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With Love
Quilt with cyanotype printed images

In my research I explored the heat death of the universe, a process where over the course of thousands of billions of years, space expands, stars burn out, black holes evaporate, particles decay, and the universe comes to a cold, dark and empty end. I concluded my paper by saying that in the face of the inevitable end of the universe, we should instead be comforted by the fact that nothing is expected of us and awed by our very existence in the vast universe. My final project is a physical representation of this conclusion. All of the images on the quilt are cyanotypes of pictures I took (with the exception of one, courtesy of Seven) of moments at Oxbow. Although the imagery of my quilt is designed to represent the conclusion of my paper, I think that the process says as much about its meaning as the finished quilt does. Sewing in sculpture while we watched Teen Beach Movie, preparing fabric for cyanotyping in the darkroom with Dion, Melody helping me with the math to figure out the what size my fabric needed to be, hand sewing the binding on the floor of New Media and everyone cheering when I finished and playing with Mateo on the deck while we should have been writing our artist statements. Additionally, this piece serves as a way for me to remember and honor my experiences here, because although I am comforted by the impermanence of the world, endings are still hard.

And Here We Have Figs

J M.

The Oxbow School

OS48

Author's Note: Much of what we know about the history of the universe cannot be proven. We have no way to look at the Earth in its infancy, or see what happened during the Big Bang. Additionally, there is so much we don't know about the universe. Although we have been looking into the stars and wondering where they came from for millenia, only in the last century have many major cosmological discoveries been made. Taking this into account, most of the scenarios I present in this paper have other possible explanations and/or interpretations. I have tried to focus only on ones which the majority of the scientific community has reached a consensus, though for vital events where definite information is still scarce I made sure to note this uncertainty.

I: All Things End[1]

In approximately 10^1000[2] years the universe will end.[3] [4](Well, that will be the end of the end. It's hard to define when the end really starts). This process, called heat death, is fueled by the dark energy induced expansion of the universe. It was previously thought that the expansion of the universe was slowing as the momentum produced from the Big Bang fought against gravity's urge to pull everything together. But as researchers in 1998 discovered, it turns out that the expansion of the universe is accelerating. This acceleration is measured by redshift and blueshift, which uses the change in frequency of light emitted by objects in space to measure if they're moving towards or away from us. As the expansion of the universe accelerates, everything will spread further and further apart. Eventually, only our neighboring galaxies in the Local Group will be visible. All

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[1] After the Hozier song
[2] To give you a better idea of this number the calculator on google says it's infinity
[3] This is kind of a lie. Although heat death is the most probable way the universe will end we still aren't sure. It depends on a few unknowns 1) the shape of the universe: closed, flat or open. Heat death can only occur in a flat or open universe 2) the value of the cosmological constant. If represented by dark energy, the shape of the universe no longer matters and heat death will most likely occur.
[4] Mack, Katie. *The End of Everything: (Astrophysically Speaking)*. Penguin Books, 2021.

other objects will slowly become unreachable as they spread beyond the particle horizon of our observable universe. Over the course of billions of years stars will burn through the rest of their fuel and go out. Even black holes, the last embers of the once bright universe, will evaporate. After this, the very particles that used to make up these grand structures will break down. First neutrons into protons, protons into electrons, and electrons into antineutrinos. Finally, when nothing is left but scattered radiation and dark energy, the universe will have reached thermodynamic equilibrium, a maximum entropy state. This is what really spells the end. Entropy can be defined as the disorder of a system, the more disordered the system the higher the entropy.[5] Additionally, the entropy of an isolated system can only increase. In this case the universe is an isolated system. All spontaneous processes increase entropy because of a system's tendency to move towards thermodynamic equilibrium. In a universe dominated by randomness and disorganization, entropy is at its highest point and cannot be increased. Therefore, no spontaneous processes can occur. Nothing can happen. Ever. This eternal nothingness is the root of heat death.

But heat death is so far away it's not something we really have to worry about. Before dark energy renders the universe cold, empty and desolate, things are going to go in the opposite direction. In 1.6 billion years, the sun's luminosity will have risen to double its current level, boiling the oceans, scorching the Earth, and leaving it completely uninhabitable to any form of life. If we somehow find a way to escape the Earth and survive, or if we're even able to stick around that long, the Andromeda galaxy will collide with the Milky Way in another 4 billion years. Since the stars in each galaxy are so far apart, it's unlikely that there will be any collisions. The Solar System might even remain intact. Not long after that, the Sun will enter its red giant phase

[5] Ting, Valeska. "What Is the Second Law of Thermodynamics?" *YouTube*, The Royal Institution, 12 Dec. 2016, https://youtu.be/mGDJO2M7RBg.

after using up all the helium in its core, causing it to expand and envelop Mercury, Venus and probably Earth. All in all, the next few billion years aren't looking too good for the Solar System.

II: Know Thyself

Fire

4.5 billion years ago, a swirling cloud of dust rich in minerals was pulled together by gravity, forming the beginnings of the planet we are standing on right now.[6] The early Earth was constantly pelted with tiny meteorites produced by the sun and combined with remnants of the cloud that formed it. Due to the continuous impact of other bodies the Earth was forced in a volcanic and magma dominated state for its first 50 million years of existence. This fiery and chaotic period of Earth's history is called the Hadean Eon after Hades, the Greek god of the underworld. This chaos was exacerbated when Theia, a planet the size of Mars struck the Earth. The impact liquidized both planets into a swirling mass of magma and mineral. As the new planet resolidified, one part broke off and became trapped in the Earth's orbit. We now know this piece as the Moon. Even though the Earth had cooled slightly since its encounter with Theia, it still had a surface temperature of thousands of degrees. Knowing what we do about the second law of thermodynamics, it couldn't stay this hot for long. Convection assisted in the slow cooling of Earth. As magma rose to the surface of the planet it cooled into basalt, forming Earth's first crust. This fragile layer was riddled with volcanoes and magma filled cracks, and subject to frequent asteroid impacts, but it was a crust nonetheless.

[6] Hazen, Robert M. *The Story of Earth: The First 4.5 Billion Years, from Stardust to Living Planet*. Penguin Books, 2013.

Water

But the Hadean Eon was not only defined by fire. Oceans formed during this period[7], covering the thin basalt crust of the Earth in a deep blue layer that would prove instrumental in the next phase of its evolution. Although ice and other signs of water have been found on many planets, (Mars may have even have had liquid oceans during its first years) Earth is currently the only planet we know of with liquid oceans. This is due to its location in the habitable zone: a specific range of distance from a star in which liquid water can exist. If that dust had been in any other place, the string of events that led Earth to the form it is in today probably would not have occurred.

Life

The first living organisms were single celled microbes.[8] The fossil record from this time is so sparse it's hard to identify exactly what these organisms were, but they most likely lived in microbial mats or deep in geothermal vents.

Air

At the end of the Archean Eon, 2 billion years into Earth's life, one event drastically changed how life on the planet worked. Before, life was solely anaerobic. But somehow, somewhere, the microbes populating Earth's oceans began to photosynthesize. The development of photosynthesis

[7] The origins of water on Earth are extremely contested to this day. Oceans definitely formed at some point during the Hadean Eon but other than that the jury is still out.
[8] This one too. We really aren't sure how or where exactly life formed. Though we are pretty sure that the building blocks of life: energy, water, and organic compounds (compounds with carbon) all existed in the same place at the same time, paving the way for life to form.

led to an increase in the atmospheric concentrations of oxygen. After the Great Oxidation Event, the middle billion years of the Proterozoic Eon were relatively stable. Then, the splitting of the supercontinent Rodinia triggered a cycle of glaciation and warming that lasted for almost 1000 million years. These quick fluctuations[9] made the concentration of oxygen in the atmosphere rise yet again, allowing more complex multicellular organisms to evolve.

Now that multicellular life had a foothold, the Earth began to rapidly evolve in a period called the Cambrian Explosion. First, soft bodied animals like worms and jellyfish emerged. Next came the development of hard shelled animals like mollusks and early arthropods. Then plants, first rootless and low to the ground then with bright green leaves and sturdy trunks. These new forests provided a habitat for fungi and invertebrates. Soon after, amphibians became the first vertebrates to venture out of the water and onto land.

But the universe was indifferent to this new flourishing community of flora and fauna in the same way it was to the young Earth. 65 million years ago, the Cretaceous-Paleogene extinction event occurred, wiping out 80 percent of all species including all non-avian dinosaurs.[10] In the aftermath of this event, amphibians and mammals flourished, filling up empty niches left by their reptilian predecessors.

It was not until less than 10 millions years ago that the first hominids evolved. Modern humans are thought to have emerged only 200,000 years ago. Some Bristlecone pines, the oldest trees in the world, have lived through some of the most seminal events in human history. One of these trees, Methuselah, is older than the United States, the Industrial Revolution, the Aztec Empire, the Silk Road, the Roman Empire, Buddhism, and the Pyramids of Giza.

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[9] Although it doesn’t seem like it, millions of years are relatively quick on the geologic time scale.

[10] Rafferty, John P. “K–T Extinction.” *Encyclopædia Britannica*, Encyclopædia Britannica, Inc., 14 Apr. 2009, https://www.britannica.com/science/K-T-extinction.

Although humans have existed for less than 0.01% of Earth's existence, and an even tinier percentage of the universe's, we are still a part of it. This is our history. You are made up of atoms created during the big bang. Elements formed in the center of an ancient star. You are the universe.

III: What Now?

Now you know. You know the fiery fate of the Earth and the dark cold one of the universe.

What now?

Sit down. Take a breath. In the turbulent and indifferent universe over the course of billions of years, a planet formed at the right time and the right distance away from a star to support a complexity of life not found anywhere else. In a few billion more, the charred husk of that planet will be its only remnant. Our existence will only be a fleeting moment in the grand story of the universe. And that's okay. Let the indifference of the universe rock you to sleep, comforted by the fact that nothing is expected of you. You have no legacy to live up to. Marvel in the glory of everything that we have the privilege of living alongside, mountains molded by thousands of years of subducting and converging plates, the steady flow of magma far beneath our feet, moving landforms on a scale that we will never see. In the vast universe there are trees that have existed for thousands of years, supermassive black holes thirty times the size of the sun, rocks nearly 4 billion years old, pale fleshy fish living 25,000 feet below sea level and microscopic animals that can survive decades in subzero temperatures. And figs. Here we have figs.

This is awesome J! My only advice? Tweaks the sub headers "air" "water" etc. so they stand out more.

Works Cited

Cole, K. C. *First You Build a Cloud: And Other Reflections on Physics as a Way of Life*. Houghton Mifflin Harcourt, 2012.

This book draws on complex physics concepts and connects them to daily life to make them more understandable and relevant to regular people. It proved useful in helping me understand how physics shapes the world. The introduction in particular touched on my topic in an unexpected way which helped me view it differently.

Filkin, David. *Stephen Hawking's Universe: The Cosmos Explained*. Basic Books, 1997.

In this book, FIlkin explains the origins of cosmological discoveries and discoveries of the laws of the universe using pictures, diagrams, and widely understood language. This helped me understand the complex concepts referenced in other sources I looked at as well as conceptualize the long path of discovery and exploration.

Hazen, Robert M. *The Story of Earth: The First 4.5 Billion Years, from Stardust to Living Planet*. Penguin Books, 2013.

Detailed in this book is the entire story of the Earth, from its atomic formation, through the changes brought by each era into today and even the future. This was helpful for me to put into perspective the massive scale of Earth’s history and gain a greater appreciation of all the factors that came together in order for life to exist which is helpful in forming an answer to my essential question that asks what humanity's purpose (if any) is.

Hill, Mary. *California Landscape: Origin and Evolution*. University of California Press, 1984.

This book provides an account of the geologic process that have shaped California's landscape over the last 10,000 years. It also explains how time is the medium through which geology is studied. The smaller time frame this book covers was useful because I want to briefly explore "recent" geologic history in my paper.

Koppes, Steve. "The Origin of Life on Earth, Explained." *University of Chicago News*, University of Chicago, 19 Sept. 2022, https://news.uchicago.edu/explainer/origin-life-earth-explained.

Mack, Katie. *The End of Everything: (Astrophysically Speaking)*. Penguin Books, 2021.

The End of Everything presents five different scenarios for how the universe could end, including heat death which is the one my research is mainly aimed at, and explains the physics that go along with each one. Katie Mack's insight into the question of "what does the end of the universe mean for us?" was particularly useful since my essential questions explore the same idea.

McKie, Robin. "The Methuselah Tree and the Secrets of Earth's Oldest Organisms." *The Guardian*, Guardian News and Media, 2 Aug. 2020, https://www.theguardian.com/environment/2020/aug/02/the-methuselah-tree-and-the-secrets-of-earths-oldest-organisms.

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"The Sun's Evolution." *Faculty.wcas.northwestern.edu*, https://faculty.wcas.northwestern.edu/infocom/The%20Website/evolution.html#:~:text=Since%20its%20birth%204.5%20billion,gently%20increased%20by%20about%2030%25.&text=This%20is%20an%20inevitable%20evolution,the%20hydrogen%20in%20its%20core.

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