

EDITORIAL

IT APPEARS THAT . . .

On that fateful day of November 22, 1963, I was placidly sitting in a classroom listening to my professor of physical geology expound upon the wonders of our earth. Suddenly the classroom door opened, the chairman of the department walked in and conferred briefly with my professor who then informed us that the President of the United States had been shot. Class was dismissed. Within a few minutes I was listening to the news as reporters tried to piece together the disjointed bits of information associated with this terrible incident. President John F. Kennedy was pronounced dead, and the suspected assassin, Lee Harvey Oswald, was arrested in a theater and charged with the assassination of the President of the United States.

One aspect of this incident was especially intriguing. I was already aware of the belief in the inexorable 20-year cycle of United States presidents dying while in office. The evidence appeared quite convincing to some, and President Kennedy's death added one more cycle to this series. Why has every United States president who has been elected on a 20-year cycle since 1840 died while in office? The cycle is as follows:

Harrison	Elected 1840	Died while in office
Lincoln	Elected 1860	Died while in office
Garfield	Elected 1880	Died while in office
McKinley	Elected 1900	Died while in office
Harding	Elected 1920	Died while in office
Roosevelt	Elected 1940	Died while in office
Kennedy	Elected 1960	Died while in office
[Reagan	Elected 1980	—————]

On a superficial level, this series appears to be beyond the realm of ordinary coincidences, but upon further investigation, I found that the argument is much less convincing than it first seems.

For instance:

- a) The cycle does not work prior to 1840. Jefferson was elected in 1800 but did not die while in office; neither did Monroe who was elected in 1820.
- b) It is not always the president's first term of office that qualifies him for the 20-year cycle. McKinley qualified by his second term, and Roosevelt by his third.
- c) The precision of the cycle seems weak. Dying while in office does not necessarily take place during the presidential term that qualifies for the 20-year cycle. Lincoln qualifies by his first term of office, but he died

during his second term in office. Roosevelt did not die until his fourth term in office.

- d) One president who does not fit at all into the cycle also died while in office. Elected in 1848, Taylor died apparently of exposure the following year.
- e) It may not be such an unusual event for a president to die while in office, because presidents tend to be men of maturity and thus more subject to the health problems of old age. Also, they are prize targets for assassins. Four of the seven presidents in this cycle (Lincoln, Garfield, McKinley, and Kennedy) were assassinated.

If objections *a*, *b*, and *c* above are considered to be valid, we find that only 4 of 9 United States presidents qualify for the proposed 20-year cycle. Objection *d* suggests a further weakness in the so-called cycle, since a president died while in office out of the cycle. Scrutiny weakens the evidence, and I remain completely unconvinced that there is any validity to this cycle — although at first it appears quite striking.

Appearances can be deceiving and, combined with other factors that influence our decisions, can lead to disastrous results. Scholarly activities are not immune from this pitfall. One of the more outstanding examples in the history of science is the so-called discovery of N-rays by the French physicist Blondlot. In 1902, while investigating the question of the polarization of X-rays, Blondlot noticed that a spark seemed to be brighter under the influence of a new kind of radiation which appeared to behave differently from the normal X-rays. He named these new rays “N-rays” in honor of his university and city, Nimes, France. His entire original system of identification and analysis was based upon his observations of the brighter appearance of the spark, and not on its length which could have been more objectively evaluated. Blondlot was not the only person taken in by appearances. The effect of N-rays were reported “by at least forty people and analyzed in some 300 papers by 100 scientists and medical doctors between 1903 and 1906” (Nye 1980, p 125). These rays were found to emanate from animal muscles, the digestion of albuminoids and by plants in the dark. It was also found that intellectual activity increased the production of N-rays by the nervous system. This new radiation improved visual perception and was used to explain spiritualistic phenomena. The study of N-rays soon became “a minor industry” (Broad & Wade 1982, p 113). Furthermore in 1904 the French Academy of Sciences, the official spokesmen for French scientists, bestowed its coveted Le Conte award on Blondlot.

All was not well, however. Several scientists were unable to reproduce the supposed results. These skeptical individuals were usually accused of having eyes insensitive to the increase in spark intensity and other apparent luminous effects of the rays. Soon a growing number of scientists became doubtful. Their doubts were enhanced in 1904 by R. W. Wood of Johns Hopkins University who, in the role of a sleuth, visited the laboratories at Nancy to investigate the

authenticity of the rays. While Blondlot was demonstrating the spectral qualities of the rays in a darkened room, Wood surreptitiously removed an aluminum prism from the spectroscope. Blondlot reported identical results when the prism was removed (Wood 1904). During his visit Wood also found other unexplainable results, showing that the data could be readily contrived. This incident, which was reported in English, French, and German science journals, did not immediately end the defense in support of N-rays. Research and discussion on the apparent effects continued for several years, although interest soon dwindled. At present the so-called N-rays have only historical interest.

Important lessons can be learned from both the apparent cyclic pattern of United States presidents dying while in office and from the purported N-rays. Man is obviously prone to draw conclusions based upon his superficial observations or those of others. One of the most important lessons to be learned is to be less gullible. The remedy is to be more thorough before drawing conclusions. In the study of origins where authentication of past events is unusually difficult, thoroughness is essential.

REFERENCES

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- Nye MJ. 1980. N-rays: an episode in the history and psychology of science. *Historical Studies in the Physical Sciences* 11:125-156.
- Wood RW. 1904. The *n*-rays. *Nature* 70(1822):530-531.

REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

Re: Roth: Where Has the Science Gone? (ORIGINS 10:48-49)

As the new editor of JASA [*Journal of the American Scientific Affiliation*] I was interested in reading the issues of ORIGINS. When I read your Editorial, I just had to drop you a note of appreciation.

I am neither a recent creationist nor a theistic evolutionist, and as a Christian biologist in a state university I have essentially taken a “plague on both your houses” position and emphasized the wide spectrum of options available to Bible-believing Christians. Therefore, I was pleased with the balanced moderation of your editorial. There has been, and unfortunately continues to be, too much “unwarranted criticism and even depreciation of character,” and unfortunately, with that attitude “We cannot learn from each other.” I too have been upset by the blatant unfairness of presentations of the issue by both evolutionists (geologists, biologists, astronomers, etc.) *and* by creationists. Your editorial is a bit like a voice crying in the wilderness, but keep it up.

Wilbur L. Bullock
Editor, JASA
Durham, New Hampshire

I would like to offer my compliments on your outstanding editorial in the latest issue (Vol. 10, No. 2) of ORIGINS, which just arrived on my desk today. I can't conceive of any real progress being made in the tremendously difficult area of origins in an atmosphere such as you describe. I had no idea things were so bad. I hope your plea is widely read, for it surely is an eloquent appeal for the kind of sanity needed just now.

Harold Jones
Professor of Mathematics
Andrews University
Berrien Springs, Michigan

As a long-time subscriber to ORIGINS, I have appreciated the useful articles which have appeared over the years. Your recent Editorial expresses many of my own concerns, and I thank you for it.

David J. Tyler
Lecturer at Manchester Polytechnic
Cheshire, England

ARTICLES

A COMPARISON OF NARRATIVE ELEMENTS IN ANCIENT MESOPOTAMIAN CREATION-FLOOD STORIES WITH GENESIS 1-9*

William H. Shea
Professor of Old Testament Studies
Andrews University
Berrien Springs, Michigan

WHAT THIS ARTICLE IS ABOUT

Numerous comparative studies have been made between an isolated extra-biblical creation or flood text and its related biblical narrative. In this article, Dr. Shea states that isolated stories from the first millennium B.C. do not provide adequate parallels to the consecutive biblical narrative in Genesis 1-9 and instead recommends comparisons with similar Mesopotamian texts from the second millennium B.C. Such "Creation-Flood texts" include three elements in a tripartite, chronological sequence: a view of the mode of creation employed by the gods, reference to antediluvian life, and a recital of events which occurred during the great Flood. Two Creation-Flood texts are examined: the Sumerian Eridu Genesis and the Babylonian Atra-hasis Epic.

The Eridu Genesis describes man's nomadic and uncultured condition which was remedied by the birth goddess Nintur's instructions for building cities as centers of culture and worship. As the humans prospered, their great noise caused sleeplessness among the gods. The god Enlil's plan to eradicate mankind through a flood was thwarted by the god Enki, who warned Ziusudra, the king of Shuruppak, to build an ark to save his family and the animals. After the Flood, Ziusudra appeased the gods by offering sacrifices and in turn was granted immortality and an eternal home.

According to the Atra-hasis Epic, mankind was created solely as drudges to appease the younger gods who rebelled against their tasks of digging rivers and canals. Fashioned from a mixture of clay and the blood of a sacrificed god, man was a combination of the divine and the human. A major step in this creation process occurred on sabattu/sabbat, and thus a possible link between man's creation and the Sabbath is found in an extrabiblical source from the first half of the second millennium B.C., and probably is derived from even earlier written or oral traditions.

In three cycles of antediluvian adversities, Enlil attempted to squelch the human population and their noise through an episode of plague and two successive periods of drought and famine. Each time, Enki averted the intended destruction. Enlil's final plan — to use water to eradicate mankind — was supported by the gods in council, but Enki saved a portion of humanity by warning Atra-hasis to build a boat to save himself, his family, and some animals.

Deprived of both their drudges and the agriculture which provided their food and drink, the gods regretted their decision to send the Flood. Though angered because some humans had escaped the destruction, Enlil was persuaded to accept their existence. Population controls were enforced to maintain human noise at a tolerable level.

*The general outline of this paper was first presented on Sept. 24, 1983, at a Geoscience Research Institute field conference, and its abstract appears in section 9 of the conference syllabus. On Dec. 21, 1983, at the annual meeting of the Society of Biblical Literature in Dallas, Texas, C. Sinclair of Chapman College presented a similar comparative study entitled "A Near-Eastern Prototype for the Primeval History." Though Sinclair noted some of the same comparisons among the Eridu Genesis, the Atra-hasis Epic, and Gen 1-2 that have been noted in this present study, his conclusions were quite different. He retained a standard literary critical approach to Gen 1-2 while this study has used these comparisons to question seriously such an approach.

A comparison of the contents of the Mesopotamian Creation-Flood texts leads to the conclusion that both follow a distinct chronology or linear time line, with successive events relating logically to each other as cause and effect. Known as mytho-historical accounts, this form of literature is highly unusual in the ancient world. A primary difference in content between these stories and the Genesis Creation-Flood story is the contrast between Mesopotamian polytheism and biblical monotheism, but in form, the biblical Creation-Flood story fits best in this mytho-historical category. All contain three sections discussing Creation, antediluvian life, and the Flood.

Although the biblical Creation-Flood story should be categorized with the Mesopotamian Creation-Flood stories described above, biblical scholars have treated the former differently. Those adhering to the documentary hypothesis have interpreted Genesis 1-9 to be a patchwork quilt of literary fragments that were composed centuries apart and later edited into its final form in the 6th or 5th centuries B.C. Dr. Shea shows the arbitrary and artificial distinctions these scholars have made. For example, the P source for Genesis is credited with specializing in genealogies and chronologies, while J is credited with a descriptive narrative style. The same argument would appear applicable to the Atrahasis Epic which also contains a series of chronological references within its text; yet, Assyriologists have not attributed this epic to several sources. To consider the former as a complete unity while separating and attributing the first two chapters of Genesis to different sources written centuries apart is not logical. The same argument is also applicable for the biblical Flood story in Genesis 6-9.

Dr. Shea points out that some of the initial criteria for literary criticism in the 18th-19th centuries arose from Homeric criticism in Greek literature, the then-known oldest available literature for comparison. Biblical scholars alone have retained these criteria, completely ignoring the contributions made by the much older cuneiform literature of Mesopotamia and the hieroglyphic literature of Egypt which is now available.

In conclusion, the biblical Creation-Flood story fits best in the age in which mytho-historical accounts were written. Thus from the parallels in form and content as compared with Mesopotamian Creation-Flood stories, it is most likely that one person (i.e., Moses) recorded the book of Genesis in the 15th (or 13th) century B.C. Certainly someone from his age is a better candidate for the authorship than is an obscure and anonymous priest/redactor in exile in Babylonia a millennium later.

INTRODUCTION

Most comparisons between Genesis and ancient Creation or Flood stories can be classified as comparative religious studies. They generally involve one text isolated from its original historical context (e.g., the Babylonian creation myth *Enuma Elish* or the Flood tablet of the Gilgamesh Epic)¹ and one related biblical narrative.² On the basis of currently available evidence, their earliest-known written form can be dated only to the first half of the first millennium B.C.³

By using only isolated, solitary Creation or Flood stories, such comparisons have neglected the corpus of literature termed "Creation-Flood texts" which include all three elements in a chronological sequence: a view of the mode of creation employed by the gods, reference to some aspects of life in the antediluvian world, and a recital of events which occurred during the great Flood. Our study, will emphasize the special contribution of these Creation-Flood texts to the literary critical problem of Gen 1-9.

Two such texts or cycles of texts have survived from antiquity. One was originally written in the Sumerian language and the other in Akkadian (the

Semitic language of Babylonia). We shall first elucidate the details of these texts to provide a basis for later comparisons with Gen 1-9.

THE SUMERIAN CREATION-FLOOD STORY: THE ERIDU GENESIS

I. Texts

While the three major fragments of tablets comprising the Eridu Genesis have long been known and treated separately, only recently have they been united to form their original Creation-Flood story⁴ which began with a reference to Creation, continued with a description of antediluvian life, and ended with the story of the Flood. The reconstructed story formed by the tablets from Nippur, Ur, and Nineveh follows below.

II. Antediluvian Life

The first thirty lines of the Nippur text are missing. The first available column recites the birth goddess Nintur's remedy for the nomadic and uncultured condition of mankind. She gave instructions for the building of the antediluvian cities not only as centers of culture and civilization, but especially for the worship of the gods, including herself:

"May they come and build cities and cult-places,
that I may cool myself in their shade;
may they lay the bricks for the cult-cities in pure spots, and
may they found places for divination in pure spots."
She gave directions for purification, and cries for quarter,
the things that cool (divine) wrath.
She perfected divine service and the august offices,
she said to the (surrounding) regions:
"Let me institute peace there."⁵

Then follows a summary statement on the initial creation:

When An, Enlil, Enki, and Ninhursaga [Nintur]
fashioned the darkheaded (people)
they had made the small animals (that come up) from (out of)
the earth come up from the earth in abundance,
and had let there be, as befits (it), gazelles,
(wild) donkeys, and fourfooted beasts in the desert."⁶

Enki (the god of wisdom) and Nintur were particularly active in creation. The reference to the fashioning of the "darkheaded people" (the Sumerians' name for themselves) and the making of the animals indicates that a creation account probably preceded this passage.

It is probable that the missing section of text related the development of mankind's plight. This idea is confirmed by the text from Ur which refers to a time when there was neither agriculture nor weaving of cloth. While these conditions produced poverty among the people, they lived in relative safety because there were no dangerous beasts, insects, or serpents, and "as there was no fear of attack, man had no opponent."⁷

The next legible portion of the text discusses the establishment of kingship which was believed to be a gift from the gods. As the chief agent responsible for carrying out the gods' commands, the king directed the construction of cities and provided cult places and services for the gods. He also guided the people in the irrigation and growth of crops. Each city received half-bushel baskets from the harvest. Nintur assigned a patron deity to each of the five cities.⁸

At the top of the next column another break occurs. The legible portion contains the end of the list of kings who reigned in these cities. The rest of this information has been preserved in the first portion of the Sumerian King List.⁹ Antediluvian kings had remarkably long reigns. Two cities had one king each, and one city was listed as having had three kings. The longest length of reign — 64,800 years — was listed for three different kings. Three more kings supposedly ruled 36,000 years. The shortest length of reign is 10,800 years. The scribe of this source totaled the dominions of all the cities to 352,800 years for the duration of kingship during the antediluvian world.

Although attempts have been made to relate this king-list to the antediluvian patriarchs listed in Gen 5, there is no linguistic correspondence.¹⁰ Neither have precise correspondences been found between the figures given for the lengths of reign and the lengths of life in these sources.¹¹ Both convey, however, a similar picture of a relatively small number of long-lived antediluvian generations. The biblical list leads to a much shorter overall time span for this period.

III. The Flood Story

The great noise from the increasing human population prevented the gods from sleeping. Angered by this noise the god Enlil decided to eradicate mankind. Unfortunately, the text is broken at this point and resumes where the gods decided to send the Flood.¹² Nintur mourned, but Enki foiled the plan by warning Ziusudra, the last king of Shuruppak:

“May you heed my advice:

By our hand a flood will sweep over (the cities of)
the half-bushel baskets, and the country.

The decision that mankind is to be destroyed has been made,
a verdict, a command by the assembly, cannot be revoked.

An order of An and Enlil is not known
ever to have been countermanded.

Their kingship, their term, has been uprooted,
they must bethink themselves (of that).”¹³

The remainder of Enki's advice is missing in the break at the top of column four. Parallels in other Flood stories indicate that Enki instructed Ziusudra to build an ark and load it with his family and the animals. The text resumes with the storm:

All evil winds, all stormy winds gathered into one
and with them, the Flood was sweeping over (the cities of)
the half-bushel baskets for seven days and seven nights.

After the flood had swept over the country,
after the evil wind had tossed the big boat about on great waters
the sun came out spreading light over heaven and earth.¹⁴

The final scene records a speech by Enki who apparently obtained the agreement of the gods to accept the survival of Ziusudra and his family. When Ziusudra sacrificed to An and Enlil, they responded by offering him immortality and an eternal home:

And An and Enlil did well by him,
were granting him life like a god's,
were making lasting breath of life, like a god's,
descend into him.
That day they made Ziusudra,
preserver as king of the name of the small animals
and the seed of mankind,
live toward the east over the mountains in Mount Tilmun.¹⁵

IV. Interpretation

T. Jacobsen was the scholar who synthesized the text of these fragments into a coherent story. He has selected three main themes to explain the significance of this text. In the first theme the culture that developed from Nintur's directions is considered to be superior to man's nomadic state. In the third theme Jacobsen holds that the Flood story was well-preserved and known in the ancient world because it is a story of *survival* rather than one of destruction.

The second theme is important for our literary critical study. For the section of the Eridu Genesis which deals with the antediluvian kings and their cities, Jacobsen has noted:

*In style this section is clearly modeled on the great Sumerian King list and its formulaic language and arrangement. As to its import one is somewhat at a loss. ...the closest one can come is probably to credit the inclusion of this section in the tale to pure historical interest on the part of its composer.*¹⁶

Since similar passages in Genesis also can be viewed historically, Jacobsen's conclusion about this section of the Eridu Genesis is significant for comparative purposes.

Next, Jacobsen compares the Eridu Genesis with the biblical parallel found in Gen 1-9. The tripartite divisions of both narratives obviously correspond. The first two sections deal with Creation and the antediluvians, especially through lists of the leading figures of that period. Both conclude with a story of the Flood.

Jacobsen has further noted that both sources have arranged these main segments along a linear time line, rather than grouping them around a folk hero as is more common in such literature. This arrangement allows the successive events to relate logically to each other as cause and effect. Such arrangements in literary compositions from the ancient world are so unusual that Jacobsen was compelled to suggest a new designation:

... [this arrangement] is very much the way a historian arranges his data, and since the data here are mythological we may assign both traditions to a new and separate genre as mytho-historical accounts.¹⁷

An additional component is their unusual interest in chronology:

*In both [traditions] we are given precise figures for respectively the length of reigns and the lifespans of the persons listed, and in both traditions the figures given are extraordinarily large....This interest in numbers is very curious, for it is characteristic of myths and folktales that they are not concerned with time at all.*¹⁸

Jacobsen believes that “interest in numbers of years belongs elsewhere, to the style of chronicles and historiography.”¹⁹ His best analogy for this literary style is in historical documents such as the royal annals which have provided further confirmation for categorizing the Eridu Genesis in the mytho-historical literary genre.

Jacobsen’s study offers valuable contrasts. In the Eridu Genesis man’s lot improved from his original wretched state while in the biblical account man’s condition, along with his environment, worsened through his sinfulness which led to the Flood. This element of moral judgment is both absent in the Sumerian story and conveys a more pessimistic view of man’s nature. Jacobsen urges caution in interpreting myths and their relationships because myths are fluid, relative and changeable in different cultural contexts, thus prohibiting easy generalizations.

Unfortunately Jacobsen’s further comparisons follow a flawed literary critical model. He attributes much of the corresponding sections of Gen 1-9 to the so-called P source, a writer or school of writers who supposedly wrote during or after the Babylonian exile. Jacobsen uses this geographical location to suggest that the Eridu Genesis influenced the writing of the biblical Genesis in some features, but such a dependence is unlikely.

Jacobsen provides considerable evidence that the passages in Gen 1-9 which have been attributed to P have been misdated. Unfortunately, he has missed an important point suggested by his parallels: Gen 1-9 actually belongs to a much earlier source which parallels in content the entire tripartite literary unit that he has found in the Eridu Genesis. Also, Jacobsen did not deal with the other similar Babylonian source which comes from approximately the same time as far as extant copies are concerned — the Atra-hasis Epic. We will examine next this Creation-Flood story for possible literary structural and critical parallels to Gen 1-9.

THE BABYLONIAN CREATION-FLOOD STORY: THE ATRA-HASIS EPIC

I. Texts

The Atra-hasis Epic is named after its human hero who served as the Babylonian Noah. Several whole and partial copies of the cuneiform tablets comprising this series are known. All tablets and fragments have been edited

together in a definitive edition of the textual series by W. G. Lambert & A. R. Millard.²⁰

II. Creation

The commencement of the Atra-hasis Epic is set in a time before the creation of man, a time when Enlil forced the younger gods to dig rivers and canals. After forty years the junior gods rebelled, burned their work tools, and marched on the house of Enlil:

“Let us confront the chamberlin,
That he may relieve us of our heavy work.
The counsellor of the gods, the hero,
Come, let us unnerve him in his dwelling!”²¹

Awakened and warned by a servant, Enlil called an assembly of the gods to deal with the situation. To satisfy the younger gods, Enki proposed that man should be created to be drudges. They agreed to this suggestion and summoned Nintu, the mother goddess, to cooperate with Enki in the project. Made from clay mixed with the blood of a sacrificed god (We-ila), man would be a mixture of the divine and human. We-ila’s identity and nature remain obscure, and perhaps his name is a deliberate distortion of the word for man, *awilum*.

Enki opened his mouth
And addressed the great gods,
“On the first, seventh, and fifteenth day of the month
I will make a purifying bath.
Let one god be slaughtered
So that all the gods may be cleansed in a dipping.
Let Nintu mix clay,
That god and man
May be thoroughly mixed in the clay.”²²

These instructions were then carried out, as is related in an almost word-for-word repetition of the instructions.²³

The date of man’s creation has not previously attracted much attention. Purifying baths for the god to be sacrificed took place on the 1st, 7th, and 15th days of the lunar month. Though not exactly chronological weeks, these quarters of the moon are relatively close in length. The god’s execution and the Creation of man apparently followed directly after the purifying bath on the 15th day of the month. This places man’s creation at the *end* of one lunar quarter or “week.” Similarly the biblical creation of man took place on the 6th day of a 7-day week.

Although the name for the 7th day of the lunar month was derived from the number seven, the name for the 15th day of the lunar month — the day of the full moon — was derived independently from this numerical cycle: *sa-pa-at-tu* or *sapattu*.²⁴ Since the second sign in this word can also be read as *ba*,²⁵ this word can be read either as *sapattu* or as *sabattu*. The significance of this resemblance to the Hebrew word *šabbat* (the final case ending vowel has been lost in Hebrew) has long been debated.²⁶ While there is no serious phonetic

problem in linking these words, it has been unpopular because this word — if it is the same — has been applied to different objects in the two cultures. The Hebrews applied it to a rest day which recurred at the end of a 7-day week, while the Babylonians applied it to the day of the full moon which recurred monthly.

By linking *sabattu/šabbat* to the creation of man, the Atra-hasis Epic supports the idea that the names for these institutions may have been derived from the same source. *Sabattu* appears to have been the day in which We-ila was killed and his blood mixed with clay. This was the great initiating point in man's creation, though more steps in this process remained to be accomplished. The clay/blood mixture ensured that man would be a combination of the divine and human. In a sense, therefore, man was created on *sabattu*. In Genesis man was created on the day before *šabbat*, but this difference is much less important than the over-arching connection between *sabattu/šabbat* and the creation of man. It is unlikely that such a specific linkage occurred in both accounts by chance. Both accounts can be traced to the same basic conception which was known to both cultures.

Therefore the idea of the link between Sabbath and the Creation of man can now be found in an extra-biblical source from the first half of the second millennium B.C., and as is commonly believed by Assyriologists, many elements in this type of story undoubtedly derived from still older written or oral traditions. From the biblical point of view the differences involved in the Babylonian account would have been introduced by gradual corruption from polytheistic conceptions.²⁷

The second phase in the process of Creation involved Enki, Nintu, and some assistant birth goddesses who broke bits of clay from the central stock and formed these pieces into inert statuettes of seven men and seven women. These were located adjacent to the birth “bricks,” the place of parturition for Babylonian women in labor. The womb broke open in the 10th month and mankind was born. At this point Nintu diverges to give advice on marriage and obstetrics. Evidently the reading of this story served as a good-luck omen at the time of childbirth.

III. Antediluvian Life

The next major segment of the Atra-hasis Epic concentrates upon antediluvian adversities. With a brief introduction to the post-creation works of man, the story considers three major episodes of adversity. Before 1200 years had passed, Enlil brought a plague to reduce the population and squelch their noise.²⁸ Enki circumvented this plan by instructing Atra-hasis to offer sacrifice to Namtara, the goddess of the plague. This Atra-hasis and the people did, and the effects of the plague were averted.

After another 1200 noisy years, Enlil developed another plan to reduce the human population by starvation through drought and famine:

“The noise of mankind (has become too intense for me),
(With their uproar) I am deprived of sleep.

Cut off supplies for the peoples,
Let there be a scarcity of plant-life to satisfy their hunger.
Adad should withhold his rain,
And below, the flood should not come up from the abyss.
Let the wind blow and parch the ground,
Let the clouds thicken but not release a downpour,
Let the fields diminish their yields.²⁹

Again Enki instructed Atra-hasis to lead the people in offering sacrifice to Adad, the storm god. Thus satisfied, Adad yielded his rains and the fields bore grain.

The third plan also involved drought and famine. Frustrated by his failures, Enlil added the extra insurance of posting divine guards at every level of heaven and earth to prevent water from reaching the fields. There is no indication of another 1200-year interval,³⁰ and it seems somewhat unlikely because this episode is cast in different terms than the first two. The text enumerates and describes the successive years of famine, estimated to have continued for seven years or some similar period of time.

The black fields became white,
The broad plain was choked with salt.
For one year they ate couch-grass (?);
For the second year they suffered the itch.
The third year came
(And) their features (were altered) by hunger
(Their faces) were encrusted, like malt,
(And they were living) on the verge of death.³¹

Although the tablets at the end of this episode are badly damaged, it appears that Enki removed the bar which held back the subterranean waters. Man was thus saved from drought and famine. Dissatisfied with Enki's attempt to explain away his interference, Enlil determined to use water — which had been a savior — to eradicate mankind. The gods in council agreed to Enlil's plan.

IV. The Flood

This portion begins with Atra-hasis communing with his divine protector Enki through the walls of his house. Enki told Atra-hasis to tear down these walls and use them to construct a boat in which to save himself, his family, and some of the animals:

Reed wall, observe all my words!
“Destroy your house, build a boat,
Spurn property and save life.
The boat which you build...
Roof it over like Apsu,
So that the sun shall not see inside it.
Let it be roofed over above and below.

The tackle should be very strong,
Let the pitch be tough, and so give (the boat) strength.”³²

Atra-hasis then informed his people that he would be forced to leave because his god Enki was disputing with Enlil.³³

The damaged portion of the tablets contain the story of the building of the ark and the collection and loading of the animals which follows. Atra-hasis’ family went aboard the boat while he attended a farewell banquet with his people. Overcome with horror at the prospect of the destruction ahead, he was unable to eat. The storm came and Atra-hasis entered the ark. He sealed its door, cut its hawser and set sail.³⁴

The next clear section of text describes the reactions of the gods to the Flood. Enki was distraught, and Nintu mourned and wept at the destruction of mankind. The destroyed agriculture deprived the gods of food and drink. They concluded that the Flood was not a very good idea.³⁵

Unfortunately there is another gap, but the story resumes as Atra-hasis promptly reinstated offerings for the gods. Given the mental and physical condition of the gods, it was a religiously astute procedure. Meanwhile Enlil was enraged upon hearing that some humans had escaped the Flood:

(The warrior Enlil) saw the vessel,
And was filled with anger at the Igigi (gods),
“All we great Anunnaki (gods)
Decided together on an oath.
Where did life escape?
How did man survive in the destruction?”³⁶

Enki received the blame, but in further negotiations in the divine council Enlil was cajoled into accepting the existence of mankind on earth. To limit the population and maintain the noise at a tolerable level, the gods agreed that some classes of women, e.g., priestesses, would not bear children. Further details have been lost in damage to the tablet copies.

This focus upon human reproduction provides a direct link between the first and last main sections of the Atra-hasis Epic. The Creation story ends on the note of assistance to women who were to bear children. The Flood story ends with an explanation for women who would not bear children or who were to lose their children.

The book of Genesis has a similar link. At Creation Adam and Eve were told to “be fruitful and multiply and fill the earth” (Gen 1:28). The same instructions were repeated to Noah’s family as they left the ark (Gen 9:1). The more negative biblical note (which comes the closest to the statements at the end of the Atrahasis Flood story) occurs in the sentence upon Eve regarding the greater difficulty of childbirth after the fall (Gen 3:16). Since no moral fall is present in Mesopotamian texts, this biblical negative side of childbearing appears to have been transposed to follow the Flood story. Atra-hasis’ “curse” upon the Babylonian Eves differs in content.

V. Comparisons

Comparisons can now be drawn between the contents of the two tripartite Creation-Flood stories: the Atra-hasis Epic and the Eridu Genesis.

While comparisons between individual segments are possible, it is difficult to compare the Creation stories of the Eridu Genesis and the Atra-hasis Epic, because that portion of the Eridu Genesis is missing and its contents can only be inferred from later passages. Both Flood stories are somewhat fragmentary but appear to be relatively close in content.

The greatest difference comes in the middle segment dealing with antediluvian life. The Sumerian source — the Eridu Genesis — provides a relatively optimistic view of this period, and its duration is framed in a long chronology. In contrast, the Semitic source — the Atra-hasis Epic — takes a more pessimistic view of man's physical environment and frames its duration in a short chronology. While there is no unified and monolithic view of Creation, antediluvian life, and the Flood in these Mesopotamian sources, it is clear that both had a distinct chronology or length of time for the antediluvian period. Both sources provide a number of points for comparison with relevant biblical passages that deal with these events.

THE HEBREW CREATION-FLOOD STORY: GENESIS 1-9

I. Comparisons

In this section we will presume that most readers of this study are familiar with the biblical narratives about Creation, antediluvian life, and the Flood. A comparison of Gen 1-9 with the Creation-Flood stories discussed above will be approached on the bases of literary form and thought content. Each of the three main elements in the tripartite accounts can be compared individually with its counterpart in Genesis. We will also compare the tripartite accounts as a corpus with all of Gen 1-9.

II. The Creation Story

A. Content

We cannot compare the Creation narratives of Gen 1-2 with the Eridu Genesis, because the latter's portion is badly damaged. The main comparison therefore must come between Atra-hasis and Genesis.

In Atra-hasis several gods were involved in the project of Creation. When the lesser gods rebelled against Enlil after forty years of labor, man was created to remedy the conflict. The book of Genesis describes creation as the sole and undisputed work of the sovereign God Yahweh who rested from his work of creating, not from dredging rivers and canals. All the earth was fitted for man during the same week in which he was created.

There are also similarities. The relationship between the creation of man and *sabattu/šabbat* has already been described above. Further comparison can be made between other aspects, e.g., the substance from which man was made. Both were formed essentially from the same material — dust of the

ground, or clay, and in both cases an element of the divine was incorporated into man at his creation. The modalities were different, but a similar purpose was served.

Both accounts emphasize the creation of woman at the same time as man's creation. In both cases male and female were made from the same material, but in the biblical account the Creation of woman was mediated through a part taken from man. The Creation story in the Eridu Genesis is more fragmentary, but we can infer that the animals were created with man. The same relationship holds true for the biblical Genesis.

B. Form

Literary critics maintain that Genesis contains two quite different accounts of creation, one in the second chapter of Genesis that derives from the so-called J source in the 10th century B.C., and the other in the first chapter that derives from the so-called P source in the 6th or 5th century B.C.³⁷ It is therefore of interest to note the form in which the Atra-hasis Creation story appears.

The entire Atra-hasis Epic is tripartite, i.e., it divides into three sections that deal with Creation, antediluvian life, and the Flood. Its Creation segment is also tripartite, i.e., it narrates the events that necessitated the gods' decision to make man, describes the substance from which man was made (including plans for the preparation and execution of the god whose blood was to be mixed with the clay), then concludes with the formation and gestation of the seven male and seven female statuettes.

General parallels can be drawn between Atra-hasis and Gen 1, Gen 2A, and Gen 2B. Both tell the story of man's creation in more than one segment. This parallelism extends to the smaller units of the story. In Atra-hasis the divine council decided to make man, and the way in which Enki and Nintu were to accomplish this task was outlined specifically. This was repeated almost verbatim in the story of their accomplishment of the task.

Such repetition in Atra-hasis is another example of the Semitic parallel writing style that is also found in Gen 1-2. It is particularly prominent in the Gen 1 account of the acts of Creation on the first six days. This parallelism can be seen either in terms of smaller literary units, as is the case with Atra-hasis or Gen 1-2. When judged by the literary standards of its time and place, separating Gen 1 from Gen 2 and attributing them to different sources written down centuries apart appears artificial and arbitrary.³⁸

III. The Flood Story

A. Content

The incompleteness of the Flood stories in the Atra-hasis Epic and the Eridu Genesis limits the extent of comparisons. More direct comparisons have already been made between the biblical Flood story and the Flood tablet of the Gilgamesh Epic, because extant editions of its story are in a much better state of preservation.³⁹ Our attention is directed mainly to Flood stories within the Atra-hasis Epic and the Eridu Genesis.

Table 1 itemizes the various parallels between these Flood stories according to the sources in which they are present. It is evident that these sources refer to the same central event, though differing in details. More specific aspects of the Flood story (e.g., the dimensions of the ark, or the sending of the birds from the ark before the more general disembarkation) cannot be compared because of damage to the tablets.

TABLE 1

	BI	ER	AT
1. The Flood was brought upon mankind by a decision of the God/gods	+	+	+
2. This information was relayed to the Flood hero by God/a god	+	+	+
3. The Flood hero was selected because he was righteous or a devotee of the gods	+	+	+
4. The purpose of the Flood was to destroy mankind in general	+	+	+
5. The Flood hero was given instructions on how to build his boat for escape	+	[?]	+
6. After completing the boat, the hero took his family and animals aboard	+	+	+
7. The boat was caulked with pitch	+	[?]	+
8. The boat was roofed over in such a way that it limited the amount of sunlight admitted to it	+	+	+
9. A special period of 7 days occurred just before or right at the beginning of the Flood	+	+	+
10. Upon exiting from the boat the hero sacrificed to God/gods and his sacrifice was accepted	+	+	+

BI = Biblical Genesis; ER = Eridu Genesis; AT = Atra-hasis Epic

In minor differences between the biblical and the Mesopotamian Flood stories, the latter appear to limit the entire Flood to seven days and nights and also emphasize strongly the winds accompanying the Flood. According to Gen 7:10, the last seven days before the Flood only demarcated the time until the Flood came, and Gen 7:11-12 emphasizes the rain and the effects of the subterranean waters. The reference to the animals in the ark is the most general in the Eridu Genesis, on an intermediate level of specificity in Atra-hasis (clean and unclean),⁴⁰ and most specific in Gen 7 where even their numbers are given.

A major difference between the Flood stories involves the contrast between biblical monotheism and Mesopotamian polytheism. In Gen 6 the decision to bring the Flood was the sole, undisputed decision of the one and only God who was sovereign over man and all aspects of nature. In Mesopotamian sources this decision was debated in the council of the gods.

According to the Atra-hasis Flood story the majority of the gods regretted their decision. Enki and Nintu mourned the loss of their creatures, but the other gods had more self-centered motives, having lost their drudges. In sharp contrast as recorded in Gen 6, God was sorry that he had made man because man had turned to such a great degree of wickedness.

The biblical Flood was morally motivated, being sent as a judgment upon the wicked antediluvians. No such motivation appears in the Mesopotamian

sources. In stark contrast, the Atra-hasis Epic gives the reason for the Flood as being basically a whim of one of the more powerful gods, Enlil.

There is also a difference over the preservation of the human race. The biblical God intended that a righteous seed of mankind should be preserved through the Flood, while the Babylonian god who brought the Flood intended all mankind to be destroyed and was enraged when he learned that some had escaped.

B. Form

Contrary to the view of literary critics who have divided the biblical Flood story into some 20 fragments of J and P, Gen 6-9 stands as one unified, consecutive whole.⁴¹ This unity stands in contrast to the bipartite biblical Creation story, as has been discussed above. The fragmentary nature of the two Mesopotamian Flood stories makes it difficult to judge their full literary form. As far as we can determine from the surviving portions of their texts, they also consisted of one solitary and consecutively narrated unit each.

IV. The Story of the Antediluvians

A. Content

The central segment of these Creation-Flood stories deals with antediluvian life. This portion of the texts has been preserved to the greatest extent and is also an area having some of the greatest contrasts.

The Eridu Genesis framed its optimistic view of this period in a long chronology oriented around the cities of that time, Atra-hasis framed its more pessimistic view of that period in a short chronology without focusing much attention on the cities. The biblical account focused its pessimism upon the spiritual nature of man and framed the outworking of these effects in a short chronology that paid minimal attention to the cities.

B. Form

Both Mesopotamian stories lack parallels to the moral elements in Gen 3, 4, and 6A, but there are two main sections for comparison: the story of the development of cities and culture before the Flood (Gen 4B, cf. especially v 17 and 20-22), and the list of the long-lived personages before the Flood (Gen 5). Both the biblical Genesis and the Eridu Genesis follow the same order in their arrangement of these materials, the narrative first and the list second.

The biblical account seems to stand between the two sources, e.g., its list is similar to the Eridu Genesis but its resultant chronology resembles Atra-hasis. In other ways (e.g., its picture of the development of wickedness) it goes beyond both or gives a different picture or emphasis to the story.

V. The Creation-Flood Story as a Whole

Our final section will deal with the literary structure and criticism of these Creation-Flood stories, especially focusing upon the biblical Creation-Flood story and the illumination shed upon it by the two Mesopotamian Creation-

Flood stories. We will begin our discussion with the way that literary critics have dealt with them.

The following outline is very general and does not take into account all the individual variations of each critic.⁴² The Creation story in Gen 1 has been assigned to P, while the Creation story in Gen 2, the story of the fall in Gen 3 and the story of antediluvian life in Gen 4, have been assigned to J. The genealogical list of Gen 5 has been assigned to P. The Flood story of Gen 6-9 was supposedly edited together from more than twenty different individual pieces of J and P. The Table of Nations in Gen 10 has been divided into four sections attributed to P and three sections attributed to J. The Tower of Babel story at the beginning of Gen 11 is assigned to J while the rest of the chapter dedicated to another genealogy is attributed to P.

This interpretation makes Gen 1-11 supposedly a veritable patchwork quilt of literary fragments that were composed four centuries apart during the first half of the first millennium B.C. None should have been written earlier than the time of J in the 10th century B.C. It is only supposed to have reached its final form at the hands of P who wrote during or after the Babylonian exile, in the 6th or 5th centuries B.C. A Mosaic authorship in the second half of the second millennium B.C. is not considered for any of it. Doubtless such literary criticism of these passages has had a major impact upon the way that scholars have viewed the (non-)historicity of the contents of these narratives.

The past criteria for literary criticism have been derived either from features of the text itself, or from presuppositions brought to the text. Some of these criteria and presuppositions came from Homeric criticism in Greek literature⁴³ which during the last half of the 18th century and the first half of the 19th century A.D. was the most ancient literature available for comparison. Although the much older cuneiform literature of Mesopotamia and the hieroglyphic literature of Egypt now have been opened through the work of scholars over the past century and a half, biblical criticism still retains the Greek tradition, especially in dividing the present unified canonical form of the Pentateuch into multiple original sources. It is as if J, E, D, and P wrote in a cultural vacuum without receiving any literary influences from their environment.

One basis upon which the documentary hypothesis sorts its sources is from their use of divine names. Thus the name Yahweh is found in passages attributed to J, standing as it does for that divine name, while P is thought to have used Elohim along with other divine epithets. Not only are certain words and phrases said to be characteristic of each source; their authors are also credited with special interests, theological and otherwise. Though P has centered more on God in heaven while J has emphasized man on earth, neither excludes the alternate idea. P is thought to have been especially interested in purity of line and thus the genealogical material in these texts has been attributed to him. Many of the chronological statements in these passages are also attributed to P, because he is credited with being especially interested in dates. The sources differ in writing styles. P is credited only with a leaden hand that did not make its scenes come to life. In contrast, J has been called one of the greatest

descriptive narrative writers of the Bible because of his succinct and vivid word pictures.⁴⁴

Of many criticisms that can be leveled against this scheme, we shall mention only two. First, a certain amount of circular reasoning is evident in these critical conclusions. The characteristics of these sources are supposedly derived from the text and then reapplied to the text to determine their source. Second, judging writing styles is also a subjective procedure. Authors have been known to employ different writing styles for different types or genres of literary materials.

The reason why P was considered the only source having any particular interest in chronology or genealogy is not only obscure; it is also contradicted by comparative data from the Babylonian text. The Atra-hasis Epic contains a series of chronological references: 40 years for the junior gods to work on the canals, 9 months for the gestation of man after his conception on the 15th day of the lunar month, 1200 years until the plague and the drought occurred, another 7 years for the second drought and famine, 7 days for the preparation for the Flood, and 7 days for the Flood itself. Assyriologists have not sorted these chronological details and attributed them to a source different from that responsible for the main narrative.

All three Creation-Flood stories discussed above contain chronological details of this type; hence, it is evident that the practice of placing the progression of events narrated in Creation-Flood stories upon such a chronological framework was common in the Ancient Near East. It was not exclusive to the biblical Hebrews, and thus such a sorting in the biblical narrative is quite arbitrary and artificial.

In our study, we will first compare the critical source distribution model of Gen 1-11 with similar subject matter in extra-biblical texts from the 1st millennium B.C. J is dated at the beginning of that millennium and P is dated in its middle. Both the Enuma Elish Creation story and the Flood story in the Gilgamesh Epic date, in terms of presently extant copies, to the 8th or 7th centuries B.C. This locates them almost equidistant between the dates estimated for J and P. Table 2 serves to demonstrate these relationships.

The most glaring discrepancy is the way in which the Flood story of the Bible has been treated as compared to the Assyriologists' treatment of the Flood story of the Gilgamesh Epic. The former has been fragmented into more than twenty different literary units derived from two major sources that were supposedly written four centuries apart and finally edited together in its present canonical form. This has been considered a parade example of the applicability of the documentary hypothesis to the biblical text. As we have already seen, such a dissection of the biblical Flood story is an artificial academic exercise unrelated to literary practice in the ancient world.

A comparison of the Creation stories yields a similar point. Enuma Elish is a much more complex literary creation than Gen 1-2, having at least five main themes, but Assyriologists have not divided it into different literary sources. Its complexity is already seen superficially from the fact that seven tablets were used to record the story.⁴⁵

TABLE 2

I. Babylonian Creation Story, ca. 700 B.C.

Enuma Elish -----
Creation Story

II. Assyrian Flood Story, ca. 700 B.C

----- Gilgamesh Epic
Flood Tablet

III. Biblical Creation-Flood Story, critical view, 10th-5th century B.C.

Gen 1	Gen 2-4	Gen 5		Gen 6-9
P	J	P		
Creation Story	Creation, Antediluvian World	Antediluvian Genealogy	6:1-8, J 6:9-22, P 7:1-5, J 7:6, P 7:7-10, J 7:11, P 7:12, J	7:13-16, P 7:17, J 7:18-21, P 7:22-23, J 7:24-8:2, P 8:2b-3a, J 8:3b-5, P
				8:6-12, J 8:13a, P 8:13b, J 8:14-19, P 8:20-22, J 9:1-17, P 9:18-27, J

Beyond these individual comparisons, we should note especially that these extrabiblical sources deal with an individual Creation story and an individual Flood story in relative isolation from any other events. These individual episodes only play a part of what is described in full in the successive narratives of the biblical text.

Regardless of how many fragments into which Gen 1-9 is broken, the cumulative collection still reads as one continuous narrative starting from Creation and ending with the Flood. Between these events are found further narratives that deal with antediluvian life on earth. They are not as well paralleled on an individual basis in extra-biblical texts.⁴⁶

Thus these solitary, isolated stories from the first millennium B.C. do not provide an adequate parallel to the consecutive biblical narrative that is found in Gen 1-9. For this larger comparison one must turn to the earlier, similar Mesopotamian texts from the first half of the second millennium B.C. The two main texts involved in this comparison have been examined in some detail above, the Eridu Genesis and the Atra-hasis Epic. Their pattern resembles that which is found in the biblical narratives of Gen 1-9. Table 3 depicts the similarities of these three texts. A black box indicates the overall literary unit in all three texts. As this major literary unit is tripartite, the three main sections of these texts are divided by a red line. Subsections have been indicated by the dashed blue line. The major overall literary unit is the same, and the three main sections and the principal levels are present in all three texts. It is mainly on the lowest literary level, the subsections, that the most variation is found between their contents.

From presently extant written sources, it is not evident, though possible, that either one or both Mesopotamian Creation-Flood texts used various sources, oral or written. Regardless of the sources that were employed, they

TABLE 3

I. The Sumerian Creation-Flood Story; the Eridu Genesis, ca. 1600 B.C.

CREATION	ANTEDILUVIAN WORLD		FLOOD
	Culture	King-List	

II. The Akkadian Creation-Flood Story; the Atra-hasis Epic, ca. 1600 B.C.

CREATION	ANTEDILUVIAN WORLD			FLOOD
	Plague ¹	Plague ²	Plague ³	

III. The Hebrew Creation-Flood Story; Genesis 1-9

CREATION	ANTEDILUVIAN WORLD			FLOOD
	Fall	Culture	Genealogy	

Gen 1 2

3

4

5

6-9

had already been unified into one concrete overall literary unit by the mid-second millennium B.C.

Since the individual stories from the first millennium have been taken out of context and used for other purposes, the best available parallels to the biblical Creation-Flood story come from the first half of the second millennium B.C. These correlations therefore suggest that this biblical narrative originates from the same period. To date the Mesopotamian Creation-Flood stories at 1600 B.C. and the biblical Creation-Flood story (which is similar in content and style) at 600 B.C., with cases of individual Creation and Flood stories intervening between them, would be quite exceptional and unlikely. The biblical Creation-Flood story fits best in the age in which this type of literature was written.

Historiography may also be a factor. There is a good analogy to this situation in the Hellenistic age. When Hellenism made its impact upon the culture of the Near East, the many changes caused nostalgia for the golden age. Three Hellenistic historians — Manetho of Egypt, Berossus of Babylon, and Philo of Byblos — attempted to recapture in words the great past history of their respective cultures.

Likewise, perhaps different historians from the late 17th century B.C. attempted simultaneously to record the Creation-Flood story in their presently available form. If parallels from the ancient world are relevant to understanding biblical materials of a similar nature (and they appear to have proved themselves useful in this regard in a number of instances), then the biblical Creation-Flood story should belong to the same era in which these Mesopotamian Creation-Flood stories were written. They should not be separated by a millennium as has been done by the documentary hypothesis.

Thus from these parallels in form and content it is more likely that someone (i.e., Moses) recorded such a work in the 15th (or 13th) century B.C. rather than to attribute them to a collection of fragments that were distributed through the first half of the first millennium B.C. This does not prove, of course, that Moses wrote the biblical Creation-Flood story, but certainly someone from his age makes a much better candidate for the author of this work than does an obscure and anonymous priest in exile in Babylonia a millennium later. To modify an old saying, one might observe that if Moses did not write these chapters of Genesis, then we would have to invent someone who lived in his times to have done so.

ENDNOTES

1. For a translation of these two texts see: Pritchard JP, editor. 1955, *Ancient Near Eastern texts relating to the Old Testament*. Princeton, NJ: Princeton University Press, p 60-72 for the *Enuma Elish* Creation myth, and p 93-95 for the Flood story in the Gilgamesh Epic.
2. For individual comparisons between the biblical and Babylonian Creation stories, see (a) Heidel A. 1963a. *The Babylonian Genesis*. Chicago: University of Chicago Press; (b) O'Brien J, Major W. 1982. *In the beginning: creation myths from ancient Mesopotamia, Israel and Greece*. American Academy of Religion Study Series No. 11; (c) Davis JD. 1980. *Genesis and Semitic tradition*. Grand Rapids, MI: Baker Book House, p 1-22. Note that O'Brien & Major have extracted the creation of man from the Atrahasis Epic for consideration in this connection, but they have not dealt with the text as a larger whole, p 69-88. For individual comparisons of biblical and Babylonian Flood stories, see (d) Heidel A. 1963b. *The Gilgamesh Epic and Old Testament parallels*. Chicago: University of Chicago Press, p 1-2; and (e) Davis 1980, p 110-124 (Note 2c). These references are not meant to be exhaustive; they simply illustrate what is true of the more extensive corpus of literature on this subject: that comparisons between these stories have been made on an individual basis.
3. Heidel (1963a), p 1 (Note 2a). See also Pritchard, p 60 (Note 1). Tablets I-III and X of the Gilgamesh Epic are known from copies of the Old Babylonian version from the first half of the 2nd millennium B.C. From the same period comes a Sumerian version of Tablet XII which shows that the Akkadian version of this tablet was translated from the Sumerian. Tablets V and VI are known from the Akkadian version which was in use in the Hittite capital of Hattushash in the mid-2nd millennium B.C. Some fragments of the story are even known from tablets that were written in Hurrian (biblical Horite), which shows how far and wide the story of Gilgamesh spread in ancient times. The Flood tablet (Tablet XI), however, is only known from the 8th or 7th century edition found in Ashurbanipal's library at Nineveh. Pritchard, p 72-73 (Note 1). See also Heidel (1963d), p 1-2 (Note 2d).
4. Two of the tablets, written in Sumerian, are dated to the late Old Babylonian period (ca. 1600 B.C.) and come from Nippur and Ur. The third fragment, bilingual in Sumerian and Akkadian, comes from Ashurbanipal's library in Nineveh and dates to the 7th century B.C. T. Jacobsen synthesized these tablets and fragments into one whole and complete story in his study: (a) 1981. *The Eridu Genesis*. *Journal of Biblical Literature* 100:513-529. Previously the third tablet in particular was known as the Sumerian Flood story. For earlier translations of this text, see (b) Pritchard, p 42-44 (Note 1), and (c) M. Civil's translation in: Lambert WG, Millard AR. 1969. *Atrahasis: the Babylonian story of the Flood*. NY: Oxford University Press, p 138-145.
5. Jacobsen, p 515 (Note 4a).
6. *Ibid.*
7. *Ibid.*, p 516.
8. *Ibid.*, p 518.

9. For the Sumerian King-List as a whole, see Pritchard, p 265-266 (Note 1). For its use in this text for the antediluvian period, see Jacobsen, p 519-521 (Note 4a).
10. Hasel GF. 1978. The genealogies of Gen 5 and 11 and their alleged Babylonian background. *Andrews University Seminary Studies* 16:361-374.
11. Walton J. 1981, The antediluvian section of the Sumerian King List and Genesis 5. *Biblical Archaeologist* 44:207-208.
12. Jacobsen, p 522-523 (Note 4a).
13. *Ibid.*, p 524.
14. *Ibid.*, p 525.
15. *Ibid.*, p 526.
16. *Ibid.*, p 528.
17. *Ibid.*
18. *Ibid.*
19. Lambert & Millard (Note 4c). The best-preserved edition was copied on three tablets by a scribe named Ku-Aya in the 12th year of king Ammi-Saduqa of Babylon (ca. 1635 B.C.) and came to the British Museum from Sippar which was located in the vicinity of Babylon. The second tablet in this series, also dated to the same time and thought to have come from Sippar, is known from the museum at Istanbul. Three more fragments are known from other Old Babylonian pieces of approximately the same date. Two Middle Babylonian fragments which include only portions of the Flood story are known from Nippur and from Ras Shamra on the coast of Syria. Fourteen Neo-Assyrian tablet fragments from this textual series have come from the excavations of Ashurbanipal's library at Nineveh.
20. *Ibid.*, p 43, lines 41-44.
21. *Ibid.*, p 57-59, lines 204-213.
22. *Ibid.*, p 59.
23. *Ibid.*, p 58, line 221 for this reading of this Akkadian word in transliteration.
24. Labat R. 1976, *Manuel d'Épigraphie Akkadienne*. Paris:Paul Guethner, p 135, sign no. 295.
25. For two convenient collections of the literature on this subject, see: (a) Andreasen N-E. 1972, *The Old Testament Sabbath*. Society of Biblical Literature Dissertation Series 7:1-16, and (b) Hasel GF. 1982. *The Sabbath in the Pentateuch*. In: Strand KA, editor. *The Sabbath in Scripture and History*. Washington DC: Review and Herald Publishing Association, p 21-22, 37-38.
26. Modern terminology would call this a functional shift in mythology. Note Jacobsen's comparison between Gen 1-9 and the Eridu Genesis (Jacobsen, p 529; Note 4a). Yet this source reflects a recognition of a similar relationship as the original conception behind this aspect of both accounts. For one example in the ancient world and an observation on the nature of this occurrence, see: Shea WH. 1977. *Adam in ancient Mesopotamian traditions*. Andrews University Seminary Studies 15:27-41.
27. Jacobsen, p 529 (Note 4a).
28. Lambert & Millard, p 67, lines 352-359 (Note 4c).
29. *Ibid.*, p 73, II, lines 5-18.
30. As do Lambert & Millard in *Ibid.*, p 20.
31. *Ibid.*, p 79, IV, lines 7-14.
32. *Ibid.*, p 89, III, lines 21-33.
33. *Ibid.*, p 91, lines 40-44.
34. *Ibid.*, p 93, lines 43-55.
35. *Ibid.*, p 99, V, lines 37-45.

36. Ibid., p 101, VI, lines 5-10.
37. For a somewhat standard approach to the application of the documentary hypothesis to the narratives of Genesis, see: Speiser E. 1964. *Genesis*. Anchor Bible, vol. 1. Garden City, NY: Doubleday, p xxii-xxxvii and 3-81.
38. For my own approach to the literary criticism of Gen 1-2, see: Shea WH. 1978. The unity of the Creation account. *Origins* 5:9-38.
39. For a useful comparison of the Gilgamesh Flood story and that of Gen 6-9, see Heidel 1963a (Note 2d).
40. For the reference to the “clean” animals in the Ark of Atra-hasis, see Lambert & Millard, p 93 (Note 4c).
41. For the unified nature of the narratives of Gen 6-9, see my study: Shea WH. 1979. The structure of the Genesis Flood narrative and its implications, *Origins* 6:8-29.
42. See Note 38 above for a rather standard approach to this subject. For more detailed analyses with variations, see the discussion in Eissfeldt O. 1965. *The Old Testament: an introduction*. Ackroyd PR, translator. NY: Harper & Row, p 158-211.
43. For a useful discussion of the relationships between biblical and Homeric criticism and their respective fates, see: Yamauchi E. 1965. Do the Bible’s critics use a double standard? *Christianity Today* 10:179-182.
44. Speiser, p xxvii (Note 37).
45. For the seven tablet division, see the translation in Pritchard, p 60-72 (Note 1).
46. While the antediluvian portion of the Sumerian King-List might provide isolated information about the antediluvians, as a whole it already included the reference to the Flood and the post-Flood dynasties by the time it was edited together in the 18th century B.C. The antediluvian portion was also utilized in the Eridu Genesis, as has been described above. There is a Sumerian composition which deals with the activities of the god Enki and the goddess Ninhursag in a paradise-like setting, but no human actors are involved, as S. N. Kramer (1963) has noted in *The Sumerians*, University of Chicago Press, p 148. The Sumerian text known as “Enki and the World Order” refers to Enki’s establishment of various features in the world, but it also contains references to “post-Flood” people such as the Martu and the Elamites, and it discusses rituals conducted by the spiritual leaders in the temple of Enki known at the time this composition was written.

For a comparison between the literary forms of another Sumerian Creation story and the biblical Creation story, see: (a) Kikawada IM. 1983. The double creation of mankind in “Enki and Ninmah,” “Atra-hasis I, 1-351,” and “Genesis 1-2,” *Iraq* 45:43-45. Concerning parallels between biblical and Sumerian views on the antediluvians, Kramer once concluded that “no Sumerian parallels to the story of the Garden of Eden and the Fall of Man have yet been found” (p 293). Since then he thought that he found a text which referred to paradise and the later corruption of human language (Kramer SN. 1968. The “Babel of Tongues”: a Sumerian version. *Journal of the American Oriental Society* 88:108-111). Subsequently B. Alster has more correctly connected this text with a Sumerian literary cycle known as “Enmerkar and the Lord of Aratta” (Alster B. 1973. An aspect of “Enmerkar and the Lord of Aratta.” *Revue d’Assyriologie* 67:101-110). No satisfactory example of an isolated story of antediluvian human existence has yet been located in either Sumerian or Akkadian sources.

NEWS AND COMMENTS

RECENT GRI ACTIVITIES

Some of the programs and recent activities of the Geoscience Research Institute which sponsors *Origins* are summarized below.

RESEARCH GRANTS

This year 9 research grants ranging from \$1000 to \$3870 were awarded to college and university professors and graduate students. The grants cover a breadth of scientific research topics pertinent to the creation-evolution controversy, many of them dealing with the question of time for past events of earth history. Some examples are: 1) a study of depth and light regime on daily coral growth bands, 2) an analysis of tree-ring growth patterns in fossil trees, 3) paleocurrent direction patterns in the fossil record, 4) biogeography and speciation in selected North American plants, 5) growth lines in vertebrate otoliths, and 6) growth increment analysis using computer image processing.

The Geoscience Research Institute awards research grants on a semiannual basis. Potential investigators should contact Dr. Clyde Webster at the Geoscience Research Institute for information and application forms. The spectrum of funded research is quite broad, but must relate to issues regarding the origin and past history of the earth.

FIELD CONFERENCES

The staff of the Geoscience Research Institute devotes a significant amount of time to educational activities which include the teaching of classes, public lectures (over 70 last year) and field conferences. This past summer, from July 9-18, a group of 50 educators, editors and administrators in Europe (Figure 1) were introduced to the dramatic geology of the Alps by the Institute staff. Topics of study included: 1) concepts of Alpine genesis as related to plate tectonics, 2) fossil reefs in Austria and France, 3) gravity tectonics and time, 4) normal rates of erosion and Alpine erosion, and 5) sedimentary patterns as related to tectonic catastrophism. The conference traveled through some of the most dramatic scenery in Europe, beginning in the Austrian Alps, continuing through Switzerland and extending to the French Jura Mountains. Between field excursions, lectures on various topics related to the creation-evolution controversy and their implications were presented. To facilitate communication with this multinational group, the conference was conducted in both French and English.



FIGURE 1. Some of the fifty participants who attended the Geoscience Research Institute European Field Conference. With Dr. Ariel A. Roth they are discussing time factors related to metamorphism and rates of erosion in the Alps. The majestic Matterhorn which lies between Switzerland and Italy is on the left.

The Institute will be conducting another overseas, bilingual field conference in Puerto Rico from November 18-24. Dr. Clyde Webster is in charge of this English-Spanish conference.

During the summer of 1985 the Institute will be hosting a special comprehensive field conference in the western United States with in-depth study of locales important to the interpretation of the past history of the Earth. It will begin on July 8 in Keene, Texas, and conclude on August 6 in Loma Linda, California. Some areas of special study are: fossil tracks in the Paluxy River; the Permian Reef near Carlsbad, New Mexico; Florissant fossil beds and clastic dikes of the Front Range of Colorado; Yellowstone Fossil Forests; Dinosaur National Monument; Monument Valley; Grand Canyon; Bryce Canyon; the Paria Valley; and the Bristlecone pines of Utah. This conference is open to a limited number of participants. Those desiring further information should contact the Geoscience Research Institute at (714) 824-4548.

Katherine Ching

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

GEOMAGNETIC INTENSITY DECAY: THE FIT OF THE DATA

SCIENTISTS CONFRONT CREATIONISM. Laurie R. Godfrey, editor. 1983. NY: W.W. Norton. 324 p.

Reviewed by R. H. Brown, Geoscience Research Institute

When asked what was the greatest factor preventing a more widespread appreciation of poetry, Goethe is reported to have responded, "Poets." Any issue of human commitment that has emotional overtones is likely to be handicapped more from zealous advocates than from opponents. Creationism appears to be a good example. At least such a conclusion could be drawn from the book *Scientists Confront Creationism*, edited by Dr. Laurie R. Godfrey of the University of Massachusetts Department of Anthropology. This book is essential reading for any creationist who wishes to, or ought to, understand how the scientific community at large views "Scientific Creationism."

An individual who holds the conservative view of Biblical Creationism that characterizes a large portion of recent creationist literature should expect to encounter in *Scientists Confront Creationism* the strongest inducement to abandon or modify his faith. Many individuals who have derived great comfort from certain supposed scientific support for a Biblically based conviction will be devastated by a careful reading of this book. It is unfortunate that the literature favorable to creationism does not include a comprehensive treatment that is as well written and scholarly. But in recognizing the book's merits, I do not imply that it presents a balanced and altogether accurate treatment. It does not. Many of the chapters strongly indicate that the primary concern of their author was to make creationism appear ludicrous.

An adequate review of this book would require a book-length treatment. Dealing only with the areas of my greatest competence, I will make a few observations on Chapter 3, "The Ages of the Earth and the Universe" by the late George Abell of the University of California, Los Angeles, and Chapter 4, "Ghosts from the Nineteenth Century: Creationist Arguments for a Young Earth" by Stephen G. Brush of the University of Maryland. While they have not given due allowance for the Big Bang Theory as only the best naturalistic hypothetical explanation for the currently available data, or for the possibility that a radioisotope age for a mineral may not specify the real-time age of an associated fossil any better than a radioisotope age for cemetery soil specifies the real-

time age of tombs located therein, the discussions in these chapters are basically sound *from a uniformitarian viewpoint*.

The proponent of Biblical Creationism needs to recognize that the data from the physical sciences do *not* naturally and logically lead to the concept that the existence of the universe or Planet Earth is limited to the order of 10,000 years. These are concepts that must be accepted on the basis of confidence in a particular interpretation of the Hebrew-Christian scriptures, and that may be used as a basis for seeking an interpretation which is different from that which would be suggested most readily by current observations.

In his discussion of lead/lead dating Brush confuses isochron and concordia concepts (p 61), but his conclusions are essentially correct.

In his treatment of the geomagnetic decay model for the age of Earth, Brush states that a linear extrapolation from observatory data requires “more than 100 million years” (p 77) to reach the intensity specified for 20,000 years ago by the Barnes exponential extrapolation. Regression analysis of the 34-item geomagnetic intensity data set collected by D. Russel Humphreys (*Creation Research Society Quarterly* 20:89-94) yields $M = 15.88 - 0.004010 A$ for a linear model, and $M = 20.88 \exp(-A/2049)$ for an exponential model, with M the geomagnetic dipole moment in units of 10^{22} amp-meter², and A the corresponding year A.D. (B.C. years are negative). To achieve the value of M predicted by the exponential model at 20,000 years B.C. (3.56×10^5 units of 10^{22} amp-meter²) requires 90.3 million years B.C. in the linear model, substantiating Brush’s estimate based on regression constants derived from a smaller set of observatory measurements. The prediction of the exponential model for 4000 B.C. is achieved by the linear model at 32,720 B.C. Brush points out that there is not adequate theoretical support for extrapolation with either an exponential or a linear model, and that both models are contradicted by the geomagnetic intensity measurements that have been derived from induced magnetism in samples known to be older than A.D. 1000. [See Ivan Rouse, *Origins* 10(1):18-36; 10(2):66-89]. It is significant that the regression constants cited in this note yield a Standard Error of Estimate 0.0365 for the linear model, and 0.0369 for the exponential model, indicating that a linear model gives a slightly better fit to the observatory data collected since magnetic intensity measurements were first made in A.D. 1829, and should be preferred to the extent that interpolation and extrapolation from experimental data is appropriate.

The other thirteen chapters in *Scientists Confront Creationism* deal with history, sociology, public education, probability, thermodynamics, molecular biology, genetics, paleontology, and anthropology.

A concluding comment I would like to make after reading this book is that both creationists and evolutionists should take greater care to make the essential distinction between “proof” for a viewpoint, and success in interpreting a particular observation or set of observations from that viewpoint. A creationist and an evolutionist each can be successful in interpreting a particular set of data without proving the other’s viewpoint right or wrong.

GENERAL SCIENCE NOTES

NASA'S NEXT INTERPLANETARY MISSION

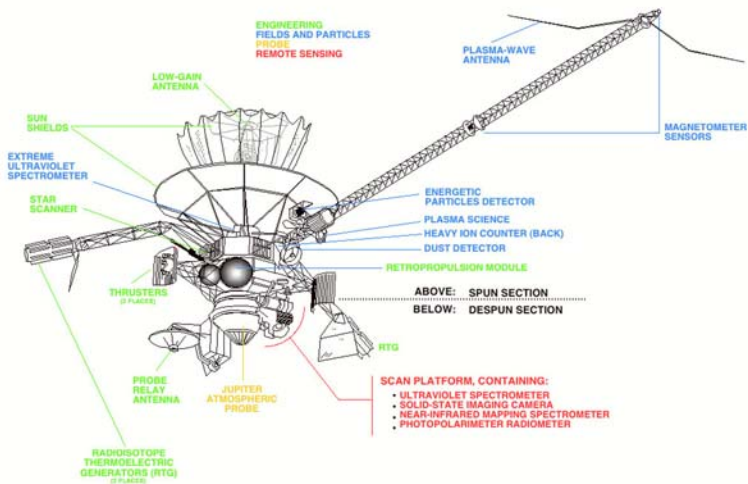
By David H. Rhys, Research Fellow,
Geoscience Research Institute

Mission Galileo, assigned to Caltech's Jet Propulsion Laboratory, is a NASA project to orbit the planet Jupiter and send an instrumented probe into the giant planet's atmosphere. The spacecraft (Figure 1) is virtually completed, and the instrument testing began in September 1984.

Galileo is scheduled to be launched in May 1986 with the scientific objectives of studying 1) the chemical composition and physical state of Jupiter's atmosphere and selected Jovian satellites, and 2) the dynamics of the Jovian magnetosphere.

The spacecraft will be carried to Earth orbit by the space shuttle and from there the 2½ ton Galileo will be sent toward Jupiter by a modified Centaur. About 150 days before arrival (August 1988) the probe will separate from the orbiter and follow an independent path to Jupiter. The orbiter will fly within 1000 km of the volcanic satellite Io, making close observations of this unique moon.

FIGURE 1. Schema of the Galileo Spacecraft identifying the main components.
Figure courtesy of NASA and the Jet Propulsion Laboratory.



At about the time Galileo begins orbiting Jupiter, the probe will strike Jupiter's upper atmosphere at about 180,000 km/hour, decelerating rapidly and deploying a parachute. While penetrating the atmosphere containing clouds of water and ammonia, the probe will be sampling and relaying the data to Earth through the orbiter. After about 60 minutes the pressure (15-20 Earth atmospheres) and temperature is expected to crush and finally vaporize the probe.

The orbiter is scheduled to complete 11 orbits of Jupiter in 20 months and make a close flyby of at least one Galilean satellite on each orbit. It carries 11 scientific instruments:

- ◆ a new camera system, a solid-state charge-coupled device with resolution 20 to 300 times better than that of the cameras on Voyager.
- ◆ a near-infrared mapping spectrometer which will also measure heat from Io's volcanoes.
- ◆ an ultraviolet spectrometer to study the composition and structure of the atmospheres and the cloud of charged atoms injected into the magnetosphere by Io.
- ◆ a photopolarimeter-radiometer.
- ◆ a magnetometer to measure the magnetic fields and their changes due to interactions of the satellites.
- ◆ a plasma instrument to study energetic particles in the magnetosphere.
- ◆ an energetic-particle detector for high-energy particles trapped in Jupiter's magnetic field.
- ◆ a plasma-wave instrument that will investigate waves radiated from lightning discharges.
- ◆ a dust-detection instrument to identify dust and micrometeorite sources, and perhaps the source of the ring discovered by Voyager.
- ◆ an instrument to measure the gravity fields and gravity waves.
- ◆ a radio propagation experiment using radio signals from the orbiter to probe the structure of the atmospheres and the ionospheres.

The probe will also carry seven additional instruments: a neutral mass spectrometer, a helio-abundance interferometer, a nephelometer, a net-flux radiometer, a lightning and radio-emission instrument, another energetic particle detector, and an atmospheric composition and structure analyzer.

This can be considered a multinational mission, because the teams comprise a total of 114 scientists from 10 nations who are assembled to interpret the data from these instruments.

WHY SCIENTISTS ARE SO INTERESTED IN THIS MISSION

Jupiter is similar to a “mini-solar system” with its 16 revolving satellites. It is different from the terrestrial planets in its major constituents; like the Sun, it is mainly composed of hydrogen and helium. Jupiter’s magnetosphere is the largest object in the solar system and, with the exception of the Sun, is the noisiest source of radio signals. The storms that appear at the tops of Jupiter’s clouds seem to come from deep within the planet. Major unanswered questions are: Does Jupiter have a rock core? Why do two of the planets have retrograde (spin opposite from the Sun) orbits?

Another reason for this mission is dominant in the minds of many scientists, especially those who believe in strictly naturalistic origins for our system. These scientists consider Jupiter to be made of the same original material from which our Sun was made. They expect close-range studies of Jupiter to provide information about the birth and development of our solar system. Also there is the lingering and seldom expressed hope of some space scientists that Io, with its 8 volcanoes, may nurture some type of life, in spite of the evidence from previous planetary probes for a sterile extraterrestrial environment.

The scientist who believes in a Divine-fiat cosmogony also has an intense interest in the Jupiter missions. Jupiter’s retrograde moons are one of the evidences for the inadequacy of a simple LaPlacean theory of cosmogony. Why are all the other planets lifeless and marked with scars of a convulsed past? Are they similar to our planet a few millennia ago when it was “without form, and void,” with “darkness ... upon the face of the deep” (Genesis 1:2)? If so, why? *Mission Galileo* may yield information pertinent to these great concerns.

EDITORIAL

IS CREATION SCIENTIFIC?

One of the most common arguments used against the inclusion of creation in the United States public-school science curriculum is that creation is not scientific. It is asserted that the biblical account of beginnings is beyond the realm of scientific investigation because it describes the miraculous. The especially abundant verbiage against the term “scientific creationism” has included such labels as semantic fallacy, glorious fake, pseudoscience, the equivalent of medical quackery, and oxymoron. Creationists have countered by asking whether evolution might not also be a religion.

Actually, the question of whether creation is scientific is trivial because it is too simplistic. I shall illustrate this with only three points, although several more could be added.

- 1) Science can be pursued without a knowledge of primary causes. Many extensive scientific endeavors have flourished even though the investigators remained ignorant of the basic causes for the observed phenomena. An outstanding contemporary example is the plate tectonics concept. Though it has generated many thousands of scientific papers, at present we remain woefully uninformed as to a good mechanism for the movement of plates over the surface of the earth. Likewise, the scientific study of gravity or the earth’s magnetic field has also proceeded without an understanding of primary causes.

If science can operate without a knowledge of primary causes, it can also operate whether those primary causes are naturalistic (evolution) or supernatural (creation), as long as the subject is consistent enough to be analyzed by the methodology of science. Thus the effects and products of both creation and evolution are subject to some scientific analysis, and creation does not negate science.

Although present concepts of science tend to exclude the supernatural (e.g., creation), creation and science were not mutually exclusive concepts when the foundations of our modern science were established. Many leading pioneers of science believed in creation and used science to discover the law and order the Creator had placed in nature.

There is no question that the current capabilities of science are unable to analyze the primary causes conceived for either creation or a worldwide flood as described in Genesis. On the other hand, expected effects of these events such as the complex nature of life systems or the evidence for catastrophism as seen in the rocks are very much amenable to scientific analysis. Hence, creation and science are compatible, and to label creation as unscientific is in disharmony with the scientific

practice of not requiring knowledge of primary causes for scientific study.

- 2) The academic limits of science, like those of most other disciplines, are ill-defined, and it is difficult to categorically state where science ends and another area begins. For instance, should the history of science be classified as history or science? Is the philosophy of science categorized as science or philosophy? The creation concept is pertinent to both the history and philosophy of science, and the attempt to exclude creation from the science classroom as being unscientific is intellectually restrictive. Science which prides itself on openness and revisability finds itself stymied when evolutionists suggest that anything related to the concept of creation must be rejected. It causes one to wonder about a hidden agenda. Creationists have been accused of trying to impose their religion in the public schools under the guise of creation science, but the evolutionist's argumentation is likewise suspect.
- 3) Both evolutionists and creationists use the scientific method to evaluate creation. A commonly voiced objection to creation as science is that creation does not meet the testability requirement stipulated for good science. Although evolutionists state that creation as a miraculous event cannot be tested by science, some of their recent books (e.g., *Science Confronts Creationism*, edited by Laurie R. Godfrey) are prima facie evidence that they try to test creation with science. The claim that creation is not testable by science loses credibility when science is used to test it, and methodology becomes suspect of bias. Both creationists and evolutionists are using present scientific data to test past events that are difficult to establish, but nevertheless are subject to some evaluation by science.

As I have stated earlier, the question of whether creation is science is trivial. It revolves around varied definitions of science and conflicting scientific practices. By promoting the proposition that creation is not scientific, evolutionists are directing their energies to a non sequitur that distracts from the more basic question of origins, *C'est magnifique, mais ce n'est pas la guerre!* (This is magnificent, but this is not the war). The real question is whether evolution or creation is true.

Furthermore when the question of origins is being considered, it would seem appropriate to consider many approaches. Until science can find more cogent explanations for the great questions of ultimate origins, purposes, and the duty and destiny of man, wisdom dictates that we look beyond science for answers. To limit our inquiry into the question of origins entirely to naturalistic causes and to exclude other realms such as creation under the guise that they are not science is obscurant and counterproductive.

Ariel A. Roth

REACTIONS

Readers are invited to submit their reactions to the articles in our journal. Please address contributions to: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA.

Re: Rouse: Paleomagnetism I and II (ORIGINS 10:18-36; 66-89)

Professor Rouse has written a useful summary of the paleomagnetic studies, although I am far more critical than he is of current interpretations. Nevertheless, the observations regarding Barnes' model are well made. For some time, I have been wary of this model, as it seems to ignore more data than it explains.

David J. Tyler
Lecturer at Manchester Polytechnic
Cheshire, England

ARTICLES

CHROMOSOMAL CHANGES IN MAMMALIAN SPECIATION: A LITERATURE REVIEW

L. James Gibson
Geoscience Research Institute

WHAT THIS ARTICLE IS ABOUT

Species are defined as groups of individuals which do not interbreed with other groups under natural conditions. In order for a new species to appear, it is necessary that some change occur which prevents natural interbreeding between two groups which formerly could interbreed. Several mechanisms by which this could be accomplished have been proposed. One proposal which has been widely discussed is based on structural changes in chromosomes. Various kinds of structural changes in chromosomes and how they affect fertility are discussed in this article.

Fusion of two chromosomes and reversal (inversion) of a portion of a chromosome are the most commonly observed structural changes in mammalian chromosomes. Some populations which differ by such chromosomal rearrangements can interbreed, while other populations with similar chromosomal differences cannot. This suggests that the reasons for sterility are somewhat complex and may often be caused by factors other than differences in chromosomal structure. The fact that most species show chromosomal differences may be due to changes which have occurred after the species became reproductively isolated.

INTRODUCTION

The way in which new species arise has long been a subject of speculation and debate. From Darwin (1869) up to recent times (e.g., Mayr 1970, Fitch 1982) it has been believed that species change gradually over long periods of time. In recent years this concept has been challenged by both paleontologists (e.g., Eldredge & Gould 1972, Gould & Eldredge 1977, Stanley 1975) and geneticists (e.g., Carson 1975, Dover 1982, White 1978a, Wilson, Maxson & Sarich 1974, Wright 1982). One mechanism which has been proposed as important in rapid speciation is changes in chromosomal structure (e.g., White 1978a). This idea has stimulated a great deal of research and discussion.

Comparisons based on the number of chromosomes, or the number of chromosome arms, have not generally been helpful in determining relationships between species (e.g., see Greenbaum & Baker 1978). The development of modern techniques of studying chromosomes (see Hsu 1979) has made it possible for scientists to make much more accurate and detailed comparisons of chromosomes in various species of animals. The development of banding techniques, beginning about 1970 (Caspersson, Zech & Johansson 1970, Pardue & Gall 1970, Seabright 1971) made it possible to identify each pair of chromosomes with certainty, at least for most species of mammals, and to compare chromosome structure in different species to an extent not possible previously. This method

has received a great amount of attention in recent years (e.g., Fredga 1977, Patton & Sherwood 1983, White 1978a).

Results from these kinds of studies have led to the discovery that some species of mammals were actually composed of two or more chromosomal races which could not interbreed. Since interbreeding is the basic criterion for defining a species, each of these chromosomal races can now be considered a separate species (e.g., see Wahrman, Goitein & Nevo 1969). In addition, the results have been important in proposing relationships between species (e.g., Baker, Koop & Haiduk 1983, Rumpler et al. 1983), and even to infer modes of evolutionary change (Bickham & Baker 1979, Key 1968, White 1978b). This paper will review several kinds of chromosome variability and their effects on reproductive success. A future paper will discuss examples of comparative studies of G-banding patterns in chromosomes of mammals, especially those which have been used to propose or to clarify relationships.

VARIATION IN CHROMOSOMES

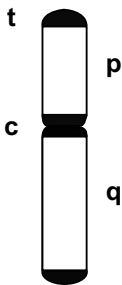


FIGURE 1. Parts of a chromosome:
t = telomere; c = centromere;
p = short arm; q = long arm.

Chromosomes can be classified on the basis of the position of the centromere (see Figure 1). Chromosomes with two nearly equal arms are called *metacentric*. Chromosomes with the centromere at or near one end of the chromosome are called *acrocentric* (White 1973; see also Levan, Fredga & Sandberg 1964). The chromosomal complement of an organism is called its *karyotype*.

In comparing chromosomes, it is necessary to take into account the possibility of structural changes which may have occurred. These changes in the chromosomal structure can be detected by using a special staining technique

called *G-banding* (Seabright 1971). Chromosomal rearrangements may alter the number of chromosomes, the number of chromosome arms, or both, with no apparent effect on the animal's appearance. Some kinds of rearrangements produce obvious chromosomal changes, while other kinds may be less obvious. Genes may be duplicated or deleted, or their sequence on the chromosome may be changed. Change in the position of a gene may affect its action (see Lewis 1950, Wahl, de Saint Vincent & DeRose 1984). A brief discussion of the various mechanisms producing chromosomal rearrangements will help in understanding their significance in comparative studies.

Changes in Chromosome Number

Robertsonian rearrangements. A Robertsonian rearrangement (see Figure 2) is the result either of the fusion of two centromeres into one, or the fission of one centromere into two. Occasionally, a metacentric chromosome is

found in one population which matches in banding pattern two acrocentric chromosomes of a different population. Matching patterns of G-banding indicate that the chromosomes are *homologous* (members of a pair) (see John & Freeman 1975).

The situation in which a species shows a large variation of chromosome numbers due to Robertsonian rearrangements is called a *Robertsonian fan*. The house mouse, *Mus musculus*, provides a good example. The “normal” complement of chromosomes (karyotype) consists of 40 acrocentrics. This karyotype is seen in laboratory strains of the mouse, and in wild populations from North America and many other parts of the world (see White 1978a, p 206).

A population of house mice from the Italian Alps, which had previously been discovered to possess slight morphological differences, was discovered to have 22 chromosomes. This difference was used to confirm its specific status under the name *Mus poschiavanus* (Gropp, Tettenborn & Von Lehmann 1970). Many other populations have been discovered, with chromosome numbers ranging from 22 to 40 (Gropp & Winking 1981). In each case, the total number of arms is the same. Banding studies have shown that each metacentric chromosome is homologous with two acrocentric chromosomes from the “normal” karyotype (Capanna et al. 1975). It is clear that either “fusion” or “fission” is involved.

To determine whether fission or fusion is responsible for changes in chromosome number in the house mouse, it is helpful to examine the metacentric chromosomes and see which acrocentrics are involved in each. If any specific acrocentric is found only in combination with one specific partner in metacentrics from many populations, one would interpret this as evidence for the mechanism of fission. On the other hand, if any particular acrocentric may have different partners in metacentrics from many populations, one would interpret this as evidence for the mechanism of fusion. The results show that fusion has been the mechanism responsible for Robertsonian rearrangements in the house mouse, since a specific acrocentric may be found fused to a number of different partners in different populations.

Odd numbers of chromosomes are found in some individuals (Gropp & Winking 1972). This represents cases where one member of each of two pairs of acrocentrics have fused to form a metacentric, but their respective homologs have remained separate. If one of the sex chromosomes is involved, the result will be that males and females of a species will have different numbers of

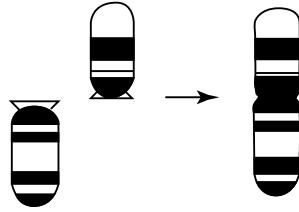


FIGURE 2. Robertsonian fusion in *Mus musculus poschiavanus* between two acrocentric chromosomes (12 and 14), producing a metacentric chromosome. (Capanna et al. 1975).

chromosomes. Several examples are known of species in which the number of chromosomes is different for each sex (Vorontsov 1973).

Although Robertsonian fusion is one of the more common types of chromosomal rearrangement (Fredga 1977), *Robertsonian fission* appears to be relatively rare in mammals. It has been seen in cultured cells (Kato, Sagai & Yosida 1973), in a family of zebras (Whitehouse et al. 1984), and has been suggested to have occurred in the black rat of Mauritius (Yosida 1980, p 61-73). In addition, Todd (1970, 1975) has proposed that fissioning of the entire complement of chromosomes (*karyotypic fissioning*) has happened during the evolution of canids and artiodactyls, but this theory has not gained general acceptance.

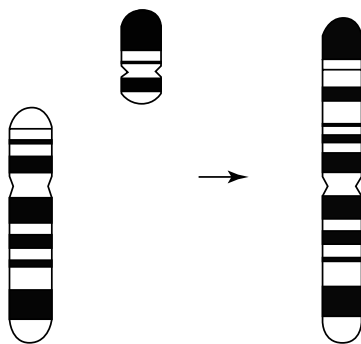


FIGURE 3. Tandem fusion between chromosomes 4 and 9 of the water buffalo. (After Bongso & Hilmi 1982).

Tandem fusion. A tandem fusion is a fusion of two chromosomes in which the end of one chromosome is fused either to the end or to the centromere of another chromosome. An example of a tandem fusion distinguishing Malaysian swamp water buffaloes from Asian river buffaloes is illustrated in Figure 3.

Probably the most interesting example of this kind of variation is the case of the muntjacs, a small group of Asian deer. One species, *Muntiacus muntjac*, has only 6 chromosomes in the female, and seven in the male. This is the smallest chromosome number known in mammals (Wurster & Benirschke 1970). Another species,

M. reevesi, has 46 chromosomes in both male and female (Liming, Yingying & Xingsheng 1980). Comparison of banding patterns suggests that essentially the same genetic material is present in both species, since there is a one-to-one correspondence of bands, and indeed they appear very similar. However, in order for the chromosome number to be so drastically different, it appears that either the large chromosomes of an ancestral species have fragmented to produce the many small chromosomes seen in *M. reevesi*, or tandem fusion has occurred in an ancestral species to produce the large chromosomes present in *M. muntjac*.

A third species, *M. feae*, has 13 chromosomes in the female (Soma et al. 1983). The male has not been studied. Comparison of banding patterns has not been done with original data, but a comparison of the photographs in the papers seems to indicate that the larger chromosomes of *M. muntjac* and *M. feae* are derived from different tandem fusions of the smaller chromosomes of an ancestor having chromosomes like *M. reevesi*, since the banding patterns of the larger chromosomes in *M. muntjac* and *M. feae* do not appear to match.

Supernumerary chromosomes. Still another type of variation in chromosome number is seen occasionally in mammals, and more frequently in birds and reptiles. This is the presence of extra, often very small chromosomes, called *B chromosomes* or *supernumerary chromosomes*. These have been found in several species of mammals (Volobujev 1980). The number of supernumerary chromosomes may vary between individuals in the same population. No difference in appearance is generally seen between individuals differing in the number of B chromosomes, and it has been proposed that they are not genetically active (Shellhammer 1969). However, Ellenton & Basrur (1981) found a positive correlation between the number of B chromosomes and weight in male red foxes. In addition, they may increase the potential for genetic variability of a species (Volobujev 1980). They may interact with the genetically active chromosomes and become incorporated into the ordinary karyotype (Henriques-Gil, Arana & Santos 1983). They are usually, but not always, in a tightly condensed state known as *heterochromatin*. Their origin is unknown, but they may be remnants of chromosomal rearrangements (White 1973, p 314).

Changes in Arm Number

Pericentric inversions. The number of arms of which a chromosome is made is determined by the position of the centromere. If the centromere is terminal or nearly so, there is one arm. If the centromere is near the middle, two arms are present. If the position of the centromere is changed, as in a *pericentric inversion* (an inversion in which the centromere is included, see Figure 4), the number of arms may be changed. An acrocentric chromosome may be converted to a metacentric chromosome, or the reverse may happen.

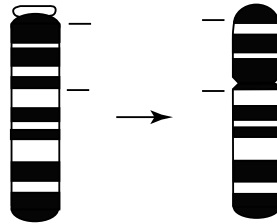


FIGURE 4. Pericentric inversion in chromosome 4 of *Peromyscus maniculatus*. The portion between the lines has been inverted. (After Dixon, Nelson & Priest 1980).

Examples of genera with species which differ by pericentric inversions include *Neotoma* (Mascarello & Hsu 1976) and *Peromyscus* (Robbins & Baker 1981). However, some differences in arm number which were originally interpreted as pericentric inversions before the advent of chromosomal banding techniques have been reinterpreted as due to additions or deletions of heterochromatin (Ohno et al. 1966, Pathak, Hsu & Arrighi 1973). Pericentric inversions have also been proposed to have occurred in speciation of bats (Baker & Bickham 1980).

Heterochromatin. Heterochromatin can be identified by a technique called *C-banding* (Pardue & Gall 1970). The development of this technique led to the discovery that some species differ in arm number because of the presence or

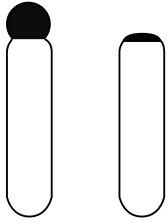


FIGURE 5. Arm difference in chromosome 18 between *Peromyscus maniculatus* (left) and *P. melanotis* (right). The short arm of *P. maniculatus* stains darkly with the C-band staining technique, showing it to be heterochromatic. (After Greenbaum, Baker & Bowers 1978).

absence of chromosome arms made of heterochromatin. This was first discovered in *Peromyscus* (Duffy 1972, and see Figure 5), and has since been found in other genera as well (e.g., Hatch et al. 1976, Patton & Sherwood 1982). The extra heterochromatic arms appear to be inactive genetically, and their origin is unknown. It is

generally believed that the original chromosomes lacked the heterochromatic arms, and that they have been added at some time in the past. Blocks of

heterochromatin may be found *interstitially* (within a chromosome arm) (e.g., see Mascarello & Mazrimas 1977; and see Figure 6) and may also represent additions to the original chromosomes.

In summary, tandem fusion and karyotypic fissioning change both chromosome number and arm number; Robertsonian rearrangements change chromosome number but not arm number; and pericentric inversions and the gain or loss of heterochromatin arms change the arm number but not the chromosome number. The presence of supernumerary chromosomes would change both chromosome number and the arm number, but they are generally counted separately.

Other Changes in Chromosomes

Translocations. Chromosomes may change in other ways, with no change in either the chromosome number or the arm number. A *translocation* occurs when a piece of one chromosome breaks off and attaches to another chromosome. Ordinary translocations between unlike chromosomes result in a change in shape of the chromosomes involved, but not in the number of chromosomes or chromosome arms. An example of a translocation found in a human is illustrated in Figure 7.

Deletions and duplications. A portion of a chromosome may be deleted or duplicated as a result of an inversion or translocation. If the deleted or duplicated segment carries essential genetic material, the individual is likely to be unable to survive. Deletions and duplications of heterochromatin seem to be viable, and many examples are known in which variations in heterochromatin occur. A possible example of a partial deletion of an X chromosome in a female ground squirrel is described by Nadler & Hughes (1966).



FIGURE 6. Interstitial heterochromatin of chromosome 3 of *Ammospermophilus insularis*, stained by C-banding. (After Mascarello & Bolles 1980).

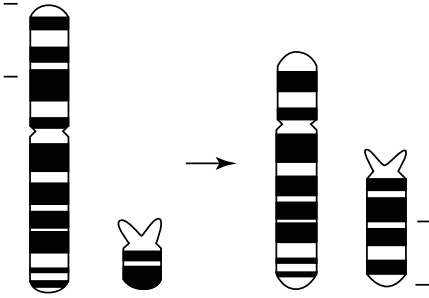


FIGURE 7. Translocation in a human of a segment of chromosome 5 onto chromosome 18. The portion between the lines has been translocated from the large chromosome to the small chromosome. (After Schultz-Schaeffer 1980).

Paracentric inversions. A *paracentric inversion* (an inversion of a part of one arm; see Figure 8) will change the order of genes on a chromosome without changing the size or shape of the chromosome. Differences between species due to a paracentric inversion appear to be uncommon in mammals, but such inversions have been proposed as a factor in speciation of bats (Baker & Bickham 1980), hares (Schroeder, Antoni & van der Loo 1978), and apes (Yunis & Prakesh 1982). A paracentric inversion found in the

laboratory mouse (Davisson & Roderick 1973) is illustrated in Figure 8.

Radical reorganization. In addition to these relatively simple kinds of chromosomal changes, a more complex situation may sometimes occur. In a comparison of G-bands of the bats *Tonatia minuta* and *T. bidens* (Baker & Bickham 1980), the authors were unable to determine homologies or to trace the changes which had occurred. The same situation applied to another pair of bat species in the same study, *Micronycteris megalotis* and *M. minuta*. Apparently the *genome* (genetic material) has been completely rearranged. The mechanism for this is unknown.

It would be of interest to know whether such extensive chromosomal rearrangements occur all at once or whether they accumulate over time. White (1978b) has suggested that chromosomal rearrangements may accumulate in a series of independent events. A possible example of a geographic sequence of chromosomal rearrangements is found in the mole rats, genus *Spalax*, of Israel (Wahrman, Goitein & Nevo 1969). King (1982) has argued for the opposite view, that many rearrangements may occur simultaneously. Bickham & Baker (1979) have suggested that many new rearrangements are produced in a short time "when a new adaptive zone is invaded" (see below under Canalization model).

Transposable elements, or movable elements, are segments of DNA which can move from one chromosomal location to

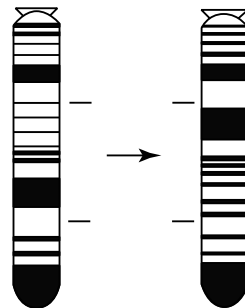


FIGURE 8. Paracentric inversion in chromosome 1 of *Mus musculus*. The region between the lines has been inverted. (After Davisson & Roderick 1973).

another, sometimes resulting in the movement of genes. The discovery that transposable elements are widespread in natural populations has prompted some to suggest that multiple chromosomal breaks and rearrangement might occur simultaneously by this mechanism (e.g., Patton & Sherwood 1983). Breakage sites might be determined by specific DNA sequences which would depend on the particular transposable element involved (Inouye, Yuki & Saigo 1984, Nevers & Saedler 1977).

Effects on Heterozygote Fertility

Meiosis. An individual which possesses two different forms of a gene or chromosomal arrangement is said to be *heterozygous*. Individuals heterozygous for a chromosomal rearrangement may not be able to reproduce normally. During *meiosis* (the production of reproductive cells), homologous chromosomes line up side by side along their entire length in a process called *synapsis*. The pair of chromosomes, called a *bivalent*, is held together at certain points by attraction of their corresponding parts, and some of the corresponding parts are exchanged by the two chromosomes. When the chromosomes later separate, it is important that each chromosome be complete and be free to move away from its partner, and that each chromosome move to the proper location in one of the *daughter cells*.

If the chromosomes are different due to a rearrangement, they may not line up correctly. This may result in the exchange of parts which are not equivalent, so that one chromosome has extra material and one chromosome is missing some material. Such chromosomes are almost always inviable. Individuals with such abnormalities would not be able to reproduce very well, and their line would soon die out. This creates a problem in understanding how such chromosomal rearrangements could be important in speciation.

Since chromosomal structure and the processes of meiosis seem to be controlled by some of the same genes (see Baker et al. 1976), chromosomal rearrangements could sometimes be associated with meiotic irregularities in heterozygotes without either being the cause of the other (see Patton & Sherwood 1983). Mutations in such genes could cause both the rearrangement and the failure of meiosis to proceed normally.

In any case, if the two chromosomes are different due to a rearrangement, it is likely that something will go wrong during meiosis, and that such a heterozygous individual will be partially sterile. Different kinds of rearrangements differ in their effects on meiosis in the heterozygote. The most important of these are discussed below.

Robertsonian rearrangements. A *Robertsonian heterozygote* is a cell which contains one metacentric chromosome which is homologous to two acrocentric chromosomes. If only one such Robertsonian fusion has occurred in a cell line, three chromosomes line up together during meiosis, rather than a bivalent. If the chromosomes separate properly during cell division, such hetero-

zygotes may be fertile. If the chromosomes do not separate properly, the individual will be at least partially sterile. In a heterozygote for multiple Robertsonian rearrangements, a group of as many as fifteen chromosomes may line up together during meiosis (Capanna et al. 1976). In this situation the chromosomes will not separate properly, and the individual will probably be sterile (Gropp & Winking 1981).

In populations which differ only by a single Robertsonian rearrangement, hybrid fertility may not be significantly impaired, but hybrids between two chromosomal races which differ by multiple Robertsonian rearrangements are usually at least partially sterile (Gropp & Winking 1981, Searle 1984). Extensive study of karyotypes of European house mice, *Mus musculus*, has shown that *reproductive isolation* (inability to interbreed) exists between at least some of the chromosomal races (Capanna & Corti 1982). This species appears to be in the process of speciating (Capanna et al. 1976). Congruence has been found between chromosomal and *morphological* (anatomical) differences among at least some chromosomal races (Thorpe, Corti & Capanna 1982).

Tandem fusions. An individual heterozygous for a tandem fusion will likely suffer a reduction in fertility of 50% if the chromosomes exchange parts in the area between the centromere and the point of fusion (White 1973, p 225). This is due to the formation of deletions and duplications in the chromosomes.

A tandem fusion has been identified in one race of the Asian water buffalo, which has not interfered with cross-breeding in attempts to improve the breed (Bongso & Hilmi 1982), although its potential for survival without the aid of man is uncertain. Similar species differing by one or more tandem fusions are known in cotton rats, *Sigmodon* (Elder 1980) and in muntjacs, *Muntiacus* (Liming, Yingying & Xingsheng 1980), but the fertility of hybrids is not known.

Inversions. The effects of inversions on fertility in heterozygotes depend on the relationship of the positions of the inversion, the centromeres, and the parts of the chromosomes which are exchanged. If an exchange takes place within the inverted segment, the individual will be partially sterile. Otherwise, the individual may be fertile (White 1973, p 216).

Inversions probably contribute to loss of fertility in heterozygotes in many cases, but their importance in speciation has been minimized by Zouros (1982). Two populations of *Peromyscus leucopus* which differ by three pericentric inversions are known to be interfertile (Baker et al. 1983b).

Translocations. Translocations between non-homologous chromosomes can severely reduce the fertility of a heterozygote because of mechanical difficulties during meiosis. Two pairs of chromosomes will be involved, which will form a group of four at synapsis. The effects on fertility depend upon the number of chromosomal exchanges and their location, as well as the way in which the chromosomes separate. In general, translocation heterozygotes suffer a loss of fertility due to improper separation of the chromosomes during meiosis. However, in some plants and insects (see Schultz-Schaeffer 1980, p 227), there

seems to be a special mechanism (termed *meiotic drive*) which causes the chromosomes to separate properly as much as 95% of the time.

Different translocations have been discovered to distinguish the karyotypes of the goat and the ox, and those of the goat and the oryx (Buckland & Evans 1978). In eleven species of the genus *Oryzomys* (Baker, Koop & Haiduk 1983), 21 translocations were identified among 55 rearrangements. On the other hand, an extensive study of bats (Robbins & Baker 1981) failed to discover any translocations.

Heterochromatin. The effect of heterochromatin on heterozygote fertility varies with the specific situation. Some populations of the pocket gopher, *Thomomys bottae*, differ from other populations in having extra arms on some of their chromosomes (Patton & Sherwood 1982). C-banding studies reveal these extra arms to be heterochromatic. The populations are interfertile. A similar situation is reported in the woodrat *Neotoma lepida* (Mascarello & Hsu 1976) and in the vole *Microtus pinetorum* (Wilson 1984). In general, it appears that differences in arm number due strictly to heterochromatin additions or deletions may not affect fertility.

When heterochromatin blocks are found interstitially, reproductive success may be affected. In the study of *Thomomys* mentioned above, populations which differed in the arrangement of interstitial heterochromatin were not interfertile. However, the authors suggested the reason for this might not be due to the heterochromatin itself, but that the interstitial heterochromatin may be a result of a pericentric inversion, and the inversion is the actual isolating mechanism. That interstitial blocks of heterochromatin may be remnants of chromosomal rearrangements is supported by a study of the Australian rodent *Uromys* (see Baverstock, Gelder & Jahnke 1982) but not by a study of the American rodent genus *Sigmodon* (Elder 1980).

A study of an Australian rat, *Uromys caudimaculatus*, revealed two chromosomal races which differ significantly in the amounts of both terminal and interstitial heterochromatin (Baverstock, Gelder & Jahnke 1982). In spite of the differences, hybrids show no abnormalities at meiosis, and are fertile.

Supernumerary chromosomes. The presence of B chromosomes does not seem to have any major effect, but if the number of such extra chromosomes becomes too large, fertility may be affected (John 1973, Gillies 1975, Volobujev 1980). This is presumably because they may interfere with normal separation of the ordinary chromosomes. The presence of B chromosomes also may increase the frequency of chromosomal exchanges in the regular chromosomes (Patton 1977).

In summary, some types of rearrangements are more effective than others in reducing heterozygote fertility. The fact that some populations are interfertile in spite of differences in chromosomal structure shows that one cannot always determine in advance whether a particular chromosomal rearrangement is important in reproductive isolation. However, there often seems to be an associ-

ation between chromosomal rearrangements and species differences (Bengtsson 1980). The kinds of changes most frequently involved in reducing heterozygote fertility appear to be Robertsonian rearrangements (but see Ponsa et al. 1981) and inversions (but see Zouros 1982). This may be because these are the most common types of rearrangements seen in mammals.

CHROMOSOMAL REARRANGEMENTS AND SPECIATION

In order for speciation to occur, a *reproductive barrier* (a biological factor which prevents successful interbreeding under natural conditions) must be formed between members of a species. Chromosomal rearrangements themselves would not prevent mating between different chromosomal forms but could act as post-mating reproductive barriers (Mayr 1970) by lowering hybrid fertility. Abnormal separation of chromosomes during meiosis will reduce the percentage of viable gametes produced by such a hybrid animal, thus reducing the reproductive ability of the individual. In the presence of significant competition, such individuals will be at a reproductive disadvantage, and their family line will soon be crowded out.

The Heterozygote Bottleneck Problem

Chromosomal rearrangements are estimated by White (1978a, p 171) to occur in about one of every 500 individuals. A very important question in chromosomal speciation is how a chromosomal change, once it arises in an individual, is established in a population. Because individuals *heterozygous* for a chromosomal aberration generally have lowered fertility, it is to be expected that they will be eliminated from the population by competition. Those rearrangements which are most easily established would be those having the least effect on heterozygote fertility, but which would therefore be the least effective in speciation. This problem has been much discussed and is frequently referred to as the *heterozygote bottleneck*.

Despite our difficulties in explaining it, or in determining cause and effect, the results of many studies in natural populations clearly show that chromosomal changes have occurred and are often associated with species differences.

If the rearrangements most likely to survive in a population are those which have the least effect on heterozygote fertility, and if they occur with any reasonable frequency, one would expect to find examples of populations with chromosomal *polymorphisms* (more than one form in the same population). Examples of polymorphisms are discussed in the next section, and further problems in the establishment of rearrangements are discussed in succeeding sections.

Polymorphisms

Most populations exhibit a uniform karyotype, but chromosomal polymorphisms are occasionally found in natural populations. The most common

chromosomal polymorphisms seen are those involving Robertsonian rearrangements (e.g., Koop, Baker & Genoways 1983), supernumerary chromosomes (e.g., Shellhammer 1969), and in the amount and distribution of heterochromatin (e.g., Patton & Sherwood 1982, Rao et al. 1983).

Polymorphisms for pericentric inversions have also been reported in *Rattus rattus* (Yosida 1980, pp. 13-42) and in *Mus dunni* (Sen & Sharma 1983). In another study, a female Belding ground squirrel and her presumed offspring were found to differ from the main population by a partial deletion in an X chromosome (Nadler & Hughes 1966).

Are Chromosomal Rearrangements Adaptive?

If chromosomal rearrangements are not *adaptive* (contributing to the ability of an organism to survive and reproduce in a particular environment), then chromosomal speciation is a totally random process. The establishment of newly arisen rearrangements by chance would be very difficult. It may be possible that a new population could be established by an individual carrying a rearrangement (*founder effect*), which could then become established in the new population through inbreeding. The probability of such an event seems too low to account for the many examples of chromosomal differences between species.

Because founder events seem so rare, some have argued that a chromosomal rearrangement may confer some kind of advantage, thus making it easier for a new rearrangement to become established (White 1978b). If so, then one would expect to find some relationship between chromosomal rearrangements and genetic or environmental factors.

In a study of *Peromyscus* (Dixon, Nelson & Priest 1980) a relationship between the number of acrocentric chromosomes and altitude was discovered. However, in one study of *Thomomys* pocket gophers (Patton 1970), more acrocentrics were found at high elevation, while in another study (Berry & Baker 1971), more acrocentrics were found in warmer, drier habitats. There does not seem to be a consistent relationship between the environment and the number of acrocentrics, at least in this case.

The notable lack of congruence between karyotypic variation and morphological differences (see below) also casts doubt on the idea that the karyotype is subject to *natural selection* (interaction of individuals with the environment which favors the survival and reproduction of one individual over another, due to genetic differences). Nevertheless, Baker et al. (1983a) present evidence which they believe shows that a selective advantage of a heterozygous karyotype exists in a population of *Geomys* pocket gophers from Texas. They argue that such chromosomal heterosis supports the idea that the karyotype may be *adaptive*. Differential survivorship among chromosomal races of mole rats has also been reported (Nevo, Heth & Beiles 1982). Robbins, Moulton & Baker (1983) reported that species of *Peromyscus* with larger geographic ranges have

higher numbers of chromosomal rearrangements, suggesting some possible advantage to species with more rearrangements.

Chromosomal Variation and Geographic Barriers

The relationship between geographic barriers and chromosomal speciation has been vigorously debated. The controversy centers over whether geographic separation is required for chromosomal speciation, or whether such speciation may occur within a population. Some examples from the real world may help to shed some light on the problem.

Coincidence with geographical barriers. Differences in karyology can be found within a species, across a geographical barrier. The desert woodrat, *Neotoma lepida*, is found on both sides of the Colorado River. Woodrats from east of the river have at least 10 large banded chromosomes, while on the west side, eight or fewer banded chromosomes are found (Mascarello & Hsu 1976). The difference between the two populations is due to heterochromatic arms.

Two species of antelope squirrels provide another example (Mascarello & Bolles 1980). *Ammospermophilus insularis*, found only on Espiritu Santo Island (in the Gulf of California), has a karyotype most similar to that of *A. harrisii* on the mainland. Differences in the banding patterns are apparently due to a translocation and an inversion. The situation is made more interesting by the fact that a third species, *A. leucurus*, occupies a range between the two more similar species.

Geographical barriers lacking. Chromosomal differences can also be found within a nominal species without the presence of an obvious geographical barrier. In this case, it appears the forms are reproductively isolated by a chromosomal rearrangement. An example of this is found in the ground squirrel *Spermophilus richardsonii* (Nadler, Hoffmann & Greer 1971). One form, *S. r. richardsonii*, has 36 chromosomes. Another form, which has been considered as a subspecies, *S. r. aureus*, has only 34 chromosomes. A study of the boundary between the two forms indicated almost no hybridization. Because of this, these two forms are now considered to be different species, with *S. r. aureus* taking the name *S. elegans aureus* (Honacki, Kinman & Koepl 1982). Partial reproductive isolation between species as a result of chromosomal differences is also known in the *Peromyscus maniculatus* species complex (Caire & Zimmerman 1975).

Lack of chromosomal differences in isolated populations. On the other hand, geographic isolation may exist between populations without chromosomal differences. Some interesting examples are found in the ground squirrel genus, *Spermophilus*. An Asian species, *S. undulatus*, and an American species, *S. columbianus*, have identical chromosome numbers and identical G-banding patterns (Nadler et al. 1975). The two species are separated by *S. parryi*, which lives on both sides of the Bering Strait and has a different chromosome number. Two other forms in the same genus, *S. elegans nevadensis* and *S. e. elegans*,

have ranges separated by over 100 miles, yet apparently have identical karyotypes (Nadler, Hoffmann & Greer 1971).

Based on these examples, it appears that geographic isolation and chromosomal variation are not necessarily related. However, they are often associated, and it seems likely that some rearrangements would be more easily conserved in small isolated populations. The problem is complicated because one cannot conclude, on the basis of present distributional patterns, that a population has never been isolated in the past.

Genetic Aspects of Chromosomal Variation

Genetic changes can be divided into two groups (Carson 1975), those which result in changes in proteins, such as enzymes, and those which affect *regulatory genes* (genes which regulate the activity of other genes are known as regulatory genes). Changes in the genes which produce proteins are known to be very common (e.g., see Avise & Aquadro 1982), and there is increasing evidence that regulatory genes are also subject to change (MacIntyre 1982).

There often is a relationship between chromosomal differences and differences in proteins within species (Patton & Yang 1977, Cothran & Smith 1983). Such differences need not be causally related (Patton & Sherwood 1983), and sometimes the differences are not congruent (Baker, Bleier & Atchley 1975). Species which differ by chromosomal rearrangements sometimes appear to be more similar genetically than other species pairs with nearly identical karyotypes (e.g., see Baker and Bickham 1980).

If a chromosomal rearrangement removes a gene from the influence of its regulators, the organism could be affected in a very significant way. If the affected gene was important in controlling the development of the embryo, such a genetic change might result in a sudden morphological change (Wilson, Maxson & Sarich 1974). However, chromosomal changes are not required in order for malfunction of a regulatory gene. In addition, chromosomal rearrangements do not necessarily cause morphologically significant genetic changes. This is demonstrated by the existence of *sibling species* (species which are morphologically very similar, but are reproductively isolated) which were not detected as different until chromosomal studies were applied (e.g., Olert & Schmid 1978). Further evidence of this is the existence of species in the same genus which have karyotypes so different that the changes cannot be traced (see above on Radical reorganization).

Karyotypic Orthoselection

One result of the numerous comparative studies has been the discovery that different types of rearrangements are often typical of different taxonomic groups. The tendency for similar types of changes to accumulate in a lineage has been termed *karyotypic orthoselection* (see White 1978a, p 49). The use of the term "selection" could be misleading, as there is no evidence that selection

is involved. The reason for the trend is not known, but it can be illustrated with a few examples.

In a study of 18 species of *Peromyscus* (Robbins & Baker 1981), a minimum of 60 chromosomal changes were proposed as having occurred in divergence from a common ancestor. Thirty-four of these involved heterochromatin additions, and the remaining 26 were pericentric inversions. No fusions or translocations were detected. In a comparison of four families of bats, involving 78 species (Baker & Bickham 1980), Robertsonian fusions and pericentric inversions were dominant, with tandem fusions uncommon, and heterochromatin arms very rare. In the much-studied *Mus musculus* complex, Robertsonian fusions are by far the most common rearrangement (Gropp & Winking 1981).

Models of Chromosomal Speciation

The most widely accepted model of speciation is the *allopatric model* (based on geographic isolation), according to which speciation occurs when genetic changes accumulate in geographically separated populations (see Mayr 1970, Futuyma & Mayer 1980). Speciation is achieved when the extent of genetic change is enough to act as a *reproductive barrier* (a factor contributing to reproductive isolation) between the two populations. Among the more important challenges to this allopatric model of speciation has been the so-called *stasipatric model* (see below) proposed by White (1968, 1973, 1978a), in which chromosomal rearrangements play an important role.

Stasipatric speciation. According to the stasipatric model of speciation (White 1978a, chapter 6), a new chromosomal rearrangement may spread from its point of origin throughout a population, in spite of the reproductive disadvantage of the heterozygote. Because the fertility of the heterozygote will be reduced, a partial reproductive barrier will exist between individuals carrying the original chromosomal arrangement and those carrying the new rearrangement. In order for the new rearrangement to persist, some means of overcoming the reproductive disadvantage must be obtained by the heterozygotes. White (1968, 1978a) proposed that several factors, alone or in combination, would be sufficient to permit establishment of the rearrangement. These factors are *meiotic drive* (preferential movement of chromosomes during meiosis, see above on translocations), random *genetic drift* (random changes in gene frequencies) in small populations, *selective advantage* (superiority) of individuals carrying the new rearrangement, and *inbreeding*.

The four factors advocated by White as helping in the establishment of a rearrangement were analyzed by Hedrick (1981). He concluded there were four situations which could theoretically be important in this respect. They are meiotic drive alone, meiotic drive plus genetic drift, inbreeding plus selective advantage of the new rearrangement, and inbreeding plus genetic drift. White's model has stimulated a great deal of discussion, and several attempts have been made to modify or refute it (e.g., Walsh 1982).

Negative heterosis. In order for speciation to occur, a reproductive barrier must be established between members of the parent species. The importance of *negative heterosis* (disadvantage suffered by individuals due to being heterozygous) in chromosomal speciation is discussed by Templeton (1981). He concluded that chromosomal speciation probably does occur, but that negative heterosis is not likely to be effective in providing the necessary reproductive barrier. He admits that a rearrangement could become fixed in a local *deme* (interbreeding population) under conditions of extremely small population size and intense inbreeding, but he argues that such fixation in a local deme is not speciation. However, if fixation of a chromosomal rearrangement in a local deme results in the reproductive isolation of that deme from the main population, this would seem to be speciation, by definition. The effectiveness of negative heterosis in speciation is also challenged by Spirito, Rossi & Rizzoni (1983).

Importance of geographic isolation. Perhaps the most controversial aspect of White's model has been the issue of whether geographic isolation is necessary for establishment of a new chromosomal variant. Key (1968) suggested that geographic isolation was necessary for initial establishment of a chromosomal rearrangement, which could then slowly spread through the range of the original species if the new rearrangement carried a selective advantage over the previous one. This seems very much like the allopatric model of speciation, followed by secondary contact of the populations.

Lande (1979) argued that random genetic drift in a small geographically isolated deme is the only way a rearrangement could be fixed initially. He compared the rate of fixation of a chromosomal rearrangement in a species composed of many nearly isolated demes to the rate of fixation of a genic mutation in a local population. He concludes that many species must have arisen from small demes with populations in the range of 50 to 200.

Social behavior and small demes. The importance of social behavior in maintaining small semi-isolated demes with resulting inbreeding has been stressed by some authors (e.g., Bush et al. 1977, Wilson et al. 1975). Bush (1975) gives as an example the difference in chromosome variability between dogs and foxes. All members of the dog genus, *Canis*, have 78 chromosomes, while in foxes the number varies at least from 38 to 78. The uniformity of chromosome number in *Canis* could be due to the fact that dogs range widely and interbreed freely. Foxes live in smaller family groups and do not range over such a wide territory. This means that a new chromosomal rearrangement would be more likely to persist among foxes, due to inbreeding.

The relationship between population structure and rate of chromosomal speciation has been challenged in a study of two genera of lemmings (Gileva 1983). The genera *Lemmus* and *Dicrostonyx* have similar population structures, but there is little chromosome variability in *Lemmus* and much variability in *Dicrostonyx*.

Area effects. In another paper White (1978b) has proposed that groups of genes which are advantageous in a particular environment can be protected against mixing with other genes from a neighboring population by chromosomal rearrangements. As these chromosomal changes accumulate, they act to prevent the chromosomes of a heterozygous individual from lining up properly during meiosis, thus producing a reproductive barrier between the two populations. This is the so-called *area effects* phenomenon. This paper has been vigorously criticized by Bickham & Baker (1980), who attack the concept of *group selection* (natural selection acting on groups rather than on individuals) espoused in White's paper.

Canalization model. Bickham & Baker (1979) have presented their own model of chromosomal evolution, termed the *canalization model*. They argue that the karyotype is adaptive, and that there is an optimum karyotype for each *adaptive zone* (way of life). When a new adaptive zone becomes available, the karyotype will be destabilized by selection until the optimum or near-optimum karyotype is evolved. During this process of optimization, rapid changes in chromosomes will occur. After stabilization, evolutionary change will be primarily by other mechanisms, such as changes in proteins. This model did not provide a satisfactory explanation of chromosomal speciation in cricetid rodents (Baker, Koop & Haiduk 1983) or in bats (Baker & Bickham 1980) in studies by those who proposed it.

Genomic disease. Transposable elements (see above under Radical reorganization) appear to be important in gene regulation in bacteria (Cohen 1976), and it is reasonable that a similar mechanism might be present in animals (Bresler 1983, Whitney & Lamoreux 1982). Changes in the DNA of a transposable element might result in a change in the genetic program of embryological development or gene regulation, which could have significant morphological effects. Transposable elements are also able to carry genes with them, which may be established in the reproductive cells of an infected individual (Rubin & Spradling 1982).

It is known that chromosomal rearrangements can be caused by the action of transposable elements (Campbell 1980, Wahl, de Saint Vincent & DeRose 1984). A theory of speciation, called genomic disease by Rose & Doolittle (1983) proposes that transposable elements may sometimes act to produce reproductive barriers by disrupting development, increasing the mutation rate, and causing chromosomal rearrangement. However, one should not assume such a mechanism without definite evidence (Doolittle & Sapienza 1980).

SUMMARY

In summary, there is little doubt that species differences are often associated with chromosomal rearrangements, but this does not show a cause and effect relationship (Patton & Sherwood 1983). Reproductive isolation may be achieved by several genetic mechanisms, among which is chromosomal rearrangement.

Many karyotypic differences between species may be the result of different events occurring in populations already reproductively or geographically isolated. Reproductive isolation and chromosomal rearrangements may both be the result of mutations in genes controlling chromosome structure and behavior. Transposable elements may play a part in such mutations, or in other genetic incompatibilities between species. In any case, we do not yet understand the events which connect speciation with chromosomal changes (Fredga 1977).

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ARTICLES

RAPID EROSION AT MOUNT ST. HELENS

Steven A. Austin

Research Associate in Geology

Institute for Creation Research

El Cajon, California

WHAT THIS ARTICLE IS ABOUT

How long does it take for a canyon to be eroded? Is erosion accomplished primarily by the cumulative effects of slowly operating agents acting more or less continuously? Or, is erosion accomplished primarily by the singular effects of catastrophic agents acting intermittently?

Research at Mount St. Helens in Washington State shows that gorges and canyons can form rapidly. This article contains several photographs which depict the rapid changes which have been caused by erosion (gravitational slumping, jetting stream, flowing mud, sheetflooding of water, and channelized flow of water) forming a branching pattern of canyons, some over 100 ft deep.

The data reveal that tremendous changes may be accomplished very rapidly by an erosional agent having power which exceeds a certain threshold. The erosional features at Mount St. Helens are compared to erosional forms at Lituya Bay (Alaska), Surtsey Island (Iceland), Lake Peigneur (Louisiana), Sao Nicolau (Brazil), Waiho River (New Zealand), Providence Canyon State Park (Georgia), and the Imperial Valley (California).

The processes which conventional geomorphic theory has suggested takes thousands of years may, instead, be accomplished within a few years.

INTRODUCTION

The violent eruption of Mount St. Helens volcano in Washington State on May 18, 1980, produced a series of geologic surprises. At 8:32 a.m., an earthquake under the volcano shook the swollen and oversteepened north slope, dislodging a rockslide of more than one-half cubic mile of rock and ice. As the pressure was released by the departure of the rockslide, superheated water inside the volcano flashed to steam creating a twenty megaton, northward-directed blast of hot gas and rock fragments. In six minutes the blast leveled 3.2 billion board feet of prime forest (enough lumber to build 640,000 houses) over an area in excess of 150 mi². The nine-hour eruption which followed was one of the most photographed and studied volcanic events in history.

EROSION FEATURES

Not as well understood are the erosional and depositional events associated with and following the eruption of May 18. Part of the rockslide debris catastrophically displaced the water of Spirit Lake, producing waves up to 850 ft high at the north shore of the lake (Coffin 1983, Voight et al.



FIGURE 1. Wave-cut cliff up to 20 ft high on western shore of Spirit Lake in August 1983. The erosion of the cliff occurred during the first 12 months that the lake level was stabilized. The slope above the cliff was scoured of trees and soil by the enormous water waves generated by the May 18 rockslide.

1981). As the water returned to its basin, it scoured slopes of trees and soil, and, together with material from the initial eruption, produced a 320-ft-thick deposit on the bottom of the lake (Meyer & Carpenter 1983). The new level of Spirit Lake has been stabilized since August 1982 by the Army Corps of Engineers at an elevation of 3460 ft, 262 ft higher than its pre-eruption level. Figure 1 shows the new shore of Spirit Lake with a cliff up to 20 ft high that was cut by erosion since the lake level was stabilized. Above this cliff is the slope scoured by the enormous early water waves.

Most of the rockslide debris from the volcano's north face filled the upper 16 miles of the North Fork of Toutle River across its entire width, diverting tributary inflow to the river and blocking the outflow of Spirit Lake (Voight et al. 1981). Two-thirds of a cubic mile of rockslide and eruption debris occupies approximately 23 mi² of the valley to an average depth of 150 ft and a maximum depth of 600 ft (Voight et al. 1981). The hummocky surface of the rockslide and eruption deposits has been highly susceptible to the ravages of erosion.

An enormous plain of hot pumice was deposited over the headwaters of the North Fork of the Toutle River and the south shore of Spirit Lake. The pumice was deposited on May 18 and during subsequent eruptions. Within a few days after May 18 the pumice plain was cratered with steam explosion pits which formed as a result of steam jetting from ice and

water trapped in the rockslide debris buried beneath 300°C pumice (Rowley, Kuntz & MacLeod 1981). Figure 2 shows the largest steam explosion pit on the headwaters of the North Fork of the Toutle River in the process of formation on May 23. As the jet of steam continued to ream the 125-ft-deep pit, mass wasting enlarged it to a length of 2300 ft and a width of 1000 ft.

The pumice is composed of fine dacite ash and coarse rock fragments. Initially, it was poorly compacted, and because of its high temperature (up to 300°C), contained no water to hold particles together by surface tension. Consequently, a variety of erosional forms developed quickly. The pumice is now cool at the surface, compacted, saturated with water, and has enough coherence to stand in near vertical cliffs.

Figure 3 shows the same large explosion pit as in Figure 2, but after a flat floor had been formed by a pyroclastic flow on June 12 that deposited an additional 25 ft of pumice, reducing the depth to 100 ft. Also evident in Figure 3 is an elaborate dendritic pattern of rills and gullies on the sides of the pit that resembles badlands topography. Virtually all of these gullies and rills formed within the first five days after May 18 by the retrogressive slumping of the rim, not by water erosion. According to traditional interpretations, this topography might be assumed to require many centuries of

FIGURE 2. Largest steam explosion pit in the process of formation on May 23, 1980, looking east. The pit is 2300 ft long (E-W), 1000 ft wide (N-S), and extends 125 ft deep into the pumice deposit of May 18. Mount St. Helens volcano is to the right of the photograph. The southwest shore of Spirit Lake is in the upper left corner. (Photograph courtesy of the Washington State Department of Natural Resources).





FIGURE 3. Largest steam explosion pit viewed from the east on June 18, 1980. The pit is 2300 ft long and has a flat floor of pumice deposited by the volcano's June 12 eruption. The dendritic pattern of gullies and rills forms 100 ft of relief at the margin of the pit. The pit was later breached by a mudflow on March 19, 1982, and forms the new canyon in the left side of Figure 5. (Photograph courtesy of the Washington State Department of Natural Resources).

rill and gully erosion if the rapid progress of its development had not been observed.

Further evidence of the rapidity of the erosion process is shown in Figure 4. Here another steam explosion pit was reamed in the May 18 pumice, with a flat floor formed by more pumice from the June 12 eruption. Again, distinct gullies eroded to 50 ft into the pumice deposit appear to have formed by mass wasting and water erosion.

An explosive eruption of Mount St. Helens on March 19, 1982, melted a thick snowpack in the crater creating a destructive sheetlike flood and mudflow which downcut the rockslide and pyroclastic flow deposits north of the volcano. The largest steam explosion pit (shown in Figure 3 as it was previous to March 19) overflowed its west rim and cut a deep ravine into the 1980 pumice deposits to the west (Waite et al. 1983). The flow formed anastomosing channels over much of the hummocky rockslide debris allowing cataracts to erode headward and established for the first time since 1980 a dendritic integration of the North Fork Toutle drainage. Erosion has occurred intermittently with most of the established drainage lines being formed in March 1982.

The new drainage of the North Fork of the Toutle River is shown in Figure 5. A miniature "Grand Canyon" over 100 ft deep divides into several



FIGURE 4. Gully erosion around a 500-ft-diameter steam explosion pit photographed in August 1983. Individual gullies are up to 50 feet deep. The floor of the pit contains pumice from a later eruption of Mount St. Helens.

FIGURE 5. Westward view looking down the North Fork of the Toutle River in August 1984. The rockslide and pumice deposited in the region of the headwaters of the river have been eroded to a depth of more than 100 ft forming a new dendritic drainage pattern. The deep canyon on the left includes the breached remnant of the large steam explosion pit (Figure 3). The canyon on the right is shown in detail in Figure 6. Significant canyon erosion by mudflow which established the dendritic drainage pattern occurred on March 19, 1982.



tributary drainages. The upland flat between the tributary canyons has already been severely altered by rill and gully erosion. Figure 6 shows one of these canyons in detail. Most of the major excavation of the new canyons of the North Toutle River appears to have occurred during the mudflow erosion on March 19, 1982. The new headwaters of the North Fork of the Toutle River contain other smaller drainage channels that connect steam explosion pits. One smaller channel, believed to have been breached by mudflow activity between explosion pits on March 19, 1982, is shown in Figure 7. The breaching should have occurred rapidly, and it is reasonable to suppose that this gorge formed in a single day.

OTHER EXAMPLES OF RAPID EROSION

Mount St. Helens is exceptional in the variety of erosional features formed within a limited, intensely studied area. It has allowed geologists to document local rates of erosion. An entire landscape has been subjected to various agents of sculpture including wave erosion, jetting steam, mass wasting, rill and gully erosion, sheet flooding, and mudflow erosion. The erosional features at Mount St. Helens are not unique, but are similar to those observed elsewhere.

The water wave scour along the shore of Spirit Lake (Figure 1) brings to mind Lituya Bay, Alaska, the site of an enormous rockslide-generated wave in 1958 which deforested the shore up to 1720 ft above sea level (Miller 1960). The wave-cut cliff along Spirit Lake is similar to that at the volcanic island Surtsey south of Iceland where a precipitous rock cliff was eroded in 1964, just three months after a lava flow had cooled in the sea. At the base of the cliff were boulders rounded by the surf and a broad sandy beach (Thorarinsson 1964).

The mass wasting which produced the dendritic rill and gully pattern at the margin of steam explosion pits (Figure 3) resembles the dendritic pattern formed on November 20, 1980, at Lake Peigneur, Louisiana. A well drilling operation in the rock beneath the lake accidentally penetrated an underground salt mine, allowing the 240 million ft³ of lake water to empty suddenly into the mine. The drainage and associated slumping produced a pronounced dendritic pattern of channels in the lake bed within a large collapse feature for a depth of 200-300 ft (Martinez et al. 1981). Geologists were amazed at the rapidity with which the intricate pattern of gullies and rills was eroded in the fine-grained sediments.

Water is known to rapidly erode channels of the size and scale found on Mount St. Helens. On the night of June 8, 1974, a rain storm in southern Brazil eroded a valley 16 ft deep, 50 ft wide, and 1600 ft long in a gently sloping field that before the storm was marked by only a small gully. The valley is believed to have formed in less than five minutes due to channel erosion and mass wasting during intense rainfall (Kloosterman 1976). The Waiho River of New Zealand deposited 70 ft of sediment on its bed



FIGURE 6. Detailed view of deep canyon on the right side of Figure 5. The flat plain of pumice deposited on May 18, 1980, was eroded to a depth of more than 100 ft by August 1984.

FIGURE 7. Deeply eroded gorge through May 18, 1980 pumice deposit. Photograph taken in August 1983. Man provides scale. The gorge is believed to have been breached between stream explosion pits by the mudflow of March 19, 1982. Mass wasting of the sides and water erosion of the channel have kept the gorge open, forming part of the new drainage network on the pumice plain at the headwaters of the North Fork of the Toutle River.



over several miles during a single, high-intensity rainstorm in 1965; then, during succeeding weeks, downcut and eroded its bank to produce a sequence of 10-ft-high terraces (Gage 1970). An extensive canyon system has formed at Providence Canyon State Park near Lumpkin, Georgia. Erosion of Providence Canyon began in the 1820s with the clearing of the land by the first white settlers. Ditches dug in the 1850s became gullies which eroded to features as wide as one quarter mile and as deep as 150 ft (Heys 1984).

What may be the world's largest man-made disaster was the unrestrained flooding of the Imperial Valley of California by the Colorado River from 1905 to 1907. In February 1905, during a flood of the Colorado River, irrigators in Mexico were unable to control water entering a diversion canal. Soon the entire river was diverted. In nine months the runaway waters of the Colorado River had eroded the New River and Alamo River channels removing about 450 million yd³ of recent alluvial and lacustrine sediment, almost four times the volume excavated while digging the Panama Canal (Cory 1913). Forty-three miles of channels were formed with an average width of 1000 ft and depth of 50 ft. The sediment eroded was deposited in a large delta at the south shore of a new lake called the Salton Sea. When the breached levee on the Colorado River was closed in 1907, the lake was 45 miles long, 20 miles wide, and covered an area of about 520 mi².

DISCUSSION

The analysis of the erosion features at Mount St. Helens and elsewhere causes one to ask how erosion progresses on a newly formed landscape. Is erosion accomplished primarily by the cumulative effects of slowly operating agents acting more or less continuously? Or, is erosion accomplished primarily by the singular effects of catastrophic agents acting intermittently? Stated simply, is erosion chiefly a uniformitarian or catastrophic process?

According to popular geomorphic theory, landforms have evolved by the relentless operation of slow erosion processes. Canyons are believed to have deepened slowly and extended headward imperceptibly becoming the end product of minute changes accumulated over millions of years. William Morris Davis, whose theories have dominated geomorphology, sketched the theory that landscapes evolved slowly through the "cycle of erosion" in stages from "youthful" to "mature" to "old age." According to Davis (1902), the equilibrium profile of a slope became precisely graded to slow erosive agents more than one million years after the completion of the "youthful" stage.

The observations at Mount St. Helens and elsewhere, however, show in miniature that adjustments toward the graded equilibrium condition can occur rapidly, especially when a critical energy threshold is exceeded by

erosion processes. Even the first four years of erosion at Mount St. Helens was noticeably discontinuous. Mudflow erosion on March 18, 1982, established the dendritic drainage which could be regarded as approaching a “mature” landscape on the North Fork of the Toutle River with canyons over 100 feet deep. Mass wasting has been most significant in headward erosion forming rills and gullies within a period of a few days. What conventional geomorphic theory says takes thousands of years may, instead, be accomplished within a few years. Geomorphologists have learned that the time scale they have been trained to attach to landform development may be misleading.

ACKNOWLEDGMENTS

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NEWS AND COMMENTS

CREATION IN THE PUBLIC SCHOOLS

Although the case for evolution was supposedly won by the famous lawyer Clarence Darrow at the Scopes (“Monkey”) Trial in 1925, it has been well documented that in the succeeding years evolution was downgraded or removed from high-school biology textbooks. While the decades following the Scopes Trial were quiet, renewed interest in the issue of evolution and creation resurged in the 60s and 70s, especially in California, Texas, and Tennessee, where numerous battles over textbooks have been waged regarding the inclusion of creation in the public-school science curriculum. Evolutionists believed themselves to have won a decided victory after the 1981 Arkansas trial when U.S. District Judge William R. Overton issued a firm decision stating that it is unconstitutional to *require* that creation be taught in public-school science classes. It is too early to evaluate the impact of this decision, and in Louisiana a trial is pending concerning a modification of Arkansas Act 590. Yet some trends are already becoming evident.

Some evolutionists have expressed concern that in consequence of efforts to win legal battles, the public has been made to realize that some creditable scientists do not believe in evolution. Furthermore, evolution is being downgraded in the elementary and secondary textbooks, not because the authors desire these changes, but because of a strongly competitive market. A textbook that does not emphasize evolution sells to more school districts than one that does, and the economics of the textbook industry have probably done more to reduce the thrust of evolution in the public schools than any other single factor.

A 1982 Gallup Poll has shown that the naturalistic evolution presented in science textbooks is not widely accepted. Of 1518 adults queried, only 9% believed that man has developed without God’s aid over millions of years from less advanced forms of life. Thirty-eight percent believed that man developed from less advanced forms of life *with* God’s aid, while 44% believed that God created man within the past 10,000 years, and 9% did not know. With such beliefs at the popular level, the considerable objection to teaching only evolution in the public schools is not surprising. When family religious beliefs are attacked through required public-school classes, some negative reaction is inevitable. Whether this is contributing to the increase in private-school attendance is a matter of conjecture.

During the past three years evolutionists have reacted with an unprecedented series of publications against creation, including three symposium volumes and at least half a dozen books. The American Geological Institute has published a pamphlet entitled “Why Scientists Believe in Evolution” (it should probably be more accurately entitled “Why *Some* Scientists Believe in Evolution”), and the National Academy of Sciences has likewise published a well-written and attractively illustrated brochure entitled *Science and Creationism — A View from the National Academy of Sciences*. To read much of these materials is a sobering experience. Some of the errors made by creationists are well depicted, while the errors of evolutionists are minimized. Likewise there is unbelievable ignorance, misunderstanding, and misrepresentation of the arguments for creation. Most of the arguments used against creation are not new, and there is considerable duplication of thought and authors. In the three symposium volumes already mentioned above, five authors appear at least twice.

Slightly different is the new symposium volume entitled *Is God a Creationist? He isn't! ...* at least not according to the authors who put little stock into the authenticity of the biblical record.

Overall the stage has changed dramatically. In the past, evolutionists largely dismissed creation as a nonthreatening myth held by a minority. Apparently this is no longer the case, and the defense of evolution is taking on an apologetic fervor.

Katherine Ching

LITERATURE REVIEWS

Readers are invited to submit reviews of current literature relating to origins. Mailing address: ORIGINS, Geoscience Research Institute, 11060 Campus St., Loma Linda, California 92350 USA. The Institute does not distribute the publications reviewed; please contact the publisher directly.

A CANDID REEVALUATION

THE MYSTERY OF LIFE'S ORIGIN: REASSESSING CURRENT THEORIES. 1984. Charles B. Thaxton, Walter L. Bradley, and Roger L. Olsen. NY: Philosophical Library. 228 p.

*Reviewed by Rene Evard, Department of Biochemistry,
Loma Linda University*

Upon noticing this book on a library table, I was immediately intrigued by its title and possible approach to the scientific solution of life's origin. Here I found a masterful critique of chemical evolution.

The scientific credentials of the authors are impeccable. Charles B. Thaxton received a Ph.D. in Chemistry from Iowa State University. He was a post-doctoral fellow at Harvard. Walter L. Bradley holds a Ph.D. in Material Science and is a Professor of Mechanical Engineering at Texas A&M University. Roger L. Olsen received his Ph.D. in Geochemistry from Colorado School of Mines.

In the late 1920s Oparin and Haldane proposed a naturalistic evolutionary scenario for the origin of life on earth. They suggested that certain conditions existed in the earth's primitive atmosphere which led sequentially to the formation of amino acids, sugars and other simple biomolecules, and their accumulation in the oceans. From these simple compounds the more complex biopolymers — proteins and nucleic acids — required for life presumably would emerge naturally. These ideas led, in the early 1950s, to a series of classical experiments in which Stanley Miller was able to demonstrate the formation of amino acids under so-called prebiotic conditions. Miller's success opened up a broad interest in chemical evolution and gave impetus over the next 25 years for a number of scientists to carry out many experiments designed to produce biologically significant compounds and subcellular structures under presumed prebiotic conditions. *The Mystery of Life's Origins* presents a thorough, objective and scientifically sound analysis and critique of these experiments.

The first two chapters of the book introduce the problems. Chapter 3 deals with experiments aimed at the synthesis of prebiotic monomers. Chapter 4 presents the serious questions concerning the character of the presumed primordial prebiotic soup. The question of whether the early earth's atmosphere was reducing or oxidizing is discussed in Chapter 5. Chapter 6 exposes the bias introduced in these experiments by the investigator, bias which must be recognized as uncharacteristic of natural prebiotic situations. The thermodynamics of living systems and its relationship to the origin of life are presented in Chapters 8 and 9. The function of presumed protocells compared to their actual living cells is presented in Chapter 10.

The scientific evidence presented in this book is overwhelmingly against the probability of life having originated through chemical evolution. Too many questions are left unanswered by the evolutionary scenarios that have been proposed. There is too much discrepancy between the results of origin-of-life experiments and the beautifully ordered systems found in nature. The low yields of the compounds formed in these experiments, the instability of key intermediates, the cross-reactions between amino acids and sugars, the condensation reaction involving a dehydration under aqueous conditions, the high level of stereospecificity found in biological systems, and sequence specificity of biopolymers are but a few of the unanswered questions relating to a naturalistic evolutionary origin of life. For these reasons in their concluding chapter the authors present five alternative solutions to the mystery of the origin of life, one of which is a special creation by a Creator beyond the cosmos.

Each chapter of the book contains a comprehensive list of references that make it a valuable tool for anyone interested in further investigation. A minor criticism could be offered regarding the omission of any discussion on the enantiomer preferences so unique to all biological systems.

It is interesting to note that within the scientific community there is decreasing interest in this field, as reflected by a diminishing number of publications and fewer new workers undertaking research on chemical evolution.

Throughout this work one is impressed by the thoroughness and objectivity of the authors in presenting the results of experiments and in giving a careful analysis of these results. While this book is addressed to a scientific audience, it can be read and understood by laymen with a solid foundation in science, and will be valuable to anyone interested in questions related to chemical evolution.

LITERATURE REVIEWS

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THE SLEUTHS CHALLENGE SCIENCE

BETRAYERS OF THE TRUTH. 1982. William Broad and Nicholas Wade. NY: Simon and Schuster, Inc. 256 p.

Reviewed by Wayne Frair, Biology Department, The King's College, Briarcliff Manor, New York

Subtitled “Fraud and Deceit in the Halls of Science,” this work exposes a series of misdeeds in the name of science by some greats as Galileo and Newton, near greats, hopefully greats, and even some unknown tricksters. Included are cases of theft, for example, by the Alexandrian Ptolemy who stole from a Greek astronomer, or the recent plagiarist Alsabti who published or republished as his own the research of other investigators. There were those, including Isaac Newton, Gregor Mendel and Robert Millikan, who utilized some procedures or factors to cause their conclusions to be more convincing. Also discussed are the hoaxes such as Piltdown man, and, according to Broad and Wade, the Shroud of Turin.

Even Charles Darwin, they say, clearly “was laggard in giving credit to earlier authors of theories of evolution” (p 31). Loren Eiseley has shown similarity in phrases, rare words and examples between Darwin’s writing and that of his unacknowledged predecessor, Edward Blyth, who published papers on natural selection in 1835 and 1837. Darwin has been accused, apparently with good justification, of failing to give appropriate credit for his own ideas to other earlier thinkers including Buffon, Lamarck and his own grandfather, Erasmus Darwin.

In reflecting on the contents of this book, I can think of additional examples of deceit such as Ernst Haeckel’s 19th-century misrepresentation of embryos in order to support his concept of embryonic recapitulation. Even though some of these stories of deceptions can make interesting reading, I have no pleasure in contemplating them, and I would prefer to recall members of the army of dedicated scientists who have

been models in standing for the highest ideals in pursuit of truth. Such were many of my professors including my own graduate advisors. But I suppose there is value in *Betrayers of the Truth* and similar writings for revealing the unbridled deceitful nature of mankind, for encouraging reevaluation of various data (facts) and concepts, and for warning present and future investigators.

On the whole the book is interestingly and insightfully written. For example, it says:

To a probably insalubrious degree, science has replaced religion as the fundamental source of truth and value in the modern world (p 119).

Science is meant to be a community of intellectuals, dedicated to a common goal. If one scientist falls prey to dogma, and tries to promote doctrinaire beliefs in the name of science, won't his colleagues immediately perceive the error and take action to correct it? History shows that, to the contrary, a community of scientists is often ready to swallow whole the dogma served up to them, as long as it is palatable and has the right measure of scientific seasoning. Just as replication is no sure defense against error, objectivity often fails to resist infiltration by dogma (p 193).

Sometimes a whole community of researchers falls prey to a common delusion, as in the extraordinary case of the French physicists and N-rays, or — some would add — American psychologists and ape sign language (p 108).

Even though Broad and Wade say nothing directly either to favor or disfavor a creationist position, they do seem to understand that because evolution deals with history, it is not to be thought of as science at least in the strict sense:

The theory of evolution is another example of a theory highly valued by scientists because of its enormous explanatory power, but which lies in a sense too deep to be directly proved or disproved (p 17).

The appendix gives a chronological list of “Known or Suspected Cases of Scientific Fraud,” and the publisher requests that other uncited cases be brought to their attention. There are good bibliographic “Notes” for each chapter, and an extensive “Index” which includes names of individuals and topics. The book expresses many years of thought and effort and will on the whole, I believe, have a beneficial influence.

GENERAL SCIENCE NOTES

LIFE, AN EVIDENCE FOR CREATION

*By George T. Javor, Associate Professor,
Department of Microbiology, Loma Linda University*

Our biosphere abounds with life. Representatives of more than two million species can be found in the atmosphere, in the deepest part of the oceans and on the surface of the earth where no fewer than ten thousand organisms exist per cubic inch. The abundance of life in our environment leads scientists to propose that whenever and wherever conditions for life are favorable, it will spring into existence.

This prediction was tested only once, when automated laboratories were sent to Mars in the 1970s to check for the presence of life. The results were negative, even though Martian conditions could support certain life forms.¹ Since no other planet in the solar system is capable of supporting life as we know it, life here on earth is more unique than many individuals had previously supposed.

How unique is life? If it can be shown that the capacity to form life is inherent in matter, as naturalistic evolutionists assert, we have the option of believing that life began here either by the spontaneous generation of primitive life forms under primordial conditions or by the creative act of a supernatural agent. (A third possibility, panspermia, is in reality a variation on either of the previous two choices and will not be considered here.)

Our knowledge of life from the evidence at hand argues against the notion of nonliving matter organizing itself spontaneously into life forms under any conditions at any time.

“Life,” as I use the term, refers to the “state of living”² and cannot be dissociated from matter. For purposes of discussing origins, “life” in the abstract sense, devoid of matter, does not exist. “Living state” is a designation which sums up the functions of unique composites of matter. Life is a property of the entire complex. If the living complex is taken apart, the system ceases to live. It follows that components of the system are not living; that living matter is made up from nonliving components. The most fundamental living systems are called cells. “Life” or “living” is also used to describe the functions of specialized cell complexes called organs. On an even higher level of organization are organ complexes called organisms.

Even though components of living cells are not alive, they are unique and different from nonliving matter found at large. The four most abundant

(by weight) elements in living matter are hydrogen (~ 60%), oxygen (~ 25%), carbon (~ 10%) and nitrogen (~ 1%); whereas in nonliving matter they are oxygen (~ 50%), silicone (~ 30%), aluminum (~ 8%) and iron (~ 5%).

In nonliving matter elements combine to form sturdy, low molecular weight compounds of high oxygen content. The extreme reactivity and great natural abundance of oxygen creates a situation in our world where these combinations of elements represent, energetically speaking, "the bottom of the hill."

In contrast, biomolecules to a large extent are highly reduced, carbon-based, fragile polymers. Considerable expenditure of energy is required for their production, and energetically they are on "top of the hill," i.e., relatively unstable.

Matter in cells is organized into successively more complex structures in the following order: precursor metabolites → building block substances → polymers → organelles → cell. According to our best estimates, a single bacterium such as *Escherichia coli* needs 12 types of precursor metabolites, about 100 types of building block substances and 1500-2000 different kinds of polymers; the total number of molecules being around 25 million per bacterium.³

The order in which building blocks are arranged in the biopolymers DNA, RNA and proteins is highly meaningful. It constitutes the basis of biological information necessary for living matter to function. This information, however, is not inherent in the building blocks. The rules of chemistry define how building blocks such as the four types of deoxyribonucleotides may be linked to form DNA, much the same way as the rules of grammar define the order in which letters of the alphabet may be arranged to spell words or how words may be put in proper order to make meaningful sentences. The rules of grammar, however, are not adequate for choosing the letters to be arranged as words or words which are to appear in sentences. This sort of information has to be superimposed upon the laws of grammar by the writer of words and sentences. Similarly, biological information residing in the biopolymers DNA, RNA and protein needs to be supplied by an intelligence, using the rules of chemistry.

Evolutionists insist that the biological information found in biopolymers is not a product of design, but is the result of random variation coupled with selection in favor of molecules which can contribute to the living state of matter.

If primordial mechanisms existed which generated biopolymers more or less at random [such mechanisms have been proposed, but their feasibility is open to grave doubt⁴], would randomly produced biopolymers

which contain biologically useful information be favored over similar molecules with no information content? The answer is no, because the utility (and hence the meaning) of biological information carried by a given polymer depends on the presence of other biopolymers possessing complementary information, and the true biological sense of each component is realized only when the system is together and functioning in the living state.

Those who argue for the feasibility of a spontaneous generation of life place great stress on the well-known ability of certain biopolymers to self-organize. This phenomenon is seen as a possible means by which living matter came into existence. However, in order to form meaningful aggregates such as a ribosome or a viral coat, one has to begin with subunits which are preprogrammed for aggregation. Randomly generated, single DNA strands or protein molecules with no information content may or may not aggregate, and aggregation of itself will not necessarily carry biological meaning.

Isolated components of living matter can perform tasks such as replication of DNA or its transcription to RNA molecules, and even production of functional protein molecules, provided that at hand are the necessary ingredients and an energy-generating system. But these “in vitro” reactions by no means approximate the living state.

Although a precise definition of the living state for cells does not exist, at the minimum we need a system which absorbs simple building-block type molecules such as amino acids, monosaccharides, purines, pyrimidines and fatty acids; builds them into polymers and supramolecular complexes in a controlled, harmonious manner; and is able to utilize the chemical energy found in highly reduced molecules for growth, active transport of nutrients, etc. A most important consideration is that the sum of the constituents of living matter should not be at chemical equilibrium. Once chemical reactions reach equilibrium they cannot be directed for the release of energy.

The bulk of living matter is made up of hundreds of types of enzymes whose specific task is to bring chemical reactions rapidly to equilibrium. However, because the product of one reaction turns out to be the starting material of the next chemical conversion, equilibrium is not reached. We find chemical transformations in which the end product of a given reaction sequence is able to terminate the initial reaction of the sequence through specific feedback inhibition. The existence of control mechanisms such as feedback inhibition enables cells to maintain relatively constant concentrations of biomolecules in a nonequilibrium steady state. It cannot

be envisioned that this situation could be established if one began with a cell in which all components were at equilibrium.

These considerations highlight two theoretical problems which evolutionary postulates concerning the origins of life cannot solve:

1. What is the source of biological information which dictates the structure and function of biopolymers?
2. In the initial development of cells, how could all molecules necessary for life be sequestered into a cell in such a way that they are in a state of non-equilibrium, when the bulk of these molecules are very efficient biocatalysts specializing in the establishment of equilibrium?

It is widely acknowledged that life is a nonspontaneous process. If this indeed is the case, life must have arisen by a nonspontaneous process, because nonspontaneous events, by definition, cannot begin spontaneously. Since creation qualifies as a nonspontaneous process, the very existence of the phenomenon of life is an evidence for creation.

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