

The Mystery of the Left-Handed Molecules in Proteins

There are here mysteries which prepare immense labors for the future, and from this time invite the most serious meditations of science.

—Louis Pasteur¹

OVER A HUNDRED years have passed since Pasteur wrote those words in 1860. He was referring to one of the strangest puzzles in biology, that proteins are made exclusively of “left-handed” molecules.² Although immense labors *have* been done as he suggested, the mystery remains without adequate solution to this day.

We now have the interesting task of applying the laws of chance learned in the previous chapter to this intriguing subject. Naturally, we will first need to know what is meant by “left-handed molecules.”

It should be pointed out that although this is a *shortcut* to certainty, it will require a bit of effort. The philosophy of evolution is so deeply entrenched in our culture that one will find it hard to counteract its error without solid evidence and accurate logic. The gold of the certainty we seek will require some digging. The effort, however, can produce the riches desired.

To avoid being superficial, we will need to get into some areas of the field of biology in detail. This may prove interesting,

¹ In Alton Meister, *The Biochemistry of the Amino Acids* (New York: Academic Press, 1965), vol. 1, p. 113.

² Pasteur was actually writing of the broader mystery that living molecules in general are “one-handed.” We will concern ourselves only with proteins at the present.

for it is the study of *life*. Those with more than a passing interest will see the value of thoroughness on the key issues for our mutual purpose.

Darrell Huff said that there are two important steps in probability reasoning: (1) bring your information on the particular subject to a maximum; then (2) bring an understanding of the laws of probability to bear.³ In this chapter, we will attempt to bring our information on the left-handed molecules in proteins to the maximum needed. Then, in the following chapter, the laws of chance will be applied: What are the odds against a protein having only left-handed components?

The plan will be to keep to the main facts which will enable the reader to get a clear picture. In so doing, we will have to bypass many interesting sidelights not involved directly in the subject, since this is not a textbook on general biology or biochemistry. Necessary technical information will usually be placed in footnotes or in an appendix, so that it will not interrupt or delay a quick grasp of the main ideas. It will thus be available to those who want to dig into the subject. It will also be possible, for those who wish, to research the sources or authority for items mentioned where space may limit us from going into details. For this purpose, the references may be consulted. Some are easily found, others are less accessible, but at least the source is indicated, as is conventional in scientific literature.

Usually, in scientific writings, references are at the end of the chapter. For the convenience of nontechnical readers, however, in this book they are on the same page, as footnotes, so they will be quickly accessible. Since many of the references contain important additional data, this may prove useful to students as well. (When an author is quoted more than once in the same chapter, a short reference form will be used after the first time, giving the author's last name, key words of the title, and page number.)

Also, since math doesn't come easy to a lot of us, we will keep the form of the calculations quite simple so that a person with practically no mathematical training may be able to get the ideas.

³ Darrell Huff, *How to Take a Chance* (New York: W. W. Norton & Co., 1959), pp. 60, 61.

Understanding Proteins—Complex, Yet Built on a Simple Plan

To preface the left-handed mystery, it may be of value to those in other fields if we first review what proteins are like. They are, of course, a major class of the complex molecules of which all living things are made. Since all molecules consist of atoms bonded together, we can get an idea of the size of a molecule by the number of atoms it contains. Water, for example, has three atoms. Nitric acid has five. Now, by comparison, the smallest of proteins contains around a thousand atoms, and the largest has close to a million! Proteins, then, are enormous compared to most molecules.

In primary structure, proteins are long, slender filaments or threads. Even giant molecules, like proteins, are unbelievably small from our viewpoint. In fact, Max Perutz of Cambridge University notes that a protein fiber is 500 times thinner than the thinnest object a good optical microscope could reveal.⁴ This miniature long filament is often precisely folded into a somewhat globular shape which differs for each type of protein.

Proteins Are Chains of Amino Acid Molecules

It seems to be a universal rule in biology that complex things are built from simple components. This is a source of amazement to scientists. It also makes it much easier for us to understand things like proteins and DNA.

Proteins are simply long chains of smaller molecules called *amino acids*. There are twenty varieties of these that are commonly used in proteins. These will be listed in chapter 6. There are indications that all of the twenty kinds occur in proteins of all organisms.⁵

The number of these building blocks in a single protein ranges roughly from 100 to 50,000, since there is great variety in the size of different proteins. The hormone insulin is usually called a protein although it is smaller than this range, having only 51 amino acids. It is not, however, a completely typical protein. The average number of amino acids in proteins of the smallest known living thing is 400, at the very least.⁶

⁴ Max Perutz, "A House for Living Molecules," *1970 Yearbook of Science and the Future* (Britannica), p. 365.

⁵ John F. Thompson, Clayton J. Morris, and Ivan K. Smith, "New Naturally Occurring Amino Acids," *Annual Review of Biochemistry*, Vol. 38 (1969), p. 137. Also:

Margaret O. Dayhoff, *Atlas of Protein Sequence and Structure 1972* (National Biomedical Research Foundation, Washington, D. C., 1972).

⁶ Harold J. Morowitz, personal communication, November, 1970.

There are many thousands of kinds of proteins, and they perform numerous different jobs in living things. Many are digestive enzymes, others are structural molecules, and some perform their specialized tasks as hormones or as hemoglobin in blood cells. All of this complexity comes from those twenty amino acids and the particular order in which they are arranged in the chain. A different sequence may make an entirely different type of protein.

Commenting on this, one scientist noted: "Thus, from about twenty different amino acids, the colossal array of different proteins required by different forms of life is constructed."⁷

Amino Acids Also Are Built on a Simple Plan

It is fortunate for our understanding that even the amino acids possess a degree of uniformity. All are made of four kinds of atoms: carbon, hydrogen, nitrogen, and oxygen. Two of the amino acids also have a sulfur atom each.

Besides this, all of the amino acids are exactly alike in the main section or "backbone" which consists of three atoms, two of which are carbon and the other nitrogen. The center one of those three, which is a carbon atom, is called the *alpha carbon*. ("Alpha," being the first letter of the Greek alphabet, is usually written in Greek in scientific writings, thus: α . To avoid complexity, we will spell out in English any such Greek letters.)

Having noted some of the similarities, we now come to the difference between the amino acids. To the central carbon atom, the alpha carbon, there is attached a *side group*, often called the *R group*. *The sole difference between the various types of amino acids is that each has a different side group.*⁸

In the various amino acids, the distinguishing side group contains from one to eighteen atoms. The considerable diversity in these side groups makes possible many of the things proteins do. They have different electrical and chemical properties which affect other molecules. Other amino acids at various distances in the same protein chain may be attracted in this way, with the following result:

When the units of the protein chain are in any particular

⁷ *Encyclopedia Britannica*, (1967), s.v. "chemistry."

⁸ In the amino acid, proline, the side group bends around and also fastens to the adjacent nitrogen atom. This technically makes proline an "imino" acid, since it replaces a hydrogen atom usually located on that nitrogen atom.

sequence, the resulting chain will coil or spiral and fold in a specific way.⁹ This final shape makes the protein able to do its unique job in the cell.

When two amino acids are united, a "peptide bond" is formed between them, and a molecule of water is released.¹⁰ It takes energy to get the amino acids to bond together. It is difficult to bring this about outside of living things. In the laboratory it can be done by special techniques.¹¹

In living organisms, on the other hand, protein chains are linked up or *polymerized* rapidly. This system for making proteins is very complex and efficient, employing special enzymes and several other unique molecules. It is an extremely interesting process that takes place under direction from the DNA code, the hereditary "language of life." It will be described in chapter 9.

How Can a Molecule Be Left-Handed?

Amino acids can exist in both right-handed and left-handed forms. A person's two hands show how this can be. They have the same components—fingers and thumbs—yet they are different. The thumb of one is on the left and the thumb of the other on

⁹Conformation is also affected by temperature, solvents, "pH" reading (acidity), etc.

¹⁰This water molecule is composed of atoms that were formerly part of the amino acids. For this reason, amino acids in a protein chain are often called amino acid *residues*, since they are no longer complete.

¹¹If the following is confusing, don't be concerned. The purpose of these technical details at this point is merely to indicate some of the difficulties in joining amino acids outside of living things:

Amino acids, in order to join, must be activated or energized by chemically combining with another substance. One such chemical is COCl_2 (carbonyl chloride, also known as phosgene), which may be prepared by passing carbon monoxide and chlorine gases over heated charcoal. COCl_2 is decomposed by water, so a nonaqueous solvent must be used as the scene where this reaction with an amino acid takes place. The product of the reaction is a high energy derivative of the amino acid called its N-carbonyl anhydride (NCA). To cause NCA's to join, an "initiator" chemical is next added to a solution of NCA's. Initiators used include various bases, salts, weak acids, and certain ions.

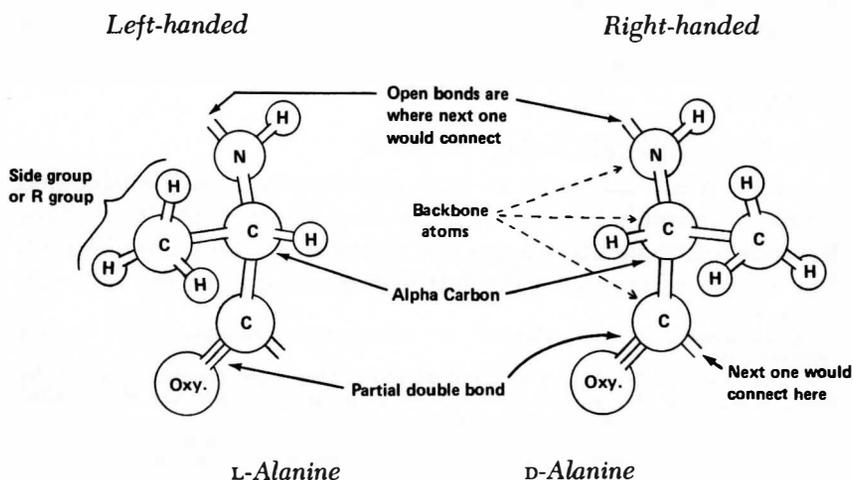
A typical example is the joining of the amino acid derivatives gamma-ethyl-L-glutamate NCA's. The reaction can be brought about in an organic solvent known as N,N-dimethylformamide, at 25° C, using the base di-isopropylamine as an initiator. (C. H. Bamford and H. Block, "The Polymerization of Alpha-Amino Acid N-Carbonyl Anhydrides," *Polyamino Acids, Polypeptides, and Proteins*, ed. Mark A. Stahmann, [Madison: University of Wisconsin Press, 1962], p. 66.) Many other factors must be attended to, such as the concentrations of constituents, and the blocking of reactive groups which are not supposed to get into the action.

Polymerization by heat can be accomplished at 180° C if certain precise artificial ratios of amino acids are used, with large amounts of aspartic acid and glutamic acids. (Sidney W. Fox and Klaus Dose, *Molecular Evolution and the Origin of Life* [San Francisco: W. H. Freeman and Co., 1972], p. 345.)

the right. They are "mirror images" of each other. Some molecules are like that.

Let's imagine that we are able to look at an amino acid molecule. Remember that each is built on the same simple plan. The three atoms of the backbone are in the direct line of the protein chain when the amino acid is united with others. In the center is the alpha carbon atom. On one end of it there is a nitrogen atom, and on the other end another carbon.¹² If we look at it from the carbon end, it will be possible to tell whether it is left- or right-handed (see Figure 2).

FIGURE 2



Left- and right-handed amino acid residues. The molecules shown are L-alanine and D-alanine (L = levo, or left-handed; D = dextro, or right-handed). Alanine is the simplest of the amino acids which are isomeric or handed.

The bonds in the figure are not drawn to scale, but are lengthened so that the left- and right-handedness is more easily seen. In real molecules, the bonds are shorter so that the "surfaces" overlap, making the molecules more compact. The initials on the atoms indicate carbon, nitrogen, oxygen, and hydrogen. Note that the only difference between the two is the position of the side group, on either the left or right side.

¹² The carbon end is called the *carboxyl* end, if that end of the amino acid is free and complete, or the *carbonyl* end if it is joined to another.

Notice the center carbon atom of the backbone. It appears to be elevated a bit compared to the other two atoms of the main part. That alpha carbon is *asymmetric*, that is, different on every side. This difference is not in the atom itself, but it results from the fact that the four items bonded to it all are different.

As we view it from our vantage point at the carbon "end" of the amino acid¹³ (considering the lower carbon atom in Figure 2 as the carbon end), we note that the central or alpha carbon has two side projections that angle outward to the right and to the left. On one side, this extension is simply a hydrogen atom. Opposite it is the side group mentioned earlier, the group which differs for each of the twenty amino acid types.

If that identifying side group is on the left, the molecule is "left-handed." If instead it protrudes to the right, the amino acid is said to be "right-handed."

These two forms of the same chemical contain the exact same components and are called *isomers* or *stereoisomers* of that chemical. Their side groups are just positioned oppositely in space. Each form is the *antipode* of the other. They are *enantiomorphs* or *enantiomers* of each other.

We may note in passing that this difference was discovered in an accidental way. A French physicist named D. F. Arago in 1811 shined a beam of plane-polarized light through a quartz crystal. He discovered to his surprise that the plane of the light was twisted or rotated as it passed through the crystal. Later it was found that some chemicals dissolved in water would also cause this twisting of the beam of light. Whether the light was rotated to the right or to the left depended on the substance used. Solutions which rotate polarized light in this manner are said to be *optically active*, since they deflect the path of light.

Pasteur, while investigating this strange phenomenon in 1848, found that the optically active substance he was studying was made of one-handed molecules.¹⁴ To his surprise, he found that optically active materials from living things were different from

¹³ J. M. Barry and E. M. Barry, *An Introduction to the Study of Biological Molecules* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969), p. 99.

¹⁴ Solutions made of the opposite enantiomorph of such a chemical will rotate the light plane the opposite way. Both forms mixed together equally will not usually rotate the light plane at all. One might suppose that left-handed molecules would rotate light to the left, but this is not necessarily so. There is no simple universal relationship between left-handed configuration, for example, and the direction of optical rotation, because complex factors are involved.

optically active crystals of inorganic substances like quartz. *Crystals* of the latter come in both left- and right-handed configuration, whereas the *individual molecules* are neither left- nor right-handed.

Only Left-Handed Amino Acids in Proteins

Francis Crick, codiscoverer of the DNA structure, describes this strange characteristic of the molecules of living organisms:

It has been well known for many years that for any particular molecule only one hand occurs in nature. For example the amino acids one finds in proteins are always what are called the "L" or "levo" amino acids, and never the "D" or "dextro" amino acids. Only one of the two mirror possibilities occurs in proteins.¹⁵

That is the mystery. English biologist John Maddox called it "an intellectual thunderbolt that natural proteins should contain only the left-handed forms of the amino acids."¹⁶

This is a special difficulty for those who believe that life originated from nonliving matter by natural processes. A. I. Oparin, Russian biochemist, has perhaps had more to do with current evolutionary thought than any man since Darwin because of his pioneering attempts to explain the origin of life through natural chemical processes. He brought up this mystery in a recent book thus: "It is necessary to touch briefly on a problem which has been discussed in the literature for a long time."¹⁷

In an earlier book he went more into detail. The atoms involved in the different positions (right and left) are subject to the same forces. When amino acids are formed, that varying side group could just as easily be on the right as on the left. Says Oparin:

The probability of the formation of one antipode or the other is therefore the same. As the law of averages applies to chemical reactions the appearance of an excess of one antipode is very improbable, and, in fact, we never encounter it under the conditions of non-living nature and in laboratory syntheses. . . .

In living organisms, on the contrary, the amino acids of

¹⁵ Francis H. C. Crick, *Molecules and Men* (Seattle: University of Washington Press, 1966), p. 60.

¹⁶ John Maddox, *Revolution in Biology* (New York: Macmillan Company, 1964), p. 59.

¹⁷ A. I. Oparin, *Genesis and Evolutionary Development of Life* (New York: Academic Press, 1968), p. 80.

which naturally occurring proteins are made always have the left-handed configuration. . . . This ability of protoplasm selectively to synthesize and accumulate one antipode alone is called the asymmetry of living material. It is a characteristic feature of all organisms without exception but is absent from inanimate nature.

Pasteur pointed out this fact as follows: "This great character is, perhaps, the only sharp dividing line which we can draw at present between the chemistry of dead and living nature."¹⁸

In modern times, many others have expressed the same surprise as Pasteur. For example, Linus Pauling, Nobel laureate in chemistry:

This is a very puzzling fact. . . . All the proteins that have been investigated, obtained from animals and from plants, from higher organisms and from very simple organisms—bacteria, molds, even viruses—are found to have been made of L-amino acids.¹⁹

He concludes, "Nobody knows why it is that we are built of L-amino acid molecules, rather than of D-amino acid molecules."²⁰

Dr. Larry Butler, who teaches biochemistry at Purdue University, has said, "In all respects chemically and physically (except for physical properties associated with asymmetry. . .) D- and L-amino acids are not only equivalent but indistinguishable."²¹

Professor Dennis Englin calls attention to an amusing experiment. Scientists now can hook up proteinlike chains which contain both the L- and D-amino acids, and put such chains into a living organism, e.g., a bacterium. The organism immediately takes them apart, and in some cases rebuilds the amino acids in the left-handed form!²²

¹⁸ A. I. Oparin, *Life, Its Nature, Origin and Development* (New York: Academic Press, 1961), pp. 59, 60.

¹⁹ Linus Pauling, *General Chemistry* (Third Edition) (San Francisco: W. H. Freeman & Co., 1970), p. 774.

²⁰ *Ibid.*

²¹ Larry Butler, Purdue University, personal communication, April 1971.

Some isomers can be distinguished from their opposites by taste, says Butler. They also can sometimes be detected by odor. ("Left- and Right-Handed Odors," *Scientific American*, Vol. 225 [August 1971], pp. 46, 47.) This may be due to physical difference in shape, if these sense receptors have "specifically shaped sites into which molecules of different forms fit."

²² Dennis Englin, Los Angeles Baptist College, personal communication, June 1971.

For those interested in biology, it is intriguing to find that D-amino acids do have an occasional role in nature but never in proteins from evidence to date. Ordinarily no more than one or two right-handed isomers occur in such

Professor William Stokes of the University of Utah sums up the situation on this baffling question of the two forms as far as normal proteins are concerned:

They are as identical in all other respects as a pair of gloves. When amino acids are prepared artificially, both L- and D-varieties occur in statistically equal amounts. But living things can use and construct only the left-handed type, probably for hereditary reasons going back to the first ancestor of all life on earth.²³

Looking at it from the naturalistic standpoint for the moment, we may ask: *How could living things have gotten started which use only left-handed amino acids in proteins?*

The first problem is to discover how *any* amino acids could originate by natural means. For this, the current explanation is to postulate a primitive atmosphere that was totally different from ours today. Then it is claimed that amino acids might have been formed from that prescribed atmosphere by the action of ultraviolet rays, lightning, and perhaps heat.²⁴

cases. These always occupy a precise position, usually in a small molecule or short peptide chain.

Bacteria have as part of the cell wall, outside the cell membrane, a molecular mesh known as *murein* which completely surrounds the cell. Murein consists of a polysaccharide containing two amino sugars crosslinked by means of tetrapeptides (which contain four amino acids, in final form.) Two of the four amino acids are the D- type, first formed as L-amino acids inside the cell and then changed to the D- variety.

The bacterium, *Bacillus anthracis*, has D-glutamic acid as the repeating subunit which forms its "slime capsule" outside the cell wall. Perhaps such use of D-amino acid units in cell walls and capsules may confer some protection from enzymes which predominantly are coded to react with L-isomers.

The antibiotic known as *polymyxin B* consists of a cyclic polypeptide ten amino acids in length. Occupying a specific site in the ring is D-phenylalanine. *Penicillin*, another antibiotic, and *luciferin*, a chemical involved in producing light in fireflies and other organisms, are other examples where one or two D-amino acids occur in small molecules.

None of these rare examples are proteins and all could give the impression that they are purposefully positioned rather than in random or interchangeable sites.

²³ William Lee Stokes, *Essentials of Earth History* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1966), p. 176.

²⁴ The hypothetical primitive atmosphere conveniently happens to contain methane, ammonia, hydrogen, and water vapor, from which it is theoretically simple to derive amino acids. In a famous experiment, Stanley L. Miller duplicated that supposed atmosphere and subjected the mixture to an electric spark for a week. He succeeded in getting the two simplest amino acids and three others of doubtful identity. (George Wald, "The Origin of Life," *Scientific American* [August, 1954], p. 48.) *The results, however, included both left- and right-handed isomers.* (Oparin, *Life, Its Nature, Origin and Development*, p. 59.) Such a mixture containing both forms, is called a *racemic modification*. Later, Sidney W. Fox and K. Harada in complex experiments obtained twelve protein-type amino acids. They used considerable heat (around 1,000° C), ammonium hydroxide, and other laboratory controlled conditions. (Sidney W. Fox and Klaus

In experiments with this presumed primeval atmosphere, whenever any amino acids have been obtained in elaborate laboratory tests, they have consisted of both L- and D- varieties.

So we still have the problem. *Even if* the amino acids had occurred in that atmosphere naturally, these experiments indicate that the supply would have been "racemic" or mixed, instead of all L- or all D-.²⁵

Efforts to Account for the Left-Handed Phenomenon

Scientists have let their imaginations range far and wide in quest of a solution. Without exception, each avenue has proved considerably less than satisfying. Materialists, for lack of anything better, have had to sound confident and to depend on one or another of the ideas put forward. One gets the impression that many just have a vague hope that maybe some one of these explanations may be valid, without specifying which specific one.

A summary of these attempts is given in Appendix 1, page 243, following the final chapter. The reader is encouraged to turn to it if he desires the details on this subject.

For a century, these efforts to find the answers have continued. Long and imaginative labors using many laboratory approaches have managed only to get "unequal amounts of enantiomers to form," by using reagents, catalysts, crystals, solvents, etc.²⁶ This is sometimes hailed as if it indicated success, and is credited to the "entirely expected effect of the atomic neighborhood, biasing, say, the ease of approach of the various reacting molecules to one of the possible sites of action." One such "success," we may note, yielded "an excess of 6 percent," the amount of one hand as compared to the other.²⁷

All well and good, but getting "unequal amounts" is a far cry from explaining nature's success in producing 100 percent (all L-) products. Even if a way is found, the question will per-

Dose, *Molecular Evolution and the Origin of Life* [San Francisco: W. H. Freeman and Co., 1972], p. 81.)

²⁵ Six protein-type amino acids have been identified in the Murchison meteorite which fell in Australia in 1969. Both left- and right-handed isomers of each of these proteins were present "in roughly equal proportions," and thought to be of inorganic origin. (James G. Lawless, Clair E. Folsome, and Keith A. Kvenvolden, "Organic Matter in Meteorites," *Scientific American*, Vol. 226, [June, 1972], p. 42.) This strengthens the conclusion that there is no natural way known which could produce all-left-handed amino acids, outside of living cells.

²⁶ Philip Morrison, in Book Reviews, *Scientific American*, Vol. 225, (July, 1971), p. 120.

²⁷ *Ibid.*

sist: *Why is it so difficult for our most intelligent scientists to solve in modern laboratories what nature has done without apparent effort?*

No Satisfactory Answer Has Been Found

After considering all the attempts, it is clear that unless chance could do it, there is at present no adequate answer from a naturalistic standpoint to explain how this left-handed condition began. As a result, there is little evidence of any agreement or consensus among scientists regarding its source. Oparin must presume that this stereoselectivity started without prior design. Any other belief would be inconsistent with his communist philosophy. (Interestingly, that viewpoint—dialectical materialism—is not atheistic after all. Professor Claude Tresmontant of the University of Paris has pointed out with unanswerable logic that communists are actually pantheists, worshiping matter-in-motion.)²⁸

Dr. Oparin never does make clear which of all the various ideas he prefers, to account for the origin of the exclusive use of left-handed amino acids in proteins, but he assumes it happened naturally, nevertheless. He is admirably straightforward in realizing the difficulty:

Even when we know how the asymmetry arose, though, we still cannot answer the question of why one antipode, rather than the other, should occupy such a monopolistic position in the life of all the organisms inhabiting the Earth. This question is important for an understanding of the essential nature of life but it remains for future investigators to supply the answer.²⁹

On that subject, Pauling made this imaginative comment:

The earth might just as well be populated with living organisms made of D-amino acids as with those made of L-amino acids. A man who was suddenly converted into an exact mirror image of himself would not at first know that anything had changed about him. . . . He could drink water, inhale air and use the oxygen in it for combustion, exhale carbon dioxide, and carry on other bodily functions just as well as ever—so long as he did not eat any ordinary food. If he were to eat ordinary plant or animal food, he would find that he could not digest it.³⁰

²⁸ Claude Tresmontant, Interview in *Réalités* (April, 1967), p. 47.

²⁹ Oparin, *Life, Its Nature, Origin and Development*, p. 61.

³⁰ Pauling, *General Chemistry*, p. 775.

Whether or not one agrees with his political actions, in the laboratory Linus

He then noted a strange coincidence. As long ago as 1872, Lewis Carroll's *Through the Looking Glass* was published. In it, Alice (in a land of mirror images) said, "Perhaps looking-glass milk isn't good to drink."³¹ It is possible that Lewis Carroll was aware of Pasteur's work in this field.

In attempting to account for the one-handed phenomenon, Oparin and others have depended upon natural selection. As we will see in chapter 5, there is no way that natural selection could have operated at all until there was a way to duplicate all the essential parts accurately. There is no method known whereby this could take place except the intricate DNA-RNA-enzymes-ribosome process which we will examine in later chapters. Therefore, natural selection is of no help whatever in the effort to find the way that left-handed amino acids obtained their complete monopoly in naturally occurring proteins.

No Natural Solution Unless Chance Could Produce This Effect

Since natural selection was unable to operate before accurate duplication, and since no way has been found to account for the exclusive use of left-handed components in proteins, chance is all that is left, from the materialistic standpoint. Some evolutionists have recognized this explicitly. For example, S. E. Bresler, a top biochemist in the U.S.S.R. Academy of Science, wrote,

How and why the complete separation of stereoisomers in living tissue was started remains an enigma... We can only speculate that this remarkable phenomenon originally occurred as the result of very rare large-scale fluctuations associated with the origin of life.³²

By this he plainly means chance fluctuations. Before applying the rules of probability, there are two questions we need to resolve: (1) Can each of the amino acids be linked with any other, regardless of hand? (2) Will they link with equal ease whether of the same or the opposite hand?³³

Pauling's scientific discoveries have been outstanding, and his books in the realm of science are classics, yet written with humility.

³¹ We have seen earlier that certain organisms can convert *some* of the D-amino acids into the L- form. Similar conversion to the natural form does not seem to be possible, however, in the case of the energy food, glucose sugar (*Encyclopaedia Britannica*, 1967, s.v. "stereochemistry"), and other vital foods, such as Vitamin C, which is L-ascorbic acid (Linus Pauling, *Vitamin C and the Common Cold* [San Francisco: W. H. Freeman & Co., 1970], p. 89).

³² S. E. Bresler, *Introduction to Molecular Biology* (New York: Academic Press, 1971), pp. 6, 7. First published in Russia in 1966.

³³ To ascertain the current status of information on these questions, the author, in 1971, talked by telephone with several prominent scientists in the United States

Left- and Right-Handed Amino Acids Can Be Linked

Are the two forms of the amino acids shaped so that any of them can unite, whether they are L- or D- in type? The answer is yes. Whether left- or right-handed, any amino acid can be linked with any other of either hand. There seem to be no exceptions.³⁴

Pauling wrote (1964): "We have no strong reason to believe that molecules resembling proteins could not be built up of equal numbers of right-handed and left-handed amino acid molecules."³⁵ Since that was written, this has actually been done on numerous occasions in many laboratories, resulting in a voluminous literature in the scientific journals.

While it is true that opposites can be linked in the laboratory, what about that question if we consider the conditions that evolution assumes to have been existing before life began? Dr. Sidney W. Fox, of the University of Miami has done experiments which involve this. Some years back, Dr. Fox heated all the common amino acids at 200° C temperature under certain conditions and obtained chains containing all the amino acids.³⁶ When asked if both left- and right-handed amino acids were included in the same chain, he replied that he was almost 100 percent certain that they were, but that there was no way to tell absolutely at the time.³⁷ Temperatures of 170° C and above were typically used in such experiments.

and England who are knowledgeable in this field. Much of the material in this chapter and the next was first published as a separate paper (James F. Coppege, "Probability and Left-Handed Molecules," *Creation Research Society Quarterly*, Vol. 8 [December, 1971], pp. 163-174.) See also Appendixes 1 and 2.

³⁴ Telephone conversations April, 1971, with James Bonner, California Institute of Technology; Sidney W. Fox, University of Miami; Arthur Elliott, King's College, London; Harry Block, University of Liverpool.

³⁵ Linus Pauling, *College Chemistry*, 3rd ed. (San Francisco: W. H. Freeman & Co., 1964), p. 731. Repeated in his 1970 edition of *General Chemistry*.

Dr. Pauling, in commenting on this question by telephone (April 1971), mentioned the possibility of "steric hindrance" (interference because of shape), but referred me to his book quoted above.

We will discuss the matter of preference for the same hand shortly, but there seems to be no doubt that any amino acid can be linked to any other, as indicated by many scientists who have experimented extensively on this particular matter.

³⁶ Sidney W. Fox, ed., *The Origins of Prebiological Systems and of Their Molecular Matrices* (New York: Academic Press, 1965), pp. 361-382.

Encyclopedia Americana (1971), s.v. "amino acids."

³⁷ Fox, personal communication, 1971.

A difficulty in using heat to join amino acids is "the easy thermal decomposition" of amino acids. (Sidney W. Fox, Kaoru Harada, & Duane L. Rohlffing, "The Thermal Copolymerization of Alpha-Amino Acids," in *Polyamino Acids, Polypeptides, and Proteins*, ed. Mark A. Stahmann [Madison: University of Wisconsin Press, 1962], p. 47.)

Will Opposites Join With Equal Ease?

Although there is a degree of uncertainty on this subject at the present stage of scientific knowledge, it appears that the answer lies in one or the other of the following extremes, or somewhere between: (1) There may be equal ease of linking opposite hands, on the average. This seems most likely, when considering all the factors. The individual amino acids are different in ease of fit. Some work better with the same hand, and some with the opposite. The shape of the chain, when it begins to form a spiral, also may be involved.

(2) The other possibility is indicated in a few reports of preference for the same hand in some particular instances.³⁸ In some other instances there is preference for the opposite hand.³⁹ The extreme limit seems to be a possible preference of 6/7 for the same hand. It is quite unlikely that this is the case on any general basis, but we will use it as one limit to consider.

Since this subject gets quite technical, we will include the details in Appendix 2, page 249, leading to the conclusions which have just been stated briefly. The reader can experiment with models of the amino acids in order to satisfy himself on the comparative equal ease of fit, whether of the same or opposite hand. Numerous opposite hand linkups are routinely made in various laboratories with no notice of any more hindrance than with the same hand,⁴⁰ except in the occasional instances mentioned.

In the next chapter, probability reasoning will be applied to these two outside limits—equal ease of linkup, or 6/7 preference for the same hand.

³⁸ R. D. Lundberg and Paul Doty, "A Study of the Kinetics of the Primary Amine-initiated Polymerization of N-Carboxy-anhydrides with Special Reference to Configurational and Stereochemical Effects," *American Chemical Society Journal*, Vol. 79 (1957), pp. 3961-3972.

E. R. Blout and M. Idelson, in *American Chemical Society Journal*, Vol. 78 (1956), pp. 3857, 3858. These authors also mention a *reverse* preference as one explanation for some of their results.

Fred D. Williams, M. Eshaque, and Ronald D. Brown, "Stereoselective Polymerization of Gamma Benzyl Glutamate NCA," *Biopolymers*, Vol. 10 (April, 1971), pp. 753-756.

³⁹ Fred D. Williams, Michigan Technological University, telephone conversation, June, 1971.

Eberhard Shröder and Klaus Lübke, *The Peptides* (New York: Academic Press, 1965), pp. 274, 275, 319-326.

⁴⁰ E. Klein et al., "Permeability of Synthetic Polypeptide Membranes," *Biopolymers*, Vol. 10 (April, 1971), pp. 647-655; E. Klein, Gulf South Research Institute, New Orleans, telephone conversation, June, 1971.

