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CAN BIOLOGY DEFINE A HUMAN LIFE?

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CAN BIOLOGY DEFINE A HUMAN LIFE?

An interdisciplinary investigation into alternatives that may compensate for a lack of discovery.

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By

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ABSTRACT

Name: Katelyn De Leon Major: Biology

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I grew up contemplating the concept of life. From my Catholic grandmother to my pediatrician mother, I always received mixed perspectives on the hot topics of abortions, vaccines, and embryo use. I found that the controversy lies in an ambiguous, mixed understanding of what constitutes a human life. From biochemical approaches to extraterrestrial life forms and spirituality there is no clear, coherent all-encompassing definition of life. However, that does not mean we can merely agree to disagree. The concept of a human life has drastic implications on our everyday lives. An insufficient definition has, and will continue to, diminish quality of life and shorten our life spans. If we cannot define a human life we can not justify vaccines, drug development, and disputes over bodily autonomy regarding a fetus. We have (and will continue to) experience the recirculation of previously extinguished diseases. Drugs necessary to help facilitate bodily processes necessary for patients to live can be banned based on their use of embryos. Female reproductive tracts may be more regulated based on various versions of timelines regarding a human life. Furthermore, the inconclusive understanding of what constitutes a human life fuels controversy and leads to social divide within our political sphere. There is no all encompassing, all-pleasing definition of life, but we must find one. A lack of a clear and coherent definition has and will continue to diminish the very quality and length of our lives.

CHAPTER I: KATIE'S LIFE

I was raised in a Roman Catholic household surrounded by the presence of strong women. My childhood included a series of discussions regarding the value of religious teachings and life experience. I especially remember the discussion between my aunt, a probation officer, and my grandmother regarding the preservation of life from conception. My aunt works with women stained by a series of unfortunate events, often including childhood trauma, domestic violence, and persistent drug addiction. As a probation officer, my aunt is tasked with helping these women regain autonomy and healthy habits that will grant them more opportunities in the future. Along the path of healing, there are a multitude of unexpected challenges that arise. One of the most difficult occurrences is the emergence of a child. Many of these women have children already, but their children are often under possession of the state and placed in foster homes. In cases of substance abuse, drugs change the environment of the fetus (due to the circulation of foreign chemicals) that can lead to abnormalities in development (Griffiths & Campbell, 2014). Additionally, these women are challenged enough in caring for themselves, so the mere thought of caring for a child can be incredibly overwhelming. With this in mind, many of these women elect to terminate their pregnancy, a decision supported by my Catholic aunt. My grandmother, conversely, treasures the creation of any human life and is in opposition to abortions (under any circumstances).

My mother is a pediatrician, and I was able to observe the conflict between a more social value of life and a scientific one. Specializing in the care of children, my mother has been exposed to a multitude of developmental malformations that causes a fetus to become incompatible with life. These include chromosomal abnormalities and the lack of vital organs, such as anencephaly (a neural tube disorder) (Golden & Chernoff, 1995). With such lethal

congenital defects, these children often experience death shortly after birth. This prompts a short and poor quality of life for the individual. Additionally, it can cause emotional distress and physical pain for the parents. As a result, my mother would advocate on behalf of removing a fetus or discouraging a pregnancy indefinitely to avoid additional suffering. This prompts me to contemplate what it even means to be living, not in the sense of life's meaning, but how we define a human life. I am conflicted in how you could embody Catholic dogmas while still justifying the end or lack of life entirely in utero. How can I honor my grandmother's beliefs while still exploring greater issues in public health?

The pandemic further accelerated my interests in this subject matter. Each night I watched the COVID-19 death tolls displayed on the evening news, with the virus exponentially claiming the lives of individuals globally. I, as a senior in high school, distinctly remember the degree of isolation I felt. This was not limited to being physically isolated, but also a mental disconnect from society. I watched my mother come home from the clinic each day, with a mask mark indented in her skin and exhaustion that manifested under her eyes. I also observed the way certain communities coped, with misunderstood statistics and conspiracy theories attempting to make sense of the situation. Only one percent of the population will die from COVID-19, which may seem like an insignificant figure (Kang, 2020). However, one percent of earth's entire inhabitants is still a massive amount of people. For example, in 2020, we had a global population of 7.8 billion people (O' Sullivan, 2023). One percent of 7.8 billion is 78 million which is still a significant amount of individuals. Does the disregard for COVID-19 related deaths stem from the inability to perceive figures as people? Joseph Stalin once said a "single death is a tragedy, a million deaths are a statistic" (Moustafine, 2002). I think events of mass casualty are overwhelming, and we are quick to become detached and desensitized to the concept of human

life. However, it is especially during these critical moments that we need to search for explanations to questions regarding life and what it means to be living. It is unanswered rudimentary questions like these and a lack of education that serve as a breeding ground for polarization.

Life is no new concept. Historically, human life definitions have become a controversial topic weaponized to pursue a certain political agenda. It seems as if we commonly fall victim to the fallacy of confirmation bias, which is the tendency to seek out answers that reaffirm a pre-existing position (Oswald & Grosjean, 2004). This leads us to take advantage of the ambiguities in science and make them malleable to fit our beliefs. Whether that is arguing for bodily autonomy in terms of vaccines or abortions, the ambiguity surrounding life catalyzes controversial hypotheses with insufficient evidence. This often happens in abortion debates, with the most controversial aspect being the presence of a fetus. The underlying procedure of the abortion itself is not necessarily the cause of conflict. Rather, the polarization stems from a lack of consensus regarding human life definitions. You can not discern between murder and a mere extraction of a fetus without knowing whether the fetus is considered living or not. In order to truly understand the ethics of abortion, we must come to a consensus regarding the status of a fetus throughout its development in utero.

As a student graduating with a degree in biology, I value the insight the hard sciences provide in perpetuating an unbiased truth through quantitative evidence, rigorous testing, and objective perspectives. However, scientific discoveries are seldomly one hundred percent correct. The scientific process itself consists of a self-correcting dynamic, where we are constantly revisiting and revising previous conclusions. That is not said to diminish the importance of scientific discovery, but instead acknowledge its progressive process. Hypotheses are accepted

and revised based on the accumulation of new evidence. They are simply a statement that reflects the most modern discovery at that time. In an effort to seek out answers regarding human life, I decided to turn to the study of life itself. My grandparents, aunt, mother, and an incredibly contagious viral particle may have sparked my interest in a human life definition but I intend to formulate my own answer. In an interdisciplinary exploration, I will search the depths of the biological realms to (dare I say) discover the ultimate definition of life. Will biology be enough to define human life, or will I have to scavenge for answers elsewhere?

From a biological perspective, the synthesis and decomposition of life through a series of metabolic processes and cellular reproduction allows us to define life in terms of an ambiguous spectrum. Moving away from the physical plane and into a galactic one, we can refer to interstellar definitions of life from NASA. NASA searches for DNA or RNA segments on different planets and uses that to infer the presence of living organisms. That implies that the presence of nucleic acids, macromolecules, and genetic material is indicative of life and beings possessing genetic material are alive. I will then search in the realm of religion to better understand a more theologian perspective of life. In the spirit of academia, I will also study how we define death (in terms of total cessation of life) and reciprocally apply that to my understanding of life.

In my extensive time spent exploring various perspectives and alternative definitions, there were several moments I had to pause and reevaluate the breadth of my own existence. These momentary relapses were mediated by reminding myself of the importance of this topic. Life is embedded in a variety of societal structures, including murder sentences, birthdays, and sacrifices. Defining life is also an important aspect of revolutionary medicine, including use of embryos, stem cell research, and decisions regarding bodily autonomy.

Life is an omnipresent concept, and its vastness makes it a difficult topic to decipher. There is no definition that completely encompasses the concept of life. Biology neglects to provide a clear unanimous definition. Religions scarcely concern themselves with the matters concerning our physical lives, as they are more focused on the concept of personhood. Lastly, societal studies are based on man-made constructs and no one is infallible. My preliminary mistake in approaching this thesis was individually examining a field of study to isolate an articulate definition of life. However, we as humans are not solely biological or social creatures. In purely relying on one discipline, we neglect to consider the nuance we possess as biosocial beings.

However, practical application of a biosocial perspective is proving to be difficult. Between methodological challenges of data acquisition and a lack of published literature, the content necessary to produce a definition is not yet available. With this in mind, I argue that biological, social, and a biosocial interdisciplinary approach all neglect to provide a sufficient definition of life. A lack of consensus regarding this topic poses a threat to public health as a whole. Until we define a human life, we cannot justify the use of life saving measures (such as vaccines, abortions, and drug development). An insufficient definition fueled by a lack of evidence has, and will continue to, diminish quality of life and shorten our life spans.

CHAPTER II: TRANSFORMING FROM SOUP TO SOMEONE

Life is often associated with static terms of beings and organisms; however, we can alternatively characterize it as a dynamic process (Penzlin, 2009). More specifically, this perspective on life encourages us to categorize living individuals through the quantifiable mechanisms they conduct to sustain life. These biochemical processes include cellular respiration, metabolism, reproduction, and growth. To shift away from life as a label and adopt a more active definition of existence seems like an abstract concept. However, some scientists will go further to argue that it is actually these biochemical processes alone that can be considered the living component of the organism, rather than the organism as a whole (Penzlin, 2009). Although I do agree with this action-based logic to an extent, I think it is important to acknowledge that these processes exist within a greater organism. Furthermore, these biochemical processes work in unison with the greater active organism, making the organism alive by affiliation. In non-scientific jargon, this is like defining the motion of rapid foot propulsion as running and taking that one step further to acknowledge that, by affiliation, that individual must be a runner themselves. It is logical to categorize an individual by the actions they conduct, and it is also logical to define an individual by those activities. Actions do have the potential to define us, especially when it comes to defining life.

In order to provide more clarity as to why these mechanisms are associated with life, we need to understand the preliminary components of life itself (which include the presence of fundamental elements such as hydrogen, oxygen, nitrogen, carbon, and phosphorus). How these elements found their way to Earth is beyond the scope of this paper, but it is interesting to think about where in the universe these atoms originated, as opposed to merely focusing on the assembly of these atoms when they are already on Earth (Malanterre et al., 2022). It is unlikely

that these atoms randomly appeared one day and decided to congregate into a rudimentary cell. Rather, these elements first coexisted in a primordial soup (the presence and combination of atoms into various molecules) (Lane et al., 2010).

The primordial soup, more specifically, is considered the birthplace of the first cell (Lane et al., 2010; Figure 1). This was attainable due to the ability of these atoms to make chemical bonds which grants them the ability to form different building blocks as macromolecules, which include amino acids, fatty acids and glycerols, nucleotides, and monosaccharides (Biological macromolecules review, n.d.; Figure 1). These building blocks then go on to form larger, more complex structures such as proteins, lipids, nucleic acids, and carbohydrates (Biological macromolecules review, n.d.; Figure 1). The macromolecules form larger components, such as hormones, phospholipid bilayers, protein responsible for expressing the deoxyribonucleic acids (DNA) into proteins, and storage of molecular energy in the form of glucose (Biological macromolecules review, n.d.). All of these structures are necessary for even the earliest, most basic prokaryotic cell (Cavalier-Smith, 2006) to survive.

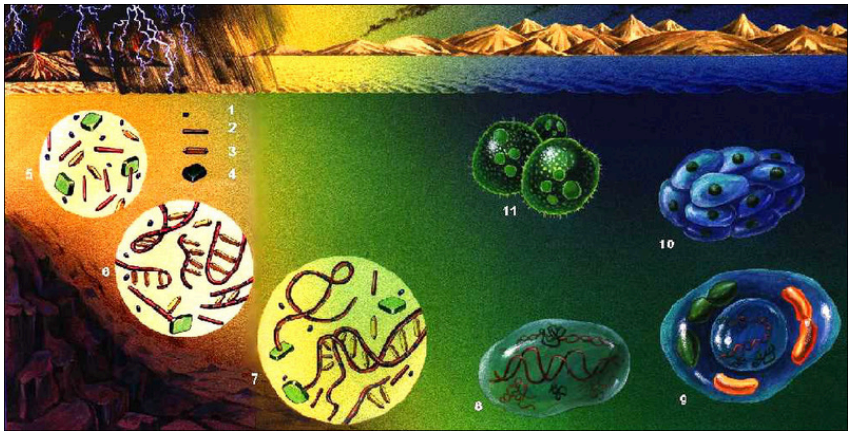

Figure 1: Primordial Soup on Early Earth. Steps 1-4 represent the nucleotides, sugars, and phosphate groups that form into DNA structures (steps 5-7) that eventually form into the first cells (steps 8-9). These cells then congregate to form more nuanced and specialized structures (steps 10-11) resulting in living organisms (Keim, 2007)

These atoms are responsible for the foundation of all living organisms and, therefore, the processes they conduct. However, it is not enough to merely rely on the presence of these atoms

to define a living organism. For example, our atmosphere contains carbon dioxide, which consists of a carbon atom bonded to two oxygen atoms. This molecule may contain two of the previously listed fundamental atoms, but carbon dioxide is not inherently living itself. Rather, it is the recycling of these elements into different building blocks that truly allows for the formation of living human organisms (Bartke & Schneider, 2020; Figure 2). This recycling process is conducted by pathways intended to break down the carbon found in complex molecules, which consists of the electron transport chain, oxidative phosphorylation, citric acid cycle, fermentation, and more (Malanterre et al., 2022) to reduced byproducts such as carbon dioxide (Figure 2). It also refers to some anabolic processes (building molecules) attained via photosynthetic pathways, which are primarily facilitated by plants and algae (Malanterre et al., 2022). Photosynthesis takes the carbon from carbon dioxide and synthesizes it into monosaccharides. This establishes life as a series of dynamic processes and activities, more specifically buildup and breakdown of organic matter that possesses fundamental atoms in some variable quantity (defined as metabolism).

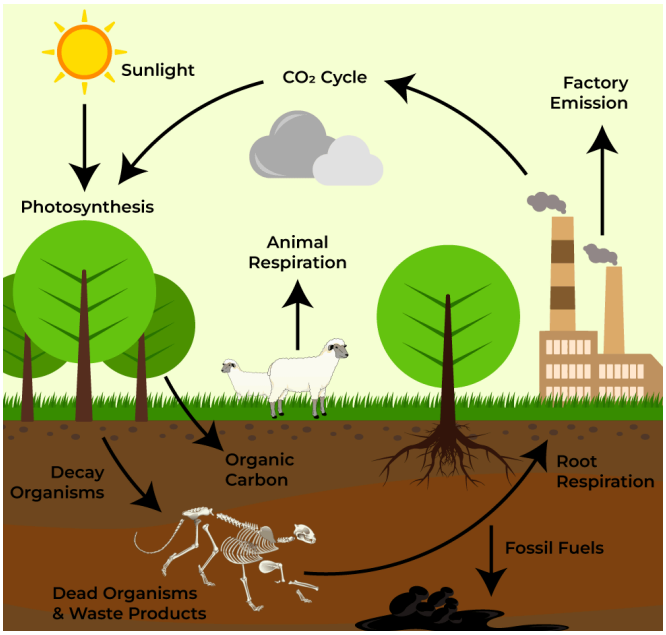

Figure 2: Carbon Synthesis and Decomposition Cycle. Carbon is recycled into various structures as it is embedded and broken down from different forms of organic matter, both living and non-living. (Geeks for Geeks, 2023)

The presence of atoms cannot be synonymous to life as our entire existence is made of these chemical elements. Equating these structures of matter to living beings would make it difficult to justify their manipulation into everyday use. Would it be ethical to produce gold and silver jewelry, as it involves extreme heat and repeated striking? How can we justify the construction of shelter or protective gear (such as PPE, construction helmets, lab goggles) as they, too, possess atoms? Even understanding life as a dynamic process has its implication in practical application. Can we justify end of life measures (that make an individual more comfortable and pleasant) if life is a constant continuation? Both of these perspectives will end up impeding our daily quality of lives and can even restrict our access to everyday materials that prolong our lifespans.

CHAPTER III: LIFE IS A RACE AND YOU ARE A RUNNER, IF LIFE IS A RAINBOW THEN YOU ARE A COLOR

With the biochemical processes explained above (that are essential for life), it is useful to perceive life as a spectrum. These are processes that were present before your existence, and they will continue to occur after your passing. However, in defining life as a spectrum, it can be confusing to understand where an individual's own life emerges. I encourage you to think of life, in a holistic sense, as a relay race and you are a single runner. You start when you get the baton, which can represent some sort of organic matter your body utilizes for fuel and growth. Once your life has expired, you will break down those atoms and molecules for another organism to utilize (Mason et al., 2022; Figure 3). Realistically, we would define this process as synthesis and decomposition, but for the sake of the analogy we can consider it passing the baton on to the next teammate (Mason et al., 2022). It is more appropriate to view life as being transferred between living humans, rather than life emerging in each successive generation (Kurjak & Tripalo, 2004; Figure 3).

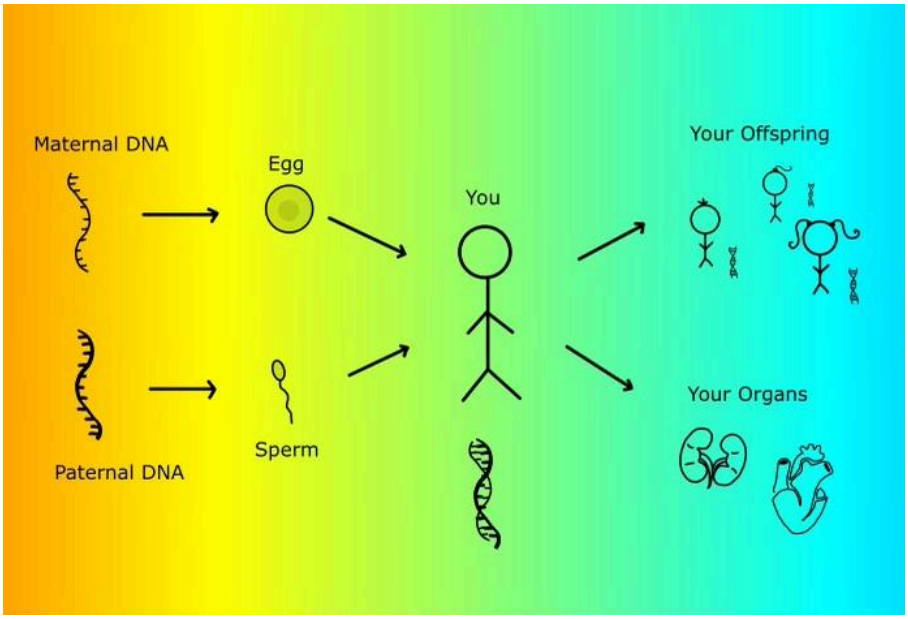

Figure 3: Life as a Spectrum. Starting from the left the parental DNA is embedded into the subsequent gametes (egg and sperm cells). The parental DNA combines to create a complete genome specific to an individual. This unique DNA can then be further dispersed beyond its original host into offspring and organ donations. (Saurini, 2023)

In perceiving life as a spectrum, it is important to understand both the organic matter and genetic code that existed before the zygote and the material that is left behind after the organism's cessation of life. The first distinguishable identifier of an individual lies within the gametes of their parents, or more specifically, the sperm and egg cells (Gamete, 2023). Although this may seem abstract, it is logical considering half of our DNA is present in the gametes before they even fuse together (Gamete, 2023). DNA molecules are the instructions that facilitate appropriate development and precise function of an organism (NCI's Dictionary of Genetic Terms, n.d.). The presence of an organism as a whole occurs after fertilization, with the formation of the zygote (Gamete, 2023). It is during this developmental stage that the cell possesses its own genetic information in its entirety (Gamete, 2023). Fourteen days after zygote formation, the zygote is focused on preparing the protective and nutritional systems necessary to sustain life by fusing with the mothers blood supply (Kurjak & Tripalo, 2004). This leads some researchers to state that prior to this point the embryo is not yet developing and, therefore, life is not yet present. However, considering this preparatory period is a part of development and still undergoing the biochemical processes required to be living, we will consider the fetal cell to be alive.

Past the zygote stage, embryos transition into the morula (solid multi-celled embryo), blastula (hollow multi-celled embryo), gastrula (formation of germ layers), and neurula stage (development of nervous system) (Muhr et al., 2023; Figure 4). It is evident that the beginning of our own life, in itself, can be considered a spectrum. This is a trend that will continue when exploring our own genetic material that may be passed down beyond us.

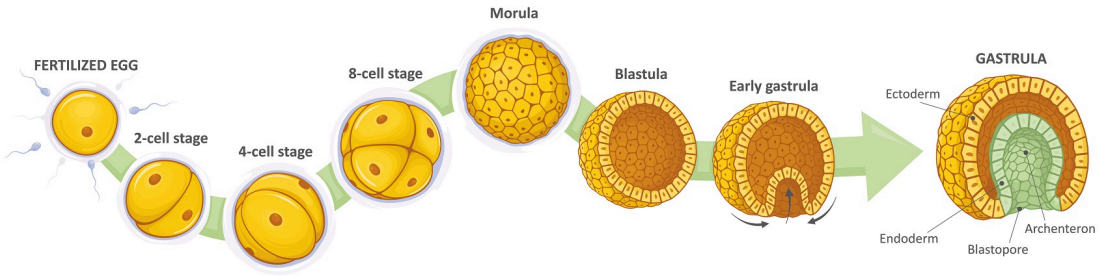

Figure 4: Embryonic Development Stages Ranging From Zygote to Gastrula

Organ transplants serve as an example as to how our remains can be sustained post death. The nature of organ transplants allows your organs to be removed and sustained in another individual. Considering that the organ originated from our own body, it is made up of our own cells. This means there can be circumstances in which you leave your cells, with your distinct genetic material, present even after you have passed away. Another example is mitochondria, which usually has solely a maternal pattern of inheritance. Mitochondria is an intracellular organelle where cellular respiration occurs. This means that if a woman decides to have kids, her mitochondrial DNA will solely be passed onto the children (however, there are recent studies that suggest paternal mitochondrial DNA may be inherited in rare circumstances) (McWilliams & Suomalainen, 2019). This allows for a sort of genetic footprint on upcoming generations (Gamete, 2023). Referring to the color gradient in figure 3, I would argue that we exist, for the majority, in a single color such as yellow. Now we can see that before yellow, there may be remnants that exist of us in the red (such as the gametes that will form us). We can also observe the partial retention of yellow into the green, implying there are components of us that succeed our death (such as organs or genetic material).

Due to the obscurity of life as a continuum, fetal development has been divided into three general stages. The first stage is referred to as the germinal stage and consists of zygote formation through egg and sperm interactions (two week period post conception) (Stages of pregnancy, 2023). This is followed by the embryonic stage, which includes the initial

development of organs (Stages of pregnancy, 2023). The first major organ in an embryo is the heart, as a primitive heart tube has developed around weeks four to six (Figure 5; Mathew & Bordoni, 2023; Donovan & Cascella, 2022). Furthermore, clinicians can use an ultrasound to measure fetal heart rate in order to confirm a pregnancy accurately as early as 37 days after the last menstrual period (Ultrasound in Pregnancy, n.d; Britten et al., 1994.). This leads to some individuals corresponding the initial development of the heart and measurement of the heartbeat as the initial marker of life.

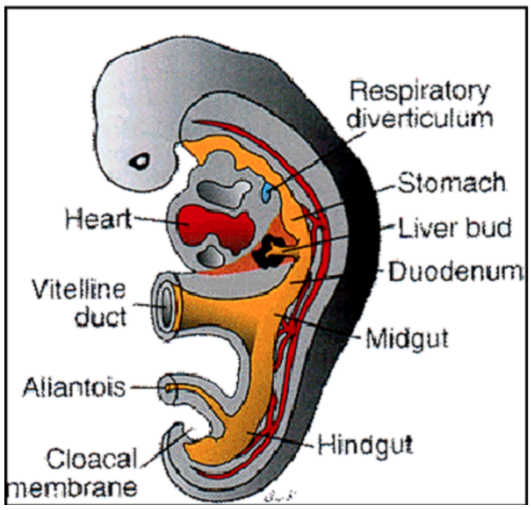

Figure 5: Diagram of Developing Embryo. The development of the heart occurs between weeks 4-6 of gestation, lungs at 5-7 weeks, and central nervous system between weeks 5-8.

The heart is succeeded by the lungs at weeks five through seven (Donovan & Cascella, 2022). The lungs can be prematurely identified by the presence of lung outpouchings, although they will not be fully functional until week 35-56 (Donovan & Cascella, 2022; Agorastos et al., 1983). However, premature babies can survive as early as 28 weeks (with medical intervention) despite underdeveloped cardio and pulmonary structures (Survival of the Tiniest, 2022; Figure 6). Simultaneously with the lungs, the central nervous system (including the brain and spinal cord) develops at weeks five through eight (Donovan & Cascella, 2022). Brain cells undergo

rapid division in weeks 15-17 of gestation (Ackerman, 1992). The brain waves can, consequently, be detected around 28 weeks (Ackerman, 1992).

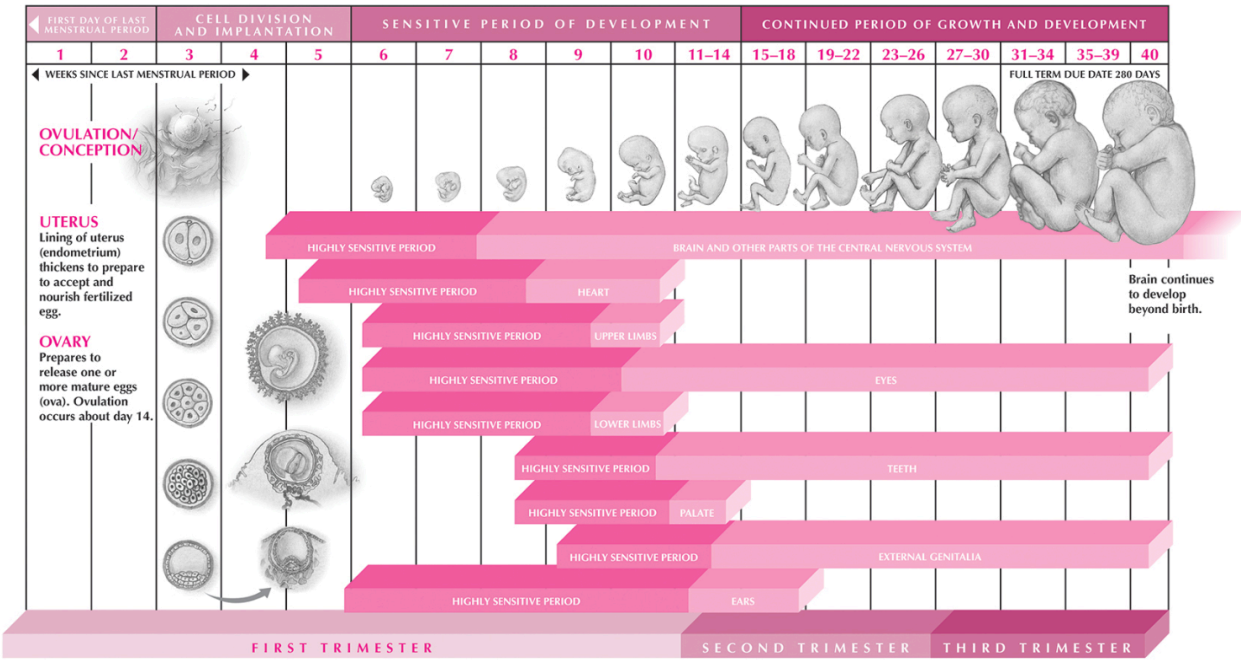

Figure 6: The Simultaneous Development of Organs. Fetal organs coincide in their developmental timelines.

The final gestational stage is referred to as the fetal stage and comprises weeks nine to birth (Stages of pregnancy, 2023). It marks a shift in the recognition of the cells from an embryo to a fetus (Stages of pregnancy, 2023). The growth of these organs is fundamentally important in the development of an embryo. This process is known as organogenesis, which refers to the germ layers' (ectoderm, mesoderm, and endoderm) formation into organs (Donovan & Cascella, 2022' Figure 7). However, the way these organs interact simultaneously and cohesively is what truly allows for the embryo to be successful (Figure 6).

With this in mind, isolating a specific organ to correlate to the beginning of human life would be challenging. This is where we see some of the limitations of biology in providing a clear definition of human life. In understanding the body as a cohesive and holistic system, it is difficult to isolate certain structures and credit them entirely for our life (Figure 6). If we do

select one organ that is responsible for life and, therefore, claim its initial development as the beginning of a human life we are neglecting to acknowledge the (equally) important roles of the other organs and their interdependent function. It may be plausible if the development of these organs occurred in the same moments, but due to their variations in timelines such a definition is unattainable. More significantly, we are limiting the use of certain medical interventions by a subjective, yet binding, timeline. For example, most women will figure out they are pregnant around weeks 5 to 6 of gestation (Branum & Ahrens, 2017). Considering the heart can begin developing as early as 4 weeks gestation, many mothers will become aware of the fetus after the initiation of a heart beat (Mathew & Bordoni, 2023). With the legal implications of ending a human life, such an early definition would significantly impact the ability to obtain abortions.

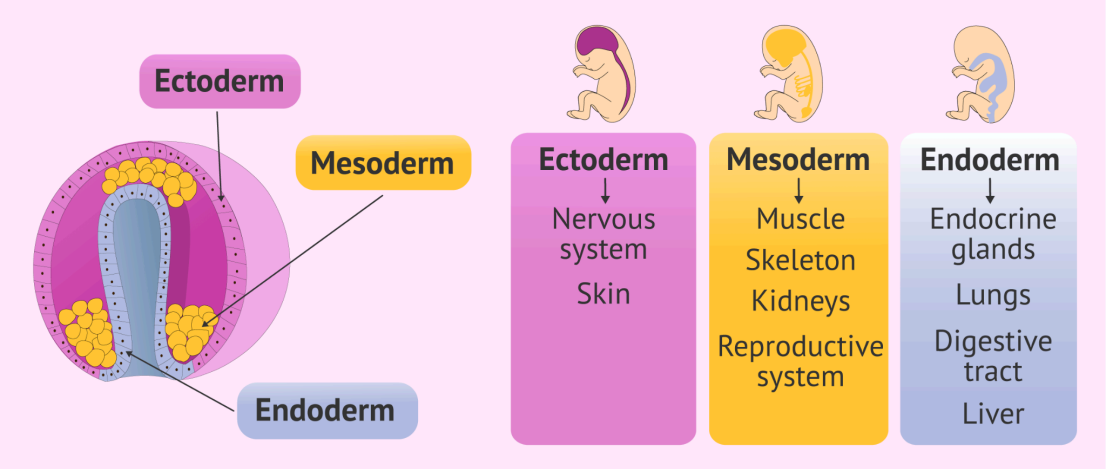

Figure 7: Embryonic Germ Layers (Gómez et al., 2022) the simultaneous development of different organs and other anatomical structures.

CHAPTER IV: ALIENS ARE REAL: APPLICATION OF GALACTIC LIFE CRITERIA TO EARTH

Is life constricted to Earth or is it a concept present beyond our own planet? The National Aeronautics and Space Administration (NASA) program explores the presence of extraterrestrial life forms on various planets. In order to quantify the presence of aliens, NASA must first define the characteristics associated with living beings. Their most rudimentary definition consists of a self-sustaining system that has the ability to undergo evolutionary processes (Brennan, 2023). Evolutionary processes are based on DNA mutations that diversify a community which then perpetuates the environmentally driven selection of the most fit traits (Hershberg, 2015). This means search for life starts off by first determining the composition of the atmosphere surrounding foreign planets (Brennan, 2023). NASA looks for the same chemical components which made life on earth plausible, which are hydrogen, oxygen, nitrogen, carbon, phosphorus (Figure 8).

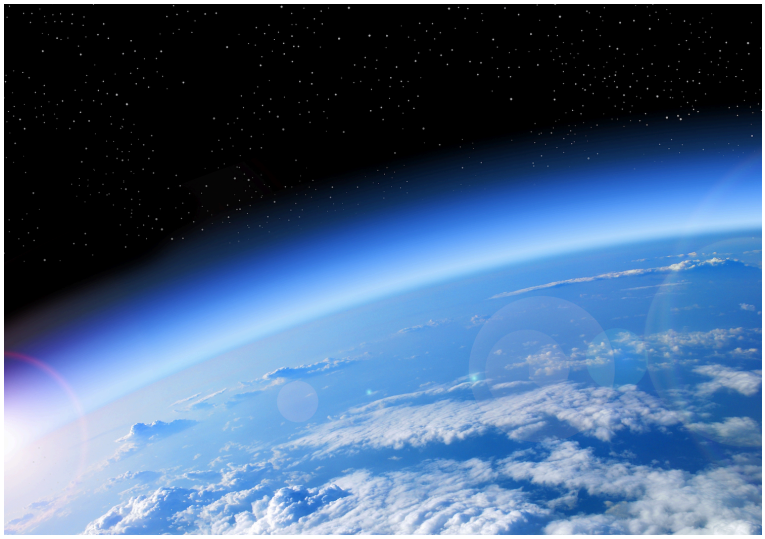

Figure 8: Atmosphere Composition (Labous, 2019)

Once NASA has determined a planet with the composition of elements necessary to sustain life, they narrow their focus onto the surface of the planet. NASA searches for signs of

water (which is composed of hydrogen and oxygen). Water is important because it dissolves more solutes than any other solvent, which is why it is considered a universal solvent (Voytek, 2023). This is an important component of life, as water facilitates both decomposition and synthesis reactions (which are fundamental biochemical processes in living organisms). NASA has hypothesized that Mars and several other moons within our solar system have possessed water at some point in time, which means they may possess the ability to host foreign life forms (Voytek, 2023) .

However, water is difficult to visualize with telescopic technology. Water can dry up and previous erosion can become covered by mobile sediments. This leads NASA researchers to collect rock samples through exploration rovers, and analyze their composition (Brennan, 2023). These rock samples are not just useful in identifying the presence of water, but they also can recognize the presence of nucleic acids (Brennan, 2023). This includes both DNA and RNA (ribonucleic acids), which are fundamental components to the composition of the central dogma of Biology. This is because they allow our cells to replicate and sustain a larger organism. Any genetic information that has been preserved would be a tell-tale sign of life, however, NASA is yet to make a discovery of that magnitude (Brennan, 2023).

NASA's perspective on life closely corresponds to the previous biochemical perspective in terms of fundamental elements and biochemical reactions. This is to be expected, as this research is considered astrobiological studies. NASA itself has released statements describing their focus on extraterrestrial life in terms as we know it (Brennan, 2023). They, as earthlings themselves, use the basic life structure found on Earth to model what life on other planets could be like. However, we are unable to hypothesize life as we do not know it (Brennan, 2023; Kaufman, 2022). For example, concepts of life that do not align with the life forms we are

familiar with on Earth. These may include strange arrangements of molecules, gelatinous cubes, incandescent spheres, or even sentient sound waves (Scoles, 2023). NASA's research is conducted by humans who are biased in observing life from a "humanistic" perspective. To elaborate, our perception of life is limited by our own man-made knowledge. Although this limits our scope of discovery on other planets, it does provide a sense of hope into broadening our definition of life once these alternative beings are discovered (Kaufman, 2022). Despite this discovery, NASA still proposes unique alternatives as to how we conceptualize life.

The initial criteria for life in terms of the presence of fundamental elements and water do not allow us to better understand human life on Earth, as Earth possesses both of these components. However, it is interesting to define life merely from the possession of genetic material. This definition is subject to fallacy, considering many things may possess these genes but not be inherently living themselves. For example, the skin cells we produce at the stratum basale layer migrate towards the surface of our skin. As these cells near the surface, they become more cornified, which causes their cytosolic organelles to be destroyed (Kroemer et al., 2009; Figure 9). These superficial skin cells may still possess DNA and RNA, but are not considered to be living due to their lack of functional organelles (which leaves them unable to facilitate biochemical processes) (Kroemer et al., 2009).

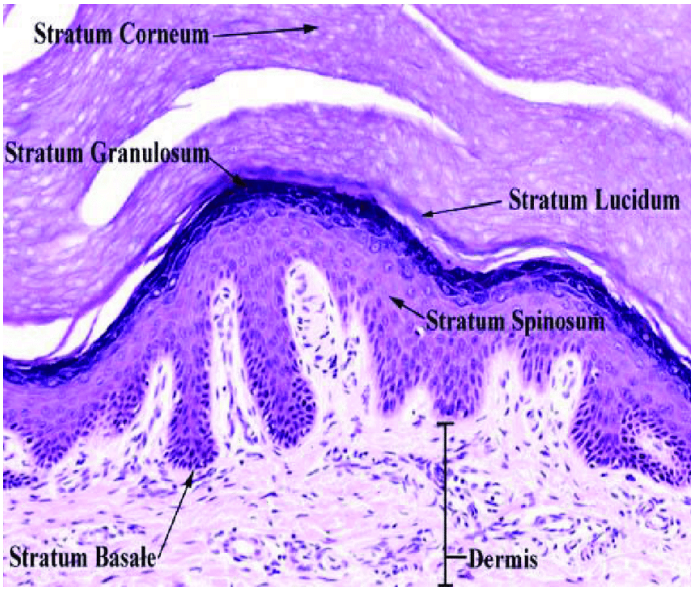

Figure 9: Layers of the Epidermis (ResearchGate, 2020). The difference between skin cells that are living and skin cells that are not.

Additionally, viruses are microorganisms that contain nucleic acids (either DNA or RNA) (Koonin & Starokadomskyy, 2016; Figure 10). Despite this discovery, viruses themselves are not considered living. This is because they are unable to conduct metabolic processes independently (Sumbria et al., 2021). Viruses are also unable to reproduce on their own, however, it would be incorrect to assume that viruses are unable to replicate at all (Koonin & Starokadomskyy, 2016). Instead, they rely on the cellular machinery of a "living" host cell to replicate themselves via the lytic or lysogenic cycle (Koonin & Starokadomskyy, 2016). This lack of autonomy causes viruses to be considered abiotic microbes (Koonin & Starokadomskyy, 2016).

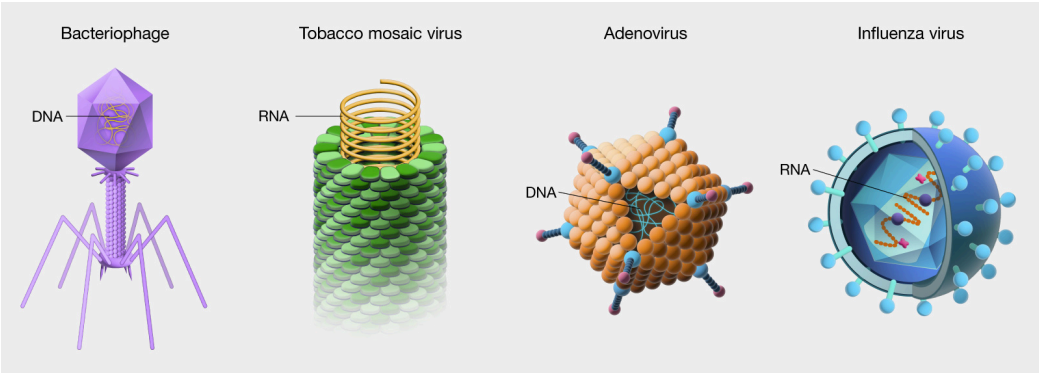

Figure 10: Viral Microbes (Segre, 2024). Viruses contain the same nucleic acids NASA searches for in the alien endeavors. Despite the presence of DNA/RNA, viruses themselves are not considered to be living.

NASA's definitions are useful in determining if life was present, or is currently present, at one point in time. However, they fall short in helping us determine the current state of living as human beings. Until the extraterrestrial aliens from the cosmos expand our perception on the concept of life, it seems as if we should explore alternative perspectives. Furthermore, integration of NASA's definitions may diminish our quality of life. If we equate the mere presence of nucleic acids to a biomarker of life, and the concept of life insinuates some ethical responsibility, we will run into some morally ambiguous situations. For example, scratching an itch on your arm could become outlawed. This is logical considering a scratch involves the (somewhat violent) removal of skin cells (which contain nucleic acids regardless if they are cornified or not). Even within the same type of cell, our definition of life can be the difference between bodily regulation and bodily autonomy.

CHAPTER V: DECIPHERING DEATH IN ORDER TO UNDERSTAND LIFE

To gain some more clarity regarding notions surrounding life, it may be intuitive to shift perspectives. More specifically, it may be beneficial to explore how we define death. We often see the connection between life and death in the most traumatic experiences. Our understanding between life and death often stems from the media's interpretation and dramatic reenactments. The most prominent example in my mind occurs when a character is drowning, and everyone nervously surrounds them. Finally, the individual is resurrected and they take a large gasping breath. In this situation, it is breath that separates their drowned lifeless state from their conscious alive one. We can also refer back to TV shows and movies where an individual flat lines and their heart activity ceases. Once they are checked with an automated external defibrillator (AED), the heart starts up again and the sinus rhythm is depicted on the electrocardiogram (EKG). In this context, the presence or absence of a heart beat is the difference between life and death. Despite pop culture's unreliability, it does influence our understanding of death and how it is defined. It turns out that maybe our favorite television shows and movies actually had it right.

To further solidify these preconceived notions, I propose a situation. If you stumbled across an individual who appears to be unconscious with no visible external injuries, you would most likely check for signs of life through two ways. You may watch the rise and fall of their chest or place your hand gently over their face to determine any signs of respiration. You also could place your fingers over a major artery to confirm the presence of a pulse. It is evident from both the entertainment industry and our rudimentary first aid training that function of the heart and lungs are often associated with the living state of the body.

This is true in medicine as well. Often times physicians will determine the time of death

based on the activity of the heart. This is logical considering the heart pumps blood around the body, providing oxygen to tissues and removing carbon dioxide waste (Heart, 2021). Without oxygen, the tissue cells are unable to undergo aerobic cellular respiration (Foucher & Tubben, 2023). This will prompt the anaerobic pathway of cellular respiration, which means the cell will undergo fermentation to oxidize vitamin B3 and turn NADH back into NAD+ (Foucher & Tubben, 2023; Figure 11). This will result in a buildup of lactic acid (Figure 11) and although the liver can metabolize lactic acid back to glucose (via gluconeogenesis), its presence in this quantity will not be effectively or efficiently broken down (Foucher & Tubben, 2023). This will further exacerbate the acidity of the environment (Foucher & Tubben, 2023). The metabolism of lactic acid into carbon dioxide and inability to remove existing carbon dioxide via blood circulation will cause the pH to drop even further leading to acidosis. This means the body will not only be unable to create the energy (via ATP) to function, but also establish an unsuitable pH for surrounding proteins to function (inevitably leading to cellular death). Acid also tends to facilitate the denaturing of proteins, which expedites the process of decomposition and allows microbes to more readily consume the organic matter (Fink et al., 1994). Considering that the heart is a muscle in itself that requires oxygen, this anaerobic environment will prevent the heart from beating and (eventually) deprive all cells of oxygen.

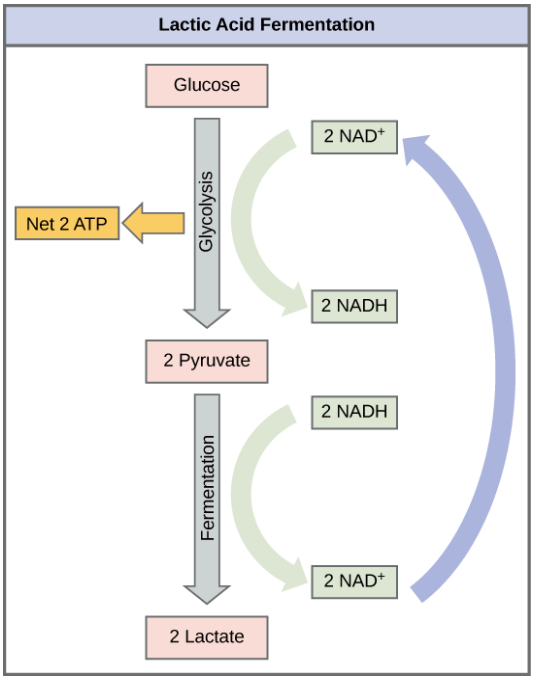

Figure 11: Lactic Acid Fermentation. Glucose, via glycolysis, is broken down into two pyruvate molecules which are transported into mitochondria for oxidative phosphorylation (which requires oxygen). In the absence of oxygen, the pyruvate molecules are fermented into two lactates (oxidizing NADH back into NAD+ inorder to continue glycolysis) (Types of Fermentation, n.d.)

Furthermore, this hypoxic state can also occur from a lack of respiration (Haddad & Sharma, 2023). If the lungs no longer contract and relax to bring oxygen into the body and carbon dioxide out, the body can go into a state of acidosis (Patel & Sharma, 2023). Although we possess mechanisms to respond to bring us back to a state of homeostasis, compensation efforts will be ineffective if the initial organ responsible is not cooperative (Sircar et al., 2007). This is most likely why we correlate lack of lung function with death, as inhalation of oxygen and exhalation of carbon dioxide is a fundamental system (Sircar et al., 2007; Haddad & Sharma, 2023). If our tissues do not receive the quantity of oxygen they need, whether that be due to a lack of cardiac or pulmonary function, the body will cease to survive (Sircar et al., 2007).

Brain waves also have the potential to discriminate between life and death. More specifically, brain activity can be measured by electrical impulses through an electroencephalogram (EEG) (Koudelková & Strmiska, 2018). Similar to the pumping of our

blood and breathing, brain waves are continuous for the duration of our life. However, the type of brain wave differs throughout the day. Beta waves appear during fully conscious states or REM sleep (Marzbani et al., 2016; Nayak & Anilkumar, 2023). Alpha waves signify a relaxed, yet aware state (Marzbani et al., 2016). Delta waves oscillate during periods of deep sleep (Marzbani et al., 2016; Nayak & Anilkumar, 2023). Cessation of these brain waves signifies a cessation of brain activity, which is the state where a patient is declared brain dead (Maiese, 2022). However, an individual may be brain dead but physiologically still alive as long as they are supplied oxygen and their heart is beating (via technological advancements in medicine) (Golia & Pawar, 2009). This is conducted through mechanical methods that may ventilate air for you (ventilation), filter blood (dialysis), and cardiopulmonary resuscitation (CPR) (Understanding Life Support, 2022). However, negating intrusive medical intervention, brain death would render the body incompatible with life. This is attributed to the brain stem's role in regulation of vital functions such as breathing and heart rate (Bassinger & Hogg, 2023). The spinothalamic tract is responsible for maintaining a body temperature suitable for essential biochemical processes to occur (Bassinger & Hogg, 2023). The brain controls these actions through electrical signals that are converted into chemical signals that regulate these functions. A lack of communication on a neurologic level would inhibit the function of organs and overall environment of the body, which would lead to death.

Death can be marked from a lack of organ function, but, it can also be determined by the onset of new processes. For example, development of rigor mortis is associated with death (Shrestha et al., 2023). Rigor mortis refers to a state of rigidness in which the muscles are stuck in a flexed position and, as a result, the body feels stiff (Shrestha et al., 2023). This often occurs after death due to the lack of ATP production, which prevents the myosin head from detaching

from the actin filament (Shrestha et al., 2023; Figure 12). These two proteins persist in the attached state, preventing the muscle fiber from relaxing (Shrestha et al., 2023). Furthermore, as the individual progresses in the death processes, their body temperature will drop (Shrestha et al., 2023). This is known as algor mortis, which translates to cold death (Shrestha et al., 2023; Eden & Thomas, 2022). Algor mortis is caused by the inability of the hypothalamus to conduct homeostatic regulation (Shrestha et al., 2023). The body will exchange heat until it reaches equilibrium at the ambient temperature of the environment. Considering the body is no longer generating heat through metabolism, heat can be lost or gained by the surroundings (Shrestha et al., 2023).

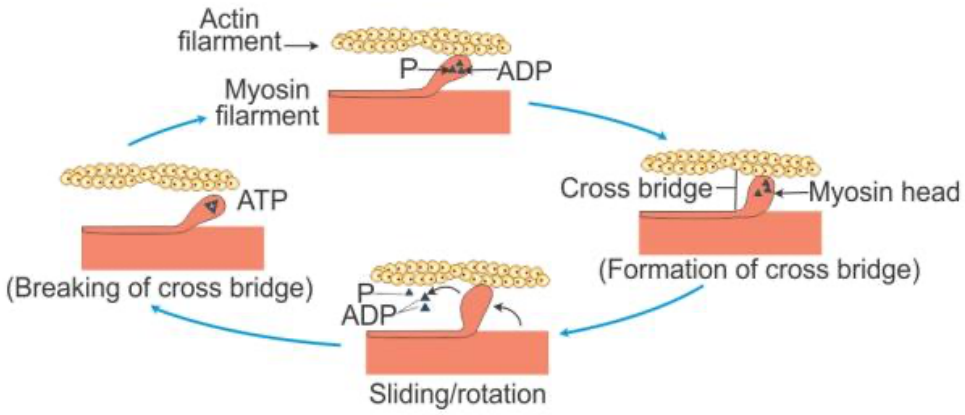

Figure 12: Muscle Contraction: Muscles that no longer have access to ATP will be bound in the contracted state.

Although death is indubitably an interesting topic in itself, there is a lot that we can apply back to the beginning of life processes. Cessation of heart function is a well established landmark of death. This poses the question as to if we can reciprocally mark the beginning of heart function as the beginning of life. Heart function is observed around week four of gestation (Valenti et al., 2011). This would imply by the fourth week of development, the embryo can be considered living.

Conversely, the lungs develop in week five but do not conduct their function until the first breath after birth (Rehman & Bacha, 2023). Previously, oxygenated blood was delivered via

the umbilical cord and shunted around the lungs through the foramen ovale and ductus arteriosus (Rehman & Bacha, 2023; Remien & Majmundar, 2023). This means that the mother is facilitating gas exchange for the developing fetus. As the uterus contracts, fluid is forcibly expelled from the premature lungs of the neonate (LoMauro & Aliverti, 2016). Once the neonate moves to an air environment, as opposed to their previous fluid one, their intrathoracic pressure causes them to inhale (Giblett et al., 2019). This first breath closes the foramen ovale and ductus arteriosus, as their lungs are now required to provide oxygen to the rest of the body autonomously (Coceani & Baragatti, 2012). This means that lung function is not observed until directly after birth. If we correspond respiratory failure with death, then could we associate the first breath with life?

The initial semblance to a brain in a fetus begins three weeks post conception (Ackerman, 1992). It starts with a neuroectoderm, a germ layer, which folds to establish a neural tube (Ackerman, 1992; Rehman & Muzio, 2023). This neural tube will go on to form the central nervous system, which includes the brain and the spinal cord (Rehman & Muzio, 2023). The brain will continue to develop for another twenty-five years, ending with the complete maturation of the prefrontal cortex (Arain et al., 2013). However, brain waves can be detected at fifteen weeks gestation (Ackerman, 2019). If we declare an individual dead due to a lack of brain waves, then could we pronounce someone as living with the presence of these currents?

Therefore, the complexity of the organ system as a whole makes it a difficult landmark for defining life. We may be able to manipulate the concept of rigor mortis and apply the opposite to living beings for a more definite timeline. In this situation, the opposite of prolonged muscle contraction would be relaxation. We could rename this concept as *mollis vivus*, which translates to soft living. Muscle development is initiated through the differentiation of cells into

mesoderm, which occurs around week two and three of fetal development (Rehman & Muzio, 2023). The functional unit of muscle, known as the sarcomere, is what allows for muscle relaxation and contraction via actin myosin interactions (Yan et al., 2022; Ahmed et al., 2022). Muscle contractions can be measured using an electromyography (EMG) or force-sensitive resistor (FSR) (Esposito et al., 2018). This equipment is limited in its application to a fetus, however, as there is not a method to accurately place it without picking up on the mother's own muscle movement. It seems as if *mollis vivus* is a difficult landmark to identify. Algor mortis, alternatively, refers to the change in temperature of a corpse. However, from the moment of conception an embryo is present within the uterus. The uterus is located in the lower abdomen behind the urinary bladder and in front of the rectum (Ameer et al., 2022). It maintains a relatively constant temperature at 36.8°F ± 0.5 (Sciscione et al., 2001). From the moment of conception, the embryo is incubated within the uterus. This means the embryo does not experience any drastic temperature changes, which eliminates the application of algor mortis to beginning of life processes. Rigor mortis and algor mortis not only fall short in their translation to fetal medicine, but also are merely a by-product rather than a direct cause of death. With that in mind, they neglect to determine the moment in which life begins within a human.

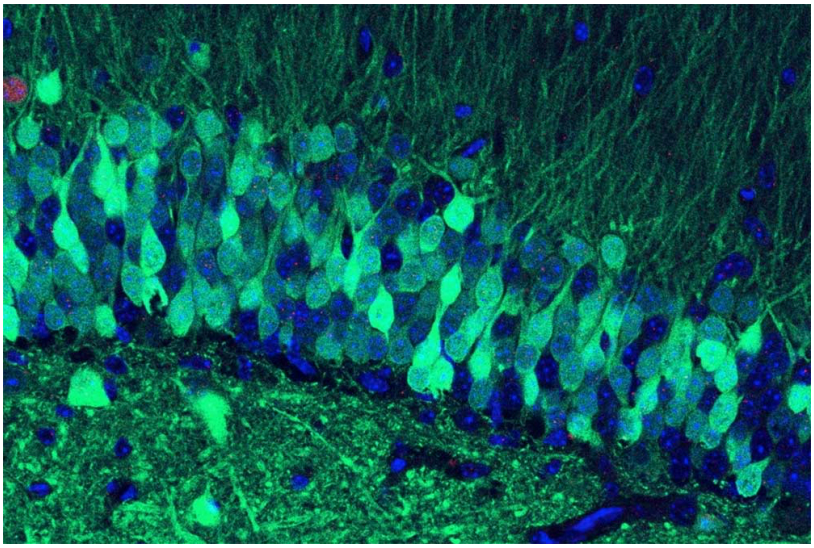

Figure 13: What a Memory Looks Like. Tangible composition of a memory under a microscope (Collins, 2019).

Additionally, it seems as if the biological transition from life to death is less distinct than I had anticipated. There are also social considerations that need to be accounted for by those living individuals experiencing the death of others. In the same way that organic matter gradually forms into you, you also gradually transition back into that organic matter and that transition can be difficult to decipher. This emotional grief can become physically manifested into the tangible presence of memories (Shear, 2012; Figure 13). It is no new concept that many of the deceased are memorialized in the minds of their loved ones. Memories may seem like imaginative, illusive images made up in our minds, and to an extent they are. However, memories are also physiological processes that can be observed in our brains. These recollections are a series of dynamic chemical reactions between neurons (Zlotnik & Vansintjan, 2019; Figure 13). Furthermore, in reference to the multiple-trace theory, memories possess their own distinct and unique chemical compositions within the hippocampus (Zlotnik & Vansintjan, 2019). This means that despite the seeming absence of an individual, there is some tangible existence of them that may still linger behind. That is, of course, under the assumption that there is someone succeeding their death with enough of an emotional connection to become encoded into their own neuronal

long-term memory stores. Hazel Gaynor, historical fiction author, describes how “[to] live in the hearts of those we love is to never die” (Gaynor, 2014). Although her interpretation of memories is more metaphorical, it still provides insight into the ways our own life can be expanded past our existence. These connections, undeniably, become diluted as time progresses and new generations arise. Nevertheless, it further emphasizes the ways in which death can also be considered a spectrum.

Overall, reversibly applying end of life biological indicators to beginning of life processes is insightful, but not all encompassing due to the ambiguity of when a human life actually ceases. A mere observation of death is insufficient to irrefutably define the beginning of life as there is no clear “end.” This is problematic considering it will lead us into medical obscurity as an individual’s life becomes blended into the overlapping existence of other life forms (Figure 3). How can we announce someone’s birth or declare an individual's death if we cannot decide where to draw those boundaries?

CHAPTER VI: BIOLOGY: THE STUDY OF LIFE-ISH

Biology is defined as the study of life, and yet, biology itself has neglected to provide clarity as to how life is defined (Cambridge University Press, n.d.). It is incredibly interesting that biologists are able to distinguish between life processes (biotic organisms), and a lack thereof (abiotic processes), without fully comprehending what life is. From primordial soup studies to aliens and exploration of death, biology has failed to provide the evidence necessary to make informed decisions regarding human life on earth. Each of these perspectives contains some degree of merit, but falls short in providing an all encompassing and definitive definition of life. This shortcoming of science is further explored in the works of metafictional novels, such as *For The Time Being*. Annie Dillard describes how "if science devotes scant attention to human culture, and if science has scrutinized human consciousness… then science, which is, God knows, correct, nevertheless cannot address what interests us most" (Dillard, 1999, p.113). Even in the fields of anthropology and sociology, we isolate the magnitude of discovery by limiting data intake to our social identities. One appeal of science is rooted in the extensive training required for scientists and discoveries rooted in tangible, beyond reasonable doubt evidence. However, as Dillard illustrates, it seems as if I was looking for an answer that science simply cannot provide. Science, in all its objectivity and rigor, fails to cohesively answer our questions surrounding human life. Dillard attests that "science has bigger fish to fry," but I would not necessarily agree with this implied hierarchy for scientists (Dillard, 1999). Finding a definitive definition to life is a fairly large fish on its own. It is not the size of the fish that is the issue, it is the limited capacity of our frying pan.

This revelation is not meant to discredit biology, as it is a fundamental pillar of scientific discovery and catalyst for the quality of human existence. Biology provides insight as to how the

mechanisms of our body function and how we, as humans, are capable of surviving. It is what has "enabled our species" to "fly jets, write poems, encode data on silicon, and photograph Jupiter" (Dillard, 1999). It is evident that biology itself is an important pioneer in novel discoveries. However, I argue that biology's lack of answer regarding when to define a human life is due to the fact that humans are not merely biological creatures. To define life merely from a biological lens would disregard our complexity as biosocial beings (considering we exist in ways beyond our rudimentary genetic code). Our biosocial identities are complex because they refer to the ways our genes not only affect our social identities, but how our social identities reciprocally affect our genes. A purely biological perspective neglects to acknowledge the ways in which our environment can alter our genetic expression, which will diminish quality of life and decrease our life spans. It is important that we acknowledge all causes of adverse health outcomes in order to better understand how they can be treated. In an attempt to construct logical human life definitions, we must acknowledge the compatibility between the social and hard sciences (Glass & McAtee, 2006). As scientific disciplines themselves, we can rely on their acquisition of evidence to hopefully bring us closer to a more indisputable and holistic truth.

Religions are one of the most influential social structures within our communities. These institutions have proposed not only the origin of life, but the beginning of an individual's life. Additionally, religions are important agents of socialization that teach us how to be a part of a society. One of the most well-known and widely accepted stances on the origin of life comes from Christianity. In the Congregation for the Doctrine of the Faith, the Vatican states that a human's life begins at conception (Flannery & Weline, 2016; Khorfan & Padela, 2010; Vatican, 1987). This means that an individual's life starts from the moment the egg and sperm fuse to create a zygote (Figure 14). However, during the emergence of Christianity, there was a lack of

knowledge regarding sperm, eggs, and zygotes. This explains why this belief was not explicitly stated in the bible. The definition of life was most likely a development out of the religious movement itself, rather than a fundamental pillar in the creation of Christianity (Dudley, 2012).

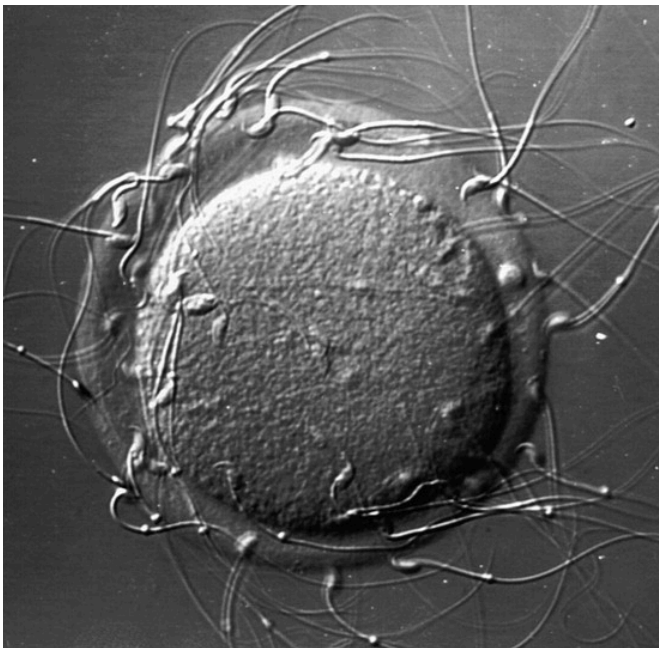

Figure 14: Mammalian Fertilization. Sperm penetrates the zona pellucida of the egg capturing the moment of conception (Wassarman, 1999).

Unlike Christianity, Judaism does have an explicit excerpt from the Torah describing initiation of life. Jewish followers believe life begins from the moment an individual takes their first breath (Poliwoda, 1993). The Torah explicitly states that God formed men by breathing the breath of life into them (Schenker, 2008). This means that life must be synonymous with breath in Jewish tradition. Considering the first breath does not occur until after the baby is born, it is logical that followers of the Jewish faith would claim life begins after birth.

Islam, similar to the other religions, places a high sanctity on life (Nasir & Yusuf, 2020). Muslims believe life begins 120 days after conception (Khorfan & Padela, 2010). The Qur'an states that after fertilization sperm is transformed into congealed blood that forms a clot (al-Kawthari, 2011). This clot develops into bone and flesh (al-Kawthari, 2011). After 120 days

of development, an angel comes down and breathes the soul into the embryo, which transforms it into a human life (al-Kawthari, 2011). This religion differs from the others in the sense that their proposal is not based on a physiological landmark. Islam, conversely, believes life begins when the individual's soul comes down from heaven and enters their earthly body (Sobotková, 2020; Khorfan & Padela, 2010).

Although some religions, like Islam, refer to personhood when defining life, the two processes can actually be separated. Personhood refers to the development of your soul and is influenced by the presence of biochemical mechanisms. However, life in terms of biological mechanisms does not require the contribution of personhood (Playford & Playford, 2018). Christianity, Judaism, and Islam all embed themes of a larger power beyond our human bodies. This type of study focuses on a metaphysical plane that cannot be directly observed, as it surpasses our own consciousness. This asynchronistic relationship between personhood and the living body is essential in better isolating life as an evolving concept (Playford & Playford, 2018). More specifically, personhood embodies the aspects of life we do not consider when defining biochemical processes. This includes a fluid progression of our psyche, physical, and social development (Playford & Playford, 2018). Personhood provides insight into complex emotions such as pain, pleasure, self-consciousness, and morality (Playford & Playford, 2018). These are key concepts in understanding what makes humans human, however, they are not key concepts in deciphering objective life processes. This is because as humans, we can lack personhood and still be considered alive (Playford & Playford, 2018). Due to this distinction between personhood and life, it is important to separate us as living entities from the souls that reside in each of us. Personhood is an interesting concept and one of the reasons life definitions get complicated, considering we can be understood more largely on a metaphysical scale.

Relying solely on religious definitions diminishes the quality of life because personhood itself is immeasurable. Furthermore, the concern and controversy surrounding human life timelines stem from the physical state. Implementation of solely a religious definition would neglect to provide answers regarding the physical state of the human body, which would not provide clarity regarding the beginning of our physical lives. This spiritual reflection, although insightful, does not improve the quality nor duration of our lives as we would still be treading on morally ambiguous and highly disputed ground. This would prevent us from making ethically informed and consistent decisions regarding human medical care involving matters of “physical” life.

CHAPTER VII: CLINICAL CONSEQUENCES

The concepts of human life and corresponding ethical responsibilities are heavily embedded in our application of medicine. A lack of a clear definition has had severe consequences on both healthcare accessibility and health outcomes in our modern day society. Abortion is one of the most heavily refuted procedures, and its polarization can be traced back to a lack of consensus regarding a human life. An abortion refers to the termination of a pregnancy and includes both voluntary and involuntary expulsion of a fetus (Costa, 1983). Distinguishing between an elective or spontaneous abortion is incredibly difficult. This makes legislation punishing one type of abortion prone to misaccusation. Purposes of abortions range from development of genetic anomalies to an exercise of bodily autonomy. Some congenitally deadly defects include anencephaly (lack of brain/skull structures), renal agenesis (absence of kidneys), and trisomy 18 (three copies of chromosome 18) (Wilkinson, 2014). There are also situations in which the mother's health is compromised and, as a result, the pregnancy is terminated. These include infection, placental abruption (separation of uterus and placenta), hemorrhagic shock (severe bleeding), and preeclampsia (high blood pressure) (Reuters, 2021). Furthermore, pregnancy may exacerbate pre-existing health problems, which ends up posing a risk to both mom and baby (Reuters, 2021). Additionally, there may be circumstances in which the mother is unable or does not want to provide adequate care for the child. This includes an ill-timed pregnancy, undesired partner, existing children, inhibition to future opportunities, and financial limitations (Biggs et al., 2013).

Interestingly, there are other effective means to interfere with a pregnancy that are less frequently met with opposition. This includes the medication Levonorgestrel, more colloquially known as Plan B or the morning-after pill (Kahlenborn et al., 2015). Levonorgestrel is an oral

contraceptive that is usually consumed after unprotected sex or contraceptive failure (Kahlenborn et al., 2015). Its mechanism of action prevents or delays ovulation by mimicking the natural hormone progesterone (Kahlenborn et al., 2015). Elevated progesterone levels are often seen in pregnant women and inhibit both ovulation and contractions (to establish a more suitable environment for the existing fetus) (Kumar & Magon, 2012). In this context, consumption of Levonorgestrel will make it seem as though the body is experiencing elevated progesterone levels and, as a result, interfere with ovulation. Levonorgestrel has even been observed to function as an abortifacient (abortion inducing agent) in certain rare cases (Kahlenborn et al., 2015). However, there are no timeline restrictions or regulations on these oral contraceptives (although the efficacy will be impacted depending on the phase of the menstrual cycle) (Kahlenborn et al., 2015). This varies from traditional abortions, which are trimester regulated (with more legal accessibility during the first trimester and increased restrictions as the pregnancy progresses) (Beller & deProsse, 1992). Contradictory regulations based on different human life definitions will inhibit both the health of the involved parties, and their quality of lives.

If undesired pregnancies are carried to term, the child is at an increased risk of obtaining adverse childhood experiences (ACE) (Guterman, 2015). ACEs are traumatic events fostered from abuse (emotional, sexual, and/or physical), neglect, and dysfunctional households (O'Neill et al., 2021). ACEs not only diminish the quality of life for those affected, but also place these individuals at greater risk for developing a chronic disease and mental health illness in the future (O'Neill et al., 2021). Reciprocally, higher incidences of ACEs are correlated with increases in unwanted pregnancy, further perpetuating this cycle (Kanamori et al., 2023). There are a variety of reasons in which a pregnant individual may want to obtain an abortion ranging from medical

necessity to purely bodily autonomy. Intentions aside, these varying legal restrictions on abortions are the result of varying definitions of a human life, which heavily shape health outcomes. A solid consensus on human lives will allow us to promote healthier individuals, increase quality of life, and respect bodily autonomy.

Another medical intervention that has become a topic of debate (due to different human definitions) is the use of embryonic stem cells. Human embryonic stem cells are the future of regenerative medicine. This is due to their pluripotent status, meaning they have the potential to differentiate into many kinds of cells including blood, bone, nerve, and muscle cells (Yabut & Bernstein, 2011; Stem Cells, 2023). Embryos contain a large quantity of stem cells during the blastula stage of development. This makes them an optimal candidate for stem cell research efforts. However, the ethics of embryo use are clouded by our variations in human life definitions. Additionally, the embryo can not be recovered after the extraction of stem cells as it becomes incompatible with life entirely.

Stem cells are an important concept considering they have the potential to reduce a patient's burden of illness and improve their quality of life. Stem cells can transform into stromal cells that prevent skin graft failure and provide immunomodulatory services during in vivo transplants (Deans & Moseley, 2000). Grafts are important in re-establishing the physical barrier of the skin and improving quality of life via cosmetic reconstruction (Elseth & Lopez, 2022). Furthermore, immunomodulation refers to stem cells' ability to better regulate the immune system (Kılıç, 2022). These cells can also transform into pancreatic cells to better regulate the blood sugar of type one diabetics (Tuch, 2006). Additionally, stem cells can combat retroviruses by inhibiting viral replication (Wolf & Goff, 2009). This is incredibly important considering retroviruses insert DNA strands into their hosts and can permanently alter their genome (Cloyd,

1996). It is evident that the potential for stem cell use in a clinical setting can significantly improve the way patients are treated.

Additionally, embryonic cell lines are an important component of vaccines. Vaccines prevent viral infections that could lead to morbidity and mortality. These embryos provide the cellular machinery required for viral vaccine development (Offit & Moser, 2011; Wadell, 1983). Vaccine hesitancy stems from the belief that human embryos are continually harvested for the sole purpose of vaccine development, but that is simply not true. The majority of vaccines that utilize live-attenuated viruses have been derived from the same two cell lines since the 1960s. The more popular stem cell line is called WI-38 which was harvested from a single elective abortion in Sweden in 1962 (Olshansky & Hayflick, 2017). The other stem cell line is called MRC-5 and was derived from an aborted fetus in 1966 (Olshansky & Hayflick, 2017). Previously researchers used monkey kidney cell lines, but that resulted in the unintended transmission of novel viruses to human patients. Those two human derived cell lines are the main contributors to modern day vaccinations. It is hypothesized that these two abortions have prevented four billion cases of disease and ten million deaths globally (Olshansky & Hayflick, 2017). The rubella vaccine specifically, which is greatly opposed by pro-life advocates, has actually prevented over 633,000 miscarriages in the United States alone due to its ability to prevent congenital malformations (Olshansky & Hayflick, 2017). Although embryos were used at some point in history, they are not repeatedly harvested in vaccine development. Furthermore, the few embryos that were sacrificed have become a fundamental pillar of public health.

Embryos also play an important role in drug development. Their proximity to developed humans allow them to serve as accurate models of disease. They allow us to mimic the structure of tissues, organs, and the human body as a whole (Rosner et al., 2021). Researchers are able to

infect a cell with a multitude of diseases and observe the pathways they affect (Rosner et al., 2021). These interactions provide meaningful insight regarding the molecular mechanism of pathogens and if we understand the mechanism, we are more informed on how to effectively treat patients. Furthermore, researchers are able to observe the interactions with both the intended target and unintended side effects. It is incredibly important to ensure exogenous drugs do not cause additional harm within the body. Embryo use is responsible for the development of many popular medications, including: acetaminophen, ibuprofen, and aspirin (Runwal, 2021).

An alternative to producing human embryos for the purpose of scientific research and clinical use is to recycle old embryos that would otherwise be discarded. Embryos destined to be disposed of include those unused during in vitro fertilization (IVF) treatments. This occurs when parents choose not to pay for their embryos to stay frozen and opt out of donation (Lo & Parham, 2010). In the past, IVF embryos have been the main source of hESC (human embryonic stem cells) included in stem cell research (Mehta, 2014). Another type of human embryo utilized are deceased embryos. These embryos are considered non-viable, most likely due to incidences of aneuploidy (abnormal quantity of chromosomes) (Mehta, 2014; Rajagopalan & Lengauer, 2004). Similar to their living counterparts, these embryos still serve as a rich reserve of stem cells (Mehta, 2014). These embryos can potentially avoid the controversy of using live human cells, as the alternative would be to merely discard them. At least these embryos can gain a new purpose in improving the quality of an individual human life (De Miguel-Beriain, 2015).

The repurposing of discarded human cells has the potential to not only significantly improve the lives of others, but save them. In treatments ranging from stem cells to vaccines and drug development, embryos are a fundamental component of public health. Use of embryos actually corresponds with the pillars of medical ethics. The repurposing of unused IVF and dead

embryos grants them a new function instead of being discarded. These embryos are supported by the beneficence value, as they would gain a valuable purpose in improving the wellbeing of others (De Miguel-Beriain, 2015). They can also be justified on the basis of non-maleficence, as the embryos do not yet possess the potential to feel pain or be aware of their use (Mehta, 2014). Sacrifices of a single non-sentient life are justified if they serve a greater purpose in improving the lives of others. As a utilitarian would argue, the most ethical decision is the one that produces the greatest good for the greatest number of individuals (Scarre, 2020).

Furthermore, this seemingly archaic controversy is still impacting our daily lives today. More specifically, the Supreme Court of Alabama just ruled that frozen embryos are considered extrauterine children (Rabin, 2024). In equating a frozen embryo to a human child, they gain a higher degree of ethical standards and moral obligations. Although this may seem unharmful, frozen embryos are an important component of fertility treatments (Lo & Parham, 2010). With the average human lifespan increasing, individuals are waiting longer to have children and, therefore, encountering more fertility issues (Mills et al., 2011). In-vitro fertilization (IVF) helps patients achieve their aspirations of producing biological children. Inhibiting treatments, such as IVF, will indubitably hinder the quality of life for these individuals. Additionally, many Alabama families with frozen embryos are now scrambling to determine their next steps (Rabin, 2024). In equating frozen embryos to living children, processes such as embryo destruction, donation, or recycling have become morally ambiguous (Rabin, 2024). Does this mean that these embryos must be implanted and birthed? Is it ethical to freeze embryos indefinitely? The legislature is unclear regarding who is held responsible for what happens to these embryos, leading many physicians to shut down their fertility clinics and avoid reproductive procedures (Bendix & Harris, 2024).

A lack of consensus regarding the definition of a human life will severely limit our magnitude of medical discovery. If we cannot claim when a human life begins, how can we justify abortions, stem cell application, vaccines, and drug development? These scientific discoveries that possess the potential to not only lengthen, but improve our quality of life, are built on a fragile foundation. Depending on where we draw the line on a human life, some of these practices may be considered unethical. For example, if we believe life begins at conception use of embryos may be considered harmful and, therefore, reduce our resistance to pathogens and limit pharmaceutical discovery. There is a huge consideration and care placed on life before birth, but what about life after birth? It is important to remember that medical interventions such as abortion, stem cells, and vaccines help to both sustain and protect the lives of billions. If we want these ground-breaking treatments to be available for the well-being of the current population (and even upcoming generations) we need to justify their use now. This can only be attained by coming to a single solid definition of a human life. If we do not, we are merely spearheading life saving discoveries that may never be cleared for public use.

CHAPTER VIII: SOCIAL CONSTRUCTS: CELEBRATIONS, INCARCERATIONS, AND SACRIFICES

Through the preliminary chapters, we have reviewed a magnitude of diverse criteria that can be used to recognize a human life. Some perspectives may resonate more closely with your own beliefs, but they most likely all fall short of an all-encompassing definition. If I have led you to perceive life as some abstract notion that lacks any applicable significance, then you have been deceived. It is not some concept that should be disregarded due to its ambiguity. Life garners value. I will draw on three social constructs and celebrations to underscore this.

The date an individual is born, their birthday, is an incredibly significant event for many cultures (including the United States). It not only represents the passage of time, but provides the individual with a sense of growth (Bytheway, 2009). Birthday celebrations originated in Rome and served as an opportunity to commemorate the blessing of another year (Shoham, 2021; Rojaka & Lesinskiene, 2018). In industrialized societies, birthdays served to mark certain rights of passages associated with youth, adolescence, and moving into adulthood (Shoham, 2021). In addition to these transitional periods, events such as Mexican quinceaneras, Jewish Bar Mitzvahs, and Chinese coming of age ceremonies serve to celebrate the concept of achieving a certain “level” of life (Shoman, 2021). Despite the evolution of birthday celebrations, the underlying purpose has remained constant. The mere presence of birthdays as a social construct makes a statement regarding the deep value of life embedded within a society. For example, someone who was born on March 3, 2002 would be considered twenty-one years old today. In other words, that is twenty-one years they have been alive. This makes me wonder if the concept of a birthday is rooted in the belief that life begins at birth, negating time spent in utero. Interestingly, South Koreans (and some other Asian cultures) were excluded from this precedent

and included the gestational period towards an individual's age (Holpuch, 2023). However, they have recently adopted the international age system in which birth equates to “0” years old and every successive year is counted (Holpuch, 2023).

Funeral ceremonies may differ in their appearance and execution, but share the same appreciation or veneration of life as birthdays. In America, the passing of an individual usually includes a casket displayed at some religious mass and a burial (Hoy, 2013). Funerals serve the purpose of honoring a life and providing a community closure in our culture (Hoy, 2013). New Kingdom Egypt also participated in the trial of burial in an effort to emphasize the worthiness of a single life (Hoy, 2013). Chinese cultures dress exclusively in white and burn incense to acknowledge the acquisition of a new ancestor (Anggrawan & Mayadi, 2020). Jews celebrate Yahrzeit, which represents the anniversary of an individual's death (Ribner, 1998). Funeral rituals are implemented on a global scale, as they serve as both periods of mourning and celebrations. Nevertheless, they revolve around the concept that we understand as life.

Furthermore, interference with life is often correlated with severe consequences. In the United States, 45% of all convicted felons will end up being charged in a court of law, but 95% of felons convicted of murder will eventually be charged (Durose & Langan, 2003). The average maximum sentence for all offenses is approximately four years in a state prison; the average maximum sentence for murder, however, ranges from fifteen to twenty years (Durose & Langan, 2003; Kaeble, 2018). Of those charged with murder, 23.03% will receive life sentences, as opposed to the average of 0.4% for all offenses (Durose & Langan, 2003). Life sentences (despite their name) refer to fifteen to twenty-five year prison stays (LII, 2021). Is the American justice system making a broader comment as to how we define life? In general, 65% of felons will be incarcerated for their crimes and 22% will be released on probation (Durose & Langan,

2003). For murder violations, 95% will be incarcerated and only 5% released on probation (Durose & Langan, 2003). The justice system values an individual's life and, as a result, mandates more severe sentences for murder than any other crime. However, it is not merely justice officials who despise murder considering 25% percent of individuals serving murder sentences will be murdered themselves by other inmates (Kaeble, 2018). Although it is ironic that inmates show their discontent with murders by murdering murderers, it nevertheless emphasizes the inherent value we place on an individual's life.

The inherent worth of life is further exemplified through the sacrifice of living beings. In ancient Greek and Rome, animal sacrifices were used as a means to to express gratitude to the gods and reside in their favor (Campbell, 2014). It was important that the animal was not only viable, but suitable to be used in sacrifice (Campbell, 2014). The mere selection of an animal sacrifice for a god further suggests the sacredness associated with life. Human sacrifices of children possessing the utmost beauty and purity were conducted in Incan societies (Socha & Perea, 2021). They believed that only the most worthy offerings could be used to persuade the gods out of enacting misfortunes (Socha & Perea, 2021). This practice was also observed amongst Aztec civilizations who would also offer the human heart, believing it was the only object that would nourish and satisfy the son god (Graulich, 2000). Only sacrifices of high merit could be used as offerings to omnipotent divine beings. The mere use of both animals and humans further illustrates the peculiar value we place on itself.

Life has been understood as valuable throughout history. Whether that is through the magnitude of life celebrations, consequences of premature death, or immense offerings, life is a fundamental concept. The mere magnitude of perspectives and discussions regarding life emphasizes its importance within society. We should not mistake controversy and disagreement

for a lack of significance. The development of these social constructs regarding the concept of life insinuate its deep roots embedded within our societies. If the idea of life has a place in our lives, as it does for many cultures, then it warrants some degree of careful contemplation and reflection.

CHAPTER IX: IN-CONCLUSION

There is no consensus regarding the definition of life, according to the evidence provided by biology, that would provide clarity as to when a human life begins or is defined. However, it is not enough to merely disregard the topic due to its lack of answers. Life is invariably important, as emphasized in the presence of social rituals that revolve around life (such as birthdays, funerals, and sacrificial ceremonies). Furthermore, how life is understood in medicine has important implications in public health regarding embryonic stem cell use, vaccinations, and abortions. The lack of consensus regarding life is detrimental. As with a lack of knowledge and education in any field, misconceptions and polarization are bound to occur. Life is too important of a concept to neglect for its complexity.

Biology possesses the merit to begin our analysis of life, but to ignore our identity as social beings would make our understanding incomplete. With this in mind, I propose we explore a biosocial definition to life that better reflects our identity as biosocial creatures. The term biosocial itself refers to the intersectionality between biomedical methods and behavioral studies (Harris & McDade, 2018). This perspective encourages us to blend the boundaries beyond the inside and outside of our bodies (Harris & McDade, 2018). External social concepts include culture, socioeconomic status (SES), and religion (Harris & McDade, 2018). The presence of social sciences in biology is not a new collaboration, as ties between social determinants of health and health outcomes have been well established in the medical field (Harris & McDade, 2018). For example, cigarette smoking is correlated with an increased risk of atherosclerosis (more rigid and obstructed arteries) (Glass & McAtee, 2006). Additionally, individuals of lower SES status (a complex social structure) tend to live in more densely populated areas near major roadways (Park & Kwan, 2020). This leads to lower SES patients to be at a greater risk of

abnormal pulmonary performance due to the abundance of pollution (Margolis et al., 2009; Tiotiu et al., 2020). It is evident that social influences are already recognized in the biologically based field of medicine. However, biology also possesses the capability to reciprocally affect our social identities. For instance, an individual who has intersex anatomy may be prompted to experience gender dysmorphia (Kreukels et al., 2018). This serves to emphasize the ways in which our biological understanding impacts the ways in which we perceive ourselves (and vice versa). We are irrefutably biosocial beings and that identity influences the way we perceive ourselves and understand our lives. It seems as if the reciprocal correlation between social influences and biology are already well documented in case studies. In an effort to be consistent, we can broaden these concepts beyond case studies and into the definition of life.

Sociobiology is not a new combination of concepts, considering it is its own field of study. To combine the wisdom embedded in both the biological and social perspectives, we can take some suggestions from this field. Sociobiology refers to the ways in which our biological mechanisms fuel our social behaviors, and vice versa (Lewontin, 1980), specifically focusing on the ways in which innate biological processes contribute to certain social behaviors. This is especially observed when social behaviors become adaptive traits, meaning they improve chances of survival and/or increase reproduction. However, sociobiology is limited in its ability to provide adequate and rigorous data (Gruenewald, 2013). Biomarkers can be difficult to identify and social variables can be invasive to measure, making it an ethically tedious process (Gruenewald, 2013). Although there is great potential in this discipline toward life definitions, there is simply not enough progress at this time to make any cohesive definitions.

Based on my analysis of scientific literature ranging from a variety of fields and perspectives, there is currently no cohesive and all encompassing definition of life. Even in a

partially social definition there will be no consensus due to the diversity of cultures and their own unique range of beliefs. Although I agree that a biosocial approach is promising, the magnitude of discovery regarding life definitions in this discipline are not quite to the quantity and quality necessary to form any clear decisions. However, this is neither a fulfilling nor a realistic conclusion. This indecision about what constitutes a human life will restrict abortions, inhibit vaccine distribution, and decrease embryo use. If we cannot decide when an embryo gains the status of a living individual, how can we justify the harvesting of a blastula? If we are unable to justify blastula use, we cannot ethically develop nor distribute vaccines. This will lead to an outbreak of previously extinguished diseases or even new infectious viruses (like COVID-19). We will have higher mortality rates from preventable infections. Additionally, those that do survive these pathogens are at risk of long-term viral effects that may leave them debilitated. If there is no clear definition of life, how can we make an informed decision on abortions? We need to define a human life in order to better understand the dynamic between a mother's life and the growing fetus.

Some of the consequences of this indecision is already evident in US society, with some states further restricting bodily autonomy in the name of a "human life" and others granting the mother the right to choose. Without a definition we will continue to perpetuate inconsistent legislation and contradictory laws in terms of a human life definition. How can we restrict abortions but not Plan B if both serve to effectively interfere with a pregnancy? Should the government even be regulating the bodies of others? Pregnancy irrefutably alters the life course of partners and the quality of life of the child involved. Unplanned, ill-timed, or incompatible fetuses may experience additional harm if medical interventions are restricted on the premise of "preserving" a life. Should my grandma be more open-minded to abortions, elective or

unintentional considering the life altering impacts it imposes on both mom and baby? Do we simply set our own values aside and allow others to make the best decision for themselves (within legal bounds) like my mother and aunt?

These are fundamental questions that greatly impact both our lives and the lives of others. Although complex topics, they boil down to a misunderstanding regarding a human life. I am optimistic that if we can come to a consensus (in consideration of both biological evidence and social perspective) as to when life begins, these morally ambiguous topics will become more clarified. Only then will we be able to further justify these discoveries and developments with more concrete evidence, or act more ethically in terms of living beings. Either way, we need to construct a solid human life definition.

Additionally, it is not enough to merely encourage others to act on their own moral compass. Even within my own life, I encounter a variety of perspectives regarding human life definitions from the people I look up to the most. Between my aunt, grandmother, and mom I find little resolution, but much interest in their beliefs. Ultimately, we will need to come to a consensus on the definition of human life. It is not realistic that a joint definition (that takes into account multiple different disciplines) will please us all, but it is imperative that we try. We are members of a larger population and constantly compromising our own freedoms for the benefit of the greater community. A human life definition is no exception to these societal sacrifices. Furthermore, as individuals belonging to a society, we are limited in our autonomy and bound by legislation. Lack of consensus on fundamental topics that influence so many aspects of our existence will inevitably lead to even more political polarization. This thesis is merely the start of a long overdue conversation. We owe it to ourselves, each other, public health as a whole, and the future of legislation to find a definition of human life that will suit us all.

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