The Genesis of Germs: The Origin of Diseases and the Coming Plagues
by
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First printing: January 2007

ISBN-13: 978-0-89051-493-1
ISBN-10: 0-89051-493-3
Library of Congress Catalog Number: 2006937547

Cover Design: Rebekah Krall
Interior Design and Layout: Bryan Miller

Printed in the United States of America

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Dedication

To the late Dr. Robert P. Williams, my mentor in microbiology and friend, and to the teaching assistants of microbiology at Liberty University.

Acknowledgments

I want to thank several people who made this book possible. They have offered useful suggestions and have given me support in this writing endeavor. The people who have helped me are: Jayne Gillen, Joy Khamvongsa, Dr. Paul Sattler, Dr. Charles Detwiler, Dr. Doug Oliver, Dr. Jay Wile, Elizabeth Paquette, Sarah Anderson, Su-Fern Tan, Hope Smith, and Racquel Sewell.

All scripture quotations taken from the King James (Authorized) Version of the Bible unless otherwise stated.

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The Genesis of Germs: The Origin of Diseases and the Coming Plagues

Chapter One

Microbes By Design

The news media writes frequently about the evolution of new microbe strains that can cause disease. New diseases such as hemolytic uremic syndrome caused by E. coli, flesh-eating Streptococcus, methicillin-resistant Staphylococcus aureus (MRSA), antibiotic-resistant malaria, and bird flu all capture the national headlines. With each passing year, news headlines reveal that some new disease outbreak or plague has "evolved" and it threatens thousands of lives. In the year 2005, the news flash "Bird Flu Threatens Globe" was broadcast across the nation, leading many people to become alarmed. The emergence of a new strain (H5N1) of flu may place millions at risk.

Another one of these prevalent and menacing diseases is MRSA, which is a new strain of Staphylococcus aureus; it is resistant to methicillin and therefore becomes very difficult to treat. Consequently, it becomes a huge nuisance and ailment to the one infected. The pace of the development of antibiotic resistance to emerging, incurable infections is faster than drug makers can keep up with and treat.

Are these examples of evolution? Are these facts of evolution? Did God make microbes by mistake? Are they accidents of evolution, out of the primordial soup? These timely questions are examined throughout this book.

First, these news headlines of bird flu and antibiotic resistance are not examples of Darwinian evolution. On the contrary, they are examples of variation, or change within "kinds." Later in the book we will explore how and why these examples of minor changes (variations within kind) in microbes can cause disease. Second, microbes are not the Creator's mistake, nor are they random accidents of evolution. Not only were microbes originally created for our good (and the biosphere's), but their design also shows creativity, diversity, intelligence, and beauty. A few microbes (five percent of the bacteria) reflect decay and degeneration from the original plan. Disease was not the Creator's original plan, but rather a reflection of man's sin, the Curse placed on nature.

The Power Unseen

Microorganisms — this term is not new to the average layperson. These "animicules," "cavorting and wee beasties," and "minute eels," as Leeuwenhoek called them, are creatures of the unseen world. They may be introduced as harmless, beneficial, or even harmful bugs. No matter how efficient or awe-inspiring the presentation about microbes is, each person views them in a different way. Maybe you were not interested in microbiology and figured it was another subject no more significant than others. However, microbes are powerfully influencing our lives whether we acknowledge it or not. The purpose of this book is to show how life and microbes are inseparable. The microbial world is both surprising and stunning. It is surprising because it contains a wealth of diversity of life forms. The microbial world

is also stunning because we rarely understand how these microbes affect our own world, and we also overlook the elegance of their design.

Bacteria are found throughout the earth, from the equator to the poles, and are presently the most common type of microorganism. It may be difficult to believe that creatures so minute can be so dynamic. They are surrounding us even as we speak. They are in our water, milk, yogurt, cheese, bread, and other foods. We never really realize their importance until something goes wrong with us. We get sick, and then we want to know something about the "bug." We want to take the first pill or antibiotic in sight to cure our sickness.

Fungi, protozoans, and viruses, like bacteria, make up the unseen world. They are also a part of our everyday life. We use yeasts in our daily bread. Protozoans are in our pond and aquarium water. Viruses are now responsible for a new and widely publicized epidemic, the bird flu. However, microorganisms also are inseparable from our world, and should be seen as relevant to our life. What would this world be like without the unseen? This book is designed to make the educated layperson and student aware of the unseen world of microbes. It also brings a creation and biblical perspective to microbiology. This book should challenge you to think of the unseen as relevant to your world and make you aware of the wondrous design in microbes given by the Creator.

BOOK OBJECTIVES

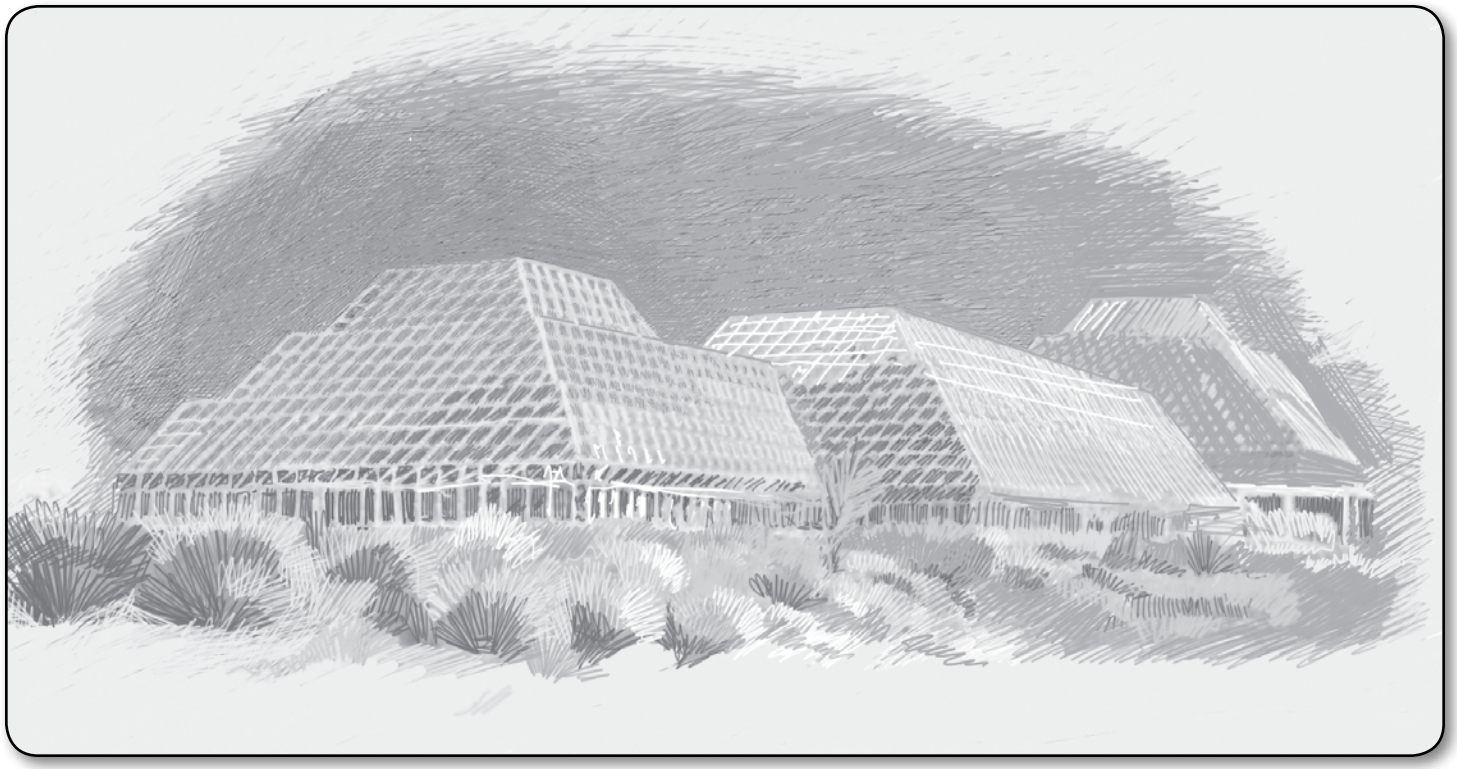
The objectives of this book are to:

- Describe the designed structures and purposeful functions for each of the microbial systems.
- Explain selective in-depth explorations for specific creative design components in bacteria, fungi, and protozoans.
- Explain the origin of disease from a creation, biblical perspective.
- Provide examples of microbiologists who have held a creation or intelligent design perspective.

What Is a Microbe?

The term microbe was first used in 1878 to describe "extremely minute living beings." At that time, this definition was chiefly applied to one major category of microbes, the bacteria. Before 1878, scientists, including Louis Pasteur, used a variety of terms (examples: animalcules, infusoires, and germs) rather loosely to label the very small organisms that had interested them. It was not clear whether microbes belonged to the animal or plant kingdoms or to a completely different one. Early biologists also did not fully realize the extent of life on earth as we know it today. Visible effects of microbes on higher plants and animals, however, were commonplace and evident long before the existence of microbes was discovered in the 17th century. They were particularly obvious when the effects were deleterious, such as from an infectious disease, and were sometimes viewed as supernatural events or mysterious, "spontaneous" phenomena. Logical explanations of infectious disease and other manifestations of microbial life had to wait on two developments: the acceptance of the concept that invisible microbes existed and the tangible evidence of their reality. Several creation scientists, including Anton Leeuwenhoek, Robert Hooke, Louis Pasteur, and Joseph Lister, would play a role in developing the notion of their reality and in proving that those germs cause disease.

In the earliest observations of bacteria, fungi, and protozoans, infusorium was the most common term used for these creatures. This is because the first cultures of microscopic organisms were made with infusions, which consisted of water with added hay, straw, and soil. In 1879, a French scientist, Charles E. Sedillot, gave the term microbe. It included any living thing that must be magnified by a microscope. Traditionally, microbes have been described as free-living organisms that are so small (less than about 100 micrometers [µm]) that they are visible only under the microscope; however, a few microbes are large enough to be seen with the naked eye. The smallest bacteria are barely 0.2 µm long, but giant bacteria and protozoa can be 1 millimeter (mm) in length or even longer. Microbes are either prokaryotes (cells lacking a true nucleus), or eukaryotes (cells with a true nucleus). Eukaryotic microbes, other than algae and fungi, are collectively called protists. These include protozoans and slime molds. A complicating factor is that some microbes are especially hard to define, partly because they have large relatives. For example, yeasts are certainly microbes, but mushrooms are not — yet both are fungi.



Biosphere 2

How Small Are Microbes?

Microbes are very small. The volume of a typical bacterium is only about 1 μm^3, roughly 1/1,000 that of human cells, such as cheek cells. However, there is a large range in size among bacteria; this illustrates that the Creator loves variety. Some species are considerably larger, while others are smaller than the average. One gargantuan species (Epulopiscium fishelsoni) that lives in the intestine of the surgeonfish is huge! It is over 0.5 mm in length and is visible to the naked eye. It is about three times bigger than Paramecium. The range in volume of the smallest to the largest known bacteria is well over one million-fold. Therefore, size is not always a good way to distinguish prokaryotes from eukaryotes. In addition, some marine algae are about 1 µm in diameter; they are the smallest known eukaryotes, well within the range of most prokaryotes. However, it is generally true that most prokaryotes are smaller than eukaryotic cells.

Why Microbes Matter

So why should we study microbiology? New and updated information about microbiology is continuously shaping our lives, especially concerning our society's healthcare. It helps us understand infectious diseases and the best ways to cure them. Microbes benefit our lives in the environment and provide the basis for many of our fermented foods. It also tells us about the Creator's handiwork; His intricate design extended down to the smallest creatures in our world. The icon for the intelligent design movement is the bacterial flagella. Furthermore, they help us recognize and understand various principles in the Bible.

Are Microbes the Creator's Mistakes?

Microbes have been designed as tiny, intricate machines that manufacture foods, vitamins, and essential materials for sustaining life. They are the Creator's provision for recycling valuable nutrients and making useful products for man. The news media publishes many articles about microbes that cause disease, but only a few discuss their usefulness. Many students have the impression that microbes are harmful and fear their hands-on study. We call this attitude microbe-phobia, or a fear of microbes. In reality, only about five percent of all bacteria are pathogenic. Most bacteria are beneficial and some are even essential for human life. Many microbiologists maintain that bacteria and other microbes have been maligned in the news

media. Bacteria make products that are used every day; many foods, like yogurt, are created by microbe action. Barely a day goes by without using some of these products.

Without our intestinal flora, we would not survive very well. In fact, if intestinal microbes are not present early in our lives, the surface of the intestine does not develop normally. The surface would remain smooth rather than developing the carpet of projections called microvilli. We would have to adjust to living with a vastly reduced ability to absorb water and nutrients. Enteric bacteria supply our bodies with vitamin K, vitamin B12, thiamin, and riboflavin, which we need for normal body functioning. These intestinal microflora bacteria also stimulate lymph node-like structures, called Peyer's patches, which contain lymphatic tissue and provide the intestines with protection, even helping to prevent colon cancer. They maintain an intensely competitive and closed community, which makes invasion from pathogens a considerable challenge.

According to Dr. Jay Wile, additional evidence that microbes are not the Creator's mistake comes from a large experiment called "Biosphere 2." A team of scientists tried to design and build a self-contained system (i.e., Biosphere 2) for supporting life. Biosphere 2 was designed to be a microcosm of life on earth, containing a variety of animals and plants; it was to be completely self-supporting. These biologists spent seven years and $200 million designing and building this airtight, enclosed facility that spans 3.15 acres in Arizona. Despite the best that technology and science had to offer, Biosphere 2 could not support life for even two years! After about one year and four months, oxygen levels could not be maintained. They had to start pumping oxygen in from the outside. Many of the animal species that had been put in Biosphere 2 became extinct, while the populations of others boomed. In the end, Biosphere 2 was a failure. At least part of the reason behind this failure is that the scientists who designed Biosphere 2 did not take into account the incredibly essential role that bacteria and other microbes play in creation. Since these microorganisms were not present in the right amounts, Biosphere 2 could not sustain itself.

This outcome was not a surprise to microbiologists. The planet earth is an intricate web of hundreds of millions of processes that work together to support life. The best design, talent, and technology that humans have could never possibly mimic what the earth does naturally. Why? The answer is very simple. An awesome Creator and Sustainer of life designed the earth. He could foresee all of life's needs, even the tiny bacteria needed to support it. Limited human beings, on the other hand, just do not have the ability to design and create what God has designed and created, even on a very small scale. Biosphere 2 was a failure, and it stands in stark contrast to the grandeur and elegance of God's creation. So, in fact, microbes are not a mistake, they are made by design!

Magnificent Microbes

Bacteria have been receiving bad press since they were first discovered. People suspected the organisms that were so small must be doing something "bad." Many felt all these bacteria were "germs." The news that they caused disease was more than enough to keep the bad image going. The response of many people was "to kill all of the bacteria." Little did people know until later that destroying all the bacteria in our body could actually kill us. Humans are dependent upon bacteria for life, such as the Escherichia coli that help digest our food.

For many years, beneficial aspects of bacteria were either not known or not widely publicized. Today, we do know the beneficial aspects of bacteria. Bacteria are used to make and add flavor to dairy products, such as buttermilk, butter, and curds that are necessary to make cheese. Yogurt, a very popular health food today, is made as a result of adding Lactobacilli to spoiled milk. Other non-dairy products made with the help of bacteria are vinegar, linen, rope, and antibiotics.

Another beneficial aspect of bacteria is that they have the ability to break down plants, animals, and other matter in nature. If bacteria did not recycle nutrients, there would be dead bodies of plants and animals lying around for hundreds of years. What a great stench that would be! Bacteria not only break down bodies, but also help to recycle such important elements as carbon, nitrogen, oxygen, and hydrogen through the biological community. Bacteria are necessary for balance in the ecosystem.

Industrially, bacteria are used in sewage treatment. In large tanks open to air, several kinds of aerobic bacteria break down the sewage. Also, bacteria are used in commercial production of amino acids. One of the important promises for use of bacteria is in the area of genetics. Using techniques that recombine DNA from different sources, bacteria have produced a variety of compounds

such as insulin, human growth hormone, and vaccines against foot and mouth disease. What would the world be without bacteria?

Having a Recent Past

Any meaningful discussion of creation and evolution must include microbes. According to Darwinists, life started with microbes, and such unicellular organisms had the planet to themselves for about 80 percent of the time that life has existed on earth. Of course, evolutionists do not know the nature or location of the "primordial ooze" (or what Charles Darwin called a "warm little pond") where life began, but they think that microbes were the first cellular life forms to arise and thrive. Being so "ancient," microbes are said to have had a very long time to evolve and to develop the basic metabolic mechanisms that made all other life possible. The just-so story of evolution tells us that microbes have come to occupy a great variety of ecological niches, including some that seem improbable from a human point of view. Microbes grow in the frozen tundra, in waters whose temperature is over the boiling point (at high pressure), in strong acid and alkali, and in concentrated brine.

The microbial fossil record is scant, but together with genomic information, evolutionists tell us that microbes diversified early on into a great variety of shapes and lifestyles. Prokaryotes were supposedly alone on earth for some two billion years (according to evolutionists, about half the time there has been life on earth), after which eukaryotic microbes arose. According to Darwinists, multicellular organisms did not arise until some 750 million years ago. Prokaryotes are the so-called ancestors of all other life forms. All eukaryotes, from simple yeasts and algae to humans, arose from prokaryotic progenitors.

So, where do microbes fit into the creation account? Were they created along with the rest of the plants and animals in the first week of Creation, or were they created later after the Fall and are a result of the "Curse"? The Bible says, "And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so. And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good" (Gen. 1:11–12). The word "plant" was used to describe microbes until the mid-1800s.

Focus1.1

Pasteur and The Origin of Microbes

The Theory of Biogenesis vs. Spontaneous Generation

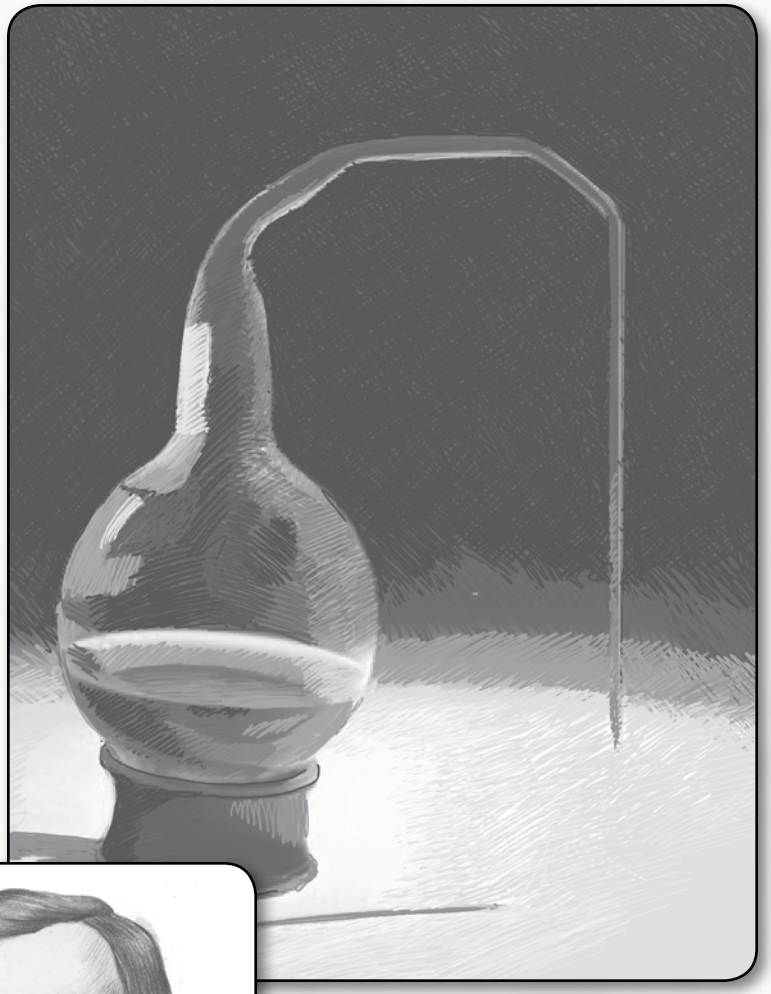
The discovery of microorganisms raised an intriguing question: "Where did these microscopic forms originate?" For thousands of years, the idea of spontaneous generation suggested that organisms, such as tiny worms, could arise spontaneously from non-living material. This idea began to fall into disfavor after the findings of Francesco Redi. By a simple experiment, he demonstrated conclusively that worms found on rotting meat originated from the eggs of flies, not directly from the decaying meat as proponents of spontaneous generation believed. To prove this, he simply covered the meat with gauze fine enough to prevent flies from depositing their eggs. No worms appeared. Despite Redi's findings, the idea of spontaneous generation was difficult to disprove, and it took about 200 years more to refute this idea. Because the gauze used by Redi could not prevent the development of microorganisms, new experiments were needed to refute the theory.

The traditional experiment designed to determine whether microbes could spring from non-living material consisted of boiling organic material in a vessel to sterilize and then sealing the vessel to prevent any air from entering. If the solution became cloudy after standing, then one could conclude that microbes must have arisen from the organic material in the vessel, thus supporting the theory of spontaneous generation. Unfortunately, this experiment did not consider several alternative possibilities: that the flask might be improperly sealed, that microorganisms might be present in the air, or that boiling might not kill all forms of life. Therefore, it was not surprising that different investigators obtained different results when they performed this experiment.

Experiments of Pasteur and Biogenesis

One creation biologist who did much to disprove the theory of spontaneous generation was the French chemist Louis Pasteur, considered by many to be the

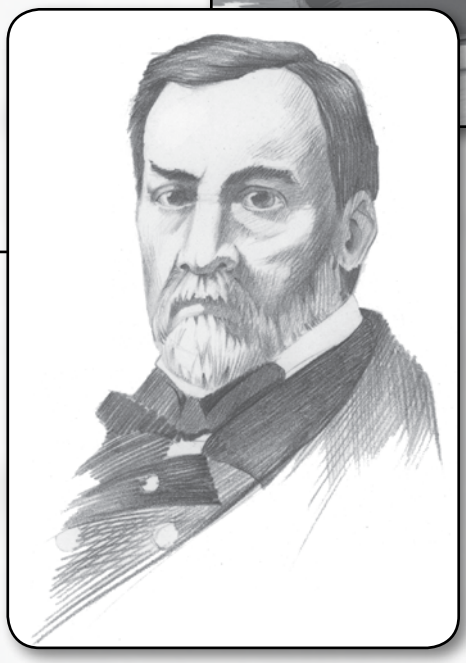
father of modern microbiology. In 1861, Pasteur published a refutation of spontaneous generation that was a masterpiece of logic. First, he demonstrated that air is filled with microorganisms. He did this by filtering air through a cotton plug, trapping organisms that he then examined with a microscope. Many of these trapped organisms looked identical microscopically to those that had previously been observed by others in many infusions. Infusions are liquids that contain nutrients in which microorganisms can grow. Pasteur further showed that if the cotton plug was then dropped into a sterilized infusion, it became cloudy because the organisms quickly multiplied. Most notably, Pasteur's experiment demonstrated that sterile infusions would remain sterile in specially constructed flasks, even when they were left open to the air. Organisms from the air settled in the bends and sides of these swan-necked flasks, never reaching the fluid in the bottom of the flask. Only when the flasks were tipped would bacteria be able to enter the broth and grow. These simple and elegant experiments ended the arguments that unheated air or the infusions themselves contained a "vital force" necessary for spontaneous generation.



Pasteur's experiments on spontaneous generation

Biogenesis

The theory of biogenesis states that life can come only from other life. This idea sounds a lot like Genesis 1 principles: life begets life and like begets like. Yet, evolutionists imagine that at one time, life did spontaneously appear. It is a well-known fact that Louis Pasteur opposed the doctrine of spontaneous generation, and he brought telling evidence against it. Pasteur believed that the idea of spontaneous generation did not fit with the view of God as Creator of life. He suggested that to get new life, some kind of preexisting created life must be present. Read the translation of Pasteur's own words on this point:



Louis Pasteur

> This is why the problem of spontaneous generation is all-absorbing, and all-important. It is the very problem of life and of its origin. To bring about spontaneous generation would be to create a germ. It would be creating life; it would be to solve the problem of its origin. It would mean to go from matter to life through conditions of environment and of matter. God as Author of Life would then no longer be needed. Matter would replace Him. God would need to be invoked only as Author of the motions of the universe.

While giving a speech about his now famous experiment demonstrating that bacteria do not arise spontaneously in sterile culture bottles, Pasteur said, "Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment!"

Pasteur not only refuted the idea that we can get something from nothing, but also proved that it must come from other life, or the Author of Life. This soon led to an understanding of both disease prevention (via

aseptic techniques) and the germ theory of disease. Pasteur clearly demonstrated that infectious disease does not spontaneously appear as "miasmas," but rather was the outcome of germs causing disease. Later, Joseph Lister, Christian physician and creationist, developed the idea of using aseptic techniques in surgery. The idea of biogenesis was antecedent to asepsis, the germ theory of disease. Creation thinking, because it embraces truth (and God's blessing), frequently leads to practical applications, including in the world of medicine.

Magnificent and Miraculous Microbes

There are many extraordinary examples of design in the microbial world. In this chapter, two examples are given: the bacterial flagella and the production of a blood red pigment in Serratia marcescens. The molecular machinery of the bacterial flagella is magnificent. The amazing ability for Serratia marcescens, a rod-shaped bacterium, to produce a pigment that resembles blood is "miraculous."

Bacterial Flagella – Icon of the Intelligent Design Movement

We begin with Michael Behe who made the bacterial flagellum a popular argument for intelligent design in Darwin's Black Box, using them to illustrate the concept of irreducible complexity. The flagellum is a corkscrew-shaped, hair-like appendage attached to the cell surface acting like a propeller, allowing the bacterium to swim.

The bacterial flagellum is an irreducibly complex process. An irreducibly complex system is one that requires several interlacing parts to be present at the same time, where the removal of one or more parts causes the whole system to malfunction. Destroy one part and the whole system falls apart. The purported mechanism of evolution, on the other hand, is that a new trait will confer a selective survival advantage, and thus enable its possessors to compete better than organisms without the trait. In neo-Darwinian evolution, a new trait would have to be completely developed — no halfway measures would do. Given this requirement, new features are so complex that neo-Darwinian gradualism is very improbable because an incompletely developed trait would offer no selective advantage.

The Mousetrap Example

Dr. Michael J. Behe, biochemistry professor and author of the 1996 blockbuster book Darwin's Black Box, has challenged the classical neo-Darwinian explanation that intricate cell structures arose by chance. In the book, he uses the flagellum to introduce the concept of "irreducible complexity." If a structure is so complex that all its parts must initially be present in a suitably functioning manner, it is said to be irreducibly complex. All the parts of a bacterial flagellum must be present from the start in order to function at all. According to Darwinian theory, any component that doesn't offer an advantage to an organism (i.e., doesn't function) will be lost or discarded. How such a structure could have evolved in a gradual, step-by-step process as required by classical Darwinian evolution is an insurmountable obstacle to evolutionists. How a flagellum is used, however, adds an additional level of complexity to the picture.

Some bacteria have a single flagellum located at the end of a rod-shaped cell. To move in an opposite direction, a bacterium simply changes the direction the flagellum rotates. Other bacteria have a flagellum at both ends of the cell, using one for going in one direction and the other for going in the opposite direction. A third group of bacteria has many flagella surrounding the cell. They wrap themselves together in a helical bundle at one end of the cell and rotate in unison to move the cell in one direction. To change direction, the flagella unwrap, move to the opposite end of the cell, reform the bundle, and again rotate in a coordinated fashion. The structural complexity and finely tuned coordination of flagella attests to the work of a Master Engineer who designed and created flagella to function in a wonderfully intricate manner.

You might call it the Maker's molecular outboard motor. Its most interesting aspect is that it is attached to and rotated by a tiny, electrical "motor" made of different kinds of protein. Like an electrical motor, the flagellum contains a rod (drive shaft), a hook (universal joint), L- and P-rings (bushings/bearings), S- and M-rings (rotor), and a C-ring and stud (stator). The flagellar filament (propeller) is attached to the flagellar motor via the hook. To function completely, the flagellum requires over 40 different proteins. The electrical power driving the motor is supplied by the voltage difference developed across the cell membrane. This motor is one of the nature's best molecular machines!

Some scientists have called bacterial flagella the "most efficient machine in the universe" with its self assembly and repair, water-cooled rotary engine, proton motive-force drive system, forward and reverse gears, operating speeds of 6,000 to 17,000 rpm, direction-reversing capability, and hard-wired signal-transduction system with short-term memory.

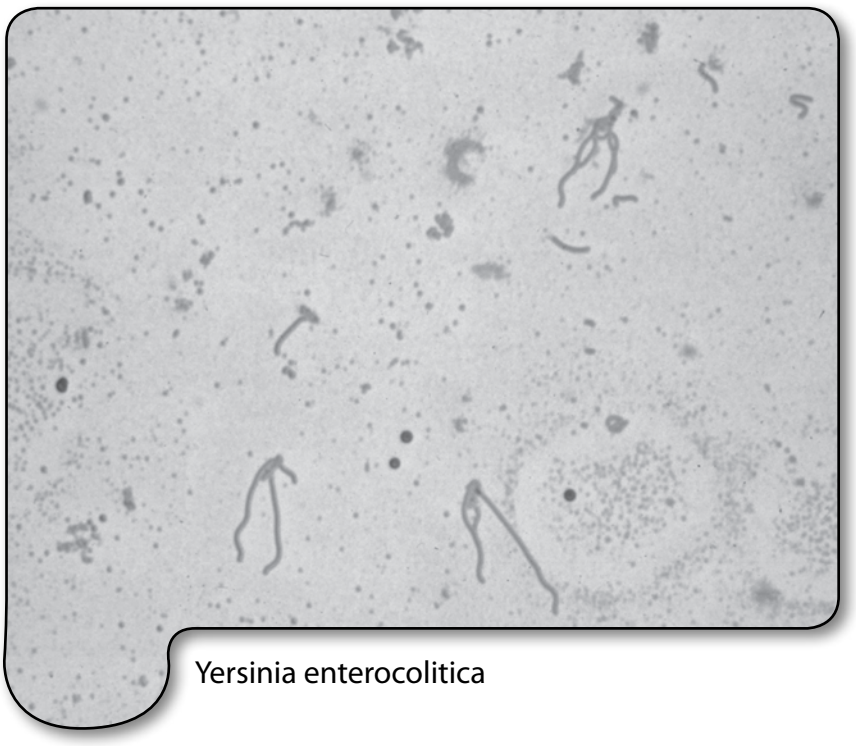
Bacterial Flagellum: Paradigm for Design in Yersinia, Example 1

After Michael Behe made the bacterial flagellum a popular argument for intelligent design in Darwin's Black Box, Scott Minnich joined the ranks of the intelligent design movement. Dr. Minnich, a geneticist and associate professor of microbiology at the University of Idaho, takes the argument to the next level by describing how this design paradigm led to new insights in his research. Minnich has been studying bacterial flagella for over 15 years and has published work in the following areas: the structure and function of flagella in Yersinia and Salmonella species; assembly blueprints and genetic instructions; detail descriptions of the transcriptional and translational regulator genes; and integrating motility with signal transduction (chemotaxis).

In extensive research, Scott Minnich has discovered that bacterial flagella provide a paradigm for design. Minnich has been working with the genetics and flagella structure of Yersinia enterocolitica (cousin of Yersinia pestis, pathogen of bubonic plague) for more than a decade. Y. enterocolitica, a cause of food-borne infection (like E. coli or Campylobacter) is commonly found in the intestines of livestock. It causes food infections due to contaminated meat and dairy products. It causes enteric fever and may produce severe, life-threatening infections.

After describing over 30 individual proteins that make up its rotary-motor mechanism (close to 50 in the entire flagellum), Minnich noticed that the basal body of the flagellum produced a toxic secretion when the bacterium was under stress. If Yersinia was kept "happy" at 20°C (68°F) and in good environmental conditions (i.e., low osmotic saline), the basal body produced a hook and filament — the remaining portions of the flagellum. Minnich had predicted from his genetic studies that a good design would be used for diverse purposes, like engineer-designed structures that serve dual functions. It is good genetic efficiency or optimal genetic design (minimum cost/benefit ratio). Even before observing this in humans, he predicted what would happen.

Yersinia was quite motile in its environment and could propel its rotary motor at up to 100 rpm. On the other hand, if Yersinia were incubated at 37°C (98.6°F) (or another stressful environment like high salt), the basal body acted as a "cannon," producing a harsh toxin. (Its technical name is a Type III secretion system. It is described in more detail in chapter 9, "The Origin of Infectious Disease"). In observing cells from the gastrointestinal tract, it was observed to avoid engulfment by macrophages. In its own defense, Yersinia produced a missile to avoid being eaten by human body defenses. The utility of a design model (instead of a Darwinian one) not only produced good science, but also has practical implications for medical microbiology and clinical medicine. Here we see evidence that design models accurately predict biological outcomes. Thinking God's thoughts after Him and openness to the idea that the Creator has made biological structures with purpose is the key to success in biological study. Evidence, not evolution. Creation, not chance. Design theory works. The bacterial flagellum is truly one of Providence's prokaryotic wonders!



Yersinia enterocolitica

Biological Rotary Motor

The sensory and motor mechanism of the E. coli bacterium consists of a number of receptors, which initially detect the concentrations of a variety of chemicals. Secondary components extract information from these sensors that in turn is used as input to a gradient sensing mechanism. The output of this mechanism is used to drive a set of constant torque proton-powered reversible rotary motors, which transfer their energy through a microscopic drive train and propel helical flagella from 30,000 to 100,000 rpm. This highly integrated system allows the bacterium to migrate at the rate of approximately ten body lengths per second.

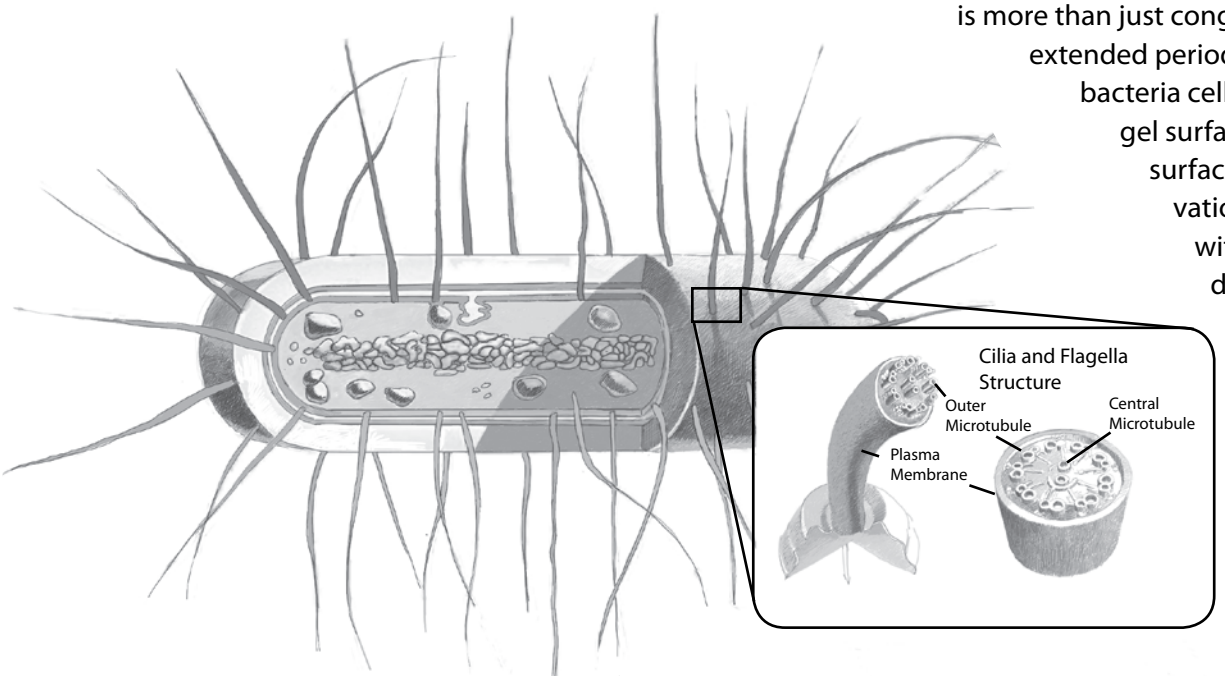
How fast do bacteria move with their flagella? Some have been "clocked" at up to 100 µm per second, or the equivalent of 50 body lengths per second. By comparison, bacteria move twice as fast as the cheetah, the fastest known animal. Cheetahs, which run up to 70 mph, go a mere 25 body lengths per second. Generally, bacteria with polar flagella move faster than those with peritrichous (many) flagella.

The complexity of the bacterial flagellum is direct evidence against neo-Darwinian evolution. All the interwoven parts of the body point to an intelligent Creator. In the early 1990s, Dr. Michael Behe argued for the intelligent design of the human body. His argument is called the principle of irreducible complexity. To illustrate the complex nature of this principle, one needs to look at the design in driving.

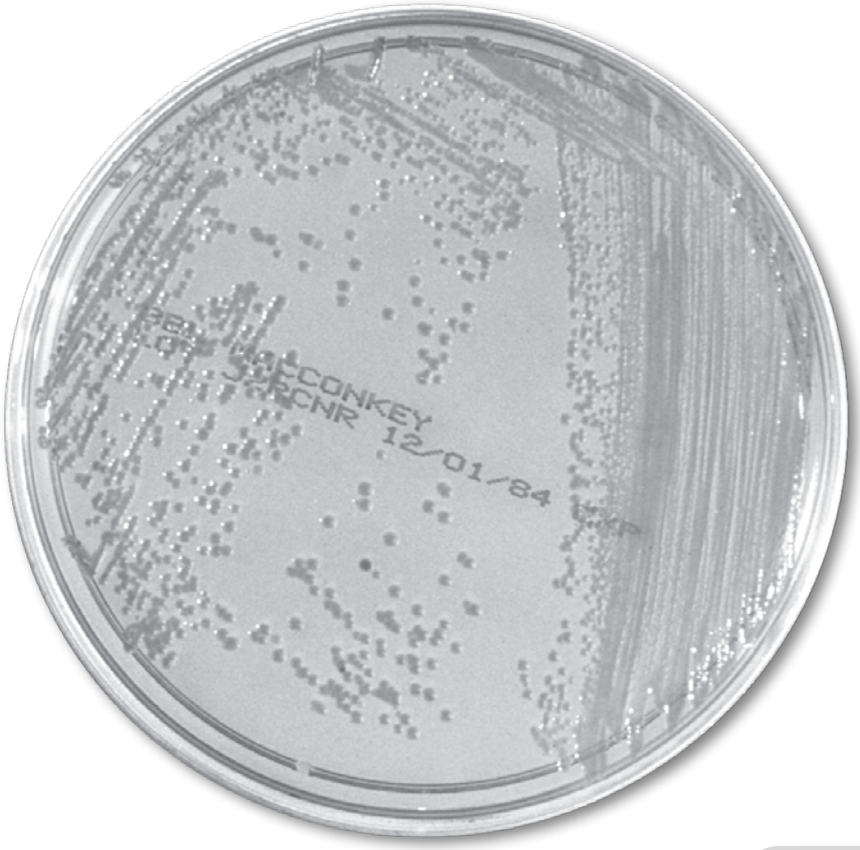
Driving by Design – E. coli Swimming Lessons

Microbiology is fun to study because the behavior of E. coli is increasingly being shown to be complex. Recent observation takes the argument of microbes by design to the next level by describing how new research has provided insight into how E. coli "drive" more orderly than some people. Harvard researchers have recently discovered that E. coli swim on the right side. The motion of E. coli is not random; it is directed, ordered, and reminds one of car traffic patterns (or even ant traffic patterns). When cells are confined to microchannels with soft agar floors made of hydrogels, they preferentially swim on the right hand side and closer to the floor of the gels. Bacteria are known to have clockwise, circular trajectories along surfaces; yet in free solution, they swim in random walk trajectories. All of these features seem to shout "design"!

In human terms, driving properly to avoid accidents takes driver's education school, intelligence, and practice. It is certainly not by random chance, nor accidental. This recent article shows E. coli driving on the right side, meaning that when placed in narrow forked tubes, they are more likely to swim up the right-hand fork, due to the anticlockwise direction in which the flagella rotate. This is more than just "fascinating fact" information; it may have clinical implications for urinary tract infections. E. coli can also cooperatively move over surfaces, called swimming. It is more than just congregating. During extended periods of migration, bacteria cells move better on gel surfaces than a solid surface. This observation, combined with the ability of directed traffic, may allow new explorations of behavior studies of factors that contribute to bacterial pathogenicity.



The sensory and motor mechanism of the E. coli illustration



Serratia marcesens, the "miracle" bacillus

Microbes by Design, Example 2, Serratia marcesens – the Miracle Bacillus

Another example of design which can be seen in the microbial world is the production of a blood-red pigment made by Serratia marcescens, the "miracle" bacillus. Serratia marcescens is a rod-shaped, facultative anaerobic bacterium. It is a Gram-negative bacillus in the family Enterobacteraciae. This common microbe is found on plants and in soil, water, and animals. Most microbiologists are all too familiar with S. marcescens, one of the most frequent contaminants of Petri plates in the lab. This brightly colored bacterium also grows well on food that has been stored in a damp place.

The pigment production by microbes can impart color to contaminated food. S. marcescens has a long history in the church, as well as in microbiology. S. marcescens has a fondness for growth on starchy foodstuffs (e.g., bread and communion wafers), where the pigmented colonies have been mistaken for drops of blood. Indeed, in numerous historical incidents, the red pigment produced by Serratia marcesens growing in bread has been interpreted as a sign of blood.

Historical Focus 1.2

The "Blood of Christ" and the History of a Red Mystery

The history of Serratia goes back to the 6th century B.C., when Pythagoras reported on the blood substance that sometimes appeared on food. Then, in 332 B.C., soldiers of the Macedonian army of Alexander the Great, found that from time to time, their bread appeared to have blood on it. The Macedonian soldiers interpreted these bizarre phenomena as evidence that blood would soon flow in the city of Tyre and that Alexander would win. Later in the Christian tradition, since the time of the Middle Ages through the Renaissance periods, it was regularly observed to grow on communion wafers. This led many to think this was the blood of Christ, hence a miracle. For example, in the dark, damp churches of medieval times, sacramental wafers used in Holy Communion often became contaminated with S. marcescens.

On more than one substance, the "blood" on it was thought to be a miracle. One such event inspired the artist Raphael to paint his awe-inspiring masterpiece, the Mass of Bolsena. In 1263, four hundred years before Anton van Leeuwenhoek would observe bacteria under a microscope, a blood-like substance appeared on the communion bread.

The German priest Peter of Prague is shown breaking bread for communion at the Church of Saint Christina in Bolsena, Italy. When the famous priest broke the communion wafer, he thought that it had blood on it and that the bread had truly become Jesus' flesh!

In 1264, to honor of the miracle of Bolsena, Pope Urban instituted the feast of Corpus Christi ("Body of

Christ"). Neither the pope nor Peter the priest could ever have known that a red bacterium, Serratia marcesens, was the probable cause of this blood-like substance on the communion bread.

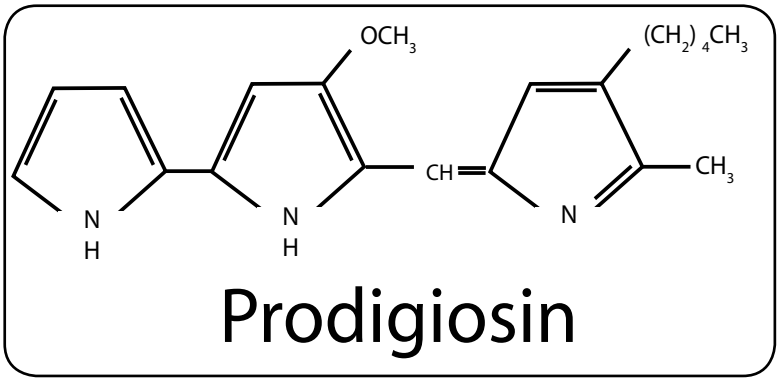
An important stimulus to the early development of microbiology came with attempts to discredit an infamous, alleged miracle. Bartholomeo Bizio, an Italian pharmacist from Padua, Italy, discovered and named S. marcescens when he identified the bacterium as the cause of a miraculous bloody discoloration in a cornmeal mush called polenta. He looked at the red spots under a microscope and saw what he described as a fungus. (Terms like fungus and virus were often used in the early microbiological literature to describe what we now classify as bacteria.) In 1817, he moistened some bread and polenta and left them in a warm, damp atmosphere. Twenty-four hours later, both the bread and polenta were covered in red growth. In 1819, Bizio named Serratia in honor of an Italian physicist named Serrati, who invented the steamboat. Bizio chose marcescens from the Latin word for decaying because the bloody pigment was found to deteriorate quickly. By 1823, he named the organism Serratia marcescens.

The Prussian microscopist Christian Gottfried Ehrenberg (1795–1876) also showed an interest in the red spots found on "bloody bread," and in 1848 he inoculated them onto potatoes, bread, and Swiss cheese kept in metal vessels, the atmosphere of which was kept moist with damp paper. In so doing he may have been the first person to cultivate bacteria. Ehrenberg is also likely to have been the first to use the term bacteria (meaning little rods). In 1836 he had described "infusoria" and named a number of bacteria, including Bacterium and Spirillum.

Irreducible Complexity of Prodigiosin Production

Serratia is most noted for its bright red pigment called prodigiosin. Over the years, it has certainly gotten the attention of churchgoers and scientists alike. It also is one of the few bacteria that produces bright pigments, and it comes in a variety of colors, including red, white, pink, and purple. Its color variation was noted as early as 1888. The first person to describe the biosynthesis of this pigment in the late 1940s was Dr. Robert P. Williams, a Christian microbiologist. His interests in Serratia were many, including what controlled the expression of the red phenotype in S. marcescens. Pigment production in Serratia is influenced by several variables, including temperature, nutrient media, and exposure to ultraviolet (UV) light.

Some strains of S. marcescens are capable of producing prodigiosin, which ranges in color from dark red to pale pink, depending on the temperature, substrate, and age of the colonies. Most strains of S. marcescens are red under 27°C (80.6°F) and white above 28°C (82.4°F). (Pigment and flagella production stops at approximately



Chemical structures of prodigiosin

28°C.) The synthesis of prodigiosin is an irreducibly complex process. An irreducibly complex system is one that requires several interlacing parts to be present at the same time, where the removal of one or more parts causes the whole system to malfunction. Destroy one part and the whole system falls apart. In evolution, a new trait would have to be completely developed, no halfway measures would do. Given this requirement, new features are so complex that Darwinian gradualism is very improbable because an incompletely developed trait would offer no selective advantage.

Prodigiosin, a linear tripyrrole, is synthesized in a bifurcated pathway, in which mono- and bipyrrole precursors are synthesized separately and then couple to form the red pigment (above). (There are parallels in the way blood clots form — think of dominos in a Y formation — one falling upon and after another.) Prodigiosin is a secondary metabolite, which is constructed from several amino acids that may accumulate in the cell as a result of primary metabolism. The terminal stop in prodigiosin biosynthesis is by the condensing of the mono- and bipyrrole components and is temperature sensitive. Proline is incorporated intact in the prodigiosin molecule,

histidine is used indirectly, methionine contributes a methyl group, and alanine is entirely incorporated except for a carboxyl group.

Prodigiosin Pigment Offers Protection

The functions of pigment have long been pondered, but only recently determined. Many texts say that there is no known function for prodigiosin. In the past, ideas range from prodigiosin associated with flagellar production to the enhancement of the aerosolization of S. marcescens, and the formation of prodigiosin allows the cell to remove toxic accumulation of metabolites such as amino acids. It appears that prodigiosin offers protection for Serratia in the natural environment. The red pigment offers protection against excessive UV in sunlight and serves as an antibiotic and has cytotoxic qualities. It appears that it is worth the energy investment to synthesize prodigiosin when it serves protection against UV light and when it has to compete with fungi in the soil and uses its red pigment as an antibiotic against neighboring molds.

Disease Focus 1.3

Serratia is an Opportunistic Pathogen

Only since the 1960s have microbiologists recognized S. marcescens as an opportunistic human pathogen. In the hospital, Serratia tends to colonize the respiratory and urinary tracts of adults, rather than the gastrointestinal tract. Serratia causes about two percent of nosocomial infections of the bloodstream, lower respiratory tract, urinary tract, surgical wounds, and skin and soft tissues of adult patients. Outbreaks of S. marcescens meningitis, wound infections, and arthritis have occurred in pediatric wards. In most cases, Serratia infections have occurred in people who have compromised immune systems or those who are aged.

The Creator's Signature, "Red-Lettered" Bacteria

So maybe S. marcescens was not the miracle that the pope expected, but this tiny organism does remind us of the wondrous invisible life that is all around. The pigment from Serratia may not be the blood of Christ, but it does in fact have a brilliant, blood-red color that attracts attention, and its natural production of variable bright colors testifies of the Creator's artistic abilities. When viewed in the Petri dish, or up close, it is a highly attractive microbe. Finally, ability of the bacterium to produce the pigment and adapt under varying environmental conditions suggests the Sustainer's foreknowledge of S. marcescens' need to survive.

The Creator formulated not only the plan for S. marcescens, but also produced the first working organisms. He is not only the Chief Architect of the red pigment, but is also the manufacturer of the prodigiosin components. He keeps everything going because He is the Maintainer. The predictable color of the prodigiosin at lower temperatures exists because the order of the precise plan was produced by an intelligent cause. These finely tuned and interdependent interactions are examples of what biochemist Behe calls irreducible complexity. It cannot be explained by Darwinian evolution. Most creation biologists would go a step further and say that it is clear, physical evidence of fingerprints from the Master's hand. Although an alleged miracle of communion, the blood of Christ may not have appeared as the church once declared; however, Serratia is still the miracle bacillus. The "miracle" is that an awesome artist would care enough to sustain and protect even His tiniest creations. He has left His signature on it — one of red-lettered importance.

Is Antibiotic Resistance Proof of Evolution?

Antibiotic resistance is one of the most important topics that a beginning biology student going into medicine should learn and understand. Antibiotic resistance is one of the so-called facts of "evolution." In this section, we will see that it is indeed a "fact" of change, but not one of real evolution (i.e., neo-Darwinian evolution). Antibiotic resistance has become one of the most serious problems to confront modern scientists. The first known antibiotics were produced by fungi, notably those from the mold Penicillium chrysogenum (see chapter 5 on fungi). An antibiotic is a substance produced by a microbe that, in small amounts, inhibits another microbe. However, today most antibiotics are produced by bacteria (esp. Streptomyces), not molds. Antibiotics have become the miracle drugs of the 20th century and have