvation, an agricultural society's very reliance on crops opens the possibility of disastrous famine. Consider the various consequences and long-term effects of famine – from the horror of widespread starvation and the lasting damage malnutrition does to childhood development, to displacement and potentially even violence from the ensuing chaos.

Certainly, a great deal of human progress – the speed at which our civilization has advanced – would not have been possible if not for the Agricultural Revolution and all its subsequent bounties. Yet have we given up something valuable by embracing this path?



Gregor Mendel (1822-1884) studies pea plants in search of a predictive theory of breeding.
(© Cosmos Studios Inc.)

Gregor Mendel

How did Gregor Mendel's research with yellow and green pea plants indicate the existence of dominant and recessive genes?

What are Mendel's three laws of inheritance?

While working as a substitute teacher, Mendel founded an entirely new science: genetics. What does it mean that such critically important scientific breakthroughs could spring from a man who flunked his qualifying exam to become a science professor?

Advancements in this science have opened up the possibility of genetic modification. Using technologies like CRISPR, what advantages are we now capable of engineering in crops, animals and humans? What might we be capable of in the coming years?

Conversely, what are the risks? What ethical considerations should we keep in mind? Imagine you are in charge of devising a set of worldwide rules for how genetic engineering can and can't be used. What will you decide?

Nikolai Ivanovich Vavilov and the Holodomor

Some scientists go into their field out of pure intellectual curiosity, seeking to better understand this amazing universe. Others go in with the desire to solve a specific problem. Nikolai Ivanovich Vavilov falls into the latter category. How would you characterize his dream of ending famine?

Are you contemplating – or actively pursuing – a career in science? If so, what motivates you? Is there a problem you hope to solve? What is your dream?

Consider the value in finding common ancestors for cultivated plants. Why was that the cornerstone of Vavilov's research? By what scientific processes did we go from knowing a seedling's origin to "deciphering life's language"? How does this tie into his idea for a world seed bank?

Vavilov was among the first to appreciate the need for biodiversity. Why is biodiversity so important?

What caused the Holodomor? What was Joseph Stalin hoping to achieve when he pursued a policy of collectivization, forcing kulaks to give up their farms? How did it lead to millions of deaths? Why did the Soviets deliberately keep entire Ukrainian towns from receiving food?

What role did Trofim Lysenko play in this atrocity? Why was Stalin willing to believe Lysenko's pseudoscience over Vavilov's actual science?

How does Vavilov's story illustrate the moral obligations of science and scientists?

"We shall go into the pyre, we shall burn, but we shall not retreat from our convictions."

— Nikolai Ivanovich Vavilov

What gave Vavilov the fortitude to never crack under torture? What kept him going?



During the 28-month Siege of Leningrad, Nikolai Vavilov's heroic team of botanists choose starvation over eating the seeds they have sworn to protect.
(© Cosmos Studios Inc.)

"In all of history, no team of scientists has ever been tested so cruelly. They were pushed beyond the breaking point and yet they did not break."

— Ann Druyan and Brannon Braga

Why did Vavilov's team work so hard to protect the seeds? Why didn't they distribute them as food to the starving people of Leningrad? Why didn't they save themselves?

If you had been in their position, what choice would you have made?

FOR ADDITIONAL READING AND STUDY

Agricultural Revolution: <https://www.nationalgeographic.org/article/development-agriculture/>

Nikolai Vavilov:

- <http://vir.nw.ru/history/vavilov.htm>
- <https://phys.org/news/2017-01-russia-vavilov-guardian-world-lost.html>

Stalin and Collectivization: <http://soviethistory.msu.edu/1929-2/collectivization/>

The Holodomor Famine: <http://blogs.bu.edu/guidedhistory/russia-and-its-empires/alexander-babcock/>

Svalbard Global Seed Vault: <https://tour.croptrust.org/>

EPISODE 5: THE COSMIC CONNECTOME



The Ship of the Imagination takes a journey of discovery into the human brain. (© Cosmos Studios Inc.)

Mysteries of the Brain

“Can we know the universe? Are our brains capable of comprehending the cosmos in all of its complexity and splendor? We don’t yet know the answer to that question because our brain remains almost as much of a mystery as the universe itself.”

— Ann Druyan and Brannon Braga

What’s the value of neuroscience? What do we gain by learning how our brains function, how they evolved and what gives us this amazing experience of consciousness?

Epilepsy

Ancient Greeks would ascribe an epileptic seizure to the whim of angry gods, and then claim the patient’s recovery (or lack thereof) hinged on whether those gods could be moved by prayers and sacrifices. How is this an example of false pattern recognition? How does the common fallacy of confusing correlation with causation play into the misunderstanding?

Can you find other examples of false pattern recognition?

What are the dangers of magical thinking and how can we best keep from falling into those traps?

Hippocrates

“Men think epilepsy divine merely because they do not understand it. But if they called everything divine which they do not understand, why, there would be no end to divine things.”

— *Hippocrates*

What contributions did Hippocrates make to his field? Why is he considered the Father of Medicine?

What’s the value of the Hippocratic oath? Why is it especially important for doctors to behave ethically?

Phrenology

“Nature may be as selfishly studied as trade. Astronomy to the selfish becomes astrology; psychology, mesmerism; and anatomy and physiology become phrenology and palmistry.”

— *Ralph Waldo Emerson*

How does a pseudoscience like phrenology take hold?

Phrenology was used as a “scientific basis” for racism, sexism and slavery (in Europe, South Africa, the pre-Civil War South and elsewhere). How does this misuse underscore the importance of strictly following the scientific method to minimize confirmation biases?

Paul Broca

In isolating where language lives in the brain, Paul Broca opened up a vast repository of neuroscience. Consider all the discoveries we’ve made since then that hinge upon understanding how each part of the brain functions. Yet, Broca was hampered by the prejudices of his time, afflicted by some of the same bigotry that allowed phrenology to flourish.

To what extent should we judge luminaries of past eras for their moral failings? What does it say about human nature that flawed individuals can nevertheless make such beneficial contributions?

“Society corrupts the best of us. It’s a little unfair to criticize a person for not sharing the enlightenment of a later age, but it is also profoundly saddening that such prejudices were so pervasive. The question raises nagging uncertainties about which of the assumptions of our own age will be considered unforgivable by the next.”

— Ann Druyan and Brannon Braga

Consider the popular beliefs of our day. Which might be deemed unforgivable assumptions by future generations?

Neuroimaging and Electroencephalography

Awake or asleep, every thought that goes through our heads has a material reality. Every memory, realization, fantasy, dream or light-bulb moment that any of us has ever had is a result of biological processes. What are the ramifications of Angelo Mosso’s discovery?

How does neuroimaging work? What is functional magnetic resonance imaging (fMRI)?

How might we use neuroimaging in the future?

Consider what we’ve achieved so far. Complex thoughts can now be decoded from an fMRI signal: people, places, actions and feelings have identifiable brain activation patterns. Scientists are at work using fMRI to reveal the imagery of our dreams — we already have the ability to reconstruct hazy likenesses of these “deep images” and being able to play back entire dreams appears to be an achievable goal, if only in a matter of time.

What is electroencephalography? In detecting and recording the electrical activity of the brain, how can an electroencephalogram (EEG) test for epilepsy?

Hans Berger invented the EEG in the hopes of proving the existence of psychic powers. Although he never found evidence of psychic energy, the EEG has been a wonderfully useful device, allowing doctors to scan for a variety of diseases. What does it mean that a “failed experiment” can nevertheless provide such worth? What does it say about the value of scientific research?

Brain Architecture

How does the story of microbes at the bottom of the sea signaling each other via ion channels — a 4-billion-year-old manner of electrochemical communication — illustrate the way neurons work in the brain?

Compare and contrast the flatworm brain (with its neurotransmitters, ganglia and modest 8,000 neurons) with our far more robust human brains (featuring 86 billion neurons and a whopping 100 trillion neural connections). What can the flatworm do? How was the brain an evolutionary advantage that allowed the flatworm to thrive?



Neil deGrasse Tyson regards the world's first animal hunter, the flatworm — a creature whose success sprang from evolving the first rudimentary brain. (© Cosmos Studios Inc.)

The episode analogizes the way New York City developed over time — incremental changes, responding to the needs of the moment — to explain how the human brain evolved. What do we learn about the complexity of our cerebral matter and how these amazing repositories of consciousness came to be?

“We are a way for the universe to know itself.”

— Carl Sagan

Consider the process through which the universe can actually know itself. What is emergence?

Given that there are over a thousand times more synapses in the human brain than stars in the Milky Way, can it successfully be “reverse engineered”? By the end of this century, will we know everything there is to know about the brain, as some futurists believe?



Surprisingly, a humble grain of salt contains far more atoms than the number of synapses in a human brain.
(© Cosmos Studios Inc.)

The Unknowable Vastness of the Cosmos

As complex as our brains are, the atoms in a tiny grain of salt outnumber our trillions of neural synapses about a hundred times over. Given the overwhelming complexity of the cosmos, how can we hope to fully understand it?

Given that difficulty, why is it so important for us to understand the laws of nature?

The Connectome

The episode closes with the great journey that neuroscientists are just beginning to take, mapping out the full human connectome – “the singular wiring diagram” of a person’s “memories, thoughts, fears and dreams.” What would it mean if we could achieve that level of understanding?

Looking so deeply into another person’s psyche, knowing them so completely, would we feel a greater sense of empathy? Would we treat each other more kindly? Would we use this knowledge ethically, healing every mental affliction? How could we misuse it?

With full knowledge of the connectome, could we master whole brain emulation (WBE), uploading and downloading complete copies of our minds to safe storage? What would it mean for our species if we could live forever? How would civilization change if any personal catastrophe – even death – could be undone, just like loading up a save from a video game? What would it mean to you personally? Would it change the way you live your life? Would it change your values? Your goals?

FOR ADDITIONAL READING AND STUDY

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Phrenology: <http://www.victorianweb.org/science/phrenology/intro.html>

Paul Broca: <https://www.encyclopedia.com/people/medicine/medicine-biographies/paul-broca>

Carl Sagan, *Broca’s Brain*

Angelo Mosso and the Study of Dreams:

<https://www.npr.org/2014/08/17/340906546/the-machine-that-tried-to-scan-the-brain-in-1882>

Hans Berger and Telepathy: <https://www.theatlantic.com/health/archive/2014/11/the-role-of-the-supernatural-in-the-discovery-of-eegs/382838/>

The Human Brain:

- <https://www.nationalgeographic.com/science/health-and-human-body/human-body/brain/>
- <https://www.newscientist.com/article/dn9969-introduction-the-human-brain/>
- <http://www.pbs.org/newshour/extra/app/uploads/2013/11/Normal-Brain-and-Zombie-Brains.pdf>

EPISODE 6: THE MAN OF A TRILLION WORLDS

Building on Previous Discoveries

“If I have seen a little further, it is by standing on the shoulders of giants.”

— Isaac Newton

In crediting those who paved the way before him, Isaac Newton put his finger on a very important dynamic: Pursuit of knowledge is cumulative, and one scientist may pick up where another leaves off. Science is an outstanding method for revealing truth but it doesn't always happen in the span of a human lifetime. Consider how Gerard Kuiper was able to solve John Goodricke's mystery some 150 years later.

Spectroscopy and Binary Star Systems

Spectroscopy is a way to examine starlight to find the properties of stars and other celestial bodies. How does it work? What bands of radiation do astronomers measure? In studying objects so incredibly far away, how are properties like temperature, density and chemical composition revealed?

How did Kuiper use spectroscopy to find that Beta Lyrae was a contact binary star system?



Gerard Kuiper (1905-1973) analyzes spectrographic images in his examination of Beta Lyrae. (© Cosmos Studios Inc.)

What's the difference between a binary star system and a contact binary star system? What links the two stars? How does gravity shape the "bridge of fire" envelope between them?

How was Kuiper able to extrapolate from Beta Lyrae that our solar system might have been a failed binary system? From there, how was he able to correctly hypothesize that many stars have worlds?

The Competing Mentors of Carl Sagan

Why did Harold Urey resent Gerard Kuiper? How did the rivalry between them develop?

Even as the rivalry grew increasingly hostile, Carl Sagan served as a bridge between the chemist and the planetary scientist, working to synthesize their findings to reveal the truth. How does this illustrate the value of interdisciplinary research?

"Hey, guys, we're the first generation of scientists to receive these riches.
We're in this together."

— Carl Sagan

How did each of these scientists mentor Carl Sagan and help him on his path? Who have been the most important mentors in your life? What have you learned from them?

Sputnik and NASA

How did the Soviet Union's success with Sputnik spur NASA into existence? Is competition beneficial to science? What, if anything, can be done to maximize the benefits and minimize the risks?



*Carl Sagan (1934-1996) visits his elementary school classroom in Brooklyn and is delighted by the scientific curiosity of the students.
(© Cosmos Studios Inc.)*

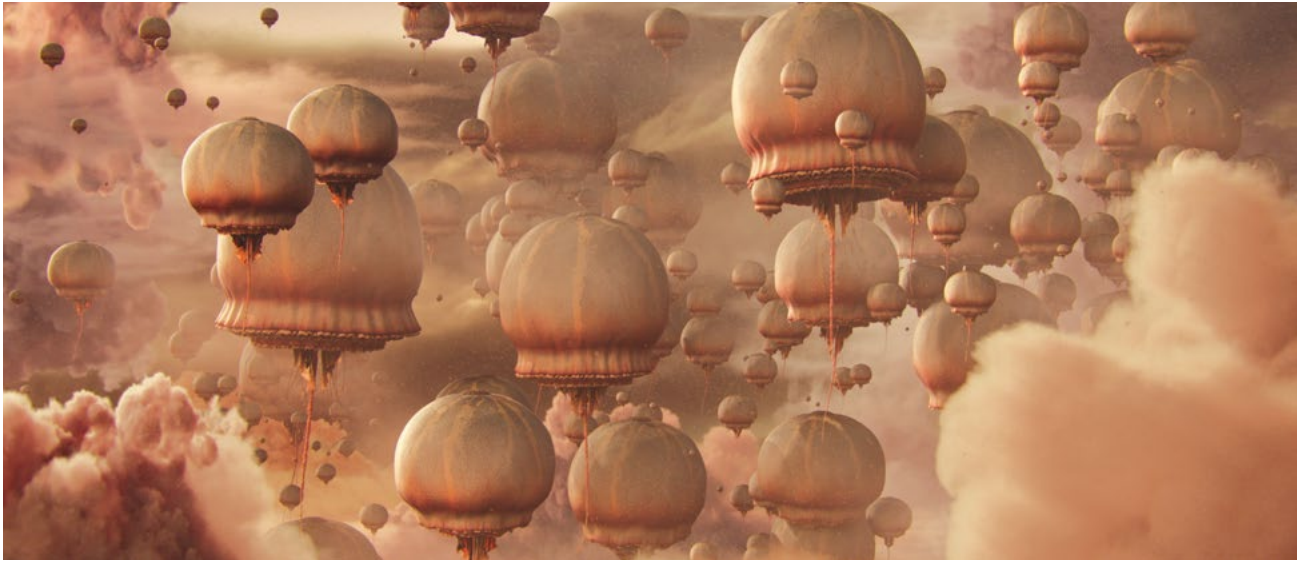
Carl Sagan

What did Carl Sagan contribute to the field of space science?

Why is sharing scientific knowledge with the general public important?
Why is this so much more important now than in the early days of science?

The planetary science journal Carl Sagan edited is called *Icarus*. Who was the Icarus of Greek mythology? How does his myth relate to us today?
What moral or message does it impart?

Why was it important for Carl Sagan and Ed Salpeter to envision potential life on Jupiter — the hunters, floaters and sinkers — without violating the laws of chemistry or physics? Compare and contrast these fictional extraterrestrials with the extraterrestrials more commonly seen in *Star Wars*, *Star Trek*, etc.



The “floaters” of Jupiter are buoyant lifeforms that could have evolved in a gas giant’s atmosphere, as imagined by Carl Sagan and Ed Salpeter. (© Cosmos Studios Inc.)

Every Second, a Thousand Worlds

“We haven’t even begun to get to know all the living things on this tiny world. Think of all the possibilities, the different kinds of life there must have been, and are, and will be in the cosmos.”

— Ann Druyan, Brannon Braga and Andre Bormanis

Because we now know how long it takes for a solar system to form, and because we now have a reasonable understanding of how many galaxies and stars inhabit our universe, we can deduce that a thousand new solar systems are born every second. That’s a mind-bogglingly large number of potential habitats for life, and it’s growing all the time. How do we make sense of that many possibilities?

What do you make of the fact that new solar systems are popping up all the time? Does it suggest to you a greater possibility of life on other worlds?

FOR ADDITIONAL READING AND STUDY

Gerard Peter Kuiper: <https://solarsystem.nasa.gov/people/720/gerard-kuiper/>

Spectroscopy: <http://astronomy.swin.edu.au/cosmos/S/Spectroscopy>

Sputnik: <https://history.nasa.gov/sputnik/>

Carl Sagan: <http://www.planetary.org/about/our-founders/carl-sagan.html>

Miller-Urey Experiment: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4089479/>

Founding of NASA: <https://history.nasa.gov/factsheet.htm>

Icarus Journal: <https://www.journals.elsevier.com/icarus>

Gliese 667: <http://phl.upr.edu/press-releases/apotentialhabitableexoplanetinanearbytriplestarsystem>

EPISODE 7: THE SEARCH FOR INTELLIGENT LIFE ON EARTH

First Contact

What is the episode title insinuating? Aren't **we** the intelligent life on Earth?

"We search the heavens for signs of intelligent life. But what would we do if we found it? Are we ready for first contact? Would we be smart enough to even know if someone was sending us a message?"

— Ann Druyan and Brannon Braga

Are we ready for first contact with extraterrestrials? Should the history of first contact between civilizations here on Earth serve as a cautionary tale? How do you think an encounter with an alien species might go?



*The FAST telescope is a colossal listening device scientists can use to investigate the mysteries of our early universe.
(© Cosmos Studios Inc.)*

FAST is the acronym for China's Five-Hundred-Meter Aperture Spherical Radio Telescope: the largest telescope humans have ever constructed. What is it designed to do? What makes it more capable than other radio telescopes we've built?

The Mycelium

How astonishing is the mycelium? Consider the extraordinary intricacy of this vast underground communication network — a hidden matrix linking fungi, plants, bacteria and animals.

How does it function as a community? How are messages sent across the ecosystem? How does it respond situationally – sending nutrients to keep a stump alive when its tree has been cut down? Or a parent tree keeping its offspring safe in the shade for its own protection?

Does this qualify as a kind of empathy? Or is it more of a long-term survival strategy?

Considering how blind we've been to the mycelium all these years, does the episode have a point about making first contact? Should we really be trying to find intelligent life beyond our world given how oblivious we've been to a consciousness right beneath our feet?

Is it strange to think that a lifeform as stately and peaceful as a tree is also capable of choreographing its enemies' worst nightmares? When caterpillars attack elms and pines, the trees first identify the species that's munching their leaves, and then – a bit like sorcerers summoning demons – they release a pheromone that attracts the caterpillars' most fearsome enemy: parasitic wasps. The wasps then lay their eggs inside the caterpillars, and when the eggs hatch the caterpillars are gobbled up from the inside out.

What makes you appreciate the capacities of the natural world? What fills you with awe as you learn more about it? How can we share and spread this appreciation for the capacity of the natural world with others?

The Great Ordovician Biodiversification Event

Forty million years after the Cambrian Explosion, life went through another period of major change: the Great Ordovician Biodiversification Event. What factors led up to it? Why did arthropods flourish so successfully during this time? How did we get the first insects from crustaceans? How did this affect the evolution of plants?

Bees and Wasps

Why was pollen such a game changer for wasps? How did the rise of flowering plants encourage some species of wasp to evolve into bees?

In turn, how did the rise of the bees provoke an "arms race" among the flowers, each competing to be more alluring to bee-kind?

"So how did the painted bee reveal the exact location of the sugar water with such precision that her hive mates could unerringly find their way there? There was a secret message in her choreography. What had seemed to countless generations of observers to be nothing more than the meaningless, spasmodic motions of a dumb animal was actually a complex message – an equation informed by mathematics, astronomy and an acute knowledge of time."

– Ann Druyan and Brannon Braga



Bees swarm out of the trees en route to a new hive. (© Cosmos Studios Inc.)

How do bees communicate through their “waggle dance”? How do they use an understanding of mathematics, astronomy and time to tell each other where delicious food can be found or where they might find their next hive?

How does the swarming of bees to a new home demonstrate a different and sophisticated intelligence?

How are scouts dispatched? By what criteria do bees look for an ideal new hive? How do bees “debate” the merits of each scout’s findings? Why do they “fact check” those findings?

What does it mean that bees are incapable of lying to each other and that they must be truthful about where they might find an ideal hive? How is the hive mind an advantage for them? Would it have been an evolutionary advantage for us humans as well? What would our society be like today? Why didn’t we evolve down a similar path?

How did Karl von Frisch figure out the language of the bees? Follow the science that allowed him to decode their dancing and effectively make first contact.

Charles Darwin

How was science “a pathway to a deeper level of empathy and humility” for Charles Darwin? What do the stories of his concern for animals – for example, stopping his research to help arrest a farmer who was mistreating his sheep – tell us about his moral compass?

If all life on Earth is related, as Darwin found, what are the philosophical implications? What responsibility do we have for the other living species sharing this planet?



Tardigrades

Why does the episode end with snuggling tardigrades? What does it mean that such tiny creatures – invisible to the naked eye and so different from us – seem to simply enjoy each other's company? Can we empathize with their desire to be close to each other?

What does that longing for connection say about them? What does it say about us?

Tardigrades are among the most successful lifeforms, having survived all five mass extinctions, but recent research suggests they may also do something we like to think only humans do: snuggle for affection.
(© Cosmos Studios Inc.)

FOR ADDITIONAL READING AND STUDY

Five-Hundred-Meter Aperture Spherical Radio Telescope: <https://www.sciencemag.org/news/2016/09/world-s-largest-radio-telescope-will-search-dark-matter-listen-aliens>

Mycelium: <http://staff.washington.edu/raista/fungi3.pdf>

Great Ordovician Biodiversity Event: <https://www.nationalgeographic.com/science/prehistoric-world/ordovician/>

Evolution of Bees: <https://www.scientificamerican.com/article/the-beguiling-history-of-bees-excerpt/>

Bee Dancing: https://www.youtube.com/watch?v=LU_KD1enR3Q

Karl von Frisch: <https://thehoneybeeconservancy.org/2011/11/20/karl-von-frisch/>

Charles Darwin: <https://www.smithsonianmag.com/science-nature/the-evolution-of-charles-darwin-110234034/>

Tardigrades: <https://www.washingtonpost.com/news/speaking-of-science/wp/2017/07/14/these-animals-can-survive-until-the-end-of-the-earth-astrophysicists-say/>

EPISODE 8: THE SACRIFICE OF CASSINI



Neil deGrasse Tyson encounters Galileo Galilei (1564-1642) on the Ship of the Imagination. (© Cosmos Studios Inc.)

Galileo Galilei

How did the telescope facilitate the modern scientific revolution? Why was being able to see distant celestial objects more clearly such a dramatic advancement?

What astronomical discoveries did Galileo Galilei make with his telescope? What was he unable to detect, due to the limitations of his technology (cutting edge though it was for the time)?

What would Galileo make of all the scientific knowledge we've gathered since his day?

Giovanni Domenico Cassini

What contributions did Giovanni Domenico Cassini (the man, not the spacecraft) make to our knowledge of outer space? With the patronage of Louis XIV, what determinations was he able to make about our moon, Mars, Jupiter and Saturn?

Cassini came very close to discovering that there is a speed of light and that it's not infinite. Why did he rule out the possibility?

Compare and contrast astronomy with Cassini's original pursuit of astrology. Why is astrology a pseudoscience and not a true science? What questions does it seek to answer? Why do you think millions of people — including approximately a quarter of Americans — still believe in it today?

"The desire to be connected with the Cosmos reflects a profound reality. We are connected, not in the trivial ways pseudosciences promise, but in the deepest ways. Our little planet is under the influence of a star. The sun warms us. It drives the weather. It sustains all living things. Four billion years ago, it brought forth life on Earth."

— Carl Sagan

In discovering that Earth is not the center of the universe, how did Nicolaus Copernicus deal a blow to astrology and help separate it from astronomy?

Yuri Kondratyuk

How did Alexander Shargei (aka Yuri Kondratyuk) and his vision of space travel help make the earliest space missions possible?

"Sometimes your dreams die with you, but sometimes the scientists of another age pick them up and take them to the Moon, and far beyond."

— Ann Druyan and Brannon Braga



Born Alexander Shargei, the spaceflight pioneer Yuri Kondratyuk (1897-1942) dreams of landing on the Moon, a triumph he would not live to see. (© Cosmos Studios Inc.)

Consider the many hardships Kondratyuk faced – the horrors of war, imprisonment, living in constant fear of the Soviets discovering his real identity. He never lived to see his dream come to fruition, yet his idea for a lunar orbit rendezvous was pivotal to the Apollo missions' success.

Likewise, consider the gravitational slingshot he envisioned in "To Whoever Will Read This Paper in Order to Build an Interplanetary Rocket." Dozens of spacecraft would use Kondratyuk's proposed technique to more nimbly navigate our solar system. Voyager I and II would use it to break free of the sun's gravity and escape to interstellar space. What does this say about the imagination and passion of scientists? What does it say about the durability of good ideas?

Ringed Planets

Why do Jupiter, Saturn, Uranus and Neptune have rings while other planets in our solar system do not?

Astronomer Édouard Roche successfully formulated an equation to answer the question. What is the Roche limit and how does it work?

How did Cassini (the spacecraft) shed light on when our gas giant planets first formed their rings?

The Extraordinary Life and Poignant Death of Cassini

Why was Cassini designed? What did the mission discover? How did the ship make use of Kondratyuk's gravitational slingshot technique?



The Cassini spacecraft obeys its last command, plummeting into Saturn's atmosphere. (© Cosmos Studios Inc.)

“Cassini is so far away, it will take the message, traveling at the speed of light, more than an hour to reach her. Every microchip in her has been programmed to resist the commands she’s now receiving. The inner turmoil of the loyal robot commanded to defy her own instincts must be fierce. The same engineers who ordered her to protect herself in every situation now force her to plunge to her death. They must be obeyed.”

— Ann Druyan and Brannon Braga

Put yourself in the position of a scientist on the Cassini mission, your life thoroughly intertwined with the spacecraft for 20 years. Could anyone blame you for feeling deeply connected to this plucky robotic explorer you’ve helped send into space? Might you come to personify the ship, seeing her as a “she” instead of an “it”? As she took every risk required of her, executing dangerous maneuvers skillfully, without hesitation, could you keep yourself from feeling, on some level, that she was a living thing? That she was being “brave”?

Now imagine mission’s end, when she’d done everything asked of her, and all that remained was to follow one last command. Picture Cassini as she plunged into Saturn, never to return, sending data back to you as long as she possibly could. How would you take that loss? Would you feel pride? Grief? Remorse? A little of all three?

FOR ADDITIONAL READING AND STUDY

Planetary Rings: <http://lasp.colorado.edu/education/outerplanets/rings.php>

Galileo: <http://galileo.rice.edu/>

Giovanni Domenico Cassini: https://www.esa.int/About_Us/ESA_history/Jean-Dominique_Cassini_Astrology_to_astronomy

Yuri Kondratyuk and Sergei Korolev:

- <http://www.nmspacemuseum.org/halloffame/detail.php?id=2015>
- https://www.esa.int/About_Us/ESA_history/50_years_of_humans_in_space/Sergei_Korolev_Father_of_the_Soviet_Union_s_success_in_space

Apollo Program to Land on the Moon: https://www.nasa.gov/mission_pages/apollo/index.html

Édouard Roche, Roche Limit: https://www.cs.mcgill.ca/~rwest/wikispeedia/wpcd/wp/r/Roche_limit.htm

The Cassini Mission; Cassini-Huygens Exploration of Titan; Death of Cassini: https://www.nasa.gov/mission_pages/cassini/main/index.html

EPISODE 9: MAGIC WITHOUT LIES

Illumination

“Nature writes her most intimate secrets in light.”

— Ann Druyan and Brannon Braga

What are some of the ways “Nature writes her most intimate secrets in light”?

As the absence of light keeps some of the universe’s most tantalizing secrets — the exact nature of dark matter and dark energy, for example — scientists can’t rely on light to reveal all the mysteries the cosmos holds. What other fundamental forces and particles can be used to probe nature? Consider how the Large Hadron Collider (LHC) seeks to reveal the mysteries of particle physics and how astrophysicists use the Laser Interferometer Gravitational-Wave Observatory (LIGO) to find ripples in space and time.

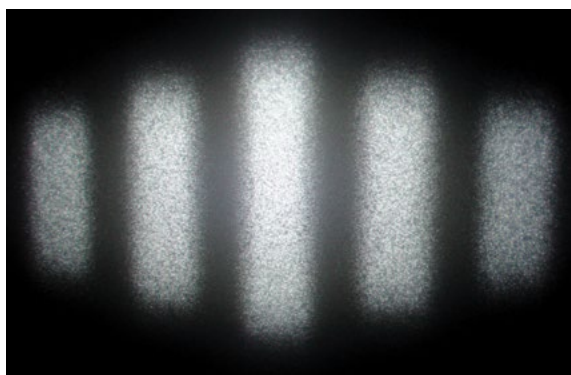
Isaac Newton and Christiaan Huygens

“Most people thought of the events Newton studied as being just the way things were. The way an apple falls. The way a ray of light shines through a window. Newton’s greatness stemmed from his questioning of the ‘why’ and ‘how’ of ordinary things.”

— Ann Druyan and Brannon Braga

What ordinary things would **you** like to know more about? How would you go about it?

Compare Isaac Newton’s theory that light is a particle with Christiaan Huygens’ theory that light is a wave.



Light waves make a telltale interference pattern, as first discovered by Thomas Young’s famed double-slit experiment. (© Cosmos Studios Inc.)

Thomas Young

How was Thomas Young able to make the case that Huygens was right and Newton wrong? How does the interference pattern in his double-slit experiment show that light is a wave?

On a side note, what a diverse skill set Young acquired! Beyond this most famous of his discoveries, he made advances in math, medicine, physiology and physics. Additionally, he helped crack the mystery of hieroglyphics, and even developed “Young temperament,” a method of tuning musical instruments. For his expansive range of knowledge, he was hailed as a polymath. Can you think of other famed polymaths throughout history?

Wave-Particle Duality

How is it possible that light functions as both a wave and a particle, depending upon whether a given photon is being observed? What do we understand about this paradox, and how much remains opaque? What are the implications of how much we don't know?

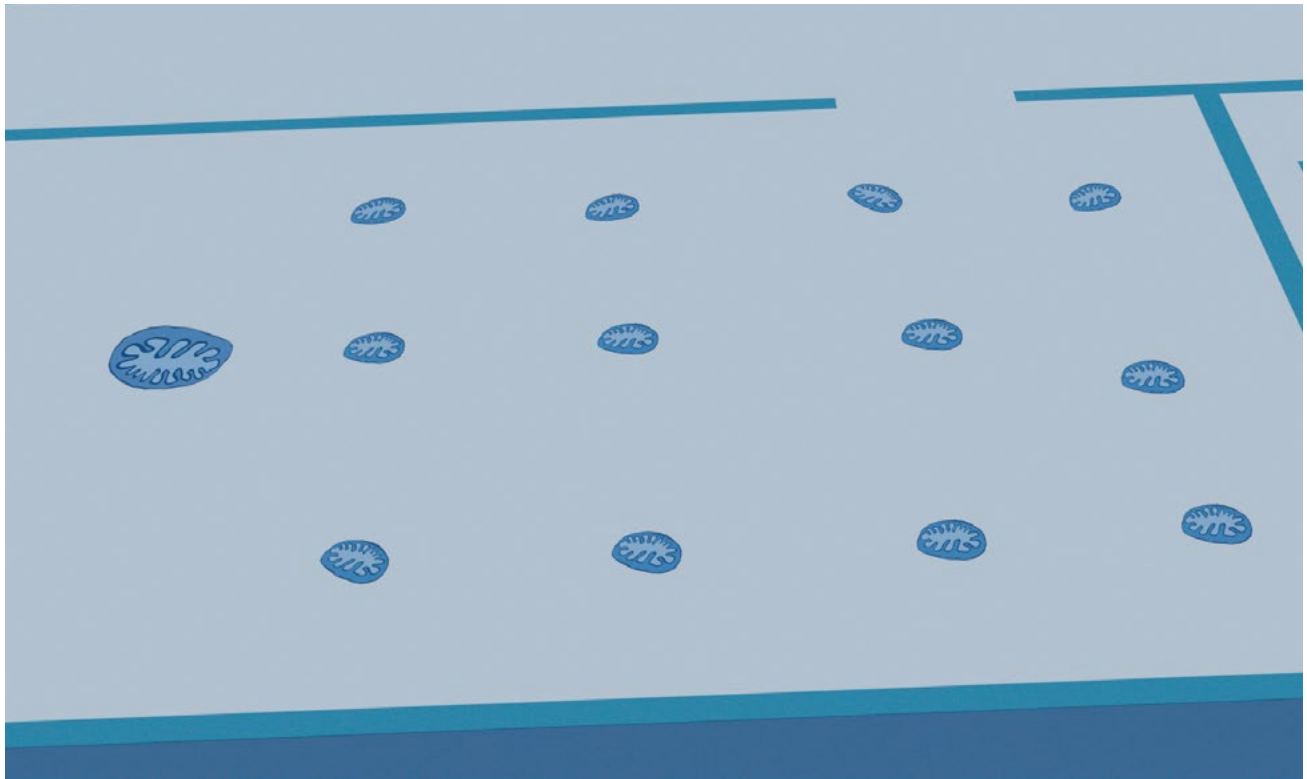
“In the quantum universe, there’s an undiscovered frontier where the laws of our world give way to the ones that apply on the tiniest scale we know. They’re divorced from our everyday experience. How can you think about a world that has different rules than ours?”

— Ann Druyan and Brannon Braga

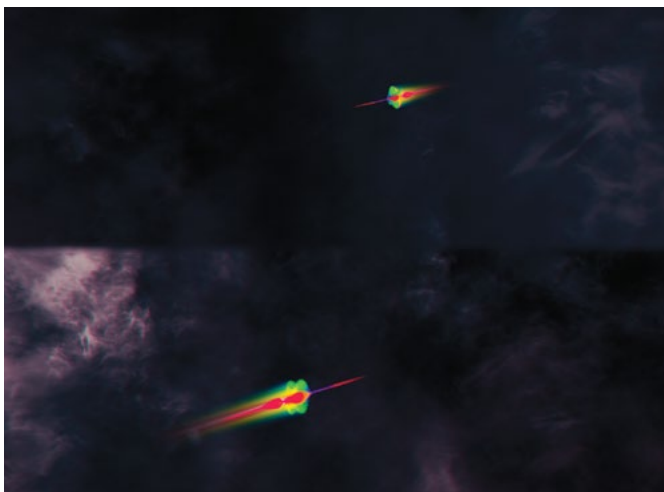
Why are quantum physics problems so difficult for us? As biological creatures used to solving problems of classical physics, are we inherently disadvantaged for mysteries of this nature? Are there ways we can mitigate the problem?

Flatworld

Consider Flatworld’s utility as a teaching tool. Is our trouble comprehending a quantum reality akin to a two-dimensional Flatworlder trying to make sense of a three-dimensional visitor?



Because Flatworlders live in a two-dimensional space, they have a tricky time making sense of three-dimensional visitors.
(© Cosmos Studios Inc.)



No matter how far apart they travel in space or time, quantum entangled photons remain bonded together. (© Cosmos Studios Inc.)

Quantum Mechanics and the Quantum Universe

What is quantum entanglement? How can two photons communicate instantaneously across vast distances? Are they actually breaking the speed of light?

Can we liken our struggles with quantum physics to our ancestors domesticating fire? Unable to comprehend what exactly fire was, they nevertheless learned how to make use of it and gradually discovered its various properties. Is that where we stand with quantum physics today? Are we on the path to a comprehensible set of rules but are simply too early in the journey to crack the code? What will it mean for us if the quantum universe remains always beyond our ken?

Superdeterminism

How does a superdeterministic universe potentially solve the riddle of quantum entanglement?

What are the pros and cons of living in a reality where everything we experience was “set in lockstep motion” from the instant the universe began?

Could everything be playing out as if it were a script? If we enjoy the experience of free will, does it matter that we might not actually have free will at all?

FOR ADDITIONAL READING AND STUDY

Thomas Young, Jean-François Champollion, and the Rosetta Stone:

http://www.bbc.co.uk/history/ancient/egyptians/decipherment_01.shtml

Sir Isaac Newton's v. Christiaan Huygens' Theories of Light:

- http://www.schoolphysics.co.uk/age16-19/Wave%20properties/Wave%20properties/text/Theories_of_light/index.html
- <https://www.olympus-lifescience.com/en/microscope-resource/primer/lightandcolor/particleorwave/>

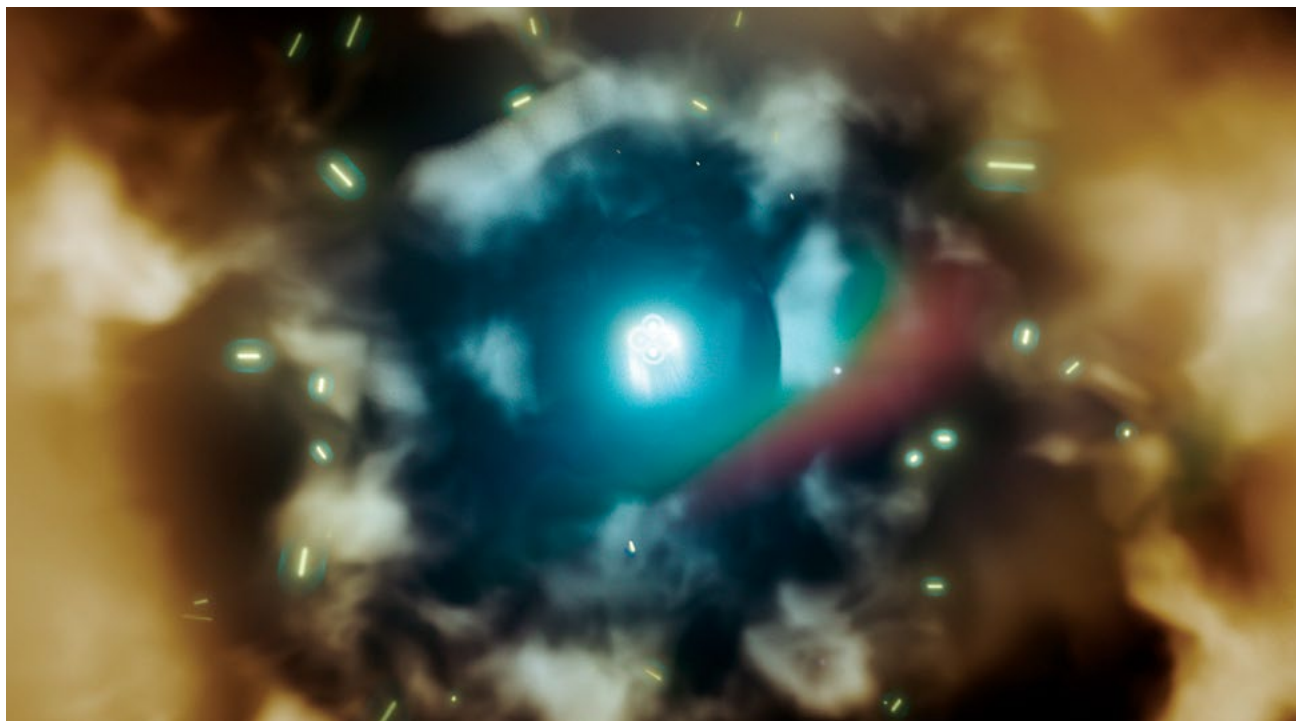
Photons: <https://www.universetoday.com/74027/what-are-photons/>

Tesseract: <https://www.scienceabc.com/pure-sciences/what-exactly-is-a-tesseract-real-life-geometry-4-dimensional.html>

John Stewart Bell and Superdeterminism:

<https://www.quantamagazine.org/physicists-are-closing-the-bell-test-loophole-20170207/>

EPISODE 10: A TALE OF TWO ATOMS



Starlight emanates from nuclear fusion, a source of awe-inspiring power. (© Cosmos Studios Inc.)

The Secrets of Starlight

“When we make a fire, we release this hidden chemical energy. But there is a deeper level of matter that houses another kind of energy. Inside the heart of the atom: its nucleus. This hidden treasure was forged billions of years ago in distant stellar furnaces. Long before Earth was formed. It’s what powers the stars.”

— Ann Druyan and Brannon Braga

How can such astonishing power be hidden in something as small as an atom? Why does it seem counterintuitive to us? How does this apparent incongruity highlight the importance of questioning everything?

Marie and Pierre Curie

How did Marie Curie come to the conclusion that reactions might be taking place inside atoms? That smaller, subatomic particles might exist?

What scientific advances have sprung from the Curies’ work?

“When radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of the direct usefulness of it. It must be done for itself, for the beauty of science, and then there is always the chance that a scientific discovery may become like the radium a benefit for humanity.”

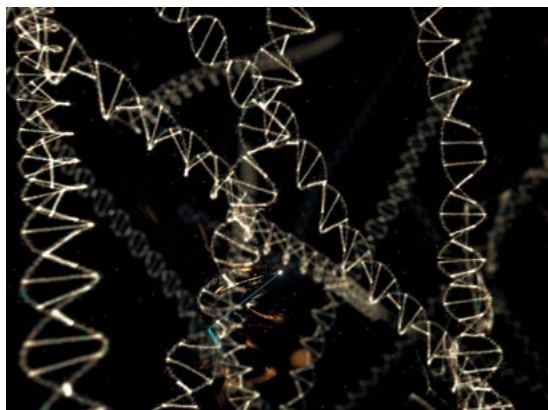
— Marie Curie, *Vassar* 1921

Science and Science Fiction

Consider the reciprocal relationship between science and science fiction: Inspired by Marie Curie’s work in radioactivity, H.G. Wells imagines how atoms can be weaponized and crafts this into a story, coining the phrase “atomic bombs.” Leo Szilard then reads the story, and it inspires his scientific research into the nuclear chain reaction.

Similarly, Robert Goddard’s invention of the first liquid-fueled rocket evolved from his fascination with H.G. Wells’ *War of the Worlds*. It’s not uncommon for robot designers, when asked why they entered their field, to explain how the droids of *Star Wars* captured their childhood imaginations.

How does popular science fiction portray science? How does it portray scientists? What does it tend to get right, and where does it go wrong? What value does it bring in exploring how science and technology can be used or misused?



Chromosomes take massive damage from radiation, unable to withstand the assault. (© Cosmos Studios Inc.)

Dangers of Radiation

Why are high levels of ionizing radiation so dangerous? How does it affect human tissue? How can it cause cancer?

What allows it to potentially “vandalize our future,” causing mutations in offspring?

The Atomic Bomb

After discovering the catastrophic real-world destructive potential of an atomic bomb, and upon seeing the Nazi efforts to create such a weapon, Szilard recruited Albert Einstein to help encourage President Franklin Roosevelt to develop the bomb first. This led to the Manhattan Project and eventually to the A-bombs that would be dropped on Hiroshima and Nagasaki. Einstein would later express regret for helping Szilard. In retrospect, should Einstein not have signed the Einstein-Szilard letter? Where weapons of mass destruction are concerned, what are scientists’ moral obligations?

What about Edward Teller? Does he bear moral culpability for nuclear proliferation and the increased lethality of thermonuclear bombs? Or after the Manhattan Project, was a nuclear arms race completely inevitable?



The threat of nuclear annihilation remains a horrific possibility: an existential risk that haunts our civilization. (© Cosmos Studios Inc.)

Can We Awaken in Time?

“What about us? Would we know when to sound the alarm?
Can we see what’s coming?
Can we awaken in time?”

— Ann Druyan and Brannon Braga

The episode likens the horror of the Mt. Pelée volcano claiming some 30,000 lives to the explosion of a single nuclear warhead. Our kill range and our kill ratio have ratcheted up to such a point that nuclear arsenals now have the power to destroy human civilization many times over. We might not survive our technological adolescence.

Is there any way to put the nuclear genie back in the bottle? What steps can we take to minimize the risks of annihilating ourselves?

FOR ADDITIONAL READING AND STUDY

Marie and Pierre Curie: <https://www.nobelprize.org/prizes/themes/marie-and-pierre-curie-and-the-discovery-of-polonium-and-radium/>

Science Fiction: <https://www.smithsonianmag.com/arts-culture/how-americas-leading-science-fiction-authors-are-shaping-your-future-180951169/>

Development of the Atomic Bomb: <https://www.thoughtco.com/history-of-the-atomic-the-manhattan-project-1991237>

Eruption of Mt. Pelée Volcano in Martinique: <https://www.earthmagazine.org/article/benchmarks-may-8-1902-deadly-eruption-mount-pelee>

Effects of Radiation: <http://teachnuclear.ca/all-things-nuclear/radiation/biological-effects-of-radiation/effects-of-ionizing-radiation-on-dna/>

EPISODE 11: SHADOWS OF FORGOTTEN ANCESTORS



The domestication of fire was a life-changing invention for our Homo erectus ancestors, setting them on the path to civilization. (© Cosmos Studios Inc.)

Domestication of Fire

Why was the domestication of fire such a pivotal event in our ancestors' cultural evolution? How was it first acquired? What advantages did it provide? Beyond warmth, think about protection from wild animals, hunting, preserving meat, toolmaking, ceramic art and perhaps most important of all, cooking.

Cooked food provides more energy than its raw equivalent, and your body spends less energy processing it. That allowed our ancestors a greater energy budget, which they needed to power their growing brains. (Our brains are 2% of our body weight but eat up about 25% of our energy budget.)

Also, consider the role firelight played in extending the waking day. Our ancestors could take greater advantage of the nighttime, which included hours spent bonding around the hearth, sharing stories as they sought to make sense of their world.

Belief in Fire

Celebrating the domestication of fire is a core Zoroastrian belief — adherents to the faith face a source of light as they pray. What role does fire play in other religions? What about Easter candles, Hanukkah candles, Hindu cremation ceremonies, the homa votive ritual, and the frequent depiction of fire as a source of purification and/or punishment (hellfire) in various faiths?

What other natural-world constructs find their way into multiple religions?

Mistaking Microbes for Evil Spirits

Natural selection allows microbial organisms to alter their hosts' behavior with amazing complexity and specificity. A virus might make us sneeze because sneezing helps to spread the contagion. Given the many ways rabies affects an animal — triggering rage, forcing salivation, paralyzing the nerves for swallowing — is it any wonder so many mistook these symptoms for the malevolent influence of an evil spirit?

What further bizarre, complex behavior can microbes force their hosts to undertake?

Consider parasites that cause their hosts to be eaten by predators. For example, *Toxoplasma Gondii* makes mice lose their fear of cats. When a cat then devours that oddly courageous mouse, the parasite reproduces inside the feline digestive tract. Or take the parasitic worm, *Leucochloridium*, which hijacks a snail's eyestalks, causing them to pulse

and dance. Imagine you are an infected snail – are you perhaps hoping to hide yourself from all the hungry birds likely to mistake your eyestalks for delicious caterpillars? No luck there – *Leucochloridium* makes you lose your will to hide. Zombielike, you venture out into the open where you can be more readily seen by the very birds you need to avoid.

Do rabies and other parasitic organisms explain the enduring prevalence of zombies in our popular culture? Might other popular monsters be explained through similar natural phenomena?

The vampire legend may have resonated in part because of a hemoglobin disorder called porphyria, which can shrink your gums (thereby making your teeth look more conspicuous), while also making you sensitive to sunlight. Similarly, the congenital hypertrichosis mutation confuses systems that regulate body and facial hair, potentially giving you a “wolf-man” appearance.

Is it significant that we have more bacterial cells in our intestines than human cells in our bodies? Or that while we have tens of thousands of human genes, our microbiotal genes number in the millions? To what extent are we mere vehicles for the tiny but powerful forces within us? To what extent are we at their mercy?

“Do the dead hands of forgotten ancestors impel us in some direction beyond our control? Can we free our children from the demons that torment us and haunt our species? Can we be trusted with our own future?”

– Ann Druyan and Brannon Braga

We saw in the episode how the rabies virus can make a helpless but dangerous pawn out of a faithful friend. Other viruses, microbes and our own DNA affect us as well. Given these examples, do we even have free will?

Animal Consciousness

Consider the bees who recognize oleic acid as a call to remove their dead, the goose who mistakes a ping pong ball for one of her eggs, and the beetle whose complete range of behaviors is determined by a brain approximately the mass of a grain of salt. When they take actions that feel natural to them, what do they understand and what remains mysterious? Are they effectively just robots programmed by evolution? Or are they more than that? What about us? Are we more than that?

What Makes Us Unique

Is there anything that separates humans from other animals? Anything that elevates us as special and unique?

With the wide range of proposed theories for why humans are unique – tool use, politics, bartering, artistry, treachery, kissing, parenting our young into adulthood, etc. – none of these are unique to humanity, certainly not consciousness. To believe that other animals aren’t conscious, you’d have to disregard everything we know about animal cognition.

Can you think of **anything** that makes us truly unique?

Why do so many of us want to believe that we're special, separate from the rest of nature? What's driving that need? Is it simply a function of the kind of narcissism that led us to believe Earth was the center of the universe? Or is it a coping mechanism for the guilt we'd otherwise feel over how ruthlessly we've exploited and mistreated animals over the eons?

Kin Selection

The heroism that many animals exhibit — a willingness to die if they must so their young can live — is exactly the kind of generosity, courage and self-sacrifice we find so moving in popular entertainment. When a protagonist overcomes their fear and braves death to help someone they love, we often respond to that dramatic climax as a moving celebration of the human spirit. And yet, this is another behavior not unique to humans.

Whether human or another member of the animal kingdom, one's willingness to risk injury comes down to kin selection. But whom do we consider our kin?

Would you be willing to lay your life on the line for your family? Your friends? Your neighbors? Your country? How about complete strangers in need of help? Or a loud cat stuck in a very high tree? Where do you draw the line? If you could save a life but knew you'd be greatly risking your own in the process, what would motivate you to take the leap?

What are some examples of how kin selection can be exploited "by the demagogue and the supremacist"? How can a person's DNA-driven desire to help those in their circle be turned into fear or violence against those they see as outside their circle?

To the extent that we view the world through a lens of "us against them," how do we decide what's "us"? Are there ways to make "us" more inclusive and bring in some of "them"?

During the Cold War, President Ronald Reagan and Soviet Premier Mikhail Gorbachev discussed the ramifications of a potential extraterrestrial invasion, each agreeing that in such an event they would immediately work together against a common foe. What do you think? If extraterrestrials materialized on our doorstep tomorrow, would world leaders unite? Or would the aliens become just another global threat that we remain hopelessly divided on — like climate change?

Animal Empathy

What did the macaque experiments in the 1960s demonstrate?

Are primates more capable of empathy than other animals?

In a mutualistic or symbiotic relationship, how does an animal of one species view the other? What does the crocodile think of the plover bird that cleans its teeth? An oxpecker is a type of bird that not only eats the ticks off a zebra but also squawks a warning cry when it spots the zebra's predators. For this alarm system, does the zebra feel gratitude? Does it identify the oxpecker as a friend? Does its heart leap to have the little bird near?



Macaque monkeys are members of what might be the most compassionate species on Earth. (© Shutterstock)

What does it mean that — on rare occasions — an animal's kin selection can extend to other species, while so many humans would never think of risking their safety for an animal? Humpback whales have been documented saving the lives of gray whales — an entirely different species — by protecting them from hungry orcas. In a 2012 incident, after killer whales brought down a gray calf, over a dozen humpbacks converged on the scene, mobbing to keep the predators away. Humpback whales have even been seen coming to the aid of seals, scooping them away from danger when killer whales attack.

Is this “inadvertent altruism”? In other words, are the humpbacks helping simply because they identify killer whales as predators that should be opposed whenever possible? Or can humpbacks truly empathize with gray whales and seals, treating them with the same kindness they would want for themselves?

Ashoka

Why do you think the episode ends with Ashoka? How does his story relate to all that's come before?

What does it mean that someone as monstrously cruel as this could have his consciousness broadened — that he could stop in his path and instead dedicate his life to mercy, compassion and peace?

“All are my children. I desire for my own children their welfare and happiness, and this I desire for all.”

— Ashoka



The tyrant and conqueror Ashoka (304-232 BCE) reflects on his life choices, the possibility of Buddhist compassion dawning in his mind.
(© Cosmos Studios Inc.)

His edict – “All are my children” – is the very essence of expanded kin selection, extending his kindness toward not only other humans but animals as well. Is this the journey we humans are on?

Despite a violent, often painful history, and despite many setbacks along the way, is the story of humanity one of increasing empathy and consciousness? Can we learn to overcome our tribal divisions and expand our kin selection to embrace all creatures big and small?

Can we follow Ashoka’s redemptive arc? Will we?

FOR ADDITIONAL READING AND STUDY

Domestication of Fire: <https://www.smithsonianmag.com/science-nature/why-fire-makes-us-human-72989884/>

Zoroastrianism: <http://www.bbc.co.uk/religion/religions/zoroastrian/>

Historical Figures (from the Internet Encyclopedia of Philosophy):

- Plato: <https://www.iep.utm.edu/plato/>
- Diogenes: <https://www.iep.utm.edu/diogsino/>
- Aristotle: <https://www.iep.utm.edu/aristotl/>
- Montaigne: [https://www.iep.utm.edu/montaigne/](https://www.iep.utm.edu/montaign/)
- Adam Smith: <https://www.iep.utm.edu/smith/>

Kin Selection: <https://www.britannica.com/topic/kin-selection>

“Rudimentary Empathy in Macaques’ Social Decision-Making”: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4687595/>

Animal Empathy and Humpback Whales: <https://www.nationalgeographic.com/news/2016/08/humpback-whales-save-animals-killer-whales-explained/>

Biographies of Ashoka:

- <https://www.biographyonline.net/royalty/ashoka-biography.html>
- <https://www.culturalindia.net/indian-history/ancient-india/ashoka.html>

EPISODE 12: COMING OF AGE IN THE ANTHROPOCENE



Behold the Earth of 4 billion years ago: so very different from the home we know, a turbulent world inhospitable to humanity.
(© Cosmos Studios Inc.)

Planet Earth Then and Now

How were conditions on the infant Earth different from how they are today? Why was the early solar system a more chaotic environment?

Over billions of years, how did the environment gradually transform into one hospitable for humans?

Dangers of the Anthropocene

"I see a great future for you, little one. But a shadow hangs over it. We're not exactly sure when the darkening began. When did we become a force of nature, altering the skies, the seas and the land of the planet? When did the age of the Anthropocene begin?"

— Ann Druyan and Brannon Braga

What is the "shadow" hanging over our future?

Why is this new epoch called the Anthropocene? What's the origin of the term?

Discuss the extent of human activity on the environment – the most significant transformation of our world since cyanobacteria.

What's the origin of the plight we're facing? Is it accurate to trace the start of the Anthropocene all the way back to the Agricultural Revolution? Or is it more precise to tie it to more recent perilous choices our species has made?

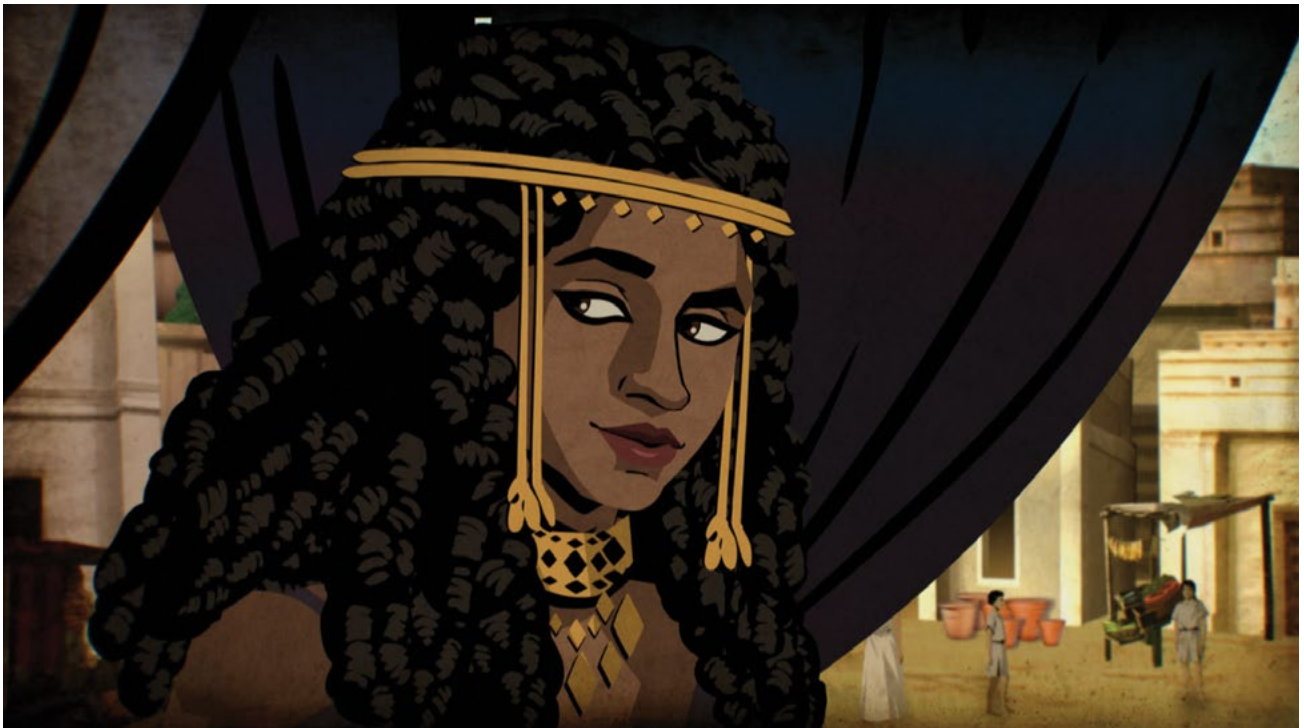
Consider the various origins the episode proposes: settling into cities, domesticating fire, domesticating animals, puddling rice – all with wonderful benefits but unexpected consequences over long periods of time. Was it perhaps the detonation of the first atomic bomb, as some geologists have proposed?

What is carbon 14, and how did it get into our body tissues?

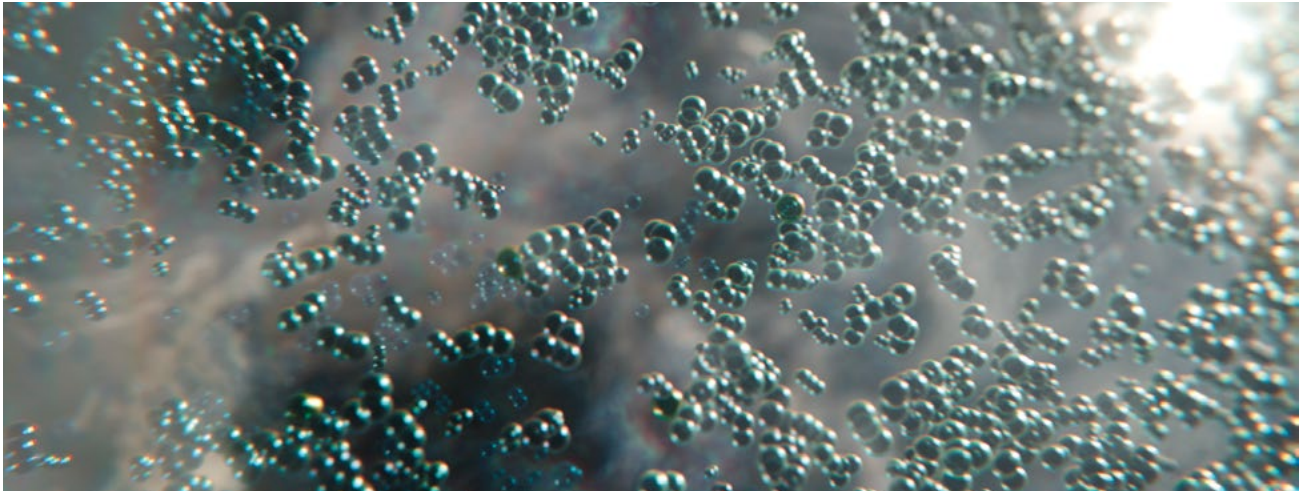
Cassandra

How does the Greek myth of Cassandra's curse illustrate the problems environmental scientists face in convincing governments and corporations to take meaningful action on climate change?

What, if anything, can be done to break the curse?



As the result of a curse, the fabled Cassandra could see impending disasters and yet was powerless to prevent them.
(© Cosmos Studios Inc.)



*Chlorine atoms devour ozone molecules, depleting our protective layer against the danger of ultraviolet radiation.
(© Cosmos Studios Inc.)*

Chlorofluorocarbons

What are chlorofluorocarbons (CFCs)? Why were they invented?

How did Mario Molina and Sherwood Rowland determine that CFCs were thinning the ozone layer? On a chemical level, how was the damage being done?

Why do we need the ozone layer? Without it, why was life unable to leave the safety of the oceans?

Consider the far-reaching unintended consequences of something as innocuous-seeming as an improvement to shaving cream and hairspray: each chlorine atom released into the stratosphere annihilating precious, life-preserving ozone molecules. What other modern conveniences do we enjoy now that may have dangerous environmental repercussions over time?

Sounding the Alarm

"The science isn't settled," "There must be a nonhuman cause," "Wear more sunblock." Why did Molina and Rowland encounter such resistance? To what extent was it simply corporations unwilling to compromise their profits? Why do so many of us resist the idea that we humans have advanced to such a point that we're capable of doing powerful and lasting damage to our home?

A dangerous counterpart to the belief that we're incapable of spoiling our environment is the notion that the Earth is disposable, ours to ruin. Consider various belief systems and how they value or dismiss the importance of environmental stewardship.

How did the CFC ban come about and what lessons can we take from it?

Discuss the Montreal Protocol and the Kigali amendment. With the ozone layer now under gradual repair, can we take some encouragement knowing how international agreements have the power to stave off environmental collapse?

“To be alive is to be in some manner of jeopardy. Life is dangerous. In every generation, in every time, everywhere on Earth. Our species, and fellow Earthlings, have gotten through the tough times, when the prospects for life looked bleak. Somehow, we manage to endure.”

— Ann Druyan and Brannon Braga

Climate Change

How were Syukuro Manabe and Richard Wetherald able to predict the rise in Earth’s temperature so successfully over such a long period of time?

“There are broken branches on the 4-billion-year-old tree of life. And this is their monument. Each hallway memorializes the mass extinctions that were so widespread that life itself came close to dying. The first five catastrophes happened a long time before we got here. But the sixth is now, and it has our name on it.”

— Ann Druyan and Brannon Braga

Why is climate change a potentially existential threat to humanity? What damage is it already causing? If left unchecked, what can we expect in the years ahead?

How do we avoid this catastrophe? What small steps can we take as individuals? What bigger steps can governments and corporations take?

What can we do together to make a better future for us all?

FOR ADDITIONAL READING AND STUDY

Early Human Migration: <https://genographic.nationalgeographic.com/human-journey/>

The Anthropocene: <http://www.anthropocene.info/index.php>

The Story of Cassandra: <https://www.greeklegendsandmyths.com/cassandra.html>

The Fall of Troy: <https://theconversation.com/fall-of-troy-the-legend-and-the-facts-92625>

Fluorocarbons: <https://phys.org/news/2013-05-global-chlorofluorocarbons-carbon-dioxide.html>

Kigali Amendment to Montreal Protocol: <https://www.uschamber.com/series/above-the-fold/the-kigali-amendment-win-the-environment-and-the-us-economy>

Global Warming: <https://www.nrdc.org/stories/global-warming-101>

EPISODE 13: SEVEN WONDERS OF THE NEW WORLD

The World's Fair

“For me, the romance of science remains as appealing and new as it was on that day when I was shown the 1939 New York World’s Fair.”

— Carl Sagan

Consider the lasting appeal of World’s Fairs. Why have they been so inspirational to so many, including scientists such as Carl Sagan and Neil deGrasse Tyson?



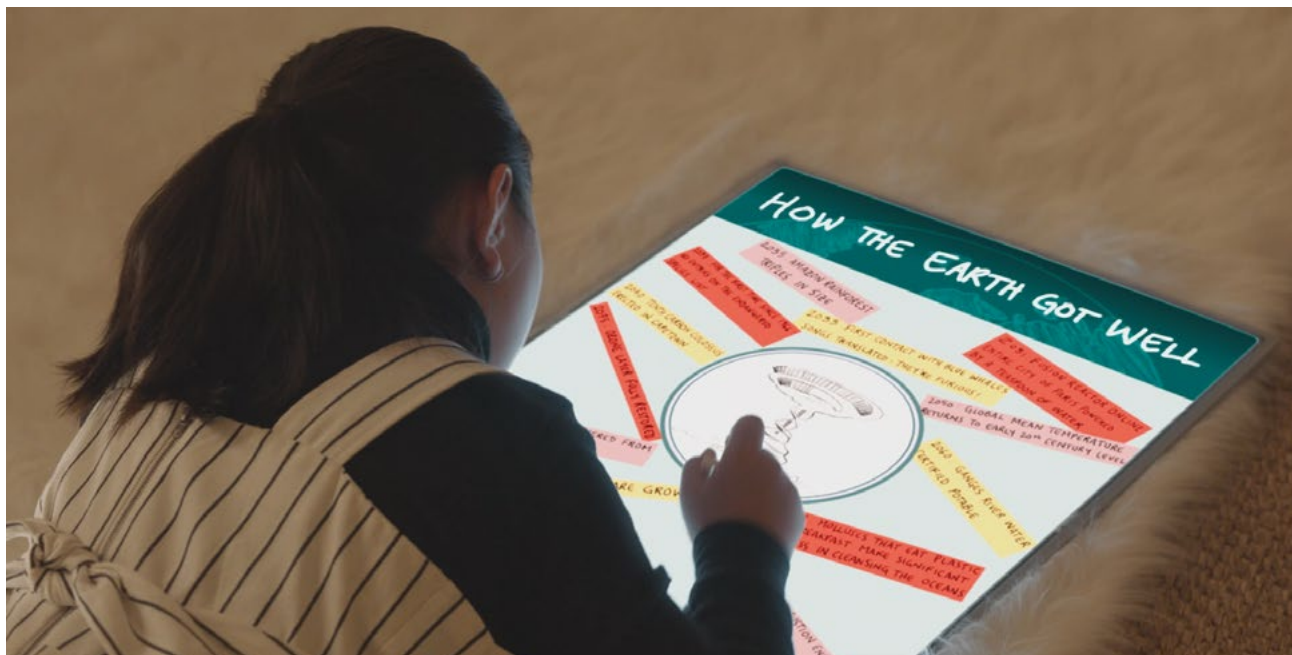
The 2039 World’s Fair awaits us in all its wonder and splendor, sparking the imagination of future scientists. (© Cosmos Studios Inc.)

The dystopias and apocalyptic nightmares of our popular entertainment serve a valuable purpose as cautionary tales, showing what might happen if society stumbles down the wrong path. But optimistic imaginings of our future play an equal, or perhaps even more valuable, role. Why is it so important for us to envision positive possibilities for humanity?

How the Earth Got Well

“Dreams are maps. Without them, we go nowhere.”

— Ann Druyan



“How the Earth Got Well” speaks to the question of our time: Can we find a way forward from our current predicament, and make the world a better place for all its inhabitants? (© Cosmos Studios Inc.)

Discuss the headlines the little girl in the episode creates as she imagines how the future might unfold.

- 1 QUANTUM PHYSICS PROVES MULTIPLE REALITIES ARE REAL
- 2 FUSION REACTOR ONLINE – ENTIRE CITY OF PARIS POWERED BY A TEASPOON OF WATER
- 3 FIRST CONTACT WITH BLUE WHALES SONGS TRANSLATED – THEY’RE FURIOUS!
- 4 AMAZON RAINFOREST TRIPLES IN SIZE
- 5 FOR THE FIRST TIME SINCE 1966 – NO ENTRIES ON THE ENDANGERED SPECIES LIST
- 6 TENTH CARBON COLOSSUS ERECTED IN CAPETOWN
- 7 LAST INTERNAL COMBUSTION ENGINE DONATED TO MUSEUM
- 8 POLAR ICE CAPS ARE GROWING
- 9 MOLLUSKS THAT EAT PLASTIC FOR BREAKFAST MAKE SIGNIFICANT PROGRESS IN CLEANSING THE OCEANS
- 10 GANGES RIVER WATER CERTIFIED POTABLE
- 11 GLOBAL MEAN TEMPERATURE RETURNS TO EARLY 20TH CENTURY LEVEL
- 12 OZONE LAYER FULLY RESTORED
- 13 EARTH HAS RECOVERED FROM INDUSTRIAL REVOLUTION

Which headlines speak most to you personally? Which seem most readily achievable?

What new headlines would you add to the list?

The Pavilion of the Searchers

“Imagine a world where the still unfolding story of the universe was told to every child as naturally as we tell them our nursery rhymes and fairy tales.”

— Ann Druyan

Consider the prospect of virtually recreating the greatest heroes in the history of science. As our understanding of neuroscience increases, could we in fact reproduce their neural networks, with ideas, memories and connections? What would it take to capture their connectome?

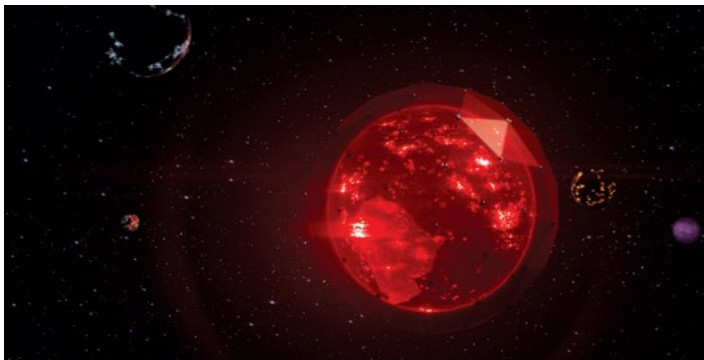
If we could, in fact, achieve this, which scientists would you most want to meet? What questions would you ask them?

Unexpected Solutions: Thale Cress and Poplars

Around the world, over 100 million landmines remain buried in the ground. Every year, they kill or maim thousands of innocents. How does the thale cress help detect these traps and save lives?

Although it's wise to be cautious for how genetic engineering might be misused, what a tremendously positive use of the technology the thale cress represents! Is it counterintuitive that botanists might devise a way for us to disarm weapons of war?

Take also the example of how the crossbreeding of poplars has fashioned a tree capable of detoxifying contaminated areas. What as-yet-unthought-of solutions to our problems might come from surprising applications of technology?



The Encyclopedia Galactica

Compare the various hypothetical extraterrestrial species in the Encyclopedia Galactica: We Who Survived. We Who Flower in Darkness. We Who Became One. We Who Drink Light. Is there a similarly evocative name you might give us? What descriptor do you think best captures our story? We Who...?

*You might find this extraterrestrial civilization in the Encyclopedia Galactica, a compendium of possible worlds we can only imagine.
(© Cosmos Studios Inc.)*

“Science, as of now, has no means of making us wise and farsighted.
That’s up to us.”

— Ann Druyan

Why do you think the Encyclopedia Galactica gives humanity only a 50% chance of surviving the next 100 years?

Given our resourcefulness as a species, given our capacity to learn from past mistakes, given all our intelligence, compassion, courage and humility...is 50% too low?

Given the worrisome state of the world, given the all-too-real existential threats we face, given all our shortsightedness, thoughtlessness and capacity for cruelty...is 50% too high?

“Fifty percent, huh? That’s all? I know a way we can up those odds.
It’s about taking what science is telling us to heart.”

— Ann Druyan

What would it mean for our society, our species, to take what science is telling us to heart? How can we make that happen? How can you be a part of it?

FOR ADDITIONAL READING AND STUDY

World’s Fair:

- <https://www.youtube.com/watch?v=GW1G7e9ld7c>
- <https://www.youtube.com/watch?v=LdWnrjCcDWI&t=529s+%281964%29>

Holograms: <https://science.howstuffworks.com/hologram.htm>

Thale Cress Plants and Landmines: <http://www.landminefree.org/2017/index.php/support/facts-about-landmines>

Poplars and Toxins: <https://www.cabi.org/environmentalimpact/news/25756>

Mohenjo-Daro: <https://www.nationalgeographic.com/archaeology-and-history/archaeology/mohenjo-daro/>

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PHOTOGRAPHY CREDITS

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EDUCATING FOR GLOBAL UNDERSTANDING



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