Evolutionary Dynamics
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Week 01
Lecture 01

Hi, everyone.

Welcome to the first lecture of the course, Evolutionary Dynamics. And in this lecture, we'll talk about the story of the people involved, which led to the proposal of the theory of natural selection.

You would have all heard of the name Charles Darwin, famous for his 1859 book called The Origin of Species. But there are a few more characters involved who were responsible for the publication and the proposal of theory of natural selection as we understand it.

So these people, as you can see on the slide, are of course Charles Darwin, we know, but also Alfred Russel Wallace, who was a co-proposer of the theory of natural selection, and we'll discuss the story.

And also Wallace's collaborator, Henry Bates. And towards the end of this lecture, we'll discuss a curious case of a Scotsman called Patrick Matthew and what his reaction was when the Origin of Species was published in 1859.

All right.

So to start this, we start with Alfred Russell Wallace and Henry Bates.

These two were collaborators.

And in the late 1840s, they went to South America to collect samples. In 19th century science, it was primarily men who were doing this. And all of these men came from family of means. And science for them was something that they were passionate about.

Alfred Russell Wallace was a big exception to this case. He did not come up from a family of means and he was reliant on donations from private collectors, museums to fund his expeditions.

And these two men had gone to South America to collect samples to understand the diversity of life there. And while Bates remained there till 1857 and in his time there sent back thousands of specimens back to England.

Wallace returned in, this is a typo, it should be 1852. Wallace returned to England in 1852. The two started working together, but very soon after starting their work,

They sort of decided to switch tasks and explore different parts of the continent while exploring these samples.

But the primary question that they are interested in is, as you can see at the bottom of the slide, is where do species come from?

And as they are looking at this question, essentially, the idea is that if this is the continent of South America and you find species coexisting species coexistent in certain types or spread over geographical areas, what is the relationship of all the species that exist here with the species that they exist here?

How did this diversity come about?

That is the key question that these two men are interested in. And this is sort of an unknown question before that.

So just to back up a little bit, what happened is that in 1852, when Wallace is returning to England, he's reliant on the sale of his collections to museums and private collectors to fund his future expeditions.

But as he's crossing the Atlantic, the ship catches fire.

Wallace escapes in a lifeboat, but all his specimens, all his notes from the expedition of the last four years are lost.

And he's finally rescued after a week or so by a passing ship. And when they are returning, he makes it safely back to England.

But as they return, he takes a vow to never step on to sea again and go for another expedition. Everything that he had done in the last four years was lost as a result.

So that's Wallace. And we'll come back to Wallace and Bates in a little bit.

But now let's let's discuss the main protagonist of the story of theory of natural selection. Darwin was born in 1809 and he was 22 when he got the offer to be an amateur naturalist on the ship called HMS Beagle.

Darwin was offered to also be the dining mate of the ship's captain, Captain Fitzroy, who himself was a young man.

And in the extremely hierarchical classist society of England of that time, Fitzroy wanted a dining mate.

And Darwin came from a family of means. His father was a famous doctor.

And Darwin finally agreed to come on this trip.

The trip wasn't supposed to last that long, but it actually was more than five years after Darwin did this round of this round of the world, as you can see by the arrows marked in red, eventually returning back to England.

The main mandate of this trip was to do coordinate mapping on the east coast of South America, exactly the locations where Alfred Wallace and Henry Bates were.

So the ship spent two to three years just mapping the coordinates and exploring the eastern coast of South America.

And while this was going on, Darwin would often come off of the ship and go deep indoors inside the continent and meet the ship several months later at another predetermined location and time that they had previously agreed on.

And this back and forth went on for two to three years. In his time of expedition and collecting and studying samples, Darwin was intrigued by a curious observation.

He noticed that the spread of species as they were spread over the continent, over a geographical location, was not random.

The species that existed in one particular place today were very similar in its morphology, in its bodily characteristics, to the characteristics of the fossils that they were found at the same location.

So, for instance, if we talk of a particular location, let us say this.

So, you are studying two kinds of samples here. One is extant species, which are the species that live there today.

And the other one is fossils that remain in this geographical area. And as Darwin is studying these two, he finds that these two are deeply related.

The morphological features of extant species is very similar to the morphological features of the fossil records that exist in that location. The sizes may be different.

In some cases, fossils were larger. The extant species were smaller or vice versa. But the basic principle held.

What this told Darwin, that spread of species in a geographical area is not random.

And that's important.

What that means is that spread and distribution of life forms over a geographical region is not random.

That means there are certain rules which dictate how life diversity is going to spread in a geographical location. And Darwin is a very meticulous collector of specimens and a very, very meticulous record keeper.

At every place that his voyage took him to, he collected samples and kept sending them back to England for people he knew, for collectors and so on and so forth.

And he's making very meticulous notes.

So after spending two to three years on the east coast, Darwin crosses into the, the ship crosses into the Pacific.

And at the northwest tip of South America, the ship spends a few weeks at the famous Galapagos Islands.

Now, Galapagos Islands are a bunch of islands where two curious things happen with Darwin.

He's collecting specimens of finches, which are birds which occupy these islands. And as he's collecting them, he doesn't really make note of this at the time that he's doing that.

But when the ship leaves Galapagos Islands, he makes the connection later.

And he sees that birds on a particular island were of a particular kind.

There were subtle differences between birds that were occupying each of these islands, but these subtle differences were very concrete. So each island had a bird which was particularly unique to that particular island.

Why would this be so?

The prevalent view up until that point was that God created species and placed them on Earth at different locations. But it didn't make sense to a young Darwin as to why would God make a slightly different form of the same bird and place on each one of these islands.

While this was going on in Darwin's head as the ship is sailing away from Galapagos, he also remembered that the locals at these islands told him of a curious observation.

They told him that just by looking at the design on the back of a tortoise's back, they could tell which island it had come from.

This was just the Finch's story repeating itself that each island had a tortoise with its shell design, back shell design, which was unique to that particular island.

And why would this specifically designed spread of these closely related species be unique to each of these islands didn't really make sense in a young Darwin's mind.

Darwin's account is actually quite fascinating to read.

And throughout his five and a half years, he was constantly seasick. He generally maintained poor health throughout his life.

And eventually, when the ship is going around the south coast of Africa and about to turn back, Captain Fitzroy decides that they should take a detour to South America again to just make a few more measurements that he wasn't quite happy with how they did it the first time around.

This made Darwin obviously very unhappy.

And eventually in December of 1836, the ship goes back to Plymouth and the journey is complete.

By the time this happens and Darwin reaches England back, he's a celebrated naturalist, not only in England, but also in all of Europe, all of continental Europe also.

The word about his exploits, his specimens, his notes have all reached there before him. And he's quite a young celebrity even before he's turned 30.

As you can see, the Beagle journey was completed in 1836.

Origin of Species was published in 1859.

That's a long 23 year gap which Darwin took to write a book which is not very large, which is 300 odd pages or so.

Why did this long gap happen is something that we'll try and understand in this lecture.

However, this question about origin of species and where they come from had been troubling Darwin right from the days when the journey left Galapagos Islands. As you can see, this is an iconic page.

Darwin maintained a set of private notebooks after his journey.

And once he returned back to England, he started maintaining these meticulous records of his private thoughts on how species came into being.

And while he was doing that, this is an iconic picture from one of his notebooks where he he's trying to come up with this with this rule which dictates spread of life.

If he says that if if if this is not random, then what is the rule of life?

How does life come into being?

And in this picture that we see, he says that the best way to describe how life exists is in a tree-like manner.

In this tree that you are looking at, each node used to be one species and this species then gave birth to two different species which are the two edges coming out of one node.

Every such diversification.

So if you see this, this here used to be one node and then this branch came out and this branch came out. Out of this particular node, three branches came out and so on and so forth.

So he says that this branching process of generation of new species is how life comes into being.

And because in, let us say, in this particular location, there used to be this one species which diversified into two different species like this.

These two species that have come into being are going to look very closely to each other.

As a result of that, all the species that are going to evolve in a particular environment or a geographical region are going to look alike each other, which is how he explained this particular observation that extant species look very much alike fossil species because this is the species that existed in the fossils and this is the species that occupied that space today.

And while they are going to be different from the species that exists in the fossil, they're going to be large similarities also.

And it is this rule that Darwin thought as early as 1837, which explained how species exist in a particular location.

And this is an iconic figure.

And what I personally really like is that on the top left of this page, Darwin writes, I think.

He's conjecturing, he's formulating a hypothesis in his mind, which is going to take shape in the coming decades.

However, this was as early as 1839.

The first public record of Darwin's voyage was published three years after the voyage in a book titled The Voyage of the Beagle.

And he describes everything that had happened in the five and a bit years that he was away.

However, he carefully avoids touching on the question of evolution. In fact, and this is a quote from the book.

In fact, he says on particularly evolution, he says that it is clear that several islands have each their peculiar species of the same genre.

So peculiar species of the same genre, which when these are placed together, they will have a wide range of character.

Which means he says that each island has its own peculiar species, which if you were to compare them will have a lot of diversity. But each island has its own peculiar species.

So he merely reports this observation, doesn't really comment anything on it.

And in order to not comment.

comment on it, he concludes his discussion of evolution in this book by saying that, but there is not enough space in this work to enter on this curious subject.

So, Darwin always anticipated that when he was going to talk about this rule about how species come into being, this was going to be a magnus opus of several thousand pages.

He wanted to lay all the evidence that he had collected over the years and decades into this magnus opus and provide as comprehensive a view of this process as he possibly could.

So he didn't want to touch upon this in any superficial or a brief manner.

Hence, he completely avoids the problem.

And Wallace reads this and thinks that arrival of species, how species come into being is an open problem.

And hence his expedition that we just learned about.

Although in 1852, Wallace's ship caught fire and he vowed never to go on the sea again.

The following year, he's back on the sea.

This time, not to South America, but to the islands between Southeast Asia, islands between South Asia and Australia.

And while he is doing that, one peculiar feature of this particular geography that he went to is that it is a lot of islands.

Now, islands are a great place to study evolution because these small islands presumably were one landmass at some point not too far back in the Earth's history.

And what must have happened is that these islands got separated so different populations of the same species that inhabited this one collective island got separated into two populations.

And now they will charter their independent evolutionary trajectories which can be studied after a long time has passed because these two, although they came from a common ancestor, have not had any subsequent contact with each other

Since the landmass became split into different islands.

And what curiously what Wallace saw in this Malaya archipelago is very similar to what Darwin saw in the Galapagos Islands.

What Wallace notes is his model systems are butterflies, marsupials and monkeys.

One of the curious features he sees is that you could draw a line between these islands roughly like this..marsupials to the northwest of this line in fact this line is this is that line on this map this is Australia this is Asia this line is actually called Wallace line now

And just as Darwin had wondered that why did God place these very closely related finches on these different islands, Wallace is asking the same question that why is it the case that there is an imaginary line that exists between these islands and to one side of this line is only marsupials and the other side there are no marsupials to be found out.

He also saw the same thing with butterflies, that different islands had peculiar butterflies associated with that particular island only.

So he's going through the same observations that Darwin went through at Galapagos Islands.

And that's why islands are a great place to study evolutionary dynamics.

Around the same time as this theory is formulating in both these men's heads at different times, at different locations, there are two influences on their thinkings.

The first one is this famous essay published first in 1798 by an economist called Thomas Malthus.

Malthus's argument is dealing with human populations. And his central tenet can be thought of in the form of the following graph.

That he says that as time increases, if I am looking at food production, as time is moving forward, more and more land is being brought into agriculture, hence you have more food.

But the production of food increases..is linearly increasing with time as more and more land is brought into agriculture.

However, Malthus says that if at the same time I look at population, human population is exhibiting an exponential growth.

So, Malthus's argument in this essay is that while food availability is increasing linearly, population, hence the demand for food, is increasing exponentially.

So eventually there is going to be a mismatch between this demand for food curve and the supply for food curve.

And as far as supply outstrips demand, things are going to be fine.

But what happens when the population crosses this particular point?

Now you have greater demand and greater demand and lesser supply.

This means that this is going to lead to competition among the individuals of this particular population.

Could be human population, could be anything.

This idea was central to forming Darwin's and Wallace's views about proposal of theory of natural selection.

They see the same thing happen in any population, in any ecological niche.

If the number of individuals that seek resources, food being one of the resources, is more than what the environment can supply, then there is going to be a problem.

Then there is going to be intense competition for that resource, food in this case, and then only those which are better suited to out-compete their opponents and hence feed themselves are going to survive.

Those which are not going to be able to get food for themselves are going to go extinct.

And this idea of competition and demand, which was proposed in the context of human populations and economics, sort of formulated views of Darwin and Wallace about theory of natural selection.

The other idea is industrialization and specialization.

And this is a topic that we'll come back to in a few weeks time when we are discussing details of evolutionary processes and what we understand.

But the key idea is that as evolution happens,

Do species become more and more specialized at using one particular resource?

Suppose you have a population in one geographical niche where there are N different resources available.

Does each population become specialist at using one of those N resources?

So, hence, there is a greater degree of specialization that occurs as we move forward in time in a given locale between the individuals that occupy that space.

But crucially, this is the idea that is going to be the key to the theory of natural selection.

So while Wallace is there, Wallace in 1855, two years after he's been in Asia, he writes an essay and which is titled On the Law Which Has Regulated the Introduction of New Species.

Because from his days in South America, he's interested in the question of how do new species come into being?

And this is just two short sentences from the write-up that Wallace wrote at the time.

And he says, every species has come into existence coincident.

Coincident here means at the same location, both in space and time with a pre-existing closely allied species.

What he is saying is that every species, if this is species A today,

This is closely related to a species A star which existed here in the history and this is today.

Every existing species today has existed with a pre-existing species and these two are very close to each other.

So he has come up with a rule to arrange life forms in a particular location.

And he further goes on to say, the best mode of representing the natural arrangement of a species is a branching tree.

Under this rule, if I'm at a location and I'm observing the biological diversity that exists today, and I study the biological diversity that existed in the history via studying fossil record, the best way to represent this natural arrangement of species that how they have been spread over space and time is through a branching tree.

Exactly what Darwin had recorded in 1837 in his book.

So he writes this up.

He sends it back to Europe for people to read and comment on.

And the general reaction he gets is that you were sent there to collect specimens for us.

Stop with this theorizing and keep sending us seminars.

Just keep sending us samples. We didn't ask you to theorize.

And this is no one really paid any attention.

Wallace keeps working at it.

And in 1858, he sends a long letter to Darwin because Darwin is a celebrated naturalist in all of Europe.

So he keeps refining his thought.

And in a letter that he sends to Darwin, he shares the following.

He says the life of wild animals is a struggle for existence and to provide for an instant offspring.

This is a key idea of natural selection that basically an organism is fit if it is able to reproduce and pass its genes to the next generation.

Wallace further says, perhaps all of variations must have some definite effect.

What Wallace is saying that in a population, if I am looking at any trait, let that trait be, let us say height.

And if I ask how is height spread in a population, so what percentage of population occupies a certain height?

So, for example, if we take the example of human height, we will say how many, what percentage of population is between 5 feet and 5 feet 1 inches?

So, there is some fraction.

Then between 5 feet 1 inches and 5 feet 2 inches.

So, you will get a histogram like this.

And this is the distribution that he is talking about here, that variation must exist, however small, however slight in the habits and capacities of the individuals.

So these variations exist.

And among that variation, any variation that slightly increases powers and by powers, he means ability to pass genes to next generations.

In this variation, if this variation exists and for some reason, if there was a population where individuals of greater height were producing two offsprings and individuals of lesser height were only producing one offspring.

then what would happen is that this population will keep on growing much faster as compared to this one.

And very soon, these numbers will change such that you would have much taller individuals in the population compared to what you started with.

There are certain caveats to that which we'll come to in a little bit.

But that's the idea.

That key is that variation must exist.

This variation must lead to differential success in reproduction.

Differential success in reproduction and this leads to evolution.

We'll discuss this idea in a little bit more detail.

He doesn't want to publish it because he wrote an essay three years ago and it wasn't quite received well.

And hence he sends it to Darwin.

And Darwin, remember, it's 1858.

It's been 22 years since Darwin has come back from the Beagle and has been working on the idea of natural selection.

So we'll discuss what happened subsequently in this story in the next lecture.

Thank you.