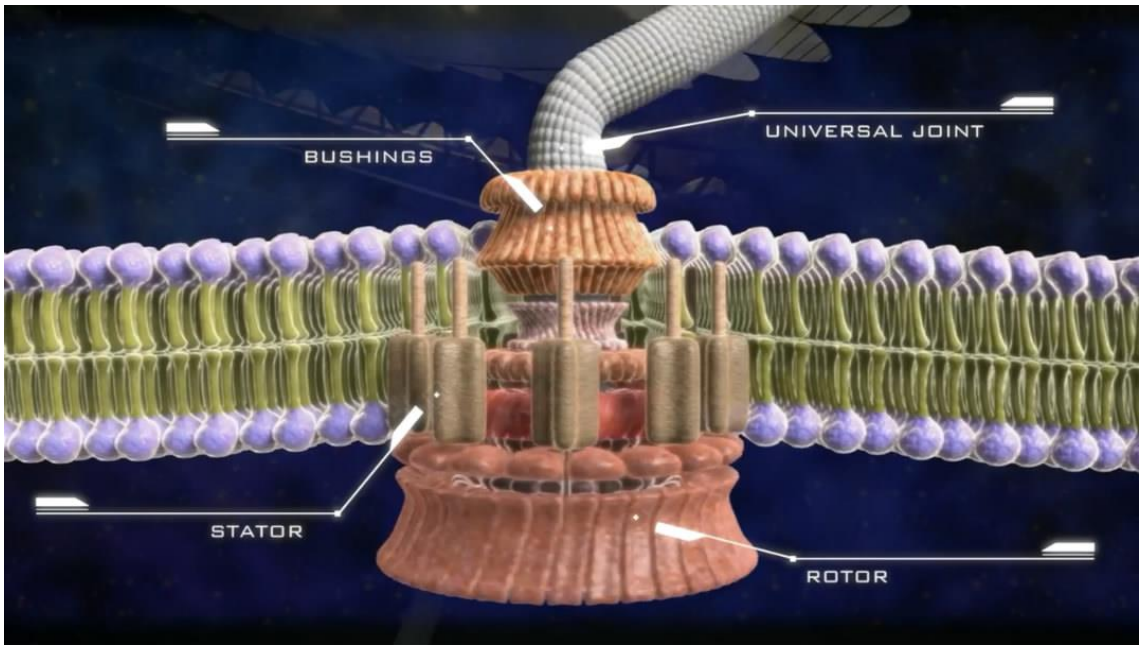
Microbiology: Michael Behe and Molecular Machines

Part I: Introduction to the Bacterial Flagellum (鞭毛) Challenging Darwinism

[They] cannot be seen by the naked eye. Perhaps the most amazing propulsion system (推进系统) on our entire planet is one that exists in bacteria. It is called the **flagellum** (鞭毛), a miniature **propeller** (螺旋桨) driven by a motor with many distinct mechanical parts, each made of proteins. The flagellum motor resembles a human designed **rotary** engine (**旋转式**发动机): it has a universal joint (万向接头),



bushings (轴衬), a stator (定子), and the rotor (转子); it has a **driveshaft** (传动轴) and even its own clutch (踩离合器) and braking system (制动系统); in some bacteria the **flagellar** motor has been clocked at a hundred thousand **revolutions** per minute (**转速** 100,000 次每分钟); the motor is bi-directional and can shift from forward to reverse almost instantaneously; some scientists suggest it operates at near 100% energy efficiency. All of this is done on a microscopic scale that is hard to imagine. The diameter of the flagellum motor is no more than five millionths of a centimeter. The bacterial flagellum is one of many molecular machines that scientists have discovered in the last several decades, including energy producing turbines (涡轮机), information copying machines, and even robotic walking motors. The origin of these exquisite (精致的) examples of nanotechnology (纳米技术) is a mystery that has

generated heated controversy (争议) among biologists over the past two decades (20 years).

@ 1:43 "Darwin under the Microscope" *pause*

Question 1) Describe the bacteria's **flagellum**. What does it do? What are its parts?

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Question 2) What kind of human designed engine is the **flagellum** similar to?

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*According to the modern version of Darwin's theory, known as Neo-Darwinism, even the most complicated biological features originated through a process of natural selection, sifting (筛分) through **random** (随机) mutations, or copying errors in the genetic instructions stored in DNA. For example, a **random** genetic mutation might give a particular bird of slightly longer beak. This small change could help the bird survive better and eventually its offspring with longer beaks would come to dominate the population. A longer beak size might not seem all that important but Darwinian theory asserts that over time many similar unintended (无意的) changes could **accumulate** (积累), ultimately (最终) producing an organism radically different (巨变) from its original ancestor. According to Neo-Darwinism new species and new biological features do not develop according to an intelligent plan, instead they arose from the **accumulation** of thousands of small undirected genetic mistakes over millions of years. The more Michael Behe studied the staggering (惊人的) **complexity** (复杂性) of life at the biochemical level the harder he found it to believe the standard Darwinian story. The bacterial **flagellum** was one of the biochemical systems that fueled (推动) Behe **skepticism** (怀疑).*

Behe: The bacterial **flagellum** is literally an **outboard motor** (舷外发动机) that bacteria use to swim. It uses a little piece that spins round and around and around and pushes against the water just like a **propeller** does in an ordinary **outboard motor** on a boat in our everyday world, and the propeller is attached to a **driveshaft** which is attached to a motor, which has **clamps** (夹子) holding it in place, and dozens of pieces that are required for it to do its job. It's just a fantastic example of what science has discovered and that is molecular machines.

*The first time Behe saw a diagram of the **flagellum** he was captivated.*

Behe: I look at it and says, "Wow that's really fascinating, I wonder how that evolved," then had turned the page and said, "Eh, go on and do something else" and just any **skepticism** was defeated by assuming (假设) that somebody must know this because everybody says Darwin's theory is true.

*But then Behe read a book by geneticist Michael Denton. Denton argued that Darwinian theory was in crisis because its mechanism of **random** mutation and natural selection wasn't capable of producing major biological innovations. After reading Denton, Behe's doubts about the origin of molecular machines like the **flagellum** [grew].*

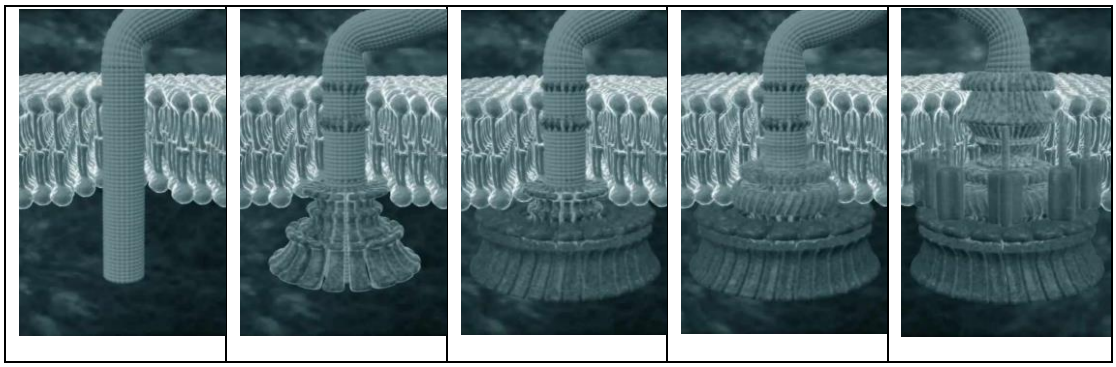
Behe began to dig deeper to find an answer.

Behe: Darwin's theory says you have to start with something that's working a little bit and then it will change, mutate a bit, and that helps a little bit, and that'll be selected, and then it improve a little bit more, and a little bit more, until you get the full fledged system. I said, "Well it does not look like some of these systems can be done that way, because they need all of these parts. You know, if you don't have this one, it's not going to work. You can't take any of the parts away." I was kind of sitting at my desk scratching my head. "You can't take the parts away. You can't reduce it at all. It's **irreducible** (不可简化的;不能减小的), and so it's **irreducibly complex**." I thought, 'bingo', that encapsulates (总结) the problem for Darwin's theory right there.

***Irreducible complexity** Behe highlighted in his book.*

Behe: If you take away the **propeller**, if you take away the motor, if you take away the **clamps** that hold it onto the cell's membrane, take away any of a number of different parts, it's not that the **flagellum** is going to spin half as fast as it used to, or a quarter, it's broken, it doesn't work at all. It's like taking the **propeller** off of an **outboard motor** on your boat and wondering how far now you can go in the water. You can't go anywhere. So, that's a problem for Darwin's theory, because Darwin's

theory says that things evolve by working a little bit, maybe not very well, but a little bit, and then a mutation, a change, comes along that helps it work a little bit better, and that helps the organism survive and have more offspring, and so on. Then another change comes along, and another, another, and it gradually (逐步地) builds up to the final structure. Well, that might work for some things, but it doesn't work for systems that are **irreducibly complex**, things like the bacterial **flagellum**, because if you wanted to build an **outboard motor** for a boat what would you start with? Would you start with, say, just an iron rod (杆子) that you know in the future would attach a motor to the **propeller**? Well, what's that going to do? It's not going to do anything. Would you start with just a **propeller**? Well, that's not going to do anything. It's not attached to anything. Would you start with just a motor? Well, that's not going to **propel** you anywhere. So, with **irreducibly complex** systems, like the **flagellum**, Darwin's idea is dead in the water, like a boat with an **outboard motor** that doesn't work. Natural selection selects or favors in variations that **confer** (授予) a **functional** (功能性) advantage on a system. Many of the simpler versions that you could imagine of the bacterial **flagella** motor perform no function at all, and so if you imagine trying to build a **flagellar** motor adding parts one by one until you finally get to the complete system you're going to encounter configurations (配置) of parts that **confer** no **function**, in which the motor simply will not work, at which point the evolutionary process will **terminate** (终止). It will cease (停止) to continue because the system **conferring** no **function** will not be preserved (保存) and passed on to the next generation.



Above: A Neo-Darwinian model of **flagellar** motor developmental stages.

*Evidence cast doubt (使人怀疑) on [Darwinian evolution of the **flagellar** motor].*

Meyer: We know from genetic knockout experiments that the 29 part, the 28 part, the 27 part, the 26 part version of that machine simply will not **function**. It will not work as a as a **rotary** engine, and so building up through those stages of non-**function** is not going to happen because there's nothing there that will **confer** a **functional** advantage on an organism that will then passed on to the next generation and therefore the evolutionary process will **terminate** when it encounters (遇到) one of those non-**functional** thresholds (阈值) in this alleged (声称的) sequence from something simpler to the **flagellar** motor.

Question 3) What kind of human designed motor is the bacterial **flagellum** similar to?

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Question 4) Why can the bacteria's **flagellum** be called **irreducibly complex**?

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Part II: Lenski's long-term experiment found what kind of evolution?

Michigan State University biologist Richard Lenski has been running a long term evolution experiment with E-coli bacteria. A staunch supporter of Darwinian evolution, Lenski wanted to follow a population of bacteria over time and see what new functions would evolve.

Behe: I'm a big fan of this experiment because it does not put out a model. It's not a computer model. It's not a theory. What he did was let evolution happen on its own and say, "What did it do?"

By 2014, Lenski and his researches had grown over 60,000 generations of bacteria.

Behe: That's equivalent to, say, a million years in the lifespan of a large animal like us, and there have been trillions upon trillions ($> 10^{12}$) of different bacteria that have been born and died in his flasks.

Although often cited as providing evidence for Darwin's theory, Lenski's experiments are perhaps most revealing in what they haven't produced.

Minnich: We don't find a new protein with a new fold, with a new function, by and large these are deletions, insertions, rearrangements of information that's already present.

Behe: He didn't see anything like the evolution of some new complex system like the **flagellum**, nothing remotely like that.

Minnich: At some point you're going to have to show that you have a gene with one function has now evolved into a gene with a different function, different protein folds, and we're still waiting.

Behe: What we see going on in the Lenski laboratory, and other places too, is that Darwinian processes, or **random** processes, degrade information, they do not build it. They are not putting in new information. They might tweak (small improvement) something here or there, and at the margins you can have differences about what you call information.

*Taken together, this flood of new data has raised a powerful challenge to claims that natural selection can explain the origin of new functional genes and proteins, let alone a **complex** biological machine like the **flagellum**.*

Question 5) What kinds of evolution did Lenski's experiments demonstrate?

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Question 6) What were the limits of the kind of evolution seen in the experiment?

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Question 7) Can evolution be explained by **random** mutation and natural selection?

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Question 8) What does this imply? Should we still believe Neo-Darwinian theory?

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