Evolutionary Dynamics
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Week 01
Lecture 02

Hi everybody, let us continue our discussion of the journey of Wallace and Darwin, which led to the proposal of the theory of natural selection.

So, we are going to continue with this letter that Wallace sent to Darwin.

And he doesn't want to publish it and send it to the celebrated naturalist that Darwin is.

And remember, Darwin had been working in the background, slowly working on his magnum opus that he thought very slowly over the last 22 years.

He'd been working on other things in the decades of the 1840s and 1850s.

But this was something that he was slowly but surely working towards.

In fact, in the early to mid-1840s, Darwin had written a short précis of his thoughts on the theory of natural selection.

And he had, as I mentioned in the previous lecture, that Darwin was not, Darwin never kept good health.

And at one point in the 1840s, he was so worried about his health and survival that he had mentioned to his wife, Emma Wedgwood, that should he not make it through his illness, just make sure that his private notes are seen by his friends, and we'll come to who those people were.

So in this context, something that he's been working and thinking about for more than 20 years, he receives a letter from Wallace which summarizes his exact thoughts in a very effective way.

To understand how similar Wallace's thoughts were to Darwin's, I have here some copies, some statements from 1857, which eventually resulted in Chapter 5 of The Origin of Species.

But if you just compare the language and read these few sentences, just see how identical the thoughts of the two men were.

Darwin says the struggle for existence as bearing on natural selection.

So this is eventually what is going to be called the theory of natural selection.

All nature is at war.

The life of an animal is a struggle for existence.

The struggle very often falls on the egg, the seed, or the seedling.

That means selection is on the is on the offspring, the egg, or the seed.

Any variation, however infinitely slight, where he's talking of variations, however slight, any variation, however infinitely slight,

If it did promote during any part of life, even in the slightest degree, the welfare of the being, such variation would tend to be preserved or selected.

So in the context of what we discussed at the end of the last lecture, you see that Darwin's thoughts were exactly identical.

And in fact, he had had those thoughts for the best part of two decades.

But now he receives this letter from Wallace, which mirrors his thoughts.

And in fact, he mentioned later on that if he were to provide a short summary of his entire thoughts, Wallace's letter was exactly that summary.

So what does Darwin do?

Darwin is conflicted here because, on one hand, he doesn't want to be unfair to Wallace by denying credit to what Wallace has obviously independently arrived at, independent of Darwin.

This is Wallace's thought.

But on the other hand, he also doesn't want to deny himself the credit for this discovery, because after all, this is something that he's had in his mind for more than 20 years.

And he knows that Wallace did not have this thought 20 years ago.

So it's a very difficult position that Darwin finds himself in.

And he confides about Wallace's letter to two friends.

One is a geologist, Charles Lyell, and the other is a botanist, Joseph Hooker.

And he shares Wallace's letter with these two men.

And these two have known for a long time what Darwin has been working on.

So they are aware of Darwin's thought process for quite some time.

Wallace's letter is shared with these two, and Hooker and Lyell propose a compromise.

The compromise is that there is a Linnean Society meeting that year, and what is proposed is that Wallace and Darwin will write papers, and their respective papers will be read on the same day at the Linnean Society meeting.

Hence, the credit will be shared, and this theory, which would eventually be called natural selection, would be proposed to the world at this society meeting at the same time by both men.

Both graciously agreed with what was being proposed.

And at the meeting, neither man was present.

Wallace was obviously away in the islands, and Darwin was mourning the loss of a child.

One of his children had died in the days leading up to the meeting.

The papers were read in absentia.

But here is a letter which Lyell and Hooker wrote to the society, communicating these two papers and strongly recommending them.

These two papers were included as part of the meeting that year.

And it's just, I think it just pays to slightly go through this read-up.

And they say, 'My dear sir, the accompanying papers, which we have the honor of communicating to the Linnaean Society.'

This is obviously Linnaeus of the classification.

England has a society named after him, although he was not English, which is related to the same subject.

That is laws which affect the production of varieties, races, and species.

Contained the result of investigations of two naturalists, Darwin and Wallace.

These gentlemen, independently unknown to one another, conceived the very same ingenious theory to account for the appearance and perpetuation of varieties of specific forms on our planet.

May both fairly claim the merit of being original thinkers in this important line of inquiry.

But neither of them having published his views, though Mr. Darwin has for many years past been repeatedly urged by us to do so, and both authors having now unreservedly placed their papers in our hands, we think it would be best to promote the interests of science that a selection from them should be laid before the Linnean Society.

And these papers were accepted by the society and they were read in the summer of 1858 when both papers were read.

And in a very curious incident, the work wasn't really acknowledged for the significance that it obviously had.

In fact, the society president in his minutes that he wrote summarizing that year's meeting said that in that year's meeting, nothing of great significance was presented, which is a blunder of Herculean proportions.

But what this told Darwin was that he needed to hurry up with this magnum opus that he was talking about.

He got lucky in the sense that Wallace was a very accommodating and a very fair man.

He was very happy to share credit with Darwin.

But the idea was out there, and he could be scooped by someone else publishing a similar book on the same line.

Hence, Darwin rushed through the publication of the book, which is The Origin of Species by Means of Natural Selection.

And this was published in 1859.

So, in just over a year, Darwin finished his book.

He imagined it to be several thousand pages long, but eventually, it wasn't.

The book is around 350 pages.

And there were 1,250 copies ordered in the first edition, and all 1,250 were sold on the first day.

And surprisingly, the fact that species are mutable, species change over time.

This idea did not meet any great hostility among the scientific community, at least.

It was fairly easily accepted that species change with time.

However, what did meet resistance was the idea that natural selection was the mechanism via which species change over time.

And we'll discuss these ideas in much more detail through the weeks that we'll be doing this course.

So, this book was published in 1859.

There are several subsequent editions that come out.

Darwin kept updating The Origin of Species in the subsequent years, and these newer editions kept coming out.

However, one of the characters that we met on slide one was Wallace's companion, Henry Bates.

And

Upon reading the work of Wallace and Darwin, Bates wrote a letter to Darwin describing what is now known as Batesian mimicry.

And this was a phenomenon that Bates had seen in South America.

So imagine that you have, let's say, any row, let's say we take the second row.

Let's say we have two different species of butterflies, and this one is poisonous.

So the predators avoid this particular species.

Predators don't, because predators, through evolutionary interactions with this particular species, know that this variant is poisonous.

So, this particular design is one that a predator does not want to eat.

So, what happens in Batesian mimicry is that a species of butterfly which is non-poisonous,

acquires mutations and changes, acquires changes such that it resembles a poisonous kind.

And now the idea is that if by physical appearances you look like a poisonous butterfly, then you are going to be avoided by the predator and hence your chances of surviving in a particular environment increase..are increased.

And this is a classical case of natural selection in action, where in a population of non-poisonous butterflies, those that do not have this characteristic, which is an appearance almost identical to the poisonous one, those which do not have this characteristic are going to be predated upon.

However, those In the variation that exists in the butterfly population, those that do look like this one are going to avoid predation and hence flourish in the population.

And Darwin read this work of Henry Bates and he was extremely complimentary because this was evidence of natural selection in action from an ecological setting that Bates had studied.

This phenomenon is called Batesian mimicry because all these non-poisonous ones are trying to mimic the poisonous variant that exists in the population.

A curious twist happened.

Before we get to that, let me give you some context.

So Darwin, in his years after the voyage of the Beagle, had always been very interested in the work of breeders, be it flower breeders, plant breeders, or animal breeders.

So a flower breeder, for instance, would try to mate two different varieties of plants together.

Hoping that the hybrid would exhibit some fantastical type of flowers such that these fantastical flowers would be very much in demand and the breeder would make a profit.

Same with animal breeders, you would try and mate different breeds of dogs, for instance, and produce a fantastical breed of dog which would then be in demand and so on and so forth.

The idea was that what should be these pairings of meetings which would lead to such fantastical phenotypes or physical manifestations that would be of appeal, that would be of commercial value.

And Darwin knew that these breeders, they do not have exact rules, but they have an intuition about that this should be, that a pairing between this individual and this variant can lead to a fantastical offspring.

And he wanted to understand that intuition.

So in the process of doing that, he would often send surveys to scientists, to breeders, gardeners, and so on and so forth.

He also subscribed to a magazine called Gardener's Chronicle.

So in the months subsequent to the publication of Origin of Species,

A certain Scotsman named Patrick Matthew read the review of Origin of Species.

Gardener's Chronicle published a review of Origin of Species.

Patrick Matthew read it and wrote a letter to the editor of the magazine.

And it's a curious letter that I think we should go through.

So Patrick Matthew wrote.

In this letter to Gardener's Chronicle and Agricultural Gazette in the April 1860 issue, remember that Origin of Species was published in late 1859.

It's just worthwhile to go through this paragraph where Matthew says, in your issue of March, I observed a long quotation from The Times saying that Mr. Darwin professes to have discovered the existence and modus operandi of the natural selection laws of selection, blah, blah, blah.

This discovery, recently published as a result of 20 years of investigation and reflection by Mr. Darwin, turns out to be, and now the key part, what I published very fully and brought to apply practically to forestry in my work, Naval Timber and Arboriculture, which was published as far back as January 1, 1831.

So what Matthew is saying is that this idea of natural selection that you say Darwin has published, and this is a result of 20 years of work,

I actually published it nearly 30 years before Darwin did in this work on naval timber and arboriculture.

And what Matthew is saying is, so if you look at this book on naval timber and arboriculture, Matthew's premise was that Britain, in order to maintain her supremacy over the world, must have the best naval fleet.

And for building a strong naval fleet, it needed high-quality timber.

So from the existing variety of timber, how do we get newer varieties which will allow you to make stronger and better naval fleets?

In this proposal of how to arrive at better timber, Matthew actually used the theory of natural selection as a mechanism to produce better timber.

So Darwin had obviously subscribed to this book.

So in the April issue, when this letter is published, Darwin reads it and replies in the following month.

And Darwin's reply is that I have been much interested by Mr. Patrick Matthew's communication in April.

I freely acknowledge that Mr. Matthew has anticipated by many years the explanation which I have offered of the origin of species under the name of natural selection.

So he freely concedes that this idea is exactly what Matthew had proposed 30 years ago.

However, Darwin goes on to say, I think that no one will feel surprised that neither I nor any other naturalist had heard of Mr. Matthew's views, considering how briefly they are given and that they appeared in an appendix to a work on naval timber and arboriculture.

So he freely acknowledges that.

The proposal of the theory of natural selection was actually 30 years prior to him, but he didn't know, and nobody else he knew about this proposal and that Matthew's claim was right.

And when this exchange was happening, the second edition of Origin of Species was already out, and Darwin was working on the third edition.

So the third edition onwards of Origin of Species contains notes which acknowledge that Patrick Matthew was the first one to arrive at the theory of natural selection.

However, Matthew is a character that has been forgotten in the history of evolution.

He has been denied his credit, and he wasn't very happy about it then.

So, he replies in the May edition as an explanation of why he did not write a long book about the idea and why his views were very brief and contained in the appendix of a book.

So he says, this law of nature came intuitively as a self-evident fact, almost without an effort of concentrated thought.

Mr. Darwin here seems to have more merit in the discovery than I have, because to me it did not appear as a discovery.

So to Matthew, the whole idea of natural selection is just extremely obvious.

He seems to have worked it out by inductive reasoning, slowly and with due caution, to have made his way synthetically from fact to fact.

While with me, it was by a general glance at the scheme of nature that I estimated this select production of species as an a priori recognizable fact, an axiom requiring only to be pointed out to be admitted by unprejudiced minds of sufficient grasp.

So he says that this idea is so simple, so intuitive that it just didn't need any elaboration.

And hence my views on the subject were so short.

And that's where the conversation between the two ended.

However, in texts of the subsequent 20th and 21st centuries, Patrick Matthew has sort of become a forgotten man in this entire episode.

But his claim of having arrived at the theory of natural selection prior to Darwin certainly seems to be true, even if just by looking at this correspondence.

All right.

So to summarize this bit, what we have covered is that the theory of natural selection was proposed in the 19th century.

We looked at the characters and what came about.

This has stood the test of time.

The theory of natural selection that evolution proceeds by the theory of natural selection.

It stood the test of time.

We have experimental evidence across genres, across species.

We are going to look at many of them, and it's unlikely to undergo any major changes anymore.

And of course, we will discuss the technicalities of the subject, but there are great books on the idea of natural selection and how evolution proceeds, which have already been written.

And these are fantastic books for laypeople to read and enjoy.

And I've listed some of the names here, which I think are worth reading.

Incidentally, Charles Darwin is also there.

If you read Victorian prose, Darwin is not difficult to read at all; he is very readable.

So before we actually get into the elements associated with natural selection, we'll start with the following question that both Wallace and Darwin are asking.

They are saying that the best way to arrange species is by a tree.

For instance, we know today that this is human beings, this is human beings, and this is chimps.

We know that these two species shared a common ancestor if we go back a few million years.

By the same logic, if we keep going back in history, every species that exists today shared a common ancestor.

But if we keep repeating this process and go back deep in time, then what must have happened is that there must have been an ancestor which is the ancestor for every subsequent species that came into being.

This

The last ancestor has a name, and it's called LUCA.

And it stands for Last Universal Common Ancestor.

And before we actually get into the elements of the theory of natural selection,

What we want to understand is that natural selection is, in some way, going to explain how diversity happens, how life forms of one kind existed.

And then natural selection acted on the variation that was present in those life forms and led to subsequent evolution.

So, in one sense, natural selection tells me of everything that happened after the arrival of LUCA and diversification, complexity increase, and so on and so forth.

But a question that we will visit now is: what happened which led to the arrival of LUCA?

Because right here, this is the last ancestor that we have.

So that means what we have here is sort of chemistry.

And then something happened which led to the arrival of life, which is LUCA.

And we will spend a few minutes just discussing this arrival of LUCA before we start a detailed discussion on the theory of natural selection.

So to look at this, I often ask this.

Earth is around 4.6 billion years old.

Just arranged an arrow of time.

This is today.

This is the origin of the planet.

Each of these blocks represents half a billion.

So I want you to guess, take a few seconds and guess as to

Where in this timeline did life first come into being?

Has life only existed on the planet for the last billion years or so, or this block, or this block, or this block, or even before that?

So.

And one way to look at this is from chemistry.

We are saying that something happened, and LUCA arose; life arose.

This step is unlikely to have happened in one step.

This entire process is unlikely to have been just one step.

It would be a bunch of small steps that led to this transition, and it probably took a long time as well.

However, each one of these steps

If it was relatively easy to cross both kinetically and thermodynamically, then we can say that the origin of life was easy, and hence it may have come up early in the life of the planet.

However, if there was one or more than one step here that was extremely hard, that means either the kinetics weren't favorable or the thermodynamics wasn't favorable, then

For life to have originated is a very fortuitous event that happened.

And then it would have perhaps the arrival of life would have perhaps happened more recently in the history of the planet than the other case.

So take a few seconds and sort of what does your gut feel or knowledge say about when life arose on the planet?

OK, so.

Well, hopefully you've made your guess.

But what I want to do is walk you through briefly about the history of life on the planet ever since it came into being.

So what do we know?

These are the different eras that are used to divide up the history of the planet for the last four and a half billion years.

And the first bit going back four and a half billion years ago is called the Hadean era.

And this was early Earth, which was meteorite bombardment, temperatures were too high, and there was constant influx between the core of the Earth and the surface, and very unlikely to have led to carbon-based life's evolution, life as we know it today.

The conditions were just too hostile.

So the first evidence of life that we have is about 3.8 billion years ago.

Which sort of subscribes to the idea that we discussed, that maybe it's a series of steps that were not very hard to take for the evolution of life on Earth.

Where on the planet it might have happened is a question that we'll come to in a bit.

Then, interestingly, Luca diversified into two different life forms.

These are both bacteria and archaea, which are both life forms called prokaryotes.

There are several differences between prokaryotes and eukaryotes, but the most common one is that prokaryotes do not have a nucleus.

So, for roughly 2 billion years or so, Earth was only inhabited by bacteria and archaea.

After that,

we have the arrival of what are called the first eukaryotic cells.

And this is a curious incident in itself because what is thought is that we had bacteria, we had archaea; archaea are usually larger, and under some environmental context, two variants of bacteria and archaea

engaged in a relationship where the bacteria was engulfed by the archaea.

So it's residing intracellularly.

Usually, when that happens, the cell that has been internalized is just opened up, and its material is used as food.

But in this case, these two engaged in a symbiotic relationship where the bacteria that was internalized is given a safe and constant environment by the archaea's intracellular environment.

In return, this bacteria provides the cell with energy.

And this bacteria that was engulfed eventually evolved to become mitochondria.

in all eukaryotic cells.

But this engulfment event was necessary for the arrival of the first eukaryotic cell, and it took a really long time. We know some details about who the participants were, what type of bacteria it was, and what type of archaea participated in this engulfment process, but there are several details missing about how this process might have happened.

So immediately, what you should see is that eukaryotes have existed for less than, or about half the time that prokaryotes have existed on the planet.

The Ediacaran fauna is a period where the first complex multicellular organisms came into being.

This was a little over 550 million years ago from today.

Then we have a period which is roughly 540 million years ago, called the Cambrian explosion.

And this is thought to be a time when novelty took place.

Novelty in terms of morphological design, novelty in terms of all the organs we know of.

Lots of innovations regarding morphology and body shape happened in this time.

It was almost as if something happened that caused this diversity to explode.

And the best-known samples for this are found in Canada, in a place called Burgess.

Then life's history is not just shaped by processes that lead to the arrival of diversity, but also by processes that lead to the elimination of diversity.

And the biggest extinction event that the planet has seen is called the Permian extinction, which led to the extinction of more than 90% of all life forms that existed on the planet.

And because of this massive extinction, it created space for newer species.

It made space available for newer species to emerge and occupy those places left vacant by other species that had gone extinct.

And the rise of dinosaurs is a result of the Permian extinction because it created space to be filled, which eventually was filled by dinosaurs.

Much more recently, we have another extinction event, which is called the KT extinction.

This one is a little over 200 million years ago.

The KT extinction is much more recent, 65 million years ago.

And in this one, dinosaurs themselves went extinct.

And this led to space for what are dinosaurs.

Ancestors of mammals to take over the niches that were left vacant.

And as a result, dinosaurs come into dinosaurs go extinct and mammals' ancestors come into being.

And much more recently, I mean, it's just a speck in terms of how long the planet and life on it has existed.

Do we come into being?

So that's sort of the brief history of how life has arrived and evolved over the last roughly 4 billion years or so.

And in the next video, we'll continue our discussion on how the first cell came into being, which led to what we know about this process, which kickstarted this whole thing.

Thank you.