Darwin's Response to His Critics
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by

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Life of Darwin and History of *The Origin of Species*

Charles Robert Darwin was born in Shrewsbury, England, on February 12, 1809, the same day Abraham Lincoln was born in a one-room log cabin in LaRue County, Kentucky. Darwin's father Robert had a large medical practice and his grandfather Erasmus was a physician who was known for his book *Zoonomia, or the Laws of Organic Life*.

In 1825, when Darwin was 16, his father sent him to the University of Edinburgh to study medicine. However, Darwin showed a lack of enthusiasm for medicine and in 1827 his father decided to send him to study divinity at the University of Cambridge. Unfortunately, his academic record there was also less than stellar. In 1831, after graduating from Cambridge, Darwin went on a three-week geological expedition to North Wales under the leadership of the famous geologist Adam Sedgwick. Darwin had been recommended for the expedition by John Stevens Henslow, a minister and botanist at Cambridge.

In August 1831, also upon the recommendation of Henslow, Darwin was invited to join the voyage of the *HMS Beagle*. The ship was to survey the east and west coasts of South America and then continue to the Pacific islands to establish a chain of chronometric stations,

which were used for determining longitude. The ship already had a naturalist-surgeon as part of its crew but the captain, Robert FitzRoy, found Darwin to be a more pleasant conversationalist and so agreed to take Darwin on as an unpaid naturalist. On December 27, 1831, the *Beagle* set sail from Plymouth, England. The voyage was originally intended to last two years but instead lasted five. Darwin was seasick during much of the voyage but still managed to record detailed observations of many species and geological formations. In 1836 the *Beagle* returned to England.

After returning to England, Darwin was supported by his father and continued to collect facts about many species through extensive reading and through conversations and correspondence with other naturalists and with breeders and gardeners. The scientific community in London also helped him better understand the specimens that had been collected during the voyage of the *Beagle*. After marrying his first cousin Emma Wedgwood on January 29, 1839, Darwin was supported by his wife's wealth and was able to continue his career as an independent naturalist until the day he died.

Darwin was very impressed with the production of new varieties by man through "the long-continued selection of the best individuals in successive generations" (p. 233), and began theorizing about a similar process in nature, which he called "natural selection". (All citations are to Charles Darwin, *The Origin of Species* (New York: NAL Penguin Inc., 1958).) In 1842, six years after having returned from his voyage, Darwin prepared a short sketch of his theory. In 1844 he prepared a longer version and showed it to his friend Joseph Dalton Hooker, a botanist. However, Darwin then spent the next decade working on a treatise on barnacles. In 1856 he decided to return to the development of his theory and began writing a fuller exposition of it.

On June 18, 1858, Darwin received a paper from Alfred Russel Wallace, a naturalist who was working in the Malay archipelago. The paper set forth the same theory of natural selection that Darwin had been working on for 20 years. Darwin was greatly disappointed because it appeared his life's work had been pre-empted by someone else. However, his friends Joseph Hooker, Charles Lyell, and T.H. Huxley arranged for papers by Darwin and Wallace to be presented at the Linnean Society of London on July 1, 1858, two weeks after Darwin had received Wallace's paper. The papers by Darwin and Wallace set forth their theory of natural selection. (However, by 1869 Wallace had abandoned his theory of natural selection and subscribed to a theory of design.)

After Darwin's paper was presented at the Linnean Society, Darwin began in earnest an abstract of the longer manuscript he had begun in 1856. This so-called "abstract" became the book *On the Origin of Species by Means of Natural Selection, or The Preservation of Favoured Races in the Struggle for Life*, which is referred to hereafter simply as *The Origin of Species*. The book was published on November 24, 1859. In the following years Darwin published revisions of the book and the last edition, the sixth edition, was published in 1872.

Darwin died ten years later, on April 19, 1882, at his home in Downe, England.

Darwin's Theory

Although today Darwin's theory is commonly called the theory of evolution, he rarely referred to it as that. To distinguish his theory from some general notion of evolution, Darwin usually referred to his theory as the theory of "descent with modification".

Under Darwin's theory, "animals are descended from at most only four or five progenitors, and plants from an equal or lesser number." (p. 446) However, he also suggested the possibility that "all the organic beings which have ever lived on this earth may be descended

from some one primordial form." (p. 446) With respect to the origin of these first forms, or the first form, Darwin believed that "life, with its several powers," was "originally breathed by the Creator into a few forms or into one …." (p. 450) Darwin presumably believed these original forms of life constituted species. For Darwin, a new species was a "well-marked and permanent" variety of an existing species. (p. 438)

Having presented his general theory that every organism now on earth descended from an originally created species, Darwin had to explain how this descent took place. To do this, he first had to account for the origin of new features in organisms. Darwin theorized that, after the first species were created, some organisms experienced inheritable modifications, which he generally referred to as "variations". Darwin believed that variations could arise from "the direct definite action of changed conditions of life" (p. 195), from laws of growth when one part is modified, including "many mysterious cases of correlation" (p. 195), from the use or disuse of a feature, or from habit, e.g., the "inherited effects of compulsory training" in the case of dogs (p. 233). He also believed there were variations with unknown causes, which he sometimes referred to as "spontaneous variations". (p. 195)

Darwin also had to account for the origin of very complex features. Darwin contended that "[a] great amount of variability … will evidently be favourable" (p. 104) and believed that over time one favorable variation could be improved by another favorable variation and so on, until, after "numerous, successive, slight modifications", a complex organ such as an eye or a lung might be produced. (pp. 249-250)

In order to explain why there are now millions of species instead of, at most, 8 to 10 (the number of originally created species), Darwin theorized that a subgroup of a species could become isolated from the other members of the species and then develop new features of its own.

Eventually, the subgroup would become significantly different and would constitute a new species (a "well-marked and permanent" variety under Darwin's definition).

Having accounted for the origin of new features, the origin of complex features, and the origin of new species, Darwin finally had to account for the absence of transitional forms in the world around us. This is where his theory of natural selection comes into play. Darwin theorized that when one member of a group has a favorable variation, that variation gives it a competitive advantage in the "struggle for existence" over other members of the group, and over time members without that variation become extinct. Thus, there are distinct gaps between the species rather than "an inextricable chaos of varying and intermediate links" (p. 162).

Darwin called this process "natural selection". However, this type of selection is different from the type of selection involved in breeding performed by man, i.e., "domestic selection". In the case of domestic selection, man is selecting "the best individuals in successive generations" (p. 233) and crossing them with other individuals of the same species with favorable traits. In the case of natural selection, what is occurring is extinction, the extinction of the less fit. Thus, it would be more appropriate to refer to natural selection as natural extinction. Darwin states that "natural selection acts by life and death,--by the survival of the fittest, and by the destruction of the less well-fitted individuals" (p. 181) and thus "extinction and natural selection go hand in hand." (p. 159) It is clear that natural selection, i.e., natural extinction, results in the *disappearance* of features in a species, *not* in the appearance of new features.

Thus, Darwin's theory consists of four parts: (1) an explanation of how new features arise; (2) an explanation of how complex features arise; (3) an explanation of why there are now millions of species; and (4) an explanation of why we do not see innumerable transitional forms in the world around us.

General Response to Darwin's Theory by Scientists of His Day

Many of the most eminent naturalists of Darwin's time strongly opposed his theory. Among these were:

1. Louis Agassiz, a world-renowned professor of geology and biology at Harvard University known as "the father of the American scientific tradition";
2. St. George Mivart, an English biologist who published *On the Genesis of Species* in 1871;
3. François-Jules Pictet, a Swiss zoologist and paleontologist who was professor of zoology and comparative anatomy at the University of Geneva;
4. Adam Sedgwick, a professor of geology and paleontology at Cambridge University and one of Britain's most distinguished geologists; and
5. Karl Nageli, a Swiss professor of botany at the University of Munich who was famous for his work on plant cells.

All five of these eminent scientists subscribed to the theory that the diversity and complexity of life on earth is the product of design. They also all believed that the earth is millions of years old. Thus, they subscribed to the theory of design but were not young-earth creationists.

Because Darwin's ideas were at odds with the general scientific thinking of his time, i.e., design, he took great care to reply to those who objected to his theory. By the time of the sixth edition of *The Origin of Species*, approximately one-third of the book consisted of Darwin's response to his critics.

Objections Raised by Darwin's Critics

In *The Origin of Species* Darwin addressed 37 objections raised by his critics. These objections concerned the following topics:

The Difficulty of Explaining the Origin of Complex Organisms and Organs
- Bats
- Wings
- Eyes
- Lungs
- Electric Organs of Fish

St. George Mivart's Objections
- Giraffes
- Insects That Resemble Various Objects
- Baleen Plates of the Greenland Whale
- The Eyes of the Flat-Fish
- Mammary Glands
- Injection of Milk by a Mother Kangaroo
- Tridactyle Forceps of Star Fish and Sea Urchins
- Avicularia of Polyzoa and Tridactyle Forceps
- The Structure of the Flowers of Orchids
- The Movements of Climbing Plants

The Difficulty of Explaining the Origin of Parts with Little Importance
The Difficulty of Explaining the Origin of Characters with No Importance
The Difficulty of Explaining a Feature of One Species That Is for the Exclusive Good of Another Species
The Difficulty of Explaining the Existence of Similar Organs in Remotely Allied Species
The Difficulty of Explaining the Existence of Different Organs for the Same Function in Closely Allied Species
The Difficulty of Explaining How a New Group Can Live Side-by-Side with Its Parent Species
The Difficulty of Explaining How It Is That Many Parts of an Organism Are Modified at the Same Time
The Difficulty of Explaining the Origin of Complex Instincts
- The Instinct of the European Cuckoo
- The Instinct of Slave-Making Ants
- The Cell-Making Instinct of the Hive-Bee

The Difficulty of Explaining the Coordination of Structure and Instinct
- The Larger Titmouse
- Neuter Ants and Their Different Castes

The Difficulty of Explaining the Inability of a Species to Breed with Another Species
The Absence of Transitional Forms in the World Around Us
The Absence of Transitional Forms in the Fossil Record
The Absence of Transitional Forms Even Within Particular Geological Formations
The Sudden Appearance of New Forms of Life in Certain Geological Formations
The Cambrian Explosion
Insufficient Time for the World's Species to Have Been Produced Through Natural Selection

Darwin's Response to His Critics

Turning now to Darwin's response to his critics, Darwin acknowledged that there were "a crowd of difficulties" with his theory and stated, "Some of them are so serious that to this day I can hardly reflect on them without being in some degree staggered; but, to the best of my judgment, the greater number are only apparent, and those that are real are not, I think, fatal to the theory." (p. 158)

The Difficulty of Explaining the Origin of Complex Organisms and Organs

A major objection to Darwin's theory concerns the difficulty of explaining the origin of complex organisms and organs. Darwin presents the objection as follows: "[I]s it possible that an animal having, for instance, the structure and habits of a bat, could have been formed by the modification of some other animal with widely different habits and structure? Can we believe that natural selection could produce … an organ so wonderful as the eye?" (p. 158) Darwin's basic response is that "in the case of any organ, if we know of a long series of gradations in complexity, each good for its possessor, then, under changing conditions of life, there is no logical impossibility in the acquirement of any conceivable degree of perfection through natural selection." (p. 189) He states that "we must be extremely cautious in concluding that any organ could not have been produced by successive, small, transitional gradations" but he admits that "undoubtedly serious cases of difficulty occur." (p. 174)

Darwin's critics referred to a number of organisms and organs that they felt could not be explained by Darwin's theory. They focused specifically on the orign of bats, wings, eyes, lungs, and the electric organs of fish, and Darwin speculated as to how each might have come into existence under his theory.

Bats

In trying to account for the formation of bats, Darwin first refers to the formation of flying squirrels (which actually glide rather than fly). He states, "I can see no difficulty, more especially under changing conditions of life, in the continued preservation of individuals with fuller and fuller flank-membranes, each modification being useful, each being propagated, until by the accumulated effects of this process of natural selection, a perfect so-called flying squirrel was produced." (p. 164) However, instead of going on to explain how a flying squirrel might then have given rise to a bat, he turns to flying lemurs (Galeopithecus) (which also glide rather than fly).

Darwin states that, although there are now "no graduated links of structure, fitted for gliding through the air," that connect flying lemurs to allied species, there is no difficulty "in supposing that such links formerly existed, and that each was developed in the same manner as with the less perfectly gliding squirrels; each grade of structure having been useful to its possessor." (p. 164) He then states that he cannot see "any insuperable difficulty in further believing that the membrane[-]connected fingers and fore-arm of the Galeopithecus might have been greatly lengthened by natural selection; and this, as far as the organs of flight are concerned, would have converted the animal into a bat." (pp. 164-165) Unfortunately, Darwin does not present any step-by-step procedure as to how the gliding mechanism of the flying lemur might have been converted into the wings of a bat. Moreover, he says he is only theorizing "as far as the organs of flight are concerned". (pp. 164-165) He provides no speculation as to how the three components of a bat's sonar (transmitter, receiver, and signal decoder) might have come into existence.

Wings

With respect to how wings in general first came into existence, Darwin says that "it is conceivable that flying-fish, which now glide far through the air, slightly rising and turning by the aid of their fluttering fins, might have been modified into perfectly winged animals." (p. 165) However, he does not speculate as to the step-by-step process by which this might have taken place.

Darwin notes that Professor Pictet "in commenting on early transitional forms, and taking birds as an illustration, cannot see how the successive modifications of the anterior limbs of a supposed prototype could possibly have been of any advantage." (p. 306) However, Darwin responds by pointing out that the penguins of the Southern Ocean have "their front limbs in this precise intermediate state of 'neither true arms nor true wings'" (apparently quoting Professor Pictet) and yet have held "their place victoriously in the battle for life; for they exist in infinite numbers and of many kinds." (p. 306) He goes on to state, "I do not suppose that we here see the real transitional grades through which the wings of birds have passed; but what special difficulty is there in believing that it might profit the modified descendants of the penguin, first to become enabled to flap along the surface of the sea like the logger-headed duck, and ultimately to rise from its surface and glide through the air?" (p. 306)

Eyes

Darwin states, "To suppose that the eye with all its inimitable contrivances for adjusting the focus to different distances, for admitting different amounts of light, and for the correction of spherical and chromatic aberration, could have been formed by natural selection, seems, I freely confess, absurd in the highest degree." (p. 168) However, he then goes on to state that "the difficulty of believing that a perfect and complex eye could be formed by natural selection,

though insuperable by our imagination, should not be considered as subversive of the theory." (pp. 168-169)

Darwin then considers primitive forms of eyes in lower animals. He states that the "simplest organ which can be called an eye consists of an optic nerve, surrounded by pigment-cells and covered by translucent skin, but without any lens or other refractive body." (p. 169) However, he says we can descend a step lower and find in certain star fish small depressions that are filled "with transparent gelatinous matter, projecting with a convex surface, like the cornea in the higher animals." (p. 169) However, this feature "serves not to form an image, but only to concentrate the luminous rays and render their perception more easy." (p. 169) Darwin believes that this concentration of rays provides "the first and by far the most important step towards the formation of a true, picture-forming eye: for we have only to place the naked extremity of the optic nerve … at the right distance from the concentrating apparatus, and an image will be formed on it." (p. 169)

Darwin then considers the diversity of sight organs in the class Articulata, which includes insects, crustaceans, and centipedes. He notes they range from "an optic nerve simply coated with pigment … but destitute of a lens or other optical contrivance" (p. 169) to the numerous facets on the cornea of the "great compound eyes" of insects, which form true lenses. (p. 169) Darwin then states, "When we reflect on these facts, here given much too briefly, with respect to the wide, diversified, and graduated range of structure in the eyes of the lower animals …, the difficulty ceases to be very great in believing that natural selection may have converted the simple apparatus of an optic nerve, coated with pigment and invested by transparent membrane, into an optical instrument as perfect as is possessed by any member of the Articlulate Class." (p. 170) Darwin then concludes, "He who will go thus far, ought not to hesitate to go one step

further …; he ought to admit that … a structure even as perfect as an eagle's eye might thus be formed, although in this case he does not know the transitional states." (p. 170)

Lungs

With respect to the origin of lungs, Darwin takes the position that they arose from the swimbladder of a fish. Darwin states, "All physiologists admit that the swimbladder is homologous, or 'ideally similar' in position and structure with the lungs of the higher vertebrate animals: hence there is no reason to doubt that the swimbladder has actually been converted into lungs, or an organ used exclusively for respiration." (p. 173)

Electric Organs of Fish

Darwin states that "[t]he electric organs of fishes offer another case of special difficulty; for it is impossible to conceive by what steps these wondrous organs have been produced. But this is not surprising, for we do not even know of what use they are. … [A]s we know so little about the uses of these organs, and as we know nothing about the habits and structure of the progenitors of the existing electric fishes, it would be extremely bold to maintain that no serviceable transitions are possible by which these organs might have been gradually developed." (pp. 174-175)

Darwin's basic position with respect to complex organs is as follows: "If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. But I can find out no such case." (p. 171)

St. George Mivart's Objections

Darwin considers a number of specific objections set forth by St. George Mivart, whom Darwin refers to as a "distinguished zoologist". (p. 200) Darwin states that Mivart has presented

the objections with “admirable art and force” and “they make a formidable array.” (p. 200) However, after considering all the objections, Darwin states that he “never before felt so strongly convinced of the general truth of the conclusions here arrived at, subject, of course, in so intricate a subject, to much partial error.” (p. 200)

Giraffes

Mivart questions how Darwin’s theory can account for the origin of giraffes, taking the general position that “natural selection is incompetent to account for the incipient stages of useful structures.” (p. 200, Darwin quoting Mivart) Darwin admits that the “giraffe, by its lofty stature, much elongated neck, fore-legs, head and tongue, has its whole frame beautifully adapted for browsing on the higher branches of trees.” (p. 201) However, he believes that the origin of the giraffe, just like the origin of bats or the human eye, can be explained by the action of natural selection over long periods of time. He states that “with the nascent giraffe the individuals which were the highest browsers, and were able during dearths to reach even an inch or two above the others, will often have been preserved; for they will have roamed over the whole country in search of food.” (p. 201) Darwin states, “These will have intercrossed and left offspring, either inheriting the same bodily peculiarities, or with a tendency to vary again in the same manner; whilst the individuals, less favoured in the same respects, will have been the most liable to perish.” (p. 201) He refers to the continued preservation of those which “could browse a little above the average height, and the continued destruction of those which could not browse so high ….” (p. 222) Darwin concludes, “By this process long-continued, … combined no doubt in a most important manner with the inherited effects of the increased use of parts, it seems to me almost certain that an ordinary hoofed quadruped might be converted into a giraffe.” (pp. 201-202)

In addition to arguing that natural selection is incompetent to account for the incipient stages of the giraffe, Mivart argues that the giraffe's increased size would require an increased food supply and it is "very problematical whether the disadvantages thence arising would not, in times of scarcity, more than counter-balance the advantages." (p. 202, Darwin quoting Mivart) Darwin argues that intermediate gradations of nascent giraffes could have survived "severe dearths." (p. 202) Darwin also notes that the giraffe's "increased bulk would act as a protection against almost all beasts of prey excepting the lion; and against this animal, its tall neck,--and the taller the better,--would … serve as a watch-tower." (p. 202) In addition, the giraffe can use its long neck "as a means of offence or defence, by violently swinging his head armed with stump-like horns." (p. 202) Darwin concludes, "The preservation of each species can rarely be determined by any one advantage, but by the union of all, great and small." (p. 202)

Mivart has one more objection relating to giraffes. He wonders "if natural selection be so potent, and if high browsing be so great an advantage, why has not any other hoofed quadruped acquired a long neck and lofty stature, besides the giraffe, and, in a lesser degree, the camel, guanaco, and macrauchenia? Or, again, why has not any member of the group acquired a long proboscis?" (p. 202) Darwin responds, "Why, in other quarters of the world, various animals belonging to this same order have not acquired either an elongated neck or a proboscis, cannot be distinctly answered …." (p. 203) He states, "In order that an animal should acquire some structure specially and largely developed, it is almost indispensable that several other parts should be modified and co-adapted. Although every part of the body varies slightly, it does not follow that the necessary parts should always vary in the right direction and to the right degree." (p. 203) Lastly, Darwin notes that "natural selection is a slow process, and the same favourable conditions must long endure in order that any marked effect should thus be produced. Except by

assigning such general and vague reasons, we cannot explain why, in many quarters of the world, hoofed quadrupeds have not acquired much elongated necks or other means for browsing on the higher branches of trees." (pp. 203-204)

Insects That Resemble Various Objects

Mivart raised an objection pertaining to insects that "often resemble for the sake of protection various objects, such as green or decayed leaves, dead twigs, bits of lichen, flowers, spines, excrement of birds, and living insects …. The resemblance is often wonderfully close, and is not confined to colour, but extends to form, and even to the manner in which the insects hold themselves." (p. 205) Mivart states, "As, according to Mr. Darwin's theory, there is a constant tendency to indefinite variation, and as the minute incipient variations will be in *all directions*, they must tend to neutralise each other, and at first to form such unstable modifications that it is difficult, if not impossible, to see how such indefinite oscillations of infinitesimal beginnings can ever build up a sufficiently appreciable resemblance to a leaf, bamboo, or other object, for Natural Selection to seize upon and perpetuate." (p. 205, Darwin quoting Mivart) In responding to this objection, Darwin first seeks to explain how an insect might initially resemble some object so that natural selection might have something "to seize upon". He states that "in all the foregoing cases the insects in their original state no doubt presented some rude and accidental resemblance to an object commonly found in the stations frequented by them. Nor is this at all improbable, considering the almost infinite number of surrounding objects and the diversity in form and colour of the hosts of insects which exist." (p. 205) Darwin goes on to state, "Assuming that an insect originally happened to resemble in some degree a dead twig or a decayed leaf, and that it varied slightly in many ways, then all the variations which rendered the insect at all more like any such object, and thus favoured its

escape, would be preserved, whilst other variations would be neglected and ultimately lost; or, if they rendered the insect at all less like the imitated object, they would be eliminated." (pp. 205-206)

Baleen Plates of the Greenland Whale

Next Darwin considers Mivart's objection pertaining to the baleen plates of the Greenland whale. Darwin states, "The Greenland whale is one of the most wonderful animals in the world, and the baleen, or whale-bone, one of its greatest peculiarities. The baleen consists of a row, on each side, of the upper jaw, of about 300 plates …. The extremities and inner margins of all the plates are frayed into stiff bristles, which clothe the whole gigantic palate, and serve to strain or sift the water, and thus to secure the minute prey on which these great animals subsist." (p. 206) Mivart states that if the baleen "had once attained such a size and development as to be at all useful, then its preservation and augmentation within serviceable limits would be promoted by natural selection alone. But how to obtain the beginning of such useful development?" (pp. 206-207, Darwin quoting Mivart) Darwin theorizes that the early progenitors of whales with baleen might have had a mouth constructed like the lamellated beak of a duck, and notes that "[d]ucks, like whales, subsist by sifting the mud and water …." (p. 207) He states, "In certain species of whales there is a tendency to the formation of irregular little points of horn on the palate; and it seems to be quite within the scope of natural selection to preserve all favourable variations, until the points were converted first into lamellated knobs or teeth, like those on the beak of a goose,--then into short lamellae, like those of the domestic ducks,--and then into lamellae, as perfect as those of the shoveller-duck,--and finally into the gigantic plates of baleen, as in the mouth of the Greenland whale." (p. 222)

The Eyes of the Flat-Fish

Another objection raised by Mivart involves the eyes of the flat-fish (Pleuronectidae). During its early youth the body of the flat-fish is symmetrical with one eye on each side. However, as the body matures, one eye "begins to glide slowly round the head" to the other side. (pp. 209-210) This is beneficial because the adult flat-fish spends most of its time lying on its side on the bottom of the ocean or other body of water in which it dwells. Thus, the adult flat-fish has one side, the lower side, pressed against the mud and the other side, the upper side, facing upwards. It is the upper side that ends up with the two eyes once the transmogrification is complete. Darwin states, "It is obvious that unless the lower eye did thus travel round, it could not be used by the fish whilst lying in its habitual position on one side. The lower eye would, also, have been liable to be abraded by the sandy bottom." (p. 210) Darwin also notes that "the Pleuronectidae are admirably adapted by their flattened and asymmetrical structure for their habits of life" and the "chief advantages thus gained seem to be protection from their enemies, and facility for feeding on the ground." (p. 210)

Mivart's objection is that Darwin's theory cannot explain how it came about that the eye on the lower side of the flat-fish moves to the upper side as the fish matures. Mivart states, and Darwin agrees, that under Darwin's theory this feature of the flat-fish must have gradually come about over many generations. Mivart then states that "if the transit was gradual, then how such transit of one eye a minute fraction of the journey towards the other side of the head could benefit the individual is, indeed, far from clear. It seems, even, that such an incipient transformation must rather have been injurious." (p. 210, Darwin quoting Mivart) Darwin notes, however, that the young of many fishes, including symmetrical fishes, "have the habit of occasionally resting on one side at the bottom" and "they often then strain their lower eyes so as to look upwards …." (p. 211) He states, "We thus see that the first stages of the transit of the

eye from one side of the head to the other, which Mr. Mivart considers would be injurious, may be attributed to the habit, no doubt beneficial to the individual and to the species, of endeavouring to look upwards with both eyes, whilst resting on one side at the bottom." (p. 211)

Darwin also notes that at some point natural selection might come into play in preserving and improving a new habit that was inheritable. He states, "We should keep in mind, as I have before insisted, that the inherited effects of the increased use of parts, and perhaps of their disuse, will be strengthened by natural selection. For all spontaneous variations in the right direction will thus be preserved; as will those individuals which inherit in the highest degree the effects of the increased and beneficial use of any part. How much to attribute in each particular case to the effects of use, and how much to natural selection, it seems impossible to decide." (p. 212) However, Darwin does state that "the transportal of the lower eye of a flat-fish to the upper side of the head … may be attributed almost wholly to continued use, together with inheritance." (pp. 222-223)

Darwin goes on to mention a feature of an organism "which apparently owes its origin *exclusively* to use or habit." (p. 212, emphasis supplied) He is referring to the extremity of the tail in some American monkeys which "has been converted into a wonderfully perfect prehensile organ, and serves as a fifth hand." (p. 212) Darwin states that another one of his critics, "who agrees with Mr. Mivart in every detail," (p. 212) questions how this organ could have arisen through natural selection. Darwin does not name the critic but quotes the critic as stating, "It is impossible to believe that in any number of ages the first slight incipient tendency to grasp could preserve the lives of the individuals possessing it, or favour their chance of having and of rearing offspring." (p. 212, Darwin quoting the unnamed critic) However, Darwin states that "there is no necessity for any such belief. Habit, and this almost implies that some benefit great or small

is thus derived, would in all probability suffice for the work." (p. 212) Thus, Darwin believes that the prehensile tail can be explained as a feature acquired through habit rather than through the action of natural selection.

Mammary Glands

Mivart also questions how Darwin's theory of natural selection can explain the origin of the mammary glands of mammals. He asks, "Is it conceivable that the young of any animal was ever saved from destruction by accidentally sucking a drop of scarcely nutritious fluid from an accidentally hypertrophied cutaneous gland of its mother? And even if one was so, what chance was there of the perpetuation of such a variation?" (p. 213, Darwin quoting Mivart) In response, Darwin first states that since mammary glands are common to all mammals and are indispensable for their existence, they must "have been developed at an extremely remote period, and we can know nothing positively about their manner of development." (p. 213) However, he believes that mammals have descended from a marsupial form and, if such is the case, "the mammary glands will have been at first developed within the marsupial sack." (p. 213) He then points out that in the case of the sea horse the eggs are hatched and the young are raised, at least for awhile, in a sack. He then notes that Mr. Lockwood, an American naturalist, believes that the young "are nourished by a secretion from the cutaneous glands of the sack." (p. 213) Darwin then asks, "Now with the early progenitors of mammals, … is it not at least possible that the young might have been similarly nourished? And in this case, the individuals which secreted a fluid, in some degree or manner the most nutritious, so as to partake of the nature of milk, would in the long run have reared a larger number of well-nourished offspring, than would the individuals which secreted a poorer fluid; and thus the cutaneous glands, which are the homologues of the mammary glands, would have been improved or rendered more effective."

(p. 213) Darwin then states, "Through what agency the glands over a certain space became more highly specialised than the others, I will not pretend to decide, whether in part through compensation of growth, the effects of use, or of natural selection." (p. 213)

Darwin goes on to note that the development of the mammary glands would have provided no benefit "unless the young at the same time were able to partake of the secretion." (p. 213) However, he says that "understanding how young mammals have instinctively learnt to suck the breast" poses no greater difficulty than "understanding how unhatched chickens have learnt to break the egg-shell by tapping against it with their specially adapted beaks; or how a few hours after leaving the shell they have learnt to pick up grains of food." (pp. 213-214) In explanation of the latter cases, Darwin states (somewhat enigmatically) that the most probable explanation seems to be that "the habit was at first acquired by practice at a more advanced age, and afterwards transmitted to the offspring at an earlier age." (p. 214)

Injection of Milk by a Mother Kangaroo

Darwin discusses another objection by Mivart which is based on the fact that a baby kangaroo "is said not to suck, only to cling to the nipple of its mother, who has the power of injecting milk into the mouth of her helpless, half-formed offspring." (p. 214) Mivart observes, "Did no special provision exist, the young one must infallibly be choked by the intrusion of the milk into the windpipe. But there *is* a special provision. The larynx is so elongated that it rises up into the posterior end of the nasal passage, and is thus enabled to give free entrance to the air for the lungs, while the milk passes harmlessly on each side of this elongated larynx, and so safely attains the gullet behind it." (p. 214, Darwin quoting Mivart) Mivart then asks how natural selection removed in the adult kangaroo "this at least perfectly innocent and harmless structure?" (p. 214, Darwin quoting Mivart) In response, Darwin, who believes that all

mammals are descended from a marsupial form, states that it may be suggested that "the voice, which is certainly of high importance to many animals, could hardly have been used with full force as long as the larynx entered the nasal passage." (p. 214) He also states that "Professor Flower has suggested to me that this structure would have greatly interfered with an animal swallowing solid food." (p. 214)

Tridactyle Forceps of Star Fish and Sea Urchins

Darwin next considers an objection involving the pedicellariae of organisms in the phylum Echinodermata. These organisms include star fish and sea urchins. Darwin states that pedicellariae are remarkable organs which "consist, when well developed, of a tridactyle forceps—that is, of one formed of three serrated arms, neatly fitting together and placed on the summit of a flexible stem, moved by muscles. These forceps can firmly seize hold of any object … [T]here is no doubt that besides removing dirt of all kinds, they subserve other functions; and one of these apparently is defence." (p. 214) With respect to these organs, Mivart asks, "What would be the utility of the *first rudimentary beginnings* of such structures, and how could such incipient buddings have ever preserved the life of a single Echinus [sea urchin]? … [N]ot even the *sudden* development of the snapping action could have been beneficial without the freely moveable stalk, nor could the latter have been efficient without the snapping jaws, yet no minute merely indefinite variations could simultaneously evolve these complex co-ordinations of structure …." (pp. 214-215, Darwin quoting Mivart)

Darwin responds, "With respect to the steps by which these curious organs have been evolved, … the pedicellariae must undoubtedly be looked at as modified spines." (p. 215) He goes on to state, "It is generally admitted that the ordinary spines serve as a protection; and if so, there can be no reason to doubt that those furnished with serrated and moveable branches

likewise serve for the same purpose; and they would thus serve still more effectively as soon as by meeting together they acted as a prehensile or snapping apparatus. Thus every gradation, from an ordinary fixed spine to a fixed pedicellaria, would be of service." (p. 215) Since Mivart was discussing *moveable* pedicellariae, Darwin then states, "In certain genera of star-fishes these organs, instead of being fixed …, are placed on the summit of a flexible and muscular, though short, stem; and in this case they probably subserve some additional function besides defence. In the sea-urchins the steps can be followed by which a fixed spine becomes articulated to the shell, and is thus rendered moveable." (pp. 215-216) Apparently the "steps" are inferred from what Darwin sees as "a long and perfect series of gradations in different species and genera, from simple granules to ordinary spines, to perfect tridactyle pedicellariae." (p. 215)

Avicularia of Polyzoa and Tridactyle Forceps

Darwin next considers the avicularia of the phylum Polyzoa (also called Bryozoa). Polyzoa are one type of zoophyte, which is an invertebrate animal more or less resembling a plant in appearance or mode of growth. Polyzoa are aquatic zoophytes that reproduce by budding and usually form permanently attached branched colonies. Darwin states that avicularia of Polyzoa are organs that "curiously resemble the head and beak of a vulture in miniature, seated on a neck and capable of movement, as is likewise the lower jaw or mandible. … When the jaws are touched with a needle they seize it so firmly that the branch can thus be shaken." (p. 216)

Mivart considers the avicularia of the Polyzoa and the tridactyle forceps of the Echinodermata (discussed earlier) to be "essentially similar" (p. 216, Darwin quoting Mivart) and questions how natural selection could have given rise to such similar organs "in widely distinct divisions of the animal kingdom." (p. 216) However, Darwin states that "as far as

structure is concerned, I can see no similarity between tridactyle pedicellariae and avicularia." (p. 216)

In order to help Mivart in his argument, Darwin states that avicularia "resemble somewhat more closely the chelae or pincers of Crustaceans; and Mr. Mivart might have adduced with equal appropriateness this resemblance as a special difficulty …." (p. 216) Darwin goes on to speculate how each could have come into existence independently through natural selection. With respect to the pincers of the Crustaceans, Darwin states that "a long series of serviceable gradations still exists" and with these gradations "the pincers are rendered more and more perfect, until we have at last an instrument as efficient as the chelae of a lobster; and all these gradations can be actually traced." (p. 217) Turning to avicularia, Darwin states that it is "impossible to conjecture by what serviceable gradations" avicularia might have come into existence "but it by no means follows from this that such gradations have not existed." (p. 216) Darwin then considers another organ of Polyzoa, the vibraculum, which consists "of long bristles, capable of movement and easily excited." (p. 217) He states, "It is not easy to imagine two objects more widely different in appearance than a bristle or vibraculum, and an avicularium like the head of a bird; yet they are almost certainly homologous and have been developed from the same common source, namely a zooid with its cell." (p. 217) Darwin goes on to state, "It is interesting to see two such widely different organs developed from a common origin; and as the moveable lip of the cell serves as a protection to the zooid, there is no difficulty in believing that all the gradations, by which the lip became converted first into the lower mandible of an avicularium and then into an elongated bristle, likewise served as a protection in different ways and under different circumstances." (p. 218) Having proposed that the avicularia and vibracula of Polyzoa have a common origin in the moveable lip of the cell of a zooid, Darwin believes he

has explained how the pincers of Crustaceans and the avicularia of Polyzoa could have come into existence independently through natural selection.

The Structure of the Flowers of Orchids

With respect to the structure of the flowers of orchids, Mivart states that "the explanation of their *origin* is deemed thoroughly unsatisfactory—utterly insufficient to explain the incipient, infinitesimal beginnings of structures which are of utility only when they are considerably developed." (p. 218, Darwin quoting Mivart) Darwin chooses to address one of "the most striking peculiarities of the flowers of orchids, namely their pollinia. A pollinium when highly developed consists of a mass of pollen-grains, affixed to an elastic foot-stalk or caudicle, and this to a little mass of extremely viscid matter." (p. 218) With respect to the viscid matter, Darwin traces its origin to the viscid matter secreted by the stigma. (The pollinium is at the top of the male component of a flower (the stamen) and the stigma is at the top of the female component (the pistil).)

With respect to the stigma, Darwin notes, "In most flowers belonging to other orders the stigma secretes a little viscid matter." (p. 219) He goes on to state, "Now in certain orchids similar viscid matter is secreted, but in much larger quantities by one alone of the three stigmas …. When an insect visits a flower of this kind, it rubs off some of the viscid matter and thus at the same time drags away some of the pollen-grains. From this simple condition, … there are endless gradations,--to species in which the pollen-mass terminates in a very short, free caudicle,--to others in which the caudicle becomes firmly attached to the viscid matter …. In this latter case we have a pollinium in its most highly developed and perfect condition." (p. 219) Darwin continues, "He who will carefully examine the flowers of orchids for himself will not deny the existence of the above series of gradations …; nor will he deny that all the gradations in

the several species are admirably adapted in relation to the general structure of each flower for its fertilisation by different insects." (p. 219)

Darwin concludes by stating "it may be asked how did the stigma of an ordinary flower become viscid, but as we do not know the full history of any one group of beings, it is as useless to ask, as it is hopeless to attempt answering, such questions." (p. 219)

The Movements of Climbing Plants

Darwin states that Mivart "alludes" to the movements of climbing plants but does not state what Mivart says about them. Apparently, as with the structure of the flowers of orchids, Mivart believes that Darwin's theory is "thoroughly unsatisfactory" to explain the origin of the movements of climbing plants. Not surprisingly, Darwin disagrees and speculates as to how the movements might have come into existence.

Darwin first states that climbing plants "can be arranged in a long series, from those which simply twine round a support, to those which I have called leaf-climbers, and to those provided with tendrils." (p. 219) Darwin then observes, "The power of twining depends, firstly, on the stems whilst young being extremely flexible (but this is a character common to many plants which are not climbers); and, secondly, on their continually bending to all points of the compass, one after the other in succession, in the same order. By this movement the stems are inclined to all sides, and are made to move round and round. As soon as the lower part of a stem strikes against any object and is stopped, the upper part still goes on bending and revolving, and thus necessarily twines round and up the support." (p. 220) Darwin notes that a number of plants that are not climbers have a slight tendency to a revolving movement of this kind but these "slight movements appear to be of no service to the plants in question." (p. 220) However, he goes on to state, "Nevertheless we can see that if the stems of these plants had been flexible, and

if under the conditions to which they are exposed it had profited them to ascend to a height, then the habit of slightly and irregularly revolving might have been increased and utilized through natural selection, until they had become converted into well-developed twining species." (p. 220)

With respect to the sensitiveness of leaf-climbers and tendril-bearers, Darwin observes that this type of sensitiveness is "found in a nascent condition in many plants which have not become climbers." (p. 221) He goes on to state that "there is no great difficulty in admitting that in the case of leaf-climbers and tendril-bearers, it is this tendency which has been taken advantage of and increased through natural selection. It is, however, probable … that this will have occurred only with plants which had already acquired the power of revolving, and had thus become twiners." (p. 221) Finally, Darwin remarks, "Whether, during the gradual development of climbing plants, natural selection has been aided by the inherited effects of use, I will not pretend to decide; but we know that certain periodical movements, for instance the so-called sleep of plants, are governed by habit." (pp. 221-222)

Darwin has now completed his consideration of Mivart's objections and concludes by stating, "I have now considered enough, perhaps more than enough, of the cases, selected with care by a skilful naturalist, to prove that natural selection is incompetent to account for the incipient stages of useful structures; and I have shown, as I hope, that there is no great difficulty on this head." (p. 222)

<u>The Difficulty of Explaining the Origin of Parts with Little Importance</u>

Darwin states, "I have sometimes felt great difficulty in understanding the origin or formation of parts of little importance; almost as great, though of a very different kind, as in the case of the most perfect and complex organs." (p. 181) He mentions the tail of the giraffe as an

example of a part with little apparent importance. He states that it looks like "an artificially constructed fly-flapper" and "[it] seems at first incredible that this could have been adapted for its present purpose by successive slight modifications, each better and better fitted, for so trifling an object as to drive away flies …." (p. 181) However, he goes on to state that "we should pause before being too positive even in this case, for we know that the distribution and existence of cattle and other animals in South America absolutely depend on their power of resisting the attacks of insects: so that individuals which could by any means defend themselves from these small enemies, would be able to range into new pastures and thus gain a great advantage." (pp. 181-182)

In general with respect to organs "of trifling importance" (p. 182) Darwin has two responses. First, he states that "we are much too ignorant in regard to the whole economy of any one organic being, to say what slight modifications would be of importance or not." (p. 181) Second, he states, "Organs now of trifling importance have probably in some cases been of high importance to an early progenitor, and, after having been slowly perfected at a former period, have been transmitted to existing species in nearly the same state, although now of very slight use: but any actually injurious deviations in their structure would of course have been checked by natural selection." (p. 182) Thus, with respect to tails found in land animals, Darwin argues that a "well-developed tail having been formed in an aquatic animal, it might subsequently come to be worked in for all sorts of purposes,--as a fly-flapper, an organ of prehension, or as an aid in turning, as in the case of the dog …." (p. 182)

<u>The Difficulty of Explaining the Origin of Characters with No Importance</u>

An objection raised by the naturalist Bronn is that "many characters appear to be of no service whatever to their possessors, and therefore cannot have been influenced through natural

selection." (p. 194) Bronn "adduces the length of the ears and tails in the different species of hares and mice … and a multitude of analogous cases." (p. 194) Darwin states, "There is much force in the above objection." (p. 194) He also states that the naturalist Nageli has made a similar argument with respect to plants. Nageli "admits that natural selection has effected much, but he insists that the families of plants differ chiefly from each other in morphological characters, which appear to be quite unimportant for the welfare of the species." (p. 194) Examples of such "characters" include "the arrangement of the cells in the tissues, and of the leaves on the axis" (p. 194) and "the numerical divisions in the parts of the flower, the position of the ovules, the shape of the seed, when not of any use for dissemination, &c." (p. 194)

Darwin believes some characters considered unimportant may actually be important. He states, "[W]e ought, in the first place, to be extremely cautious in pretending to decide what structures now are, or have formerly been, of use to each species." (p. 194) He states, for example, that "the external ears of the common mouse are supplied in an extraordinary manner with nerves, so that they no doubt serve as tactile organs; hence the length of the ears can hardly be quite unimportant." (pp. 195-196) He also states that "the tail is a highly useful prehensile organ to some of the species: and its use would be much influenced by its length." (p. 196) In addition, with respect to the flowers of orchids, Darwin states that they "present a multitude of curious structures, which a few years ago would have been considered as mere morphological differences without any special function; but they are now known to be of the highest importance for the fertilisation of the species through the aid of insects, and have probably been gained through natural selection." (p. 196)

However, Darwin does admit there are characters that are in fact unimportant and agrees that natural selection cannot account for them. He discusses a number of morphological

differences among plants, such as “the arrangement of the leaves, the divisions of the flower or of the ovarium, the position of the ovules, &c.” (p. 199), and concludes, “From the fact of the above characters being unimportant for the welfare of the species, any slight variations which occurred in them would not have been accumulated and augmented through natural selection.” (p. 199)

Thus, Darwin agrees that his theory of natural selection cannot explain the existence of characters that are unimportant for the welfare of a species. However, he makes clear that natural selection is only intended to explain “the innumerable structures which are so well adapted to the habits of life of each species.” (p. 195) He believes that “laws of growth” explain other characters of organisms. According to Darwin, “[I]t should always be borne in mind that when one part is modified, so will be other parts, through certain dimly seen causes, such as an increased or diminished flow of nutriment to a part, mutual pressure, an early developed part affecting one subsequently developed, and so forth,--as well as through other causes which lead to the many mysterious cases of correlation, which we do not in the least understand. These agencies may be all grouped together, for the sake of brevity, under the expression of the laws of growth.” (pp. 194-195)

In addition to laws of growth, Darwin states that “we have to allow for the direct definite action of changed conditions of life, and for so-called spontaneous variations, in which the nature of the conditions apparently plays a quite subordinate part.” (p. 195) With respect to spontaneous variations, he states, “In the earlier editions of this work I under-rated … the frequency and importance of modifications due to spontaneous variability.” (p. 195) However, Darwin states that “it is impossible to attribute to this cause the innumerable structures which are so well adapted to the habits of life of each species. I can no more believe in this than that the

well-adapted form of a race-horse or greyhound … can thus be explained." (p. 195) For Darwin, the explanation for such well-adapted structures was natural selection.

The Difficulty of Explaining a Feature of One Species That Is for the Exclusive Good of Another Species

Darwin states, "If it could be proved that any part of the structure of any one species had been formed for the exclusive good of another species, it would annihilate my theory, for such could not have been produced through natural selection." (pp. 186-187) Darwin admits that "many statements may be found in works on natural history" that such structures exist, but Darwin states, "I cannot find even one which seems to me of any weight." (p. 187) He states that some authors suppose that the rattlesnake "is furnished with a rattle for its own injury, namely, to warn its prey." (p. 187) However, Darwin argues that "the rattlesnake uses its rattle … in order to alarm the many birds and beasts which are known to attack even the most venomous species." (p. 187)

Darwin states, "Natural selection will never produce in a being any structure more injurious than beneficial to that being, for natural selection acts solely by and for the good of each. … If a fair balance be struck between the good and evil caused by each part, each will be found on the whole advantageous." (p. 187)

The Difficulty of Explaining the Existence of Similar Organs in Remotely Allied Species

Another objection to Darwin's theory is that very similar organs can be found in remotely allied species. For example, St. George Mivart, referred to earlier, observes that the eyes of cephalopods (a class in the phylum Mollusca) are very similar to the eyes of vertebrates (a class in the phylum Chordata) and yet the two classes are only remotely allied. Darwin agrees that the eyes "appear wonderfully alike" and also concedes that "in such widely sundered groups no part of this resemblance can be due to inheritance from a common progenitor." (p. 176) However,

he argues that beyond superficial resemblance "there is hardly any real similarity between the eyes of cuttle-fish [a type of cephalopod] and vertebrates, as may be seen by consulting Hensen's admirable memoir on these organs in the Cephalopoda." (p. 176) Darwin contends that the eyes in both classes arose independently through natural selection and states, "It is, of course, open to any one to deny that the eye in either case could have been developed through the natural selection of successive slight variations; but if this be admitted in the one case, it is clearly possible in the other; and fundamental differences of structure in the visual organs of two groups might have been anticipated, in accordance with this view of their manner of formation." (p. 177)

Darwin also considers the electric organs of fish which "occur in about a dozen kinds of fish, of which several are widely remote in their affinities." (p. 175) He states that "if the electric organs had been inherited from some one ancient progenitor, we might have expected that all electric fishes would have been specially related to each other; but this is far from the case." (p. 175) Since, in Darwin's view, all electric fishes are not specially related to each other, he believes the electric organs were not inherited from some one ancient progenitor. However, Darwin also observes that the electric organs in the separate groups of fishes are very different from each other and he posits that each type was produced by a separate series of graduated steps. Darwin goes on to note, "The luminous organs which occur in a few insects, belonging to widely different families, and which are situated in different parts of the body, offer, under our present state of ignorance, a difficulty almost exactly parallel with that of the electric organs." (p. 176)

Darwin admits the difficulty under his theory "of an organ, apparently the same, arising in several remotely allied species …." (p. 176) However, he asserts, "In all cases of beings, far

removed from each other in the scale of organisation, which are furnished with similar and peculiar organs, it will be found that although the general appearance and function of the organs may be the same, yet fundamental differences between them can always be detected." (p. 176)

The Difficulty of Explaining the Existence of Different Organs for the Same Function in Closely Allied Species

Another difficulty raised by Darwin's critics is the existence of different organs for the same function in closely allied species. Whereas one difficulty raised by Darwin's critics involved the existence of similar organs in remotely allied species, this difficulty involves the existence of different organs in closely allied species.

As a prime example of this, Darwin refers to two genera of orchid, the Coryanthes and the Catasetum. Darwin explains in detail the ingenious "contrivance" that the Coryanthes uses for pollination. The flower has a bucket "into which drops of almost pure water continually fall from two secreting horns which stand above it; and when the bucket is half full, the water overflows by a spout on one side." (p. 179) Above the bucket is a chamber with "curious fleshy ridges." (p. 179) Crowds of bees come to gnaw off the ridges and in doing so they push against each other and frequently a bee falls into the bucket. Once in the bucket, a bee cannot fly away because its wings are wet and must climb out of the bucket through the spout. "The passage is narrow, and is roofed over by the column, so that a bee, in forcing its way out, first rubs its back against the viscid stigma and then against the viscid glands of the pollen-masses. The pollen-masses are thus glued to the back of the bee which first happens to crawl out through the passage … and are thus carried away." (p. 179) The bee may then fly back to the same flower or to another flower. When it does, it may be pushed again and again end up in the bucket of the flower. When it crawls out through the passageway, the pollen-masses on its back come into contact with the viscid stigma and the flower is fertilized. Darwin concludes with respect to this

flower, “Now at last we see the full use of every part of the flower, of the water-secreting horns, of the bucket half full of water, which prevents the bees from flying away, and forces them to crawl out through the spout, and rub against the properly placed viscid pollen-masses and the viscid stigma.” (p. 180)

Darwin now turns to another orchid, the Catasetum, which is “closely allied” to the one just discussed, the Coryanthes. Darwin states that the construction of the flower in the Catasetum “is widely different, though serving the same end; and is equally curious.” (p. 180) As in the case of the flower of the Coryanthes, bees visit the flower of the Catasetum to gnaw the fleshy ridges. However, the Catasetum’s technique for achieving pollination is completely different from that of the Coryanthes. When bees are gnawing the ridges in a male flower of a Catasetum, they touch a sensitive projection, which Darwin calls the antenna. “This antenna, when touched, transmits a sensation or vibration to a certain membrane which is instantly ruptured; this sets free a spring by which the pollen-mass is shot forth, like an arrow, in the right direction, and adheres by its viscid extremity to the back of the bee.” (p. 180) When the bee then flies to a female flower of a Catasetum, the pollen-mass on the back of the bee comes into contact with the stigma of the flower and fertilization occurs. (It should be noted that even though the Coryanthes and the Catasetum are “closely allied” genera of orchid, each flower of the Coryanthes has male and female organs whereas the Catasetum has separate male and female flowers. This is another major difference between the two genera even though they are closely allied.)

Because the two genera of orchid are closely allied, Darwin considers them to have a common progenitor in the not-too-distant past. The question arises then as to why they have widely different means of pollination. Earlier, when discussing the electric organs that “occur in

about a dozen kinds of fish" (p. 175), Darwin said that "there is no reason to suppose that they have been inherited from a common progenitor; for had this been the case they would have closely resembled each other in all respects." (p. 176) The implication is that, in the case of two closely allied species, the organs they have for performing a particular function, such as pollination, will closely resemble each other in all respects.

However, Darwin admits that it is common throughout nature for the same end to be gained by the most diversified means, "even sometimes in the case of closely-related beings". (p. 178) In trying to explain how this can happen in the case of closely allied species, he states, "The answer no doubt is … that when two forms vary, which already differ from each other in some slight degree, the variability will not be of the same exact nature, and consequently the results obtained through natural selection for the same general purpose will not be the same." (p. 180) At another point Darwin states that when there are "widely different structures" in "the special parts of allied species," then "numerous and wonderfully fine gradations can be traced, connecting together widely different structures." (p. 226) However, in the case of Coryanthes and Catasetum, he does not trace the fine gradations connecting together the two mechanisms for pollination.

<u>The Difficulty of Explaining How a New Group Can Live Side-by-Side with Its Parent Species</u>

Under Darwin's theory of natural selection, a new group of organisms that is more fit than its parent species survives and supplants the parent species. Darwin states that "[t]he celebrated paleontologist, Bronn, … asks, how, on the principle of natural selection, can a variety live side by side with the parent species?" (p. 193) Darwin responds, "If both have become fitted for slightly different habits of life or conditions, they might live together; and if we lay on one side … all mere temporary variations, such as size, albinism, &c., the more permanent

varieties are generally found, as far as I can discover, inhabiting distinct stations,--such as high land or low land, dry or moist districts." (p. 193)

The Difficulty of Explaining How It Is That Many Parts of an Organism Are Modified at the Same Time

Darwin states that Bronn "also insists that distinct species never differ from each other in single characters, but in many parts; and he asks, how it always comes that many parts of the organisation should have been modified at the same time through variation and natural selection?" (p. 193) Darwin responds that "there is no necessity for supposing that all the parts of any being have been simultaneously modified." (pp. 193-194) He states, "The most striking modifications, excellently adapted for some purpose, might … be acquired by successive variations, if slight, first in one part and then in another; and as they would be transmitted all together, they would appear to us as if they had been simultaneously developed." (p. 194) Darwin apparently realizes that this does not address Bronn's concern because Bronn is not focused on the origin of a complex organ but rather on the origin of a complex organ and *other* features of an organism at the same time. Thus, Darwin states, "The best answer, however, to the above objection is afforded by those domestic races which have been modified, chiefly through man's power of selection, for some special purpose." (p. 194) He says that "[e]ven when selection has been applied by man to some one character alone, … it will invariably be found that although this one part … has been greatly changed, almost all the other parts have been slightly modified." (p. 194) He states that "[t]his may be attributed partly to the principle of correlated growth, and partly to so-called spontaneous variation." (p. 194) Unfortunately, Darwin does not shed much light on what he means by "the principle of correlated growth" and "spontaneous variation."

The Difficulty of Explaining the Origin of Complex Instincts

Darwin acknowledges, “Many instincts are so wonderful that their development will probably appear to the reader a difficulty sufficient to overthrow my whole theory.” (p. 228) Later he expands on the difficulties presented by instincts, stating, “No doubt many instincts of very difficult explanation could be opposed to the theory of natural selection—cases, in which we cannot see how an instinct could have originated; cases, in which no intermediate gradations are known to exist; cases of instincts of such trifling importance, that they could hardly have been acted on by natural selection; cases of instincts almost identically the same in animals so remote in the scale of nature, that we cannot account for their similarity by inheritance from a common progenitor, and consequently must believe that they were independently acquired through natural selection.” (p. 251)

However, undaunted by these difficulties, Darwin believes that even complex instincts can be explained by the mechanism of natural selection. Darwin states, “It will be universally admitted that instincts are as important as corporeal structures for the welfare of each species, under its present conditions of life. Under changed conditions of life, it is at least possible that slight modifications of instinct might be profitable to a species; and if it can be shown that instincts do vary ever so little, then I can see no difficulty in natural selection preserving and continually accumulating variations of instinct to any extent that was profitable. It is thus, as I believe, that all the most complex and wonderful instincts have originated.” (p. 229) He also states that “the effects of habit are in many cases of subordinate importance to the effects of the natural selection of what may be called spontaneous variations of instincts;--that is of variations produced by the same unknown causes which produce slight deviations of bodily structure.” (pp. 229-230)

The Instinct of the European Cuckoo

Darwin considers the instinct of the European cuckoo. The female adult lays her egg in the nest of another species and commonly, within three days after hatching, the chick ejects from the nest the chicks of the other species. Darwin reported "a trustworthy account of a young cuckoo which was actually seen, whilst still blind and not able even to hold up its own head, in the act of ejecting its foster-brothers. One of these was replaced in the nest by the observer, and was again thrown out." (p. 237) Darwin states, "With respect to the means by which this strange and odious instinct was acquired, if it were of great importance for the young cuckoo, as is probably the case, to receive as much food as possible soon after birth, I can see no special difficulty in its having gradually acquired, during successive generations, the blind desire, the strength, and structure necessary for the work of ejection; for those young cuckoos which had such habits and structure best developed would be the most securely reared." (p. 237)

The Instinct of Slave-Making Ants

Darwin next considers Formica sanguinea, a species of ant that makes slaves of another species of ant, Formica fusca. Darwin notes, "The slaves are black and not above half the size of their red masters, so that the contrast in their appearance is great." (p. 240) He observes that even though the masters have the slaves, the masters also do a fair amount of work themselves. He writes that "the masters alone usually leave the nest to collect building materials and food for themselves, their slaves and larvae." (p. 242)

Darwin states, "By what steps the instinct of F. sanguinea originated I will not pretend to conjecture." (p. 242) However, he goes on to speculate that "as ants which are not slave-makers will … carry off the pupae of other species, if scattered near their nests, it is possible that such pupae originally stored as food might become developed; and the foreign ants thus unintentionally reared would then follow their proper instincts, and do what work they could. If

their presence proved useful to the species which had seized them—if it were more advantageous to this species to capture workers than to procreate them—the habit of collecting pupae, originally for food, might by natural selection be strengthened and rendered permanent for the very different purpose of raising slaves." (p. 242)

Darwin discusses another species of ant, Formica rufescens, which also makes slaves of the species Formica fusca. In this case, the master species "does not build its own nest, does not determine its own migrations, does not collect food for itself or its young, and cannot even feed itself: it is absolutely dependent on its numerous slaves." (p 242) Darwin speculates that once an instinct like that of Formica sanguinea was acquired, "natural selection might increase and modify the instinct—always supposing each modification to be of use to the species—until an ant was formed as abjectly dependent on its slaves as is the Formica rufescens." (p. 242)

The Cell-Making Instinct of the Hive-Bee

Darwin now turns to the cell-making instinct of the hive-bee. He states that this instinct and the instinct of slave-making ants "have generally and justly been ranked by naturalists as the most wonderful of all known instincts." (p. 235) With respect to the cell-making instinct, Darwin states, "He must be a dull man who can examine the exquisite structure of a comb, so beautifully adapted to its end, without enthusiastic admiration. We hear from mathematicians that bees have practically solved a recondite problem, and have made their cells of the proper shape to hold the greatest possible amount of honey, with the least possible consumption of precious wax in their construction. It has been remarked that a skilful workman with fitting tools and measures would find it very difficult to make cells of wax of the true form, though this is effected by a crowd of bees working in a dark hive." (pp. 242-243)

However, Darwin seeks to explain the origin of the cell-making skill of the hive-bee by looking "to the great principle of gradation" (p. 243) and pointing to a gradation of cell-making skills in three separate species of bees. He states, "At one end of a short series we have humble-bees, which use their old cocoons to hold honey, sometimes adding to them short tubes of wax, and likewise making separate and very irregular rounded cells of wax." (p. 243) At the other end of the series of three, "we have the cells of the hive-bee, placed in a double layer: each cell, as is well known, is an hexagonal prism, with the basal edges of its six sides bevelled so as to join an inverted pyramid, of three rhombs." (p. 243) Darwin then states, "In the series between the extreme perfection of the cells of the hive-bee and the simplicity of those of the humble-bee we have the cells of the Mexican Melipona domestica …. The Melipona itself is intermediate in structure between the hive- and humble-bee, but more nearly related to the latter; it forms a nearly regular waxen comb of cylindrical cells, in which the young are hatched, and, in addition, some large cells of wax for holding honey." (p. 243)

Darwin then speculates that "if we could slightly modify the instincts already possessed by the Melipona, and in themselves not very wonderful, this bee would make a structure as wonderfully perfect as that of the hive-bee. … By such modifications of instincts which in themselves are not very wonderful,--hardly more wonderful than those which guide a bird to make its nest,--I believe that the hive-bee has acquired, through natural selection, her inimitable architectural powers." (pp. 244-245) Darwin then seeks to explain why these modifications would be favored. He states, "As natural selection acts only by the accumulation of slight modifications of structure or instinct, each profitable to the individual under its conditions of life, it may reasonably be asked, how a long and graduated succession of modified architectural instincts, all tending towards the present perfect plan of construction, could have profited the

progenitors of the hive-bee? I think the answer is not difficult: cells constructed like those of the bee or the wasp gain in strength, and save much in labour and space, and in the materials of which they are constructed." (pp. 248-249) He thus believed that the "individual swarm which thus made the best cells with least labour, and least waste of honey in the secretion of wax, … will have had the best chance of succeeding in the struggle for existence." (p. 250) Darwin notes, "Beyond this stage of perfection in architecture, natural selection could not lead; for the comb of the hive-bee, as far as we can see, is absolutely perfect in economising labour and wax." (p. 249) Darwin concludes, "Thus, as I believe, the most wonderful of all known instincts, that of the hive-bee, can be explained by natural selection having taken advantage of numerous, successive, slight modifications of simpler instincts …." (pp. 249-250)

The Difficulty of Explaining the Coordination of Structure and Instinct

Darwin considers another objection relating to instincts, one involving the coordination of structure and instinct. He states, "It has been objected to the foregoing view of the origin of instincts that 'the variations of structure and of instinct must have been simultaneous and accurately adjusted to each other, as a modification in the one without an immediate corresponding change in the other would have been fatal.'" (p. 250, no citation provided by Darwin) However, Darwin argues that this objection is based on the mistaken assumption that "the changes in the instincts and structure are abrupt." (p. 250)

The Larger Titmouse

Focusing on the larger titmouse (Parus major), a bird which "often holds the seeds of the yew between its feet on a branch, and hammers with its beak till it gets at the kernel," Darwin asks, "Now what special difficulty would there be in natural selection preserving all the slight individual variations in the shape of the beak, which were better and better adapted to break open

the seeds, until a beak was formed, as well constructed for this purpose as that of the nuthatch, at the same time that habit, or compulsion, or spontaneous variations of taste, led the bird to become more and more of a seed-eater?" (p. 250) He states, "In this case the beak is supposed to be slowly modified by natural selection, subsequently to, but in accordance with, slowly changing habits or taste …." (p. 250) He also states that if the feet of the titmouse vary and grow larger "from correlation with the beak, or from any other unknown cause," then it is probable that the larger feet "would lead the bird to climb more and more until it acquired the remarkable climbing instinct and power of the nuthatch. In this case a gradual change of structure is supposed to lead to changed instinctive habits." (pp. 250-251) Darwin notes, however, that "in many instances we cannot conjecture whether it was instinct or structure which first varied." (p. 251)

Neuter Ants and Their Different Castes

Darwin then goes on to discuss "one special difficulty, which at first appeared to me insuperable, and actually fatal to the whole theory. I allude to the neuters or sterile females in insect-communities; for these neuters often differ widely in instinct and in structure from both the males and fertile females, and yet, from being sterile, they cannot propagate their kind." (p. 250) Darwin states that here "selection has been applied to the family, and not to the individual, for the sake of gaining a serviceable end" and "we may conclude that slight modifications of structure or of instinct, correlated with the sterile condition of certain members of the community, have proved advantageous: consequently the fertile males and females have flourished, and transmitted to their fertile offspring a tendency to produce sterile members with the same modifications." (p. 253)

However, Darwin goes on to state, “But we have not as yet touched on the acme of the difficulty; namely, the fact that the neuters of several ants differ, not only from the fertile females and males, but from each other, sometimes to an almost incredible degree, and are thus divided into two or even three castes.” (p. 253) He acknowledges, “It will indeed be thought that I have an overweening confidence in the principle of natural selection, when I do not admit that such wonderful and well-established facts at once annihilate the theory.” (p. 253) However, Darwin believed that “natural selection, by acting on the fertile ants or parents, could form a species which should regularly produce neuters, all of large size with one form of jaw, or all of small size with widely different jaws; or lastly, and this is the greatest difficulty, one set of workers of one size and structure, and simultaneously another set of workers of a different size and structure;--a graduated series having first been formed, as in the case of the driver ant, and then the extreme forms having been produced in greater and greater numbers, through the survival of the parents which generated them, until none with an intermediate structure were produced.” (p. 255) However, Darwin concludes his discussion of the matter by stating, “But I must confess, that, with all my faith in natural selection, I should never have anticipated that this principle could have been efficient in so high a degree, had not the case of these neuter insects led me to this conclusion. I have, therefore, discussed this case, at some little but wholly insufficient length, in order to show the power of natural selection, and likewise because this is by far the most serious special difficulty which my theory has encountered.” (p. 255)

The Difficulty of Explaining the Inability of a Species to Breed with Another Species

Another objection to Darwin’s theory is that it does not explain the “general sterility of crossed species.” (p. 281) Darwin believed that a species was basically the same as a variety except that a species was “well-marked and permanent.” (p. 438) According to Darwin,

"varieties are species in the process of formation, or are, as I have called them, incipient species." (p. 111)

Darwin acknowledged that varieties interbreed very well with other varieties within the same species and in fact "both with plants and animals, there is the clearest evidence that a cross between individuals of the same species, which differ to a certain extent, gives vigour and fertility to the offspring …." (p. 274) However, he also acknowledged that by and large a species cannot interbreed with another species. Darwin states, "It may be urged, as an overwhelming argument, that there must be some essential distinction between species and varieties, inasmuch as the latter, however much they may differ from each other in external appearance, cross with perfect facility, and yield perfectly fertile offspring. With some exceptions, … I fully admit that this is the rule." (p. 278) Thus, he faced a conundrum: varieties in the same species interbreed very well but species in the same genus do not (and species in different genera do not interbreed at all).

Darwin considered it probable that "the sterility of distinct species when crossed and of their hybrid progeny, depends exclusively on the nature of their sexual elements, and not on any difference in their structure or general constitution." (p. 278) However, he did not know how this came about. He said he considered whether it might be the result of natural selection, but concluded it could not be. He states, "But he who will take the trouble to reflect on the steps by which this first degree of sterility could be increased through natural selection to that high degree which is common with so many species, and which is universal with species which have been differentiated to a generic or family rank, will find the subject extraordinarily complex. After mature reflection it seems to me that this could not have been effected through natural selection. Take the case of any two species which, when crossed, produced few and sterile offspring; now,

what is there which could favour the survival of those individuals which happened to be endowed in a slightly higher degree with mutual infertility, and which thus approached by one small step towards absolute sterility? Yet an advance of this kind, if the theory of natural selection be brought to bear, must have incessantly occurred with many species, for a multitude are mutually quite barren." (pp. 270-271)

Darwin also acknowledges that even though man has produced many varieties of a domestic species through his selection for special traits, man has never produced a variety that can no longer interbreed with the allied varieties. This is in contrast to nature, which, under Darwin's theory, produces a multitude of varieties which eventually can no longer interbreed with their allied varieties. Darwin states, "The real difficulty in our present subject is not, as it appears to me, why domestic varieties have not become mutually infertile when crossed, but why this has so generally occurred with natural varieties, as soon as they have been permanently modified in a sufficient degree to take rank as species. We are far from precisely knowing the cause; nor is this surprising, seeing how profoundly ignorant we are in regard to the normal and abnormal action of the reproductive system." (pp. 279-280)

However, Darwin states that "species, owing to their struggle for existence with numerous competitors, will have been exposed during long periods of time to more uniform conditions, than have domestic varieties" and he theorized that "this may well make a wide difference in the result." (p. 280) He goes on to state that domesticated productions "which, as shown by the mere fact of their domestication, were not originally highly sensitive to changes in their conditions of life, and which can now generally resist with undiminished fertility repeated changes of conditions, might be expected to produce varieties, which would be little liable to have their reproductive powers injuriously affected by the act of crossing with other varieties

which had originated in a like manner." (p. 280) Thus, Darwin believed that varieties produced by man retain their ability to interbreed because they are being constantly cross-bred with other varieties and subjected to changed conditions of life.

In summary, Darwin states that "why, in the case of distinct species, the sexual elements should so generally have become more or less modified, leading to their mutual infertility, we do not know; but it seems to stand in some close relation to species having been exposed for long periods of time to nearly uniform conditions of life." (p. 285)

The Absence of Transitional Forms in the World Around Us

Another objection Darwin considered was the following: "[W]hy, if species have descended from other species by fine gradations, do we not everywhere see innumerable transitional forms? Why is not all nature in confusion, instead of the species being, as we see them, well defined?" (p. 158) According to the argument, if Darwin's theory were true, one would see many transitional forms among currently existing species; there would be "an inextricable chaos of varying and intermediate links" (p. 162) instead of distinct gaps between the species. Darwin admits that "the distinctness of specific forms, and their not being blended together by innumerable transitional links, is a very obvious difficulty." (p. 287)

Darwin responds that the main cause "of innumerable intermediate links not now occurring everywhere throughout nature, depends on the very process of natural selection, through which new varieties continually take the places of and supplant their parent-forms." (p. 287) He states, "As natural selection acts solely by the preservation of profitable modifications, each new form will tend in a fully stocked country to take the place of, and finally to exterminate, its own less improved parent-form and other less favoured forms with which it comes into competition." (p. 159)

However, even though transitional forms might ultimately be exterminated, one would still expect to find during the on-going saga of evolution a great many transitional forms currently existing. According to Darwin, this is not the case because transitional forms exist in lesser numbers and do not endure for very long periods. He states, "Now, if we … conclude that varieties linking two other varieties together generally have existed in lesser numbers than the forms which they connect, then we can understand why intermediate varieties should not endure for very long periods:--why, as a general rule, they should be exterminated and disappear, sooner than the forms which they originally linked together." (p. 161) While he states here that the parent form generally lasts longer than the transitional forms, he does state later that "the very process of natural selection constantly tends … to exterminate the parent-forms and the intermediate links." (p. 163)

The Absence of Transitional Forms in the Fossil Record

Another objection is closely related to the one just discussed. Whereas the objection just discussed focuses on the absence of transitional forms among currently existing species, this objection focuses on the absence of transitional forms in the fossil record. In the words of Darwin, "But just in proportion as this process of extermination has acted on an enormous scale, so must the number of intermediate varieties, which have formerly existed, be truly enormous. Why then is not every geological formation and every stratum full of such intermediate links? Geology assuredly does not reveal any such finely-graduated organic chain; and this, perhaps, is the most obvious and serious objection which can be urged against the theory." (p. 287) Darwin admits that "though we do find many links—we do not find interminable varieties, connecting together all extinct and existing forms by the finest graduated steps." (pp. 335-336)

Darwin's principal response to this objection is that the geological record is "incomparably less perfect than is generally supposed." (p. 159) In this connection, he observes "that only a small portion of the globe has been geologically explored with care; that only certain classes of organic beings have been largely preserved in a fossil state; that the number both of specimens and of species, preserved in our museums, is absolutely as nothing compared with the number of generations which must have passed away even during a single formation; …." (p. 335) He also points out that because subsidence of a land mass is "almost necessary for the accumulation of deposits rich in fossil species of many kinds, and thick enough to outlast future degradation, great intervals of time must have elapsed between most of our successive formations" and "there has probably been more extinction during the periods of subsidence, and more variation during the periods of elevation, and during the latter the record will have been less perfectly kept; …." (p. 335) In summary Darwin states, "The crust of the earth with its imbedded remains must not be looked at as a well-filled museum, but as a poor collection made at hazard and at rare intervals. The accumulation of each great fossiliferous formation will be recognised as having depended on an unusual concurrence of favourable circumstances, and the blank intervals between the successive stages as having been of vast duration." (p. 448) However, Darwin realizes his view of the imperfection of the geological record is controversial. He states, "That the geological record is imperfect all will admit; but that it is imperfect to the degree required by our theory, few will be inclined to admit." (p. 431) He also acknowledges, "He who rejects this view of the imperfection of the geological record, will rightly reject the whole theory." (p. 336)

An additional reason Darwin gives for the absence of transitional forms in the fossil record is his contention, mentioned earlier, that transitional forms exist in lesser numbers and do

not endure for very long periods. He states that "although each species must have passed through numerous transitional stages, it is probable that the periods, during which each underwent modification, though many and long as measured by years, have been short in comparison with the periods during which each remained in an unchanged condition." (p. 335)

The Absence of Transitional Forms Even Within Particular Geological Formations

The objection just discussed is that one does not find in the fossil record myriads of transitional forms linking all existing species to a few common progenitors. Another objection is that one does not even find in particular geological formations transitional forms linking a species at the commencement of the formation to an allied species at the end of the formation. As stated by Darwin, "[I]t cannot be doubted that the geological record, viewed as a whole, is extremely imperfect; but if we confine our attention to any one formation, it becomes much more difficult to understand why we do not therein find closely graduated varieties between the allied species which lived at its commencement and at its close." (p. 298)

However, Darwin states, "In order to get a perfect gradation between two forms in the upper and lower parts of the same formation, the deposit must have gone on continuously accumulating during a long period, sufficient for the slow process of modification; hence the deposit must be a very thick one; and the species undergoing change must have lived in the same district throughout the whole time." (p. 299) He believes that the formation of a new species is often very localized and once the new species is formed it might then range widely. Thus, in the case of a formation that has a species in the lower part and an allied species in the upper part, the species in the upper part might have evolved elsewhere and then migrated to the area of the formation. Darwin states that "the chance of discovering in a formation in any one country all the early stages of transition between any two forms, is small, for the successive changes are

supposed to have been local or confined to some one spot." (p. 302) However, he confesses, "But I do not pretend that I should ever have suspected how poor was the record in the best preserved geological sections, had not the absence of innumerable transitional links between the species which lived at the commencement and close of each formation, pressed so hardly on my theory." (pp. 304-305)

The Sudden Appearance of New Forms of Life in Certain Geological Formations

Another objection also relates to the fossil record and points to the sudden appearance of new forms of life in certain geological formations. Darwin states, "The abrupt manner in which whole groups of species suddenly appear in certain formations, has been urged by several paleontologists—for instance, by Agassiz, Pictet, and Sedgwick—as a fatal objection to the belief in the transmutation of species. If numerous species, belonging to the same genera or families, have really started into life at once, the fact would be fatal to the theory of evolution through natural selection." (p. 305) However, Darwin again refers to the imperfection of the geological record and states, "But we continually overrate the perfection of the geological record, and falsely infer, because certain genera or families have not been found beneath a certain stage, that they did not exist before that stage. In all cases positive paleontological evidence may be implicitly trusted; negative evidence is worthless, as experience has so often shown." (p. 305)

Darwin goes on to mention a number of cases that illustrate "how liable we are to error in supposing that whole groups of species have suddenly been produced." (p. 306) He states that he had concluded that sessile cirripedes (barnacles) "had been suddenly developed at the commencement of the tertiary series. This was a sore trouble to me, adding as I then thought one more instance of the abrupt appearance of a great group of species. But … we now have

abundant evidence of the existence of this group of animals during the secondary period." (p. 307) Darwin also refers to the case "most frequently insisted on by paleontologists of the apparently sudden appearance of a whole group of species," i.e., the appearance "of the teleostean fishes, low down, according to Agassiz, in the Chalk period. This group includes the large majority of existing species." (p. 307) Darwin states that "certain Jurassic and Triassic forms are now commonly admitted to be teleostean; and even some paleozoic forms have thus been classed by one high authority" (p. 307), although Darwin does not mention the authority.

The Cambrian Explosion

Another objection that is related to the sudden appearance of new forms of life in certain geological formations involves the so-called Cambrian explosion and poses much more of a problem for Darwin. He states, "There is another and allied difficulty, which is much more serious. I allude to the manner in which species belonging to several of the main divisions of the animal kingdom suddenly appear in the lowest known fossiliferous rocks," i.e., the Cambrian system. (p. 308) He states that *if his theory is true*, "it is indisputable that before the lowest Cambrian stratum was deposited long periods elapsed, as long as, or probably far longer than, the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures." (pp. 308-309)

Darwin states, "To the question why we do not find rich fossiliferous deposits belonging to these assumed earliest periods prior to the Cambrian system, I can give no satisfactory answer." (p. 309) He says, "It does not seem probable that the most ancient beds have been quite worn away by denudation, or that their fossils have been wholly obliterated by metamorphic action, for if this had been the case we should have found only small remnants of the formations next succeeding them in age, and these would always have existed in partially

metamorphosed condition." (p. 310) Darwin also points out that "the descriptions which we possess of the Silurian deposits over immense territories in Russia and in North America, do not support the view, that the older a formation is, the more invariably it has suffered extreme denudation and metamorphism." (p. 310) Although Darwin considers it improbable "that the most ancient beds have been quite worn away by denudation, or that their fossils have been wholly obliterated by metamorphic action" (p. 310), he believes "the chance is small" of discovering "beds rich in fossils … far beneath the lowest Cambrian strata." (p. 333) However, he does not give his reason for so believing.

In conclusion with respect to the Cambrian explosion, Darwin states, "The case at present must remain inexplicable; and may be truly urged as a valid argument against the views here entertained." (p. 310)

Insufficient Time for the World's Species to Have Been Produced Through Natural Selection

Another objection, which Darwin calls "one of the gravest as yet advanced" (p. 431), relates to whether there has been enough time for the world's species to have been produced through natural selection. Darwin presents the objection as follows: "Independently of our not finding fossil remains of such infinitely numerous connecting links, it may be objected that time cannot have sufficed for so great an amount of organic change, all changes having been effected slowly." (p. 289) Darwin states that *if his theory is true*, "it is indisputable that before the lowest Cambrian stratum was deposited long periods elapsed, as long as, or probably far longer than, the whole interval from the Cambrian age to the present day; and that during these vast periods the world swarmed with living creatures." (pp. 308-309) He goes on to state, "Here we encounter a formidable objection; for it seems doubtful whether the earth, in a fit state for the habitation of living creatures, has lasted long enough." (p. 309)

Darwin cites estimates that the consolidation of the earth's crust probably occurred no more than 200 million years ago and that "about 60 million years have elapsed since the Cambrian period …." (p. 309) He states that 60 million years, "judging from the small amount of organic change since the commencement of the Glacial epoch, appears a very short time for the many and great mutations of life, which have certainly occurred since the Cambrian formation; and the previous 140 million years can hardly be considered as sufficient for the development of the varied forms of life which already existed during the Cambrian period." (p. 309)

However, Darwin does not find the objection fatal because of the uncertainty with respect to: (1) the rate at which species undergo change; and (2) the age of geological formations. He states, "With respect to the lapse of time not having been sufficient since our planet was consolidated for the assumed amount of organic change, … I can only say, firstly, that we do not know at what rate species change as measured by years, and secondly, that many philosophers are not as yet willing to admit that we know enough of the constitution of the universe and of the interior of our globe to speculate with safety on its past duration." (p. 431) With respect to the rate at which species change, he states that it is probable that "the world at a very early period was subjected to more rapid and violent changes in its physical conditions than those now occurring; and such changes would have tended to induce changes at a corresponding rate in the organisms which then existed." (p. 309) With respect to "the question whether we really know how old the world is, and at what period the various forms of life first appeared," Darwin states "this may well be disputed." (p. 331)

<u>The Relevance for Today of Darwin's Response to His Critics</u>

Such is Darwin's response to his critics. What then is its relevance for today? It has relevance in terms of both substance and procedure.

Darwin's response has relevance in terms of substance because the objections raised by his critics are relevant to today's neo-Darwinian theory of evolution *and* because Darwin's response to those objections is, for the most part, still relevant today. The neo-Darwinian theory of evolution is basically the same as Darwin's theory except for two differences. First, Darwin believed that the first form or forms of life were produced by the Creator whereas, under the neo-Darwinian theory, the first form of life came into existence through non-intelligent forces. Second, Darwin's ideas about the causes of variations have been updated in the neo-Darwinian theory for what has been learned in the field of genetics. However, none of the objections raised by Darwin's critics relates to one of these two ways in which Darwin's theory differs from the neo-Darwinian theory. Thus, all of the critics' objections are relevant to today's neo-Darwinian theory.

Moreover, Darwin's response to the objections remains relevant today, except in three respects. These are: (1) his view, contrary to current scientific thought, that the flat-fish's *striving* to move one of its eyes could produce an inherited effect; (2) new insights gained since Darwin's time as to why species cannot generally interbreed with other species; and (3) new information about the length of time from the consolidation of the earth's crust to the beginning of the Cambrian period and from the beginning of the Cambrian period to the present day. Except in these three respects, Darwin's response to his critics remains relevant today to their objections to his theory.

Darwin's response to his critics is also relevant today in terms of procedure. Darwin's response shows very clearly that he took his critics seriously and exerted great effort to respond

to them thoughtfully. As indicated earlier, approximately one-third of the final edition of *The Origin of Species* consists of Darwin's response to his critics' objections. He not only took his critics seriously but also treated them with respect, referring to them as "the most eminent paleontologists" and "our greatest geologists" (p. 312). He also honestly acknowledged that there were "a crowd of difficulties" with his theory (p. 158) and that a number of his critics' objections carried great weight.

Darwin's response to his critics makes clear that he was interested in carrying on a civilized and rational debate, taking his critics' objections seriously and responding to them not with deprecation but with evidence and logic. In this respect Darwin is an example for all to follow today.

It was Darwin's hope that young scientists would be able to carefully consider the scientific arguments both for and against his theory. He stated, "I look with confidence to the future,--to young and rising naturalists, who will be able to view both sides of the question with impartiality." (p. 444) When the rising young naturalists of our age are taught the neo-Darwinian theory of evolution, they should at least learn how Darwin responded to his critics. This would introduce an element of objectivity, consistent with Darwin's hope for the future.