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The Remarkable Way Cells Translate DNA

. . . to duplicate that which only God could conceive.[1]
—Diane Rothstein

PERIODICALLY NEWSPAPERS REPORT in bold headlines and in a variety of wordings that scientists have succeeded in "synthesizing life" in laboratory experiments. What has usually happened, however, is that living cells have been taken apart, and then some of their components have been reassembled or combined with other chemicals. In all such experiments to date, a vital part of success has depended upon one or more complex parts that grew in actual living cells. (Even if the production of life from nonliving chemicals could be accomplished in the laboratory, it would be a product of intelligence, not chance.)

C. L. Strong has said (1970), "No one has created life in the laboratory. The possibility is vanishingly small that a viable organism can be compounded. Yet that slender chance continues to intrigue some experimenters. . . ."[2] It was of these experiments that Diane Rothstein wrote in the above quotation.

To bring our knowledge of the DNA system to the maximum needed before applying probability theory, this chapter will outline the fascinating process by which DNA translates information into action.

DNA Directs the Cell's Activities

John Kendrew uses this fitting comparison:

> Any living thing can be likened to a giant factory, a factory

[1] Diane Rothstein, Letters, *Science Digest* (January, 1970), p. 9.
[2] C. L. Strong, "The Amateur Scientist," *Scientific American* (January, 1970), p. 130.

> producing chemicals, producing energy and motion, indeed reproducing itself too (which most factories cannot do!) and if one thinks of the way in which assembly lines are organized in factories one realizes immediately that all this complex of operations could not be carried out unless they were in some way organized, separated into compartments, not higgledy-piggledy. In other words, there must be some kind of organization in the structure of an animal to enable it to carry out these processes in an orderly way.[3]

In that parallel, the DNA would be like the manuals and blueprints that prescribe in detail just how each operation is to be done, and in what order of timing.

The coded information in DNA, then, would obviously be absolutely essential. It would also be absolutely helpless unless it had the entire system of the manufacturing plant, including people or computers *to read and put into action* its instructions.

Transcribing From DNA to RNA Working Copies

We will follow Kendrew's analogy of an industrial plant. The DNA master copy of the production blueprints must be kept protected. What is required first of all is a way to make *working copies* of just the sections needed at the moment. These temporary copies can then be taken out into the rough-and-tumble of the production area, leaving the DNA original safely in the office. When no longer needed, the copies are destroyed.

The temporary copies of parts of the DNA are called *RNA*, or, more properly, *messenger-RNA*, usually written *mRNA*. RNA is quite similar to DNA. In fact, it is identical in structure to one-half of the DNA double helix, except in two respects.

The difference in name comes from a very slight difference in the sides of the chains. RNA is the abbreviation for *ribonucleic acid*. DNA is *deoxyribonucleic acid*. The small sugar molecules used in RNA are ribose sugar. Those in DNA are *deoxyribose*, with one less oxygen atom. (This slight difference is very important to life. It keeps the DNA from being dismantled by the enzyme "ribonuclease," which takes apart mRNA chains when their temporary job is completed.)

There is one other difference. The four RNA bases are the same as those used in DNA, except that in place of *thymine*, RNA always has *uracil*, which is quite similar. RNA's four bases

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[3] John C. Kendrew, *The Thread of Life* (Cambridge, Mass.: Harvard University Press, 1966), p. 15.

are, therefore, adenine, cytosine, guanine, and uracil—A, C, G, and U.

The translation of DNA into proteins is done indirectly, via RNA. The reason, as we have indicated, is that DNA, the vital carrier of hereditary information from generation to generation, must be kept safe from damage at all times. This master copy of the instructions is therefore retained in the cell nucleus or otherwise protected. The wisdom of this is apparent.

The Transcription Process

When a section of DNA is to be *transcribed* into RNA, the DNA double helix divides at that location into two strands. Then, an RNA chain forms alongside one of those strands, in the same way that DNA replication takes place.

In the cell fluid are large numbers of the individual parts which can be used to form RNA chains. These are called *ribonucleotides* or RNA nucleotides. Each individual nucleotide will match one specific type of base in the divided DNA.

The same complementary base-pairing plan works here as when DNA duplicates itself, as described earlier. It must be remembered, however, that RNA uses uracil intsead of thymine. When RNA is forming alongside the DNA strand, the DNA adenine will pair with the RNA nucleotide uracil. Here are the pairing possibilities:

DNA Adenine	pairs with	RNA Uracil	(A - U)
DNA Cytosine	pairs with	RNA Guanine	(C - G)
DNA Guanine	pairs with	RNA Cytosine	(G - C)
DNA Thymine	pairs with	RNA Adenine	(T - A)

Since DNA is transcribed into RNA in order to accomplish work in the cell, the code designations are usually written in the mRNA form, rather than the DNA. The DNA version, in one regard, may be considered as the "negative" from which positive prints are made, meaning RNA copies. Code lists are therefore printed in the RNA form, as on page 144.

In chapter 8, it was seen that the DNA code apparently is read from only one side of the double helix. That side is the one which serves as the pattern strand when RNA is formed alongside it by base pairing.

As the RNA nucleotides line up opposite the matching DNA bases, they are connected together by a special enzyme. This

enzyme is found in virtually all cells,[4] and is called *RNA polymerase*. It is responsible in large measure for the precision and fidelity of the copying process. There is evidence that this copying accuracy is so exact that it might correspond to a typist's making only one error in from 7 to 700 pages.[5] As to speed, *as many as 30 or 40 nucleotides per second* may be added to the forming RNA chain, in bacteria.

As the RNA copy is formed along the DNA pattern strand or *template*, it immediately separates progressively from the DNA. The two DNA strands then join up again, thus returning to their normal double helix condition.[6]

Before proceeding to what happens next with the RNA copy, two questions arise. When are copies made, and where do they begin on the DNA template?

Turned-Off Genes and Sophisticated Controls

Although much remains to be learned, it is now clear that an elaborate and precise control system governs the timing and location of RNA transcriptions.

That portion of DNA which encodes the sequence of one particular protein chain is called a *gene*. Genes must be switched off when not needed or there would be utter chaos from overproduction of items. While research is continually adding information, it is now clear that many genes are kept in the switched-off position by *repressor* molecules which are in turn coded for by *regulator* genes. The job of a repressor is to fasten to the DNA at an *operator* site, thereby preventing any copying

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[4] James D. Watson, *Molecular Biology of the Gene*, 2nd ed. (Menlo Park, Calif.: W. A. Benjamin, Inc., 1970), p. 338.

[5] This is calculated from information by Carl R. Woese. He says it would seem that the bacterial cell, in order to function normally would require a low error frequency in transcription in the range of 10^{-6} and 10^{-4} per base pair, which means no more mistakes than 1 every 10,000 to a million letters of the code (10^{-6} is the same as $1/10^{6}$). (Carl R. Woese, "The Biological Significance of the Genetic Code," in *Progress in Molecular and Subcellular Biology*, ed. F. E. Hahn [New York: Springer-Verlag, 1969], p. 24.)

RNA polymerase (or *transcriptase*) works only if there is a DNA pattern strand present. It is therefore often called "DNA-dependent RNA polymerase." Multiple types of RNA polymerase have been discovered.

[6] RNA transcription is quite rapid, as just noted (although Watson says that DNA *replication* may be 100 times faster—*Molecular Biology of the Gene*, p. 528). In chapter 6, it was noted that many scientists think that at the time of the assumed natural origin of life, temperature would have been below freezing. Without enzymes, under those primitive conditions, it can be calculated that it might take a billion years *just to transcribe* the DNA of the smallest known cell into one mRNA copy. All that time, it would be subject to breakage and dismantling. Even if preserved, it would be helpless without all the machinery of protein synthesis about to be described.

of that gene into the form of RNA. This complex system involves two or more methods of operation. One technique employs molecules known as *inducers,* of which there are many kinds.

An inducer molecule will combine by weak bonds with a specific repressor, and this keeps the repressor from fastening to the gene. As a result, the repressor cannot turn off the gene, and so RNA polymerase begins transcribing that gene, by starting at a place on the DNA called the *promoter.* Here is one example. Suppose lactose sugar starts arriving outside of the cell of an *Escherichia coli* bacterium. An inducer will then fasten to the repressor that controls the genes which produce enzymes for processing lactose. As a result, the genes are transcribed into RNA, and proteins are formed for bringing lactose into the cell and processing it as food for the cell. It is much more complicated than this, but in this intricate way, the transcription begins at the proper place at the start of a gene and continues for the length of one or more genes.[7]

An alternative system works in this way: When there is on hand enough of a specific type of molecule used by the cell, one of those molecules will combine with a repressor, thereby causing it to fasten to the DNA at the operator site and keep the gene turned off because its product is not needed due to the supply already on hand. In this case, the molecule which fastened to the repressor is a sample of the type that is in plentiful supply or a related metabolite, and this molecule is termed a *corepressor.*

There is also a remarkable feedback system which exists in metabolic chains, preventing overproduction without involving the repressor system at the gene level. This works by what is called *allosteric inhibition* of enzymes in the chain. An end-product molecule from that chain may react with an enzyme at the start or at a key juncture of the chain, causing the enzyme to change its shape. As a result, it is no longer able to function in its usual capacity as an enzyme catalyst to keep the chain going.[8]

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[7] Related genes which are grouped together along the DNA chain are called an *operon.* One operon may control the making of several enzymes needed to complete one particular process, such as the assembling of a specific amino acid from other chemicals in the cell. This may require more than half a dozen genes. The RNA transcription may run for an entire operon, so that all these needed enzymes are made about the same time.

[8] Existence of sophisticated controls for the cell's multiple complex production systems is unthinkable without intelligent design to account for it. The lack of

FIGURE 12

The Genetic Code in Alphabetical Order[9]

The 64 Codons and Their Amino Acid Assignments

AAA Lysine	CAA Glutamine	GAA Glutamic acid	UAA End chain
AAC Asparagine	CAC Histidine	GAC Aspartic acid	UAC Tyrosine
AAG Lysine	CAG Glutamine	GAG Glutamic acid	UAG End chain
AAU Asparagine	CAU Histidine	GAU Aspartic acid	UAU Tyrosine
ACA Threonine	CCA Proline	GCA Alanine	UCA Serine
ACC Threonine	CCC Proline	GCC Alanine	UCC Serine
ACG Threonine	CCG Proline	GCG Alanine	UCG Serine
ACU Threonine	CCU Proline	GCU Alanine	UCU Serine
AGA Arginine	CGA Arginine	GGA Glycine	UGA End chain
AGC Serine	CGC Arginine	GGC Glycine	UGC Cysteine
AGG Arginine	CGG Arginine	GGG Glycine	UGG Tryptophan
AGU Serine	CGU Arginine	GGU Glycine	UGU Cysteine
AUA Isoleucine	CUA Leucine	GUA Valine	UUA Leucine
AUC Isoleucine	CUC Leucine	GUC Valine	UUC Phenylalanine
AUG Methionine	CUG Leucine	GUG Valine	UUG Leucine
AUU Isoleucine	CUU Leucine	GUU Valine	UUU Phenylalanine

Amino Acids in Alphabetical Order With Their Code Assignments

Alanine	GCA, GCC, GCG, GCU
Arginine	AGA, AGG, CGA, CGC, CGG, CGU
Asparagine	AAC, AAU
Aspartic acid	GAC, GAU
Cysteine	UGC, UGU
Glutamic acid	GAA, GAG
Glutamine	CAA, CAG
Glycine	GGA, GGC, GGG, GGU
Histidine	CAC, CAU
Isoleucine	AUA, AUC, AUU
Leucine	CUA, CUC, CUG, CUU, UUA, UUG
Lysine	AAA, AAG
Methionine	AUG
Phenylalanine	UUC, UUU
Proline	CCA, CCC, CCG, CCU
Serine	AGC, AGU, UCA, UCC, UCG, UCU
Threonine	ACA, ACC, ACG, ACU
Tryptophan	UGG
Tyrosine	UAC, UAU
Valine	GUA, GUC, GUG, GUU
End chain	UAA, UAG, UGA

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controls leads to chaos in any organized human endeavor and in the organized processes of organisms. Consider this comment on the importance of controls, by one of the discoverers of the DNA structure, who has not yet accepted the implications as to design involved in the DNA molecule which so fascinated him and us all: "Thus, the only useful distinction is that the cancer cell is less subject to the normal control devices which tell a cell not to divide." (Watson, *The Molecular Biology of the Gene*, p. 591.) For more complete details of the corepressor system described above, see this same reference, pp. 438-442. Dr. Watson also discusses the evidence for there being timing sequences between some genes, (p. 528).

[9] Adapted from data by Francis H. C. Crick, "The Genetic Code: III," *Scientific American*, Vol. 215 (October, 1966), p. 57.

"Ribosomes" Which Process the RNA Copy

When the mRNA copy of a gene or of an operon is made, the work has only begun, just as when the office staff of an industrial plant makes copies of the blueprints at the request of a shop foreman. The instructions must then be read and put into action at the cell's assembly lines. The correct amino acids must be brought in proper order and fastened together to form the needed protein chain.

We may picture the next key figure as a production foreman with a complex assembly machine. He arranges for various workers to read the copy of the instructions and to bring the items in proper order so the foreman can link them together, using the machinery which he has on hand for that purpose.

In the cell, this key figure is known as a *ribosome* (pronounced rye-bo-sohm). It fulfills the job just described—of the foreman with the assembly machinery. A ribosome is a very small object made of proteins and RNA. It looks somewhat like a volleyball pressed against a basketball. As to purpose,

> This particle coordinates the translation of the genetic information in the sequence of the nucleotide bases in the messenger RNA (transcribed from the DNA molecule, the gene) to the sequence of amino acids in each protein manufactured in the cell.[10]

As the mRNA copy is made alongside the DNA, one or several ribosomes are positioned at the start of it. Then as each ribosome traverses the length of the mRNA, the RNA triplets or codons are translated so that they indicate which amino acids are to be assembled and attached in the same order as the coded sequence. This amazing and efficient operation occurs at each ribosome assembly machine.

If a particular codon happens to be GGC, for example, a glycine molecule (smallest of the amino acid types) would be brought to the ribosome. It is as if the ribosome foreman admits into the assembly area a worker who handles glycine stock and who is carrying one glycine molecule, because the instructions in the code specify that the next amino acid to be attached should be glycine.[11]

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[10] Masayasu Nomura, "Ribosomes," *Scientific American*, October, 1969, p. 28.

[11] As we will see, the process is much more complicated. There are important intermediates now to be described. Some oversimplification may serve to give the general idea, with details to be filled in later.

Ribosomes consist of about 60 different kinds of proteins combined with a spe-

Transfer RNA, Delivery Vehicle for Amino Acids

While the mRNA is being processed by the ribosome in order to assemble amino acids into a protein, how will these amino acids actually be brought into the proper order? There does not seem to be any innate attraction or affinity between an amino acid and the RNA letters which code for it.

In the early research after the Watson-Crick breakthrough, it became apparent that there must be intermediates to bring the amino acids to the ribosome in proper order. Two such vital go-betweens were finally located. One serves as a transport molecule. It is called *transfer-RNA*, which is a different form of RNA from that which has been described. Transfer-RNA, written *tRNA*, is a comparatively short chain of RNA containing some seventy-five or eighty ribonucleotides. The RNA strand doubles back on itself, and base-pairs with its own chain in some places. The overall shape of the tRNA molecule in some ways resembles a key or a cloverleaf. If tRNA is to do its job properly, the shape must be very precise, and this seems to depend in part upon the right temperature and the correct concentration of certain ions (e.g., magnesium and sodium) in the cell fluid.

Transfer-RNA is perfectly fitted for its mission. First of all, each tRNA type attaches to only one variety of the twenty amino acids. Secondly, the particular tRNA delivers that amino acid in the proper sequence for the forming protein. This is possible because the tRNA molecule has at one end a special RNA triplet of code letters which match the mRNA codon which specifies that particular amino acid. When these complementary codons come together by base-pairing, the amino acid being transported by that tRNA is thus in position to be linked to the growing protein chain in the correct order. All this takes place at the ribosome, which is like a mobile assembly machine as it moves along the mRNA strand (or as the mRNA tape passes through the ribosomes).

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cial form of RNA–*ribosomal*, or *rRNA*. There is more RNA than protein by weight in a ribosome ordinarily. The ribosome has two sections (designated the 50-S and 30-S particles) which can exist separately but which come together to read the mRNA message. According to Watson, there may be up to 15,000 ribosomes in a single bacterium. In contrast, at a given time, there are only about 1,000 mRNA molecules in a single cell of some bacteria, because the mRNA is short-lived, being broken down into its parts to be used again in forming new mRNA messages. (Watson, *Molecular Biology*, pp. 368, 369, 395, 452, 455.) The ribosomal subunits are called 50S and 30S in bacteria, for example; whereas the main ribosomes of higher cells contain 60S and 40S sections.

There must be enough tRNA species to match each of the twenty types of amino acids. Further, there ought to be enough to read each of the sixty-one codons which signify amino acid types. Recent research is filling in the gaps in this direction. In fact, there are indications that there may be more than enough to equal the number of codons.[12] There is one instance known where two different kinds of tRNA are used for the same codon, but for a special reason. One of these two serves only to *initiate* a protein chain—in bacteria, where it has been found.[13] A tRNA may read multiple codons (wobble theory).

The Enzyme "Interpreter"

The second intermediate which is involved in bringing amino acids for proper assembly is perhaps even more vital. There seems to be no natural attraction between an amino acid and its own transfer-RNA, so something must bring them together. It is as if there were two languages, and neither party understands the other except when there is an interpreter to bridge the gap. This essential task is done by a special group of enzymes which match the different tRNA's and amino acids. One part of each such enzyme fits just its own particular kind of amino acid and no other. Another part of the enzyme interacts with its own type of tRNA. In plain language, it can be pictured as follows: the enzyme grasps its amino acid and its tRNA and fastens them together.[14]

Summarizing the Translation Process

Connecting all the parts of the protein-forming complex into an abbreviated simple description, we begin with DNA which is the master original containing the instructions for cell activities. When there is need, parts of the DNA instructions are copied and sent out into the cell in the form of messenger-RNA.

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[12] Marshall Nirenberg, personal telephone conversation, October, 1971.

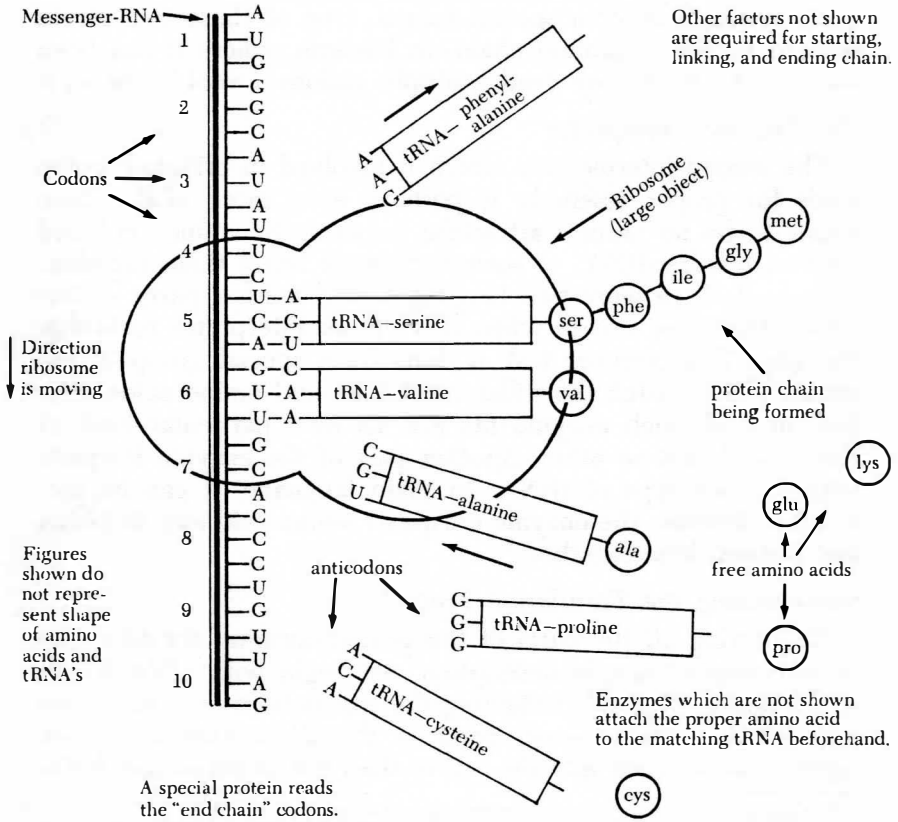
[13] The amino acid, methionine, is coded by the RNA letters AUG. Two different tRNA forms will recognize this codon. One of these responds only when the AUG occurs at or near the start of the mRNA strand. This tRNA places a modified ("formylated") form of methionine in the starting position for protein synthesis. Such a form is adapted for this initial site. When AUG occurs internally, however, it is read by the other (standard) form of tRNA, and places a regular unmodified methionine in the chain. (The formylated tRNA for methionine will also read GUG at the start of mRNA. When that codon occurs internally, it is read by the regular tRNA for the amino acid valine.) (Brian F. C. Clark and Kjeld A. Marcker, "How Proteins Start," *Scientific American* [January, 1968].)

[14] This, too, is oversimplification. The amino acid must first be put in an activated state by reaction with ATP, the universal power molecule of all known cells. This activation is catalyzed by the same enzyme just described.

This mRNA tape then passes through one or more ribosomes which "read" the coded instructions with the aid of transfer-RNA molecules which bring the particular amino acids called

FIGURE 13

Translation, or Protein Synthesis



Messenger-RNA being translated into protein as it is traversed by a ribosome

As each codon or triplet of letters is read, a transfer-RNA molecule approaches which has an anticodon that will base-pair with those letters. This tRNA carries its matching amino acid which has been attached to it by its interpreter enzyme. As the tRNA is processed by the ribosome, the amino acid is joined onto the forming protein chain in the order called for by the mRNA sequence of code letters, which in turn was transcribed shortly before from the DNA master copy. This complex process takes place with fantastic speed and precision, and is remarkably similar in all living things known, from amebas to human beings. Recent evidence indicates that both transcription and replication may often be associated with cell membranes, including the *endoplasmic reticulum*.

for in the code. These tRNA's were charged beforehand with specific amino acids by the aid of matching interpreter enzymes.

As the ribosome continues along the mRNA tape, the amino acids are linked into a protein chain in the sequence called for by the RNA triplets. The resulting protein is then released for its specific duty in the cell, having been made as ordered originally by the codon sequence in the master DNA blueprint.

The protein that is thus formed may be an enzyme to perform tasks like the job done by the special enzymes just described, to join together two specific types of molecules. It may, instead, be a structural protein, or perhaps a hormone, or a specialized protein like hemoglobin. DNA carries out practically all of its work of running the cell by ordering the manufacture of different kinds of proteins and different kinds of RNA molecules. These, in turn, are so cleverly formed that they automatically arrange themselves in proper shape and position, and then carry out their task in the ongoing processes of cell life. Around 5,000 different kinds of molecules may exist in a single cell, many of them proteins.

New Discoveries Reveal Even More Complex Precision

To anyone with an interest in biology, the protein synthesizing mechanism which has been described is fascinatingly intriguing. One can hardly wait for further experiments that may explain gaps in present knowledge. As research continues, the plan of cell operation becomes more amazing than ever.

For one example, in 1969 biochemists at the Weizmann Institute of Science in Israel reported that multiple special enzymes are required to bind the messenger-RNA to the ribosome before protein synthesis can begin. They called attention to "the complexity of this scheme . . . the mechanism which ensures correct protein chain initiation, and, thereby, accurate translation of the genetic code."[15]

Further, two other researchers gave evidence that one or more special proteins are also involved in protein *termination.*[16]

Furthermore, many other special factors are involved during the main process of protein synthesis. These include an enzyme

[15] M. Revel, M. Herzberg, and H. Greenshpan, "Initiator Protein Dependent Binding of Messenger-RNA to the Ribosome," *Cold Spring Harbor Symposia on Quantitative Biology,* Vol. XXXIV (1969), pp. 261 ff.

[16] M. R. Capecchi and H. A. Klein, "Characterization of Three Proteins Involved in Polypeptide Chain Termination," *Cold Spring Harbor Symposia on Quantitative Biology,* Vol. XXXIV (1969), p. 469.

for binding the tRNA to the ribosome at its first or "A" position, and another "transfer factor" to move this tRNA to the second or "P" position. Between these two events, the vital joining of the forming chain onto the new amino acid by the formation of the peptide bond is brought about at the "A" position by a special enzyme which apparently exists in only one copy per ribosome and is part of the larger (50-S) ribosome particle. Magnesium, GTP (similar to ATP), and several other agents are found to be involved also in protein formation. Much of the process remains to be clarified, but the above gives some idea of the picture as it seems to date.

Highly Organized Efficiency in an Intricate System

It becomes increasingly clear what a highly integrated, complex, effective system is involved in living things. This is true in the simplest known living cell, as well as in cells of the human body. In scientific literature one encounters the highest praise of this marvelous system by some of the scientists who know it best.

Atomic physicist George Gamow was involved in attempts to solve the DNA code after the first Watson-Crick breakthrough. He even obtained the help of two cryptologists who were government experts at solving secret codes. Gamow waxed eloquent over what he called in popular terminology "gene molecules":

> Indeed, considering on the one hand the remarkable permanence of genes, which carry almost without any deviation the properties of a given species through thousands of generations, and, on the other hand the comparatively small number of individual atoms that form one gene, one cannot consider it otherwise than as a well-planned structure in which each atom or atomic group sits in its predetermined place.[17]

It is tragic that such a brilliant man as George Gamow could never let himself admit that there must have been a *Planner* behind the "well-planned structure."

In connection with Gamow's admiration of the remarkable stability of the coded message making possible accurate heredity, it is interesting to note that Professor Thomas Jukes, an ardent evolutionist, stated: "The purpose of life is the perpetuation

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[17] George Gamow, *One, Two, Three . . . Infinity* (New York: Viking Press, 1966), p. 264.

of a base sequence."[18] At the conclusion of his book, *Molecules and Evolution,* he waxed religious in the manner of a dedicated materialist. Jukes seems to make DNA his object of worship, expressing the following poetic sentiment in prose form. After crediting evolution (by random changes and natural selection) for the development of life to the present stage, he said:

> MAN: Five hundred million years ago, a billion years ago, the long molecules were joined together in the pools of tepid water.
>
> Phosphate, sugar; phosphate, sugar, phosphate; A, C, T, and G; C, A, G, and T. . . .
>
> (Five hundred million years, a billion years, the long rods, immortally never-changing, mortally ever-changing, reached the day, when, through what they had wrought, they saw themselves as in a mirror.)[19]

Source of the System

How did this amazing system come to be? The only answers which an evolutionist has are vague and unsatisfying when examined closely. Crick did the best he could with the problem, considering that he clearly did not want to acknowledge any supernatural element being involved. Here is his explanation:

> It is the next steps that seem difficult, and that may not be easy to study. At the moment when natural selection started, was there only nucleic acid and no protein? Or, on the other hand, was there only protein and no nucleic acid? The difficulty of these alternatives is that if we had protein alone it is not easy to think of a simple replication process, whereas if we had nucleic acid alone (which would make the replication easy) it is difficult to see how nucleic acid could provide the necessary catalytic activity. A third possibility, which to my mind is rather promising, is that when natural selection began both nucleic acid and protein existed, and that the synthesis of protein was crudely coupled to nucleic acid in the same sort of way as it is today. At first sight it seems highly unlikely that this complicated mechanism could have arisen by chance, but it is really quite possible that some primitive version of it started in that way and although not perfect was sufficiently accurate to enable the system to get going.
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> The real difficulty about the origin of life is that the experimental evidence showing what happened has long ago

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[18] Thomas H. Jukes, *Molecules and Evolution* (New York: Columbia University Press, 1966), p. 4.

[19] Ibid., pp. 264, 266.

> disappeared. All we are left with is a certain amount of frozen history in the organisms as we see them today. This is going to make it scientifically very difficult, because it is inevitable that there will be more theories than there are facts to disprove them.[20]

A little careful rereading of that quotation and thoughtful consideration of the subject will reveal that his statement that it is "really quite possible" is merely whistling in the dark. Dr. Crick has more recently attempted at greater length to come up with an evolutionary plan for the origin of the code and protein synthesis.[21] After diligent effort, he leaves the reader with no plausible scheme.

Oparin's books take into account the need for a detailed model. The entire hope of success in his plan, however, rests upon natural selection. This was to occur *before* there was any process for making accurate copies of components. Only a vague and inexact sort of chance dividing is mentioned at that stage. As we have seen, natural selection is impossible without accurate duplication of all necessary components.

Biologist Gary E. Parker uses the following apt analogy:

> None of the parts of an airplane can fly by itself. Only the whole airplane can fly. An airplane, it seems, is a bunch of non-flying parts *organized* to fly. . . .
>
> None of the molecular parts of a living cell can live by itself. Only the whole cell can live. A living cell, it seems, is a bunch of non-living molecules *organized* to live.
>
> Organization, not substance, seems to make the difference between life and non-life.[22]

Evolution Has No Solution for the Origin of Life

Professor Parker explains the reason why life could not have started spontaneously, whether one considers proteins first or DNA first, or both.

> There's one thing protein molecules can't do: reproduce. Reproduction is the function of DNA. DNA can reproduce itself . . . and DNA can reproduce proteins. . . .
>
> DNA, however, can neither reproduce itself accurately nor make protein without a host of helpers, including several

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[20] Francis H. C. Crick, *Of Molecules and Men* (Seattle: University of Washington Press, 1966), pp. 69, 70.

[21] Francis H. C. Crick, "The Origin of the Genetic Code," *Journal of Molecular Biology*, vol. 38 (1968), pp. 367-379.

[22] Gary E. Parker, "Origin of Life on Earth," *Bible-Science Newsletter*, Vol. VIII, No. 12 (December 15, 1970), p. 4.

> already existing protein molecules. So, life really depends upon the relationship between DNA and protein—DNA (or related nucleic acid) for reproduction and protein for structure and function. This DNA-protein relationship is basic to life in viruses and all known life forms.[23]

Another impossible dilemma in trying to account for life beginning naturally is the one described in detail on page 106 in footnote 17. The reader may wish to refer again to that description, because no real solution exists to the problem. To review it quite briefly, the first task would be to form amino acids. This requires a different, primitive atmosphere with no oxygen, and with ultraviolet rays reaching earth's surface. Ultraviolet rays, however, are deadly to proteins and also to DNA (and RNA). Even if somehow life could start and there eventually were algae or plants to produce oxygen (and ozone, formed from oxygen), it might require millions of years to get the ozone shield formed. It now exists in the upper atmosphere miles above the earth and is a vital safeguard for living things on earth's surface.

Furthermore, algae tend to live at or near the surface of the water, and would be in the lethal path of those rays. The photosynthetic bacteria which sometimes live at a safe depth in the water of narrow lakes have a simpler form of photosynthesis *which does not produce oxygen,* and hence would not help in forming an ozone shield. Even these bacteria would be subject twice a year to water circulation when such lakes passed through the temperature at which water is most dense: 4° C.

Yet another possible problem, described on page 107, footnote 19, is that some scientists now believe the temperature at that period was below freezing, below the temperature at which living cells can grow at all (although they might be able merely to survive at that temperature).

In concluding this chapter, it can be noted that there is no reason to believe, from the standpoint of any actual evidence or logic, that any living thing has ever existed that was less complex or less organized than the simplest living cell known today.

In the next chapter, when we apply the laws of chance to the golden molecule of DNA, we will make it as easy as possible for chance to succeed. Instead of using the smallest known cell,

[23] Gary E. Parker, "Origin of Life on Earth," p. 4.

we will again use the smaller theoretical "minimal living system" resulting from Morowitz' research for the National Aeronautics and Space Administration.

When we remember that chance strains itself in making over five trillion attempts in order to spell "evolution" once, it seems almost ludicrous even to proceed in asking whether such amazing items as the DNA code could have started by chance. The odds against a gene sequence will be too astounding to comprehend.