Introduction: Research question- how do moths fly towards light sources? Talk about how the moths are seemingly attracted to light and even kill themselves in light sources such as fires and light traps and why entomologists speculate they fly towards light sources, then providing three primary suggestions for moths affinity to light.

Primary speculated explanation as to how they fly towards light sources: Transverse orientation. The first part of transverse orientation can be described broadly, then mention how it can be broken up into seperate parts to fully understand it.

Transverse orientation aspect 1: First aspect that should be explained is how the moths eyes are **hexagonal** and why they have this shape. (Talk about how hexagonal cells maximize rotational and reflectional symmetries, maximizes light-sensitive area coverage, minimizes edge-cell material.)

Aspect 2: Continue to explain how moths used to orient themselves to get places using the moon as a light source and reference. Then explain how artificial lights of today are different because they can be reached and the moths angle the light through a group of lenses at a right angle. The moth then adjusts its flight pattern (**fibonacci**).

Aspect 3: Go on to explain the flight pattern caused by transverse orientation, which is in the golden ratio (which is also related to fibonacci sequence). Also explain what golden ratio is and what it's relationship with the fibonacci sequence is.

Potential aspect 4: What's the relationship also with luminosity levels and the attraction to lights? (For example they don't fly towards light sources as frequently during full moon where they are already subjected to more light)

Flaws in this theory and other theories: Campfires have been around for around 400,000 years so it seems as though natural selection would kill off the moths who kill themselves? Also they may not even truly use transverse orientation and there hasn't been enough experimenting on this subject to know the truth. Other theories: escape-route theory, hormone luminosity theory.

- I. Question/Introduction
 - A. What neural network training method is the most efficient for making an AI to play minesweeper?
 - B. Brief background on minesweeper and rules
 - 1. What is the game?
 - 2. How do you win?
 - C. Gradient descent (supervised) or genetic algorithm (reinforcement)
 - 1. Both are feed forward neural networks
 - D. Hypothesis???
- II. How will this be tested?
 - A. After a certain amount of training, the Al's will both play the game x amount of times and whichever has the highest win ratio (or which one gets further into the game) is the one that is more effective
 - 1. Both will be trained the same amount of time (probably?) so that neither has an advantage of being trained more
 - 2. Maybe test them every so often to see if one is more effective short term over long term and graph it(?)
- III. How will these networks be coded/what software will be used to build(?) them
- IV. What is gradient descent? And how will it affect the effectiveness of the network training?
 - A. Supervised results are known before training, the system learns how to get these results
 - B. Backpropagation tests the network and sees how wrong it is, then corrects it
 - C. Probabilities of squares having/not having mines
 - D. Equations
- V. What is a genetic algorithm? How will it affect how effective the training is?
 - A. Reinforcement- the network is rewarded for picking the right squares and will learn what to do and then it should learn to do what it did when it was rewarded and do that over and learn
 - B. Equations
- VI. Results
 - A. Both networks will play minesweeper after a certain amount of testing, and this should show which is more effective, or if it even matters
- VII. Limitations (?)
 - A. Minesweeper is kind of a luck based game so starting the game does use luck
 - 1. Maybe don't use the games that were lost after picking 1 or 2 squares in the data, and play with each AI until they have the same amount that got past the first few hits
 - B. Whichever AI is made second could have the advantage of being made (coded?) better
- VIII. Conclusion

 <u>Abstract:</u> The purpose of the following mathematical investigation is to understand how we can evaluate and model fractals in the physiological and natural world. This is in order to use this information to better understand the connections between nature and mathematics, and to improve how we model these structures in real-world applications.

2) Introduction to Fractals

Definition - Fractals are infinitely complex patterns that are self-similar across different scales. They are created by repeating a simple process continuously in a feedback loop. Fractals are images of dynamic systems that are driven by recursion.

- This means that one can magnify the system at any point and it will appear in the same nature as the original image or function
- Fractals have non-integer dimensions: briefly discuss the relationship between magnitude and dimension (area and volume)

a) Explaining Fractals Using The Koch Snowflake

- Display an image of the Koch Snowflake
- Walk through the steps of how the function is set-up and how it is a fractal
- Apply the necessary math to give a baseline to compare to the upcoming models of fractals. This will give a reference when discussing modeling of physiological and natural structures

b) Mandelbrot Sets, Julia Sets, and Iterated Function System Fractals

Using the foundation of the Koch Snowflake, the different ways we can classify and model fractals mathematically will be discussed. How Mandelbrot Sets, Julia Sets, ad Iterated Function System Fractals are represented mathematically and how they work will be discussed, as well as the differences between them.

3) Fractals in Physiology (Deeper Analysis- discusses mathematics+applications)

- a) Bronchi- 1) measuring their length 2) modeling their structure
- **b)** Blood Vessels- 1) measuring their length 2) modeling their structure 3) dimensions of blood flow (through fractals)
- c) The Heart
 - i) Heart Beats- Heart beats are not regular and are actually a fractal, or can be predicted using fractal functions
 - **ii) Exterior of the Heart-** The veins and outside of the heart can also be modeled using a fractal setup.

d) Applications of Fractals in Physiology

- i) **Biomedical Engineering-** Could the ability to model these physiological structures aid in the growing possibility of having robots perform surgeries?
- **ii)** Aging Blood Vessels (or blood transfusions) Can we tell how old a blood vessel is by modeling it using fractals?

4) Fractals in Nature (Soft Analysis- mainly discusses applications)

- a) Lightning (tie in how similar to length of blood vessels and bronchi)
- b) Modeling Mountains in Programming (video games and computer programming)
- c) Aging Rivers and Trees (discuss similarity in modeling blood vessels to rivers)
- 5) <u>Conclusion:</u> Open ended and to be determined

1. Introduction

- a. Personal Engagement
- b. Abstract: The topic of quantizing beauty will be investigated by measuring lengths, widths, and distances between different facial features. Different faces from multiple races and both genders will be analyzed. Ratios will be found from the measurement and will be compared to find similar ratios between all of the different faces. Also, the golden ratio between facial features will be focused on as faces deemed beautiful have multiple golden ratios on their features. Results will be applied to cosmetic surgery in regards to bias of "beautiful" facial features used as a basis to operate on patients.
- 2. Cultural differences between faces
 - a. Choose 50+ beautiful faces to analyze (most beautiful people, models, celebriteis, etc)
 - b. Organizes faces by ethnicity (Caucasian, African, Hispanic/Latino, Asian, and mixed races)
 - At least 10 faces from each race, at least 5 of each gender
 - c. Measurements of faces
 - i. Interpupillary Distance (left pupil to right pupil)
 - ii. Distance between eyes to end of philtrum
 - iii. Distance of the philtrum (top to bottom)
 - iv. Distance of the chin (end of lip to the of the chin)
 - v. Distance between the eyes (inner corner of left eye to inner corner of right eye AND outer corner of left eye to outer corner of right eye)
 - vi. Length of face (top of hairline to
 - vii. Distance of top of hairline to glabella
 - viii. Distance of glabella to base of the nose
 - ix. Distance of base of the nose to the bottom of the chin
 - x. Width of the mouth (corner to corner)
 - xi. Width of the cheek (ala to side of face)
 - xii. Width of the nose (ala to opposite ala)
- 3. Analysis of faces : finding either one ratio ar a range of ratio that is similar between all faces
 - a. Midface ratio (interpupillary distance/height of face from eye end of philtrum)
 - b. Ratio between chin and philtrum (chin/philtrum)
 - c. Ratio between eyes (inner corner distance/outer corner distance)
 - d. Facial Thirds (studies have shown that in facial thirds, each section should not deviate more that ¹/₃ to be a more attractive face)
 - i. Ratio of upper third (Distance of top of hairline to glabella/length of face)
 - ii. Ratio middle third (Distance of glabella to base of the nose/length of face)
 - iii. Ratio lower third (Distance of base of the nose to the bottom of the chin/length of face)
 - e. Golden ratio (Phi 1:1.618) beautiful faces have golden ratios in 1-D in the following:
 - width of the mouth/width of the cheek, width of the nose/width of the cheek, width of the nose/width of the mouth
- 4. Connection : Dr. Stephen Marquardt and Cosmetic/Aesthetic Surgery
 - Dr Stephen R. Marquardt, a plastic surgeon tried to scientifically analyze the mathematics of perfect facial beauty and patented the "Phi Mask".
 - Cosmetic surgeons need a basis in order to alter and "beautify" the appearances of people. Therefore, there must be some type of bias that cosmetic surgeons have with certain "beautiful" parts of the face and body that they use as a template to operate on their patients.
- 5. Conclusion

Patterns of Spiral Phyllotaxy

I. Introduction

- A. Phyllotaxy is the arrangement of leaves around the plant stem.
- B. Plants can have opposite, cyclic, verticillate, or spiral phyllotaxy.
- C. Spiral phyllotaxy is characterized by leaves growing in a helical path around the stem at an angle of rotation specific to that species.
 - 1. The angle is represented by a fraction, indicating the fraction of 360° equivalent to the angle of rotation.
- II. Overview of the pattern
 - A. The numbers in the fractions are numbers also in the Fibonacci sequence
 - B. ½, ⅓, ⅔, ℁, 5/13, and so on.
 - 1. These numbers are found by adding up the numerator and denominator of the previous two phyllotaxies.
 - 2. The numerator indicates the number of rotations around the stem required to end at the same location
 - 3. The denominator indicates the number of orthostichies on the stem
 - a) Orthostichy is a fixed, vertical row of leaves present on the stem, usually apparent if looked at from the top.
 - b) Orthostichies are evenly spaced around the stem, the angle of divergence is constant.
- III. The golden rule commonly pops up in phyllotaxy
 - A. 173.5°,
 - 1. Many deciduous nascent plant leaf tips have the golden ratio as the angle of divergence.
 - 2. Mature stem typically has a different pattern
- IV. Sunflower head, commonly used example
 - A. Phyllotaxy also applies to flower formation, the seed head, but why?
 - 1. Most efficient way to pack in all seeds
 - a) The seeds exert forces on each other, creating the pattern, so they're all evenly spaced.
 - b) "the geometry can trigger the production of auxin, leading to a feedback loop"
 - c) Auxin is the plant's growth hormone
 - B. Vogel's spiral predicts the formation of a sunflower seed head
 - 1. With 137.5° being the angle of divergence, as in Vogel's model, the most same-size seeds can be within the circle.
 - 2. There are two noticeable spirals in every sunflower head, one going clockwise and one going counter-clockwise.
 - a) The number of seeds in the parastichies is always a Fibonacci number.
 - b) One parastichy has 21 and the other has 34, or one with 89 and 144, or one with 144 and 233.

How does bee population (specifically honeybees depending on available information) influence the production and supply of crops grown in the United States (namely fruits, vegetables, and tree nuts)?

My plan is to answer this question by attempting to make a prediction of the crop supply in 2025 with respect to bee population. I want to do this by graphing changes in population (probably of just honeybees) of bees and comparing it to changes in production of fruits, vegetables, and tree nuts, during the same years.

- Subtopic 1- Bee population
 - Current estimated bee population
 - http://usda.mannlib.cornell.edu/usda/current/BeeColonies/BeeColonies-08-01-2018.pdf for honeybee populations
 - Colonies rather than individual bees
 - Find rate of decline
 - http://usda.mannlib.cornell.edu/usda/nass/BeeColonies//2010s/2017/BeeColonies-08-01-2017.pdf
 - http://usda.mannlib.cornell.edu/usda/nass/BeeColonies//2010s/2016/BeeColonies-05-12-2016.pdf
 - http://usda.mannlib.cornell.edu/usda/current/BeeColonies/BeeColonies-08-01-2018.pdf
 - Predict populations
 - 2025?
 - What is affecting bee populations
 - Habitat loss
 - Required habitat for native bees
 - Basically, any USDA/conservation website
 - Rate of loss of habitats required for bees
 - Only if covering native bees
 - Pesticides and disease?
 - Pesticides in use
 - Most commonly used pesticides
 - Effect on bee population
- Subtopic 2- Crops
 - Crop production for this year (or year that matches bee pop)
 - https://www.usda.gov/topics/farming/crop-production
 - Fruit, tree nuts, and vegetables
 - Trends (decreasing vs increasing)
- Subtopic 3- ya mix em all together and get...
 - $\circ \quad \text{Influence of pollination on crop production}$
 - http://usda.mannlib.cornell.edu/usda/current/CostPoll/CostPoll-12-21-2017.pdf
 - Wind v animal pollinated crops
 - % of commercial crops pollinated by animals
 - Predict future output of crops based on decline in bee populations with no changes in influences on population
 - This is where the math-gic happens
- Conclusion
 - To what extent does bee population affect crop output?

Topic: Hydrogen Spectral Series/Rydberg Formula

- I. Introduction
 - a. Attention-getter (not sure yet)
 - b. Background/summary of basic concept for formula
 - c. Thesis (not sure yet)
- II. Background on physics
 - a. Basic atom
 - b. Electron energy levels
 - c. Photon emissions from electron orbital changes
- III. Rydberg formula background
 - a. Johannes Rydberg
 - b. Formula itself, variables defined
 - c. How it was created
 - i. Previous, hydrogen-only formula
 - ii. Revelation of wavenumber (1/wavelength) application
- IV. Using Rydberg formula to calculate hydrogen spectral series wavelengths
 - a. Values for hydrogen
 - b. Actually plug in and solve
 - c. Compare results to experimental results
 - i. Explain variations
 - ii. Explain band thicknesses
- V. Using Rydberg formula for other molecules
 - a. Show example
 - b. Limitations specific atom characteristic (1 electron) necessary
 - i. Explain reasons why it doesn't work with more
 - ii. What this means for application of formula which elements can be used?
 - c. Prove ^ by example
 - i. Try some element with multiple electrons, ignoring the other electron
 - ii. Compare/contrast incorrect result with experimental results
- VI. Quantum physics background
 - a. Basic description
 - i. What is quantum physics?
 - ii. What can it explain/why does it exist
 - b. Quantum physics in atom model
 - i. Energy levels
- VII. Rydberg formula in quantum physics
 - a. Explanation of why Rydberg formula works
 - b. How it applies to Quantum physics
- VIII. Conclusion
 - a. Thesis restated
 - b. Summary
 - c. Synthesis
 - i. Derivation from other fields applying to other things (this is very vague for now, I know)