5

WHAT IS LIFE?

This two-part lecture begins to define the qualities that all living things possess and explains how these qualities reinforce each other. David Christian also introduces the concept of natural selection — the process by which certain variations in a trait help a creature survive and are thereby passed on to future generations. After reading the text below and watching the video, you should be able to identify four qualities present in all living things, explain the importance of DNA, and describe how natural selection causes a species to change over time.

Key questions

1 What four qualities of a living organism does David Christian identify and how do they work together to help a living organism survive?

2 Why is DNA so important?

3 Who first documented his observations of natural selection? How did he first describe his observations? How were his ideas received at the time? What has changed since?

Transcript: Part 1

0:11-0:38

LIFE PROBABLY EXISTS ELSEWHERE, BUT WHERE?

Everything we've looked at has one quality in common: it's not alive. Now, and for the rest of this course, we're going to be looking at things that are alive, at living organisms. Biologists suspect that the Universe is crawling with life. There's life all through the Universe, but the truth is we just don't know. The only place we know for sure that life exists is here on our Earth. So that's where we have to study it.

0:38-1:40

ACTING WITH PURPOSE

Now, what is life? What makes life so distinctive? We all probably feel intuitively that we know what makes life different, but pinning it down precisely is actually very difficult indeed. Let's try a kind of crude comparison. Let's compare two big things. Let's compare an elephant and the Earth.

Now, we could say the elephant moves, but we've seen that the Earth is kind of dynamic too. We could say the elephant grows. Well, even the young Earth sort of grew during the process of accretion. Or perhaps we could say that the elephant, like all living things, acts with a sort of purpose. Here I suspect we're getting nearer to the truth, but it's still hard to pin down for certain. What we can do is we can list some qualities that all living things seem to have. In what follows I'm going to describe four key qualities that all living things seem to possess.

1:40-2:43

METABOLISM = PROCESSING RESOURCES TO MAKE ENERGY

The first quality we call **metabolism**. All living organisms are made from cells. All cells can metabolize, and what we mean by that is that they can take in energy and materials from the outside world in order to maintain themselves and keep themselves going. Now, this complicated process is governed by instructions that are contained in the master molecule **DNA** — that's **deoxyribonucleic acid** — that is present in all cells.

HOMEOSTASIS = ADJUSTMENTS TO ENVIRONMENTAL FACTORS

The second quality we call **homeostasis**. It's a complicated word, but it's worth getting on top of. By homeostasis we mean the ability of all cells, and in fact all living organisms, to keep constantly adjusting to tiny changes in their environment using the energy and materials they get through metabolism. Homeostasis is also governed ultimately by instructions that you can find in the DNA.

2:43-4:03

REPRODUCTION PASSES DNA TO THE NEXT GENERATION

The third crucial quality is **reproduction**. However good they are at homeostasis, eventually all cells, all living organisms, break down and die. But it's here that life has come up with a really clever trick for preserving itself. Even when the individual dies, before it dies it can make copies of itself and its DNA and scatter those copies around it. So the individual may die, but the copies will survive; and that's reproduction.

The fourth quality we call **adaptation**. Over many generations, species can slowly change and adapt and diversify as environments change. The way they do this is actually strangely through mistakes in the copying of DNA. Just occasionally DNA makes mistakes, but the copy works. When that happens and you get a new version that can actually do all these things — it can metabolize, it can do homeostasis, it can reproduce — we say that a new species is being created. It's almost as if DNA is slowly learning how to make new species that can do new things in new environments. And that's how we get the huge diversity of life all around us today.

CHANGES IN DNA THAT CREATE NEW SPECIES ARE ADAPTATIONS

Transcript: Part 2

4:07-5:19

THE FOUR QUALITIES OF LIFE REINFORCE EACH OTHER

Metabolism, homeostasis, reproduction, and adaptation seem to reinforce each other. They sort of go together. Metabolism provides the energy and materials needed for the constant tiny adjustments of homeostasis, and also for reproduction. What adaptation does is allow species to make large adaptations, large changes over time as environments change and that's the key to evolution. Homeostasis and adaptation together explain why life always seems purposeful because it's as if it's pushing back somehow against the environment.

Now, as far as we know, only living things are capable of combining all of these four qualities. So what is it that holds them together, that links them? The answer is the astonishing molecule that we call DNA. You've seen already that DNA seems to play a crucial role in all the four qualities that we suggested may define life. How does it work and how is it formed?

5:19-6:09

DNA TELLS THE CELL WHAT TO DO

Well, the best way of thinking about DNA is to think of it as being a bit like the software in your computer. DNA contains the instructions needed to make the proteins that go into the cell and do the crucial work needed to keep the cell going. It also contains the information needed for DNA to reproduce and for the whole cell to reproduce. How is it constructed and how does it work?

6:09-6:58

DNA REPLICATION

Well, DNA is a vast molecule with billions of atoms in it. They're organized in two great chains. Each chain has arms and those arms link up to form like the rungs of a ladder. So the whole thing ends up looking like a ladder. Then it twists on itself to form a double helix and that folds up compactly at the center of the cell.

This is how it works: The information is contained on the arms of the ladder in a special four-letter code. Molecules inside the cell approach the DNA, unzip the crucial part, read off the code, and then go back into the cell and make the proteins necessary to do what the DNA needs it to do.

DNA can also copy itself. This is how that works: The two parts of the ladder separate and each of the arms goes off into the sludge of chemicals around it and finds its counterpart until eventually you have two identical double strands of DNA. That's how DNA copies itself and that's the basis of reproduction in all living organisms.

6:58-7:57

MEET CHARLES DARWIN

DNA is at the center of our modern understanding of how life works. But even in the 19th century, the English naturalist **Charles Darwin** had generated a broad understanding of how these changes occur, of how life evolves. Before Darwin's time, most naturalists believed that species were fixed. They didn't change over time. But some had studied fossils and that seemed to mean that species actually did change over time. The question was how. That was the question that Darwin tried to tackle.

ANIMAL BREEDING HELD CLUES ABOUT ADAPTATION

Darwin knew that animal breeders could actually change species quite quickly within just a few generations. The way they do it is by choosing which individuals will breed and which won't. So if you want to breed fat sheep, you let the fat sheep breed and you don't let the thin sheep breed. By doing that, quite quickly you can really change an animal or species.

7:57-9:15

DARWIN OBSERVED HOW NATURE SELECTED WHICH ANIMALS REPRODUCED

Now, what Darwin noticed is that something very similar seems to happen in the natural world. It's almost as if nature itself selects which individuals will breed and which won't. Think for example of an eagle. Think of an eagle with really good eyesight. It's going to get plenty of food, it's going to reproduce. Think of another eagle that has very poor eyesight. It's going to really struggle and its chances of reproducing are rather poor. So what this means is that the eagle with really good eyesight is likely to have many more offspring and slowly over time its qualities will become more and more common and that particular group of birds is going to change and become more like the eagle with good eyesight.

NATURAL SELECTION IS NEVER-ENDING

Now, repeated many, many times over thousands or millions of generations, this Darwin realized is the mechanism that changes life. Nature is selecting which individuals will breed. He called this mechanism **natural selection** and he figured out that it's the key to the evolution of life. Evolution, it turns out, is a never-ending process because the environment keeps changing. So species keep changing. There's no end to it at all.

Now, when Darwin first came out with this theory it was received with considerable skepticism in 19th-century Britain. He actually came up with lots of evidence, but not quite enough, and some things he didn't really understand. For example, he hadn't a clue about the role of DNA. But since then a lot of new evidence has come to make his theory much, much more powerful. Today it is the dominant idea in modern biology.

9:15-10:15

NATURAL SELECTION IS THE BASIS FOR MODERN BIOLOGY

Now, we encourage you to study the evidence. First, look at the evidence available to Darwin, and the best way of doing that is to read his wonderful book, *The Origin of Species*. It's very readable. It's a classic and really worth looking at. Then look at the evidence that has kicked in since then. Now, it's really worth doing this because Darwin's idea, coupled with our modern ideas about how DNA works, are really the key to understanding life and how it works.

THE ORIGIN OF SPECIES BY CHARLES DARWIN