

## Major Events in the History of Biology:

- Darwin cannot explain the carrying of certain phenotypes → Mendel explained Darwin through the inheritance
- The term **biology** did not exist until 1802
  - The natural sciences are considered hobbies → collecting stuff and put it in boxes for display
- The definition of biology:
  - The subject matter of our investigations will be the various forms and manifestations of life, the conditions and laws controlling their existence, and the causes by which this is effected. The science, which occupies itself with these subjects, we shall designate by the name biology or science of life
- Types of Biology
  - Molecular biology and biochemistry
  - Genetics
  - Cell biology
  - Physiology
  - Developmental biology → combining evolution and embryology
  - Morphology
  - Evolution and systematic biology
  - Ecology → being respectful of the ecology of the environment
  - Behavioural biology
  - Nutrition
  - Disease mechanisms
  - Pharmacology → gene therapy
  - Genomics → 80% DNA is doing nothing → more proteins made from less genes → the noncoding is responsible in bending the material together (regulates the proteins)
  - Proteomics → working with proteins

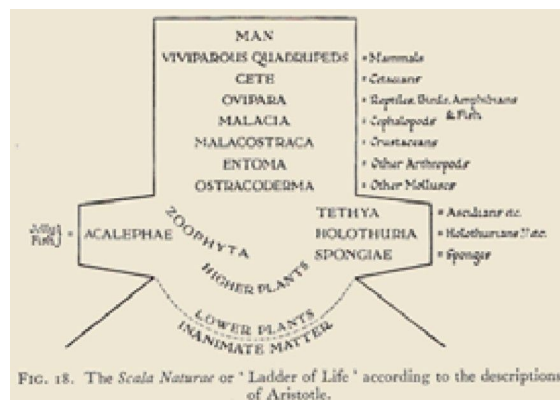
## Pre Darwinian and natural sciences (400 BCE - late 1800s)

- 400 BCE - 450 CE: Greek and Roman ages
  - Made the infrastructure to unite the territories to Rome
  - Shipping of materials and goods (commoners)
  - Because of this material and trade → buildings made specially for learning and knowledge → the people have the luxury of not having to work became the thinkers
  - Rome died because they are overextending their empires → not enough food for the people → rebellions happened and Romans lost their territories
  - The Vandals and Goths destroyed capital city of Rome and dies

- The whole of Europe destroyed because Rome fell and individual groups turned into the survival
- 450 - 16th century: Medieval ages
- 16th - 18th century: Renaissance and the scientific revolution
  - The start of modern sciences
  - Douglas Adams (1952-2001) talks about the **Four ages of sand**
    - Heat sand and silica to create glass for the modern technologies
  - First age: Telescope 1608 → the sand create glass and create lens → see the planetary motion → people ask questions and created mathematics as solutions to those questions
  - Second age: Microscope 1678 → glass is made differently to see small things → first time that we see living things that we cannot see before
    - The origin of all life is described in the bible → living things that not referenced to the bible → contradicts the bible
  - Third age: Computer chip 1961 → charged (turns to 1) and not charged (turns to 0) → 1972 creation of the calculator
    - Computer chip increase the speed of calculations and the codable → can store and retrieve massive amounts of information
  - Fourth age: Fiber optics 1980s → Get the information very quickly → allowed collaboration with scientists and movement of info from anywhere in the world

#### 400 BCE - 450: Greek and Romans ages:

- Hippocrates → made the **hippocratic corpus**
  - Was a doctor
  - Started writing down how to do medical procedures
  - Collect information of how doctors did their treatments throughout the Greek and Roman empire
  - There is a manual for medicine → gathering the information into one book
  - He started human biology
- Aristotle (384-322 BCE)



- Collected the info of living things throughout the Empire
- He started to organize the living things called the **Scala Naturae** or “Ladder of life”
- Man is the most perfect organisms in the world and the gods only thing better than man
  - He notices that man gives birth to live young and walks on 2 legs
- The next one below is the organisms with 4 legs and gives birth to live young → this is the mammals
- The next one below is the **whale and dolphins** → organism with no legs and give live birth
- The next one below is the 4 legs and laid eggs → the **reptiles**
- The next one below is the squids → no 4 legs, but laid eggs in protective cases → the **cephalopods**
- The next one below is the crusty shelled organisms and live in the seas → the **crustaceans**
- The next one below is the shelled organism that live on land → the arthropods
- The next below is the organisms that live in a shell and not a suit of armour → the **molluscs**
- Does not know where to put the jellyfish and sponges, but know they are below
- Next is the higher plants, lower plants and inorganic matter
- Tried to order the living organisms
- The organisms are arranged in the inferiority of man
- Theophrastus (371-287 BCE)
  - Student of Aristotle → he organized the plants of the world
  - Noticed that the flower part of the plant is the birthing area → so, thought if the flower parts of different plants are similar, therefore the plants are related
  - Based on how seeds are produced and how flowers look like
  - The book is created for **food** → what are edible → the **drugs** are plant based → **fibers** of wood are used for building things
  - Wrote 10 books on this topic → 2000 years later, the book of the plants was still in use
- Classification → taking a mix of thing and trying to find order
  - Giving rules to how to organize things → the rules of ordering is called **taxonomy**
- The taxonomies in which Aristotle and Theophrastus order by is called **artificial taxonomics** → is not based on anything biological (organizing list for appropriate categories)

- The other type of taxonomies is called **folk taxonomies** → one person within a primitive culture that keeps all of the collective knowledge and categorize them → they get this from a word of mouth
  - Always about 500-600 things in the inventory → 3 levels of categories
  - In cultures in the south america, they do not have a word for ice because they never seen ice → but has many words for poisonous frogs
  - 500 things in inventory because you can only store that amount of info in the brain
  - Between folk and artificial, the 500 things are written down and the capacity of the amount of things in inventory increases

#### 450 - 16th Century: Medieval Ages:

- The biggest change is the Scala naturae changes to the scale (**Great Chain of Being**)
  - Now, instead of many gods in the top from the Romans and Greeks → there is one god on top (ranges from top to the bottom)
  - Archangels
  - Lower angels
  - Humans → most important organism in the planets
  - Birds
  - Fishes
  - Wild animals
  - Domesticated animals
  - Plants
  - Devil in the bottom → living in the underground
- **Essentialism** is born → every organism has an essence → this essence is past down by generation → the essence makes a cow a cow
- The old testament → tells us that all species were created on **October 23, 4004 BCE**
- The species don't change (**Special creation**) → all species were created at once in the **garden of eden** → someone put everything there in the earth at once
- The species are not old → the planet is only 5000-6000 year old
- Everything is accounted for in the creation stories

#### Europe:

- 400-700 Early middle age (Dark ages)
  - The fall of the Roman empire caused everyone to look after themselves and create small communities to survive
  - Rome destroyed by the **Goths**
  - The church was created, but is not very dominant
  - The rebuilding of infrastructure in Europe
- 1000-1300 High middle Ages
  - Buildings and wealth is being created

- The trade and infrastructure is created
- 1300-1500 Late middle ages
  - In 1300, the Black plague killed  $\frac{2}{3}$  of the population of Europe
  - Collapse of the infrastructure, commerce, the luxury of knowledge and learning
  - Goes back to survival
  - The black plague stops sciences in Europe → not the islamic world
  - In the end, exploration starts
  - Only human biology advances and the rest of biology is forgotten

### **Byzantium and Islamic World (450-16th century):**

- The Roman books were translated into Arabic and while Europe is destroyed, it is the **Golden Age** of the islamic world
- Knowledge takes off
- Al-Jahiz (781-869)
  - He found “Animals engage in a struggle for existence; for resources, to avoid being eaten and to breed.
  - Environmental factors influence organisms to develop new characteristics to ensure survival, thus transforming into new species.
  - Animals that survive to breed can pass on their successful characteristics to offspring.
  - The concept of evolution was introduced
- Al-Dinawari (826-896)
  - Life cycles of plants and evolution of plants
  - Published 6 volumes about plants about medicinal properties and agricultural properties → 600 types of plants → how to grow, use and propagate them
- Avicenna (980-1037)
  - Work in medicine → took the Roman, Asian and Indian medicine and combined them together
  - A lot of his philosophies were abandoned due to different faith
- Alhazen (965-1040)
  - How to carry out experiments and observe the living worlds
  - Scientific Method
    - Observation
    - Statement of problem
    - Formulation of the hypothesis
    - Testing of the hypothesis using experimentation
    - Interpretation of data and formulation of conclusion
    - Publication of findings
- Ibn Al-Baitar (1197-1248)
  - Plants → 1400 plants of the world and the medicinal properties

- The kings and nobles in middle ages in Europe bring Arabs to give them knowledge of medicine
- When Europe rebuild a large population and a powerful military in the 16th century, they conquered the Islamic world and steal the knowledge
  - Marks the beginning of the renaissance in Europe for science

### **16th-18th Century: Renaissance and the Scientific revolution:**

- Copernicus (1473-1543) earth not the center of the universe.
  - The church despises this idea of saying that the earth is not centre of universe
  - He wrote about the theory → did not publish his research until he die
  - His colleagues published his findings → since he is dead, the church cannot excommunicate him (which is removing him from church activities), so he does not get exiled to purgatory
- Kepler (1571-1630) – planetary motion
- Newton (1643-1727) – laws of motion, gravity and thermal conduction
- Galileo (1561-1626) – further proof of earth revolving around the sun
  - The church threaten him with excommunication if he publishes his work
  - So, he got excommunicated → in purgatory
- Boyle (1627-1691) – behaviour of gases
- Pascal (1623-1662) – origins of Calculus
- Descartes (1596-1650) – geometry
  - Showing the pattern of the world and use math to explain them
  - Showing the pattern without changing the creation date and stuff in the bible → does not conflict with the church
- A lot of advancement in physical sciences → hardly any advances in biology, but there are some which is listed below
- **Van Leeuwenhoek (1632-1723)**
  - He created the first microscope → did not tell anyone how to make a microscope → he made 200 and now there is only 5 left
  - The first microscope → consists of a teardrop of glass at the end of the pointer → put the thing under the glass and you can see things
    - No one knew how to make a perfect spherical glass
  - Exposed to the world to small organisms that were not accounted for in the bible
  - Raises the question about the credibility of the bible
- **Andrea Vesalius (1514-1564)**
  - The father of human anatomy
  - First to make drawings of how humans work → only focused in the human biology
- **Harvey (1578-1657)**
  - Role of the blood in the body

- He looked at the blood, heart and lymphatic system
- **Linnaeus (1707-1778) → Systema Naturae**
  - Only person to focus in biology of living things → not human biology
  - First publish catalogue of organizing the living things
  - Before, only long lists of organisms
  - He put things together by similarities
  - He thought the green things are plants and the moving things are animals
  - We define **animals as multicellular, ingestive (consuming food) heterotrophs**
    - Plants are autotrophs and fungi consumes stuff outside
    - 2 kingdoms → animalia and plantae
  - Then break it in 2-3 groups → then break those groups into 2-3 groups
  - **Mechanical taxonomy** → organized in patterns that can be predicted
  - He gave us a system that is **hierarchical** and organized
  - At this time, Linnaeus did not about the microorganisms
  - Ex. he took the animal kingdom and broke it down into groups (quadrupeds, birds, amphibians, fish, insects and worms)
    - Basically he nested the characteristics → if you take an organism, the organisms has all of the characteristics down the line → because you inherit all the characteristics, so don't have to tell the whole story of the organism
  - The Taxonomic hierarchy → groups are the following
    - Kingdom
    - Phylum → was not in the Linnaeus theory
    - Class
    - Order
    - Family → was not in the Linnaeus theory
    - Genus
    - Species
  - Ex. of using this system for the Canadian Beaver
    - Kingdom: Animalia → a multicellular, ingestive heterotroph
    - Phylum: Chordata → has a cartilaginous rod (notochord) in the back of the embryo
    - Class: Mammalia → Feed and suckle the young through mammalian glands
    - Order: Rodentia → 2 incisors in the front that grows for chipping
    - Family: Castoridae → Have the oily gland
    - Genus: Castor → signature genus for Castoridae
    - Species: Canadensis → is the canadian beaver
  - Can predict where to put new organisms in the order

- Linnaeus given the genus species names → called **binomial nomenclature**
- Name and the meaning
- *Apis pubescens*, thorace subgriseo, abdominae fusco, pedibus utrinque margine ciliatis means
  - The fuzzy bee with the greyish thorax, hairless hind legs that are bordered with hairs on both sides
  - Provides the description of the organism
- Turned it into 2 words → *Apis mellifera*
- Unique genus name of specific to that one's species → when you see the genus, it is italic
- The genus is capitalized and the species is the adjective
- The first part of the name identifies a genus (plural, genera), a group of species with similar characteristics. The second part is the **specific epithet**
- **Classification** → An arrangement of organisms into hierarchical groups that reflect their relatedness.
- **Eukarya** → all of the eukarya is grouped in this

### Changing Thoughts on What Living Things are:

#### Physicalists:

- With the exception of humans, all living things are machines → you will see little machines and see how the organism works
- Everything is a machine → nothing special about

#### Vitalists:

- The chemical and physical laws applies, but the living things is different and something make something living (so, all living things have a vital force (**essence of life**))

Division of natural sciences and the physical science → don't know how living things work.

The biology is the underdog science

- Physical Science
  - Most dominant and important science
  - Work with population → ex. The Boyle law → looking at the molecules and it association with pressure
    - The population of molecules are uniformly → object behave exactly the same with little variation → all of the molecules behave the same
    - Can easily find a pattern and apply math to determine the solution of the question
  - Inanimate objects
  - Physical and Chemical laws
    - The solutions to the problems will always work

- Ex. the equation of planetary motion can be used to determine the the planetary motion of any planet
  - Universal
    - It works anywhere
    - Ex. the elements on the periodic table are always the same if it is found in different environment
    - Building blocks of the world
    - Mostly looking at things outside Earth and is universal
    - They figured out the mechanics and the mathematics of the problem
  - Based on **empirical** observations → **experiments** are used
    - Based on looking at things and predicting the pattern → making the math and equations to explain the mechanism
  - Deduction
    - Make a statement of how something works and apply it to the physical world
- Natural Science
  - Animate objects
  - Inherent variation → the population of living things do not behave the same
    - If the temperature was raised in a room of people, different people would act differently → some may find it too hot and some may find it good temperature
    - You get the range of responses → there may be a dominant response, but some may behave differently
    - There are unpredictable patterns and cannot just simply find the math to find the solution of the problem
  - More than physical and chemical law (Genetics → at this time, they still don't know about the genetic code)
    - Laws does not always predict living things
    - Ex. the amino acids can be thrown in a beaker, but may not form the enzymes that you want → because the amino acids can arrange themselves in unpredictable ways and fold in different ways to create a protein
    - In a living thing, the chemical and physical laws make unpredictable patterns
  - Not Universal
    - Looking at the Earth → do not know if it still applies to the universe
    - Just finding patterns in the organisms → don't even know the mechanics of life and how it works
  - Based on historical **narratives**

- Looking at the natural world and creating inventories of the organisms → where to find this organism
    - Looking at the plants → how to increase crop yield through observing the behaviours of different plants
    - Hardly talks about the math and numbers → the narratives are considered to be unscientific without solid math prove
  - Induction is the most used method
    - Observe the natural world → make an assumption on how it works → not a solid theory because you haven't seen the other variations of it (open to reinterpret)
    - The physical science think that they are messing around and indecisive
- **Deduction**
  - Making a statement to saying that it applies to everything → if it applies, we have a deductive reasoning behind the law
  - Ex. All insects have wings and this animal is an insect because it has wings
  - If they find something that defies the theory, the whole theory is gone
  - The deductive reasoning of physical science produces law → because it is universal and is making a statement that works all the time
  - Single falsification is enough to abandon a theory
- **Induction**
  - Ex. find all of the characteristics of an insect → have exoskeletons, have certain number of legs and everytime that I pick up a insect, I notice that it has wings
  - I'm getting a sense that every insect has wings
  - They keep on looking at a lot of insects → other scientists will also look at a lot of insect → if they find a different characteristic, they can alter criteria that defines an insect to fit the new observation
  - In the inductive reasoning of natural sciences → there are theories and nothing is 100% correct and works in any environment → **the theory of evolution is not a law because it is not universal** → only works in earth → not sure about the universe
  - Single falsification not necessary to abandon the theory

### Scientific Explanation:

- Beginning of 2 sciences going back to together → both find pattern and find the mechanism behind it
- 2 Parts
  - Pattern → physical and natural sciences want to found a pattern
    - Ex. I see that the insects are damaging the crops and I need to get rid of them

- Mechanism or process
  - Ex. The mechanism to get rid of the insects is using poison to kill them → control the insect
- Questions to be asked
  - How? (proximate cause)
    - Is an event which is closest to, or immediately responsible for causing, some observed result
    - Ex. How can it kill the insects in the plant? → How did the insects die? → the event immediately response for causing the insects to die is the poison
  - Why? (ultimate cause)
    - After a few years, more poison is needed to kill the insects
    - Found out the insects became more resistant to the poison
    - Why did the insect become resistant? → the insects have adapted to survive complex poisons from plants in past
    - The insect is applying this mechanism to resist the complex poisons that you put on the insects to kill it → no surprise that the insect adapted
- Proximate causes → more physical science-like biology
  - Phenotype - morphology and behaviour
  - Mechanical (predictable)
  - Gene in action
  - Ex. Hitting the knee will cause a reflex → the cause of the reflex is hitting the knee
  - Action result and impact
- Ultimate causes → more natural science-like biology
  - Genotype → Genes and history
  - Variable (probabilistic) → how much is variability is in a population?
  - Evolutionary past → how did genes come about?
  - Changes in the genetic programs
  - Historical narratives
  - Ex. the ultimate cause of the reflex of the knee is caused by the firing of the nerve → how did the nerve fire?
  - Why did that action create these result?

**Example of Multiple Theories in Biology:**

- The reason why giraffes have long necks → long necks help them eat the leaves in the tree (Food competition)
  - But in the empirical information → most giraffes are eating at shoulder height and therefore, the long neck is not needed to eat the leaves in tall trees

- Another group believed that the long necks are used in sexual competition → as the males fight each other for females → a long neck provides more power to hurt the other male
- Even though, this is believable → in environments with scarce amounts of food, the longer neck help them eat the leaves in tall trees
- So, in biology, multiple theories can be applied to a question → ok with multiple theories in the explanation
  - Physical sciences only have one theory → to provide the explanation of the question

### Changing Thoughts on What Living Things are:

- Physicalists and Vitalists combine → **Organicists** (1930) → the vital force replaced by the genetic program and the importance of emergence (swarm behaviour) → don't know what DNA is
  - Living things are more complex than the things that they are produced from → this is called **emergence**
  - When you bring 2 inanimate objects together in a living thing, the new substance created produces different properties from the 2 basic objects
    - These properties are called **emergent properties**
  - Ex. Na → spontaneously ignited in air and Cl gas is poisonous → NaCl is salt is edible
  - Life organizes the chemical and physical laws to produce something unexpected and different from the original subunits
  - Small organisms combine together to create a superorganism that can do more complex actions → Ex. Starling flock

### Scientific Method:

- Theory and Fact
  - No one in science will consider something as a **fact** → there are always alternations of multiple explanations
  - Ex. theory of evolution is not a fact because scientists cannot agree if something that never changes and is constant
  - Newtonian physics is altered when Einstein produce his theory of relativity
  - Always open to another explanation
  - A **theory** is the most completed and fits in most situations → the probability of the theory not being correct becomes lower as time passes → due to fitting it into most situations
  - Ex. DNA fingering → the probability of the DNA in fitting another person is extremely small → 1 in 100 000 000 000 would have the same DNA → not 100% certainty that the DNA belonged to that person

- Hypothesis
  - Studying the literature → understanding the phenomenon → research and work to create an explanation of the phenomenon
  - Start of the beginning of science
  - The more experiments (analysis) that you do and it works → the hypothesis strengthens
  - Testing the hypothesis → strengthen the hypothesis
- Law
  - Physical science have laws → universal
  - Theory of evolution is not universal → only on Earth
  - Mendel's laws → laws of segregation → Mendel's laws are probability laws → math not biology → is universal
- Prediction (logical vs chronological)
  - The prediction to predicting the result of the experiment → logical → help strengthens the explanation → the outcome of the hypothesis
  - Chronological prediction → something that will happen in the future

#### Steps and Stages:

- A question that needs to be answered → why?
  - Ex. how are the polar bears affected in the melting of the ice cap
- Gather information already known
- Develop a hypothesis and test it
  - Ex. The effects of the changing environment in the icecaps and the polar bears.
  - The hypothesis is the polar bears evolved from grizzly bears and when the icecaps melts, the polar bear will go to the land and hybridize with the grizzly bears → then the polar bears will disappear and turn into grizzly bears
  - Test it → go to the arctic ice caps and see that the polar bears is ok living as a separate species
    - When you go to the Yukon, the polar bears move into the land and off of the icecap and start hybridizing with the grizzly bears
- Interpret the results of the test
  - Ex. Interpret the results of the effect of polar bears and melting ice caps
  - The results of the test is polar bears are going to disappear or the polar bears will only live in a specific area
- Retest
- Publish results

#### Additional Experimental components:

- Controls
  - Ex. go to an area that is affected by the melting icecaps and go to an area that is not affected by the melting icecaps

- Control of Variables
  - Ex. make each experiments exactly the same as another trial
- Sampling error
  - There are certain individuals that express certain performance and variables
  - The difference and error between the sample size vs the whole population
  - Ex. If you assess the knowledge of the class by giving a test, the test scores will be in a range → you can find where most of the measurement lies → can make a general measurement of the levels of knowledge in the class
  - More measurements → means more accurate the result is
  - Ex. 99% of people think Donald Trump is an idiot → so, 18/20 people think he is dumb → this is the sampling error
- Repeat the Test

#### Distribution of Scientific Facts:

- Journal selection
  - The high end journals are **Science** and **Nature** → look for a journal that is specific in the researcher's field of study
- Manuscript preparation
  - Get people and colleagues to revise to manuscript and other researchers
- Peer review
  - The journal gets people that have been publishing in that specific journal for years to review the research paper if it fits in the journals
  - Match it to the work of someone else and strip off the name of the writer of the paper → mail it out to the editors and to you
  - The editor does not know the person who wrote it → the editor makes suggestions and comments about the paper (**blind peer review**)
  - The paper can be young scientist → you also don't know who is reviewing
  - You may review a paper of a head guru of the field, but you don't know
- Revision
  - After the editing, you receive the paper and follow the comments and suggestions of the paper → rewrite it to fit the comment
- Publication
  - You need to pay money to have the scientific paper published
  - It can cost \$1000 per page of the paper
  - The peer review → help make the paper better for the journal
  - The cost that the person need to pay → pays for the cost for publishing it
- Types of literature
  - Primary
    - Where the original scientist has published their finding
  - Secondary

- A scientist in the field → gets colleagues and write a review article about the paper
  - Tertiary
    - Someone who is not in the field → writing about things that they read and the information that was gathered
    - Ex. Scientific American, textbook
    - Good tertiary source → always leads back to the primary in which they got the information from

Stages in an investigation:

- The question
  - At the time of beginning of 4th honours project, you don't know what to investigate → so normally ask the professor what to research
  - If they have room for a honour students
- Gather information
- Develop + hypothesis and test it
- Interpret the results of the test
- Retest

**Example: → Industrial Melanism**

- Darwin → never pinned the line of survival of the fittest or evolution
- There are alleles in a population that create certain traits → change is allelic frequency in the population → some alleles have advantages → so the alleles of the advantage gene gets passed down to the next generation
  - If the alleles in the gene pool changes → natural selection has occurred
- In the time of peppered moth, the first definition or experiment of changes in the allelic frequency within a population based on an advantage
- **Observation 1:** Original museum collections had all white peppered moth and by 1900 traps 90% black → more white alleles in the past → if this shifted, it is the demonstration of natural selection
- **Question 1:** Why did the moths shift from light to dark morphs?
- **Hypothesis 1:** Fitness decreased when the moths that were more visible against the background colour of the trees
- **Null Hypothesis 1:** Fitness remains the same and is not affected by the background
- **Hypothesis 2:** The bark colour of the trees has changed
- **Null Hypothesis 2:** The bark colour of the trees has not changed
- **Experiment 1:** Artificially rear light and dark morphs and place on tree and observe survival (fitness)
  - Put tags on the moths that were released into the population
  - 50% of black moths and 50% of white moths → if you get a smaller number of moths coming back, the population should be still 50 and 50

- No white ones came back and the only the black ones → white ones are being removed from the population
- Getting the moths is easy → hang a blacklight in the woods
- The allelic frequency is changing → it is a demonstration of natural selection
- In the tree with darker colour, not many white moths came back
- Did the same experiment, but in white coloured trees and gathered the moths → different variable is controlled
- The black ones didn't come back
- **Experiment 2:** Locate light and dark coloured trees.
  - Found the frequency of black trees in different area in England
  - The areas with higher frequency of industry → showed higher frequency of black trees
- **Result 1:** Birds selected most visible moths → demonstration of allelic change
  - The moths returned to the white colour → after the clean air act
- **Result 2:** Dark trees showed same distribution as coal based industry
  - The Clean Air Act in England is created and cleaned the coal industry → the trees slowly became white again
  - Some critique the experiment and say it is flawed
    - Because the researchers released the moths in the trunk of the tree and not the branches
    - Since you are releasing in a population, this shouldn't affect the survival of the moths → the moths don't just sit there
    - Another thing is that you don't know if the alleles is inherited and follows Mendel's Laws
    - Another thing is that the researcher didn't see the birds eat the moths → basically impossible
    - This is physical science trying to disprove the research
- **Question:** Do moths “rest” on backgrounds that match their colouration?
- **Question:** What impact would the clean air act, that reduced pollutant emissions have on the moth population morphs?
- **Question:** What happens to other moths with light and dark colour morphs
  - Physical science says that it doesn't eliminated all of the possibilities
  - Natural science → open to new ideas

**Biogeography** → a branch of geography that studies the past and present distribution of the world's many species and often relates to the examination of the physical environment and how it affects species and shaped their distribution across space