

SCIENCE

Science: Torah Perspectives

Prepared by Ner Le'Elef

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1. Overview

This Ner LeElef book does not require any background in science to understand. We begin by showing that science has been highly successful in improving mankind's lot in multiple ways, including quality of physical life and life span. Science, in other words, commands our respect because it works. But science has gone further – it has affected our thinking by radically changing our relationship to time and other things and by introducing many words into our common vocabulary. Science has been so powerful, in fact, that it has taken over from philosophy all the major questions about the beginning and the end of the universe, how and when life began, and what defines death.

In principle, Judaism is pro-science – it is a part, not only of our physical realities, but often of our halachik realities as well. Having said that, there are certainly conflicts between the Torah position and individual theorems of science. Even theories that are touted as great reconciliations with religion, such as the Big Bang, are not flawlessly in harmony with Judaism. But the remarkable thing is that science, in almost every area, seems to be moving closer and closer to what Judaism has been saying all along.

As laymen, we sometimes pay more respect to a scientific theory than the scientist himself does. For the scientist, a theory is simply the best possible current explanation, usually among many, for as broad a group of phenomena as possible. Theories can contradict, and can be weaker or stronger. No theory is considered by scientists to be infallible. This reinforces the idea that science is in constant movement forwards, and, since that direction is towards Judaism, we need not feel that we have to resolve all conflicts right away. We can patiently wait until science gets closer and ultimately see all these conflicts resolved.

However, there are two more serious areas of conflict between Judaism and science. The first has to do with the fact that science is essentially a secular paradigm. Many scientists comfortably believe in G-d but would never dream of invoking Him as a part of their scientific explanations. G-d is outside of the acceptable parameters of science. Formally, science is neutral vis-à-vis religion. But the idea that all of nature would be discovered, without seeing G-d permeating every element, is highly problematic as we shall show.

The second problem is the fact that science moves so rapidly that it tends to create facts on the ground without a full exploration of the moral and ethical implications it brings. Ethicists are always playing catch-up with science, always coming from behind. In some scientific circles, progress is always welcomed as being good although many have recognized the seriousness of the current situation.

Our belief is that, in the Messianic era by the latest, science will undergo a radical revolution, a paradigm shift, which will bring G-d into the picture, will subject itself to Torah ethics, and will allow science to bathe in its true glory as a handmaiden of the Torah.

2. The Great Success of Science

Science, and in particular, twentieth century science, has changed our whole way of life. We live in houses that are heated and cooled, lit up at night, and wired to alarm systems. We turn on taps to get running water and flush toilets which connect to sophisticated sewage systems; we drive in cars, watch TV and receive e-mails; we buy in huge supermarkets and cook in microwaves; we use our credit cards and make electronic transfers; etc. Indeed, it is difficult to think of much of anything that we do which was not given to us by modern technology.

More than just saving us from going to the well for our water and using candles by night and donkeys by day, science has given us a new lease on life itself. In the USA between 1900 and 1998, the life expectancy increased from 47 years to 78 years. The average person has 31 extra years with which to fulfill his life's task. Truly remarkable! Many whose lives were measured in minutes and hours would today live long and healthy lives. Infant mortality (below one year of age) in the USA declined from 100 per 1000 births (10%) in 1915 to 11 per 1000 in 1984.¹

Horrible diseases, which over the centuries took hundreds of millions of lives, are now under control. One of the ghastliest of them all, smallpox, was totally eradicated from the face of the earth.

The more scientifically advanced a country, the better its standard of living. In these countries people eat better, have better sanitation, higher income, and generally live healthier, more comfortable lives. If we believe in science it is because we see that it works, not just by sending someone to outer space but in tangible ways that seemingly improve our lives every minute of the day: telephones access us to almost anyone, roads are better paved and greengrocers store fresh produce from all ends of the globe.

Our world is full of the glories of scientific invention. We wake up in the morning and turn on the electric kettle; we drive to work, catch the elevator, and turn on the computer. Our counterparts a century ago would not have done a single one of these things. Science came of age not only because of its great discoveries but because of the ability to put those discoveries into our homes. By the time he applied for any patent, the great American inventor Thomas Edison had already envisaged how he could translate his invention into a tangible, commercial product.

Although the dawn of the scientific revolution dates back to Copernicus and Galileo, it was really only in the last century that our world began to look like it does today. In the year Thomas Edison was born (1847), 495 inventors won patents in the USA; in the year of his 40th birthday, more than 20,000 patents were granted.

But what most of us fail to even be aware of is how science has changed our whole way of relating to the world. We are not aware of how even our daily speech has dramatically changed in the last century. After the invention of electricity, for example, effective people became "dynamos", a thrill gave one a "charge", and personalities could become "overloaded" or "burnt out".²

Our whole way of relating to time changed dramatically. Up until the 1820's, a day was divided into 12 daylight hours but it was up to each town to decide what their standard time was. One town, 20 miles away from another, could show an hour's difference. It was

¹ Figures from Dennis Flanagan's *Flanagan's Version*, Vintage Press, pp. 26-28

² *Electrifying America*, David Nye, reviewed by Claude Fisher in *Science*, May 17, 1991

American railroads, with their need for exact scheduling, which imposed modern time on mankind. No one today can imagine how revolutionary such a change was. It engendered huge resistance at the time. Banks in Louisville, Kentucky stuck to sun time for another 30 years. A school board in an Ohio town decided to run the schools on Eastern Standard Time, in defiance of the city council which kept the rest of the town on sun time. A debtor in Boston reset his watch to the new eastern time and thereby missed his court appearance before a judge who stubbornly persisted in using local time and declared the man delinquent (the state supreme court overturned the decision).¹ The world, however, progresses inexorably forward, and resistance to standard time crumbled.

The presumption is that all of this had been good for mankind. But, it was that same science that produced the atom bomb, chemical weapons, global warming, and wholesale destruction of the environment. Possibly the greatest physicist of our time, Stephen Hawking, was prompted to wonder: “It has certainly been true in the past that what we call intelligence and scientific discovery has conveyed a survival advantage. It is not clear that this is still the case: our scientific discoveries may destroy us all².” No one is suggesting that we go back to donkey carts and candles, but it is clear that science is a mighty force which needs to be understood and directed. It is clear, too, that the scientific community itself cannot handle this challenge. In fact, being a great scientist is in no way a moral advantage. “Scientists themselves show no correlation between their greatness and their ethical behavior. Some, like Einstein and Sharansky, used their fame to try and promote what they saw as ethical behavior in the world. But others were simply rascals. Heisenberg worked on an atom bomb for the Nazis and Newton was callous and vindictive. After his breakdown in 1693, he discarded academic pursuits for more heavy-handed work as a private investigator and prosecutor who was feared by many³. The power of science, where it should be going and who its leaders should be, is the subject of this essay.

¹Keeping Watch, A History of American Time, by Michael O'Malley, reviewed by Patricia Cline Cohen, in *Science*, May 17, 1991

²Stephen Hawking, A Brief History of Time, pg. 12

³ Michael White, in Isaac Newton: The Last Sorcerer 1997

3. Science as the Leader of Civilization

In the 20th Century, science became not just another endeavor of the Western world but rather the defining characteristic of our civilization. The sciences in general and theoretical physics and cosmology in particular have captured all the ancient questions of the philosophers as theirs for the answering - where does life begin and end; when did the universe begin and when will it end; how is matter created and destroyed; what are the ultimate principles by which the universe runs?

In 1988, the Harvard naturalist Edward Wilson published a book by the queer name of Consilience: The Unity of Knowledge. His was an attempt to show the complete unity of all knowledge, in particular the knowledge of human affairs, under the umbrella of the scientific endeavor. Politics, economics, society, and the individual: all will only make ultimate sense when reduced to biology – genetics, to be specific, and genetics will ultimately make sense when reduced to physics. Only then will we be able to link all the insights of diverse fields into a coherent whole that will explain all of human behavior. Why do people love, and why are there wars; why do we dream and why do we have self-awareness; why are we greedy capitalists and why are we creative; why are we moral and why do we believe in G-d - all must yield to the might of a science-based ‘consilience’.

Wilson has not been welcomed by all scientists in the scientific mainstream. His theory has too much grandeur and not enough hard science to back it up. But what Wilson explicitly wants to do has indeed already taken place without the conscious awareness of the human race as a whole. Science has, if not taken over all areas of knowledge, defined, shaped, and set the standards by which they will all be judged.

This is true not only of philosophy but of art as well. This is not to say that the painting of a picture or the composition of a piece of music has become more scientific, although this may be true. My suggestion is more radical. In the 20th century, it appears that there has been a collapse in the sense of aesthetics which always informed the formal world of culture. Simple rules like symmetry, counterpoint and harmony are no longer obviously present in works where the subjective and interpretive responses of the viewer are the only way in which one can make any sense at all of what is being communicated.

Yet, these principles of aesthetics, so orphaned by the world of art, have been adopted by a new parent, the world of science. In an astonishing unfolding, many great scientific discoveries of the 20th century were made by adherence to just those principles of symmetry, beauty, unity and simplicity.

4. Judaism is Pro-Science

Judaism is pro-science. The great conflicts of science and religion were with the Church, and not with Judaism. Thus when Galileo supported Copernicus's opinion that the sun and not the earth was at the center of the universe, he was forced by the Church to withdraw his views. Given the choice of publicly retracting or of being killed, Galileo chose

life¹. Giordano Bruno (1548-1600), who refused to retract, was burned to death². In 1997, the Pope apologized for this position of the Church, a position which may have contributed to the loss of control of the government and the people by the Church. On the day that Galileo died, Isaac Newton was born and the scientific revolution begun by Copernicus was complete.³

Judaism, in contrast, has always related to science in a positive way. For example, Judaism obligates us to use the most up-to-date medical procedures⁴. If medical science says this year that it is life-threatening for a patient to fast on Yom Kippur, it is then a mitzvah for him to eat. This is so even if last year's medicine said that it was okay to fast, and if next year things will change again, as is quite common in medicine⁵. We use contemporary scientific knowledge for halachik decisions even though we know that the knowledge will date. Halacha, in fact, demands a certain knowledge of science or access to those with knowledge⁶.

¹Until Copernicus, Aristotle and Ptolemy reigned supreme. The Church and science agreed: the earth was the center of the universe; the planets, the sun and the stars all revolved around the earth in eight spheres made of an immutable substance; their movements were circular. Copernicus, followed by Tycho Brahe (1541-1601) and Johannes Kepler (1571-1630), challenged this doctrine, introducing a sun centered universe. For over a century, the church fought this doctrine, seeing it as a challenge to man's centrality in the world. Copernicus escaped the more radical persecutions that would inflict Bruno and Galileo later on. This was partially because his doctrine was still considered weak, not being able to explain why, if the earth moves, we do not fall off it (gravity was unknown), why the position of the stars does not appear to constantly change and why there is no detectable wind induced by the motion. Nevertheless, theologians tried to prevent publication of Copernicus's "The Revolutions", John Calvin pointed out that the Bible says that the world cannot be moved, and Martin Luther condemned Copernicus.

In 1616, the Church decreed that Copernicus is "false and erroneous" and banned his writings. The Church view continued to be the Aristotelian one that the world was the center of the universe, that it did not move, and that the sun rotated the earth. In 1632, Galileo was tried by the Roman inquisition for espousing the Copernican theory of the structure of the universe, thereby violating the decree of 1616. He was not given a copy of the charges against him, nor was he allowed someone to defend him. He was given the choice of publicly retracting or of being killed. In a decision that some have criticized as damaging the cause of science, Galileo chose life. He was forced to state that "I abjure, curse and detest the aforesaid errors and heresies." Aged seventy, he was confined to his villa under strict house arrest for the remaining days of his life.

²Bruno was originally ordained as a priest, but led a troubled life with the church. Although excommunicated twice, he still managed to become one of the greatest scientists of his age. In 1593, he underwent the beginnings of a seven year trial by the Roman Inquisition who demanded that he retract his Copernican views. He declared that he had nothing to retract and was burned to death 9 days later.

³Culled from The Science Class You Wish You Had ... by David E. Brody and Arnold R. Brody

⁴אברהם בן הרמב"ם; מאמר על אודות דרשות חז"ל (בעין יעקב הקדמה): ...לא נתחייב מפני גודל מעלת חכמי התלמוד... שנטען להם ונעמיד דעתם בכל אמריהם ברפואות ובחכמת הטבע והתכונה (ע"ש)

See חזון איש in his פ"ה (אמונה ובטחון) who shows, in considerable detail, that the sages and others who lived in their time knew an enormous amount of medical and other scientific knowledge. Much of this knowledge was subsequently lost. Some of it was rediscovered by modern science and medicine. Other areas seem to elude us to this day.

⁵A medical student told me that his class was told that, by the time they graduate, half of what they were taught in medical school would be out of date. The trouble is, he said, there was no way of knowing which half would be right and which half wrong.

⁶See also *Challenge*, A Radkowsky pp. 77 (bottom)-79, p. 88, paragraph beginning "We know..."

In fair detail, the Yaaros Devash describes how mathematical, scientific, musical and other forms of worldly wisdom can all facilitate our getting closer to the Almighty¹.

The Kuzari² describes the amazing detail which the Sages had of the physical world. They had a precise understanding of the relationship of the cycles of the moon to that of the sun, many centuries ahead of Western knowledge of the subject. This required knowledge of mathematics as well as of the exact appearance of the constellations in parts of the sky at particular times of the year, and where the moon would be seen in relation to these. They could tell, without internal examination, whether a particular type of blood was coming as a menstrual flow or was coming from another source. They could do this merely by looking at a spot of blood. They knew which diseases were fatal to an animal and which were not, and

¹יערות דבש - חלק ב: דרוש ז: זהו מה שנראה לכאורה, אבל ביותר יש להבין מה ענין זה ממנה היה מתחיל ובה היה מסיים. ונראה כי שבעה נרות הם שבעה חכמות, כי ידוע כי חכמה היא מכונה בשם נר, חכמת אדם תאיר פניו, ושבעה נרות הם חכמת חיצונים, ונר מערבי היא חכמת תורתנו הקדושה, שכינה במערב, וכל החכמות משתלשלות מתורתנו ומשם מקורם ושמה ישובו, כי כולם הם נערות המשרתות את המלכה, כמ"ש הרמב"ם [אגרות הרמב"ם פאר הדור סמ"א] שהם לרקחות וטבחות, וכולם צריכים לתורתנו, כאשר הארכתי בזה וחברתי ספר מיוחד, ועל זה אדני הספר הטבעו, כי כל החכמות הם פרפראות וצורך לתורתנו, כאשר חכמת גימטריא שהיא חכמת המדידה ונכלל בה חכמת המספר ותשבורת ואלגעברא, צריך מאוד למדידת עגלה ערופה ומדידת ערי ליום ומקלט ותחומי ערים:

חכמת המשקלות שהיא חכמת מיכאנ"ק, צריך לבית דין לדקדק להבין במאזני צדק ועול. חכמת הראיה שהוא אפטי"ק, צריך בית דין הגדול לדעת לברר זיופי כומרי עכו"ם, כי יעשו בתחבולות ההם המראות משונות מורים פרצופים נפלאים, ומי שאינו בקי יאמר כי רוח זרה בתוך המראה, וכך היה מקדם, הכומרים עכו"ם מטעים להבאים בבית עבודתם, כאילו רוח מורה להם מתוך המראה אשר לא ידעם וגם מורה באצבע, והם הכומרים היו יושבים בחדרי חדרים, ועל ידי טוב מעמד ומצב המראות כפי תנועתם, כך נראה לעם במראה העומד בחדר, ואין איש למולו עושה כן, ולכך חיוב על בית דין הגדול לדעת תחבולות הללו, לבאר ולברר טעות השוטים אשר היו, וכהנה רבות, הצריך חכמה זו לעדים שאמרו שעמדו מרחוק וראו המראה אם קשת הראיה כל כך הולכת אם ביושר אם בעקלתון:

חכמת התכונה היא חכמה ישראלית סוד עיבור לדעת מהלך תקופות ומזלות ולקדש חדשים: חכמת התולדה שהיא חכמת אצטגנינים, ונשתמשו בה בימי חכמי הכלדים, היא שער גדול להלכות עכו"ם, כי כך היה כל מעשה עכו"ם להקטיר למלאכת שמים, וכל מעשיהם היה בחכמת אצטגנינים ותולדות, ויפתו אחרי הוברי שמים, ומזה נולדה כל חכמת הקסם וכישוף, בעשותם טלמסאות וצורות לכוכבי שמים, והכל על פי חשבון מהלך ושיעור התולדות, ורבים טעמי מצוות שנתייסדו על זה, כמ"ש הרמב"ם, כאשר הארכתי בזה ספרי הנ"ל:

[חכמת הטבע, אשר נכלל בה חכמת רפואה בכלליה, צריכה מאוד לחכמת התורה, הן לדעת ולהבחין דמים דמי נדה אם טהור או טמא, והיא חכמה לא שער כל חכמי רופאי זמנינו, ואחז"ל [נדה כ:]: טבע דארץ לא ידענו ודמא קחזינא, הרי צריך לכך חכמת הטבע ומחקר לרפואה, וביחוד לדעת בשפיר אם תוך מ' יום או לאחר כך, ולהבחין בין זכר לנקבה צריך חכמה הרבה וחקירה נפלאה, וכלו כל חכמות בחקירתם ולא יגיעו לכך, ומכ"ש שצריכים להבחין כאשר יכה איש את רעהו אם יש בו כדי להמית, ואם מת אם בשבילו הוא, ועל איזה חולה מחללים שבת:

חכמת צמחים ומחצבים, כמה גדול כח החכמים בזה, בענין כלאים לדעת שיעור יניקה עד כמה, ומה הוא טעם התערובות, ואיזה מין מותר בהרכבה ואיזה אסור, ובזה נכלל טבע בעלי חיים לדעת איזה מין יש בו הרכבה או לא, ואיזה מין חיה או בהמה:

וחכמת אומנות שקורין קאך, שחכם בה אפלטון בתקוני אכילות ומזגים, וממנה נולדה חכמת הרקחים ואפטיקין בלשון אשכנז, היא הצריכין להבין טעמי קרבנות מנחות ונסכים ופיטום הקטרת:

וחכמת אלקימייא, ובכללן פידמיע בכל חלקי התכת מתכות ושינוי טבעי מחצבים וכדומה, הוא צורך להבין טעמי בנין משכן ומקדש, איזה לכסף ואיזה לזהב ואיזה לנחושת וברזל, וטעם אבני חפץ באפוד וסגולתן, וכהנה סתרי הטבע מסתעפות בשורשה חכמת סימפאטי ואנטיפאטי שצריכין לבית דין של ישראל לדעת מה הוא מגדר סגולה וטבע הענין ואין בו מדרכי האמורי, ומה שאין בו כלל שורש בחכמה הנ"ל והוא מדרכי האמורי:

ובחכמת הציור ונתוח יכירו על בוריה חכמת היד וחכמת פרצוף, ומי שאינו בקי בזה בטוב לא יבין חכמה הנ"ל על בוריה, ובזה נשיג ענין שיר השירים בתוארי שבח הגוף ראשך ככרמל ופרשת אתה תחזה כמ"ש הזוהר [יתרו]:

מחכמת ההגיון ומבטא נבין כל חכמת הדקדוק ונועם מליצה, ומופתים אמתיים ומוזיפים, ודברי צחות בתורה ובנביאים:

מחכמת המוזיקא אין לדבר, כי היא חכמת השיר, ובזה נבין כל ענייני הטעמים ונקוד השירים בתורה ונועם מליצת ליום וכדומה בכל פרטי דברים, והם נגונים ישרים לשמח לבבות להסיר מרה שחורה, ולקנות הנפש שמחה שיחול בה רוח אלוך כמעשה הנביאים. ומה רב כחה של חכמה זו, אשר כל מלאכי מעלה וגלגלי שמים כולם ינגנו

they had detailed biological understanding of exactly how different animals would inflict damage through clawing. There are many other examples.

All of this required keen scientific eyes to see order, patterns and laws. The physical world is a world of *הכרח*; therefore, *השגחה* is seen through order. The use of *אלוקים* throughout *בראשית* means that the world was created according to set patterns or laws = *מדת*. This underlies the whole possibility of science, which relies on the fact that the world is consistently logical.

Avraham Avinu went further, discovering the whole Torah by intuiting the underlying spiritual implications of the world around him. Theoretically speaking, we could all be like Avraham Avinu and discover Torah through deep contemplation of the physical world¹. However, this approach is simply too inaccessible to be a reliable method of discovering what G-d wants of us². Therefore, when the Torah was given we began to rely primarily on knowledge of Torah to know and have a relationship with G-d. Unusual people are able to work in the reverse: they are actually able to discuss the physical world by study of the Torah. This is called the study of *מעשה בראשית*³, but this too is not a reliable method on a broad basis⁴. Hence the need for science.

The Maharal explains that the Sages never attempted to give scientific, medical or biological explanations to things. They were only interested in giving the inner spiritual content of the situation.⁵ Scientific laws are explanations for what happens in the world.

וישירו בשיר ונגון נועם כפי סדר טוב הקולות וחצי קולות, וכולם יש להם שורש בחכמת אמת, וכל תנועה יש לה שורשים, וכבר הארכתי גם כן בספרי הנ"ל, כיצד היתה כוונתם בתנועות עולמות עליונים בנגנם ובשירם ובתנועותם, כפי הנועם והניגון בחכמה הנ"ל בפה ובכלי להשמיע קול אחד:

²מאמר רביעי. כח-לא

ר' חיים פרידלנדר, שפתי חיים (אמונה ובטחון דף תנא): בתורה טמונה כל חכמת הטבע, וחז"ל ידעו זאת מהתורה, כמו שכתב הרמב"ן (בהקדמה לתורה) "תולדות ארבעה הכוחות שבתחתונים, כח המחצבים וכח צמחי האדמה ונפש התנועה ונפש המדבר ... הכל נכתב בתורה בפירושו או ברמז." ... [וכן בכתבי הרמב"ן] ח"א, דרשת תורה ד' תמימה עמ' קנח-ט, קסב-ג) וסיים "סוף דבר, כי בתורה נרמז לחכמים כל ענין הטבעים." ונראה לבאר שהחכמים ידעו מהתורה את כל השרשים...

¹משך חכמה על שמות פרק כד פסוק יב: והתורה והמצוה אשר כתבתי להורתם - אשר כתבתי לא יתכן על התורה והמצוה, ועיין רשב"ם, ונראה דאלמלא נתנה תורה היו למדין צניעות וכו' גזל מנמלה וכו' (גמ' עירובין ק סע"ב), לכן אמר אשר כתבתי בספר הטבע אשר יצאתי שזה ספר של השי"ת היוצרה ע"ש עוד

²רמב"ן, דרוש תורה תמימה: "חכמי הגויים אינם יודעים ביצירה מה שידוע קטן בישראל. ודבר ברור הוא שרוב תועלת שאר החכמות אינה אלא להיות סולם לזו ולחכמה שקורין הם ידיעת הבורא..."

³חגיגה יא: אין דורשין בעריות בשלשה ולא במעשה בראשית בשנים ולא במרכבה ביחיד אלא אם כן היה חכם ומבין מדעתו

מאירי: ריש פ"ב דחגיגה: וענין מעשה בראשית הוא ידיעת חכמת הטבע ונכלל בה ידיעת שני עולמות ר"ל עולם היסודות ועולם הגלגלים.

רמב"ם: (הל' יסודי התורה פ"ד ה"א): ... ולמה אין מלמדין אותו לרבים לפי שאין כל אדם יש לו דעת רחבה להשיג פרוש ביאור כל הדברים על בורין. ועיין עוד ברמב"ן בראשית א: א

⁴ כחרי: Our faith comes from the fact that the Jewish nation collectively witnessed the event at סיני, and not from the fact that there was a *מעשה בראשית*, to which there were no witnesses.

⁵מהר"ל, באר הגולה (באר שיש עמ' קו): לא באו חכמים לדבר מן הסיבה הטבעית כי קטון ופחות הסיבה הטבעית כי דבק זה יאות לחכמי הטבע או לרופאים או לחכמים. אבל הם ז"ל דברו מן הסיבה שמחייב הטבע

Behind these explanations of “what” are reasons of why, the underlying spiritual reality of things¹. Scientists exceed their mandate, and can even be dangerous, when they try to deal with the why². Ultimately, this inner content is not only in complete harmony with the outer, scientific reality, but it is the explanation behind the reason³.

¹ר' חיים פרידלנדר, שפתי חיים (אמונה ובטחון ח"ב דף תמט): חכמי הטבע אינה עוסקת בלמה, התחום שבו היא עוסקת הוא המה

²שפתי חיים שם: אוי ואבוי הוא כאשר חכמי הטבע חורגים מגבולות וממגבלות חכמתם, ומנסים להסביר את הלמה, כי אז הם בודאי שוגים, וטועים, מפני שהלמה - סיבת הסיבה היא רוחנית

³מהר"ל (שם סו): שאמרה תורה על אות הקשת (בראשית ט: יד-טז): את קשתי נתתי בענן והיתה לאות ברית ביני וביני הארץ ... והיתה הקשת בענן וראייתה לזכור ברית עולם וחכמי הטבע נתנו סיבה טבעית לקשת כמו שידוע אבל הדבר הוא כך שהסיבה אשר נתנה התורה הוא הסיבה שלכל דבר יש סיבה טבעית המחייב אותו, ועל אותה הסיבה הטבעית יש סיבה אלוקית, והוא סיבת הסיבה, ועל זה דברו חכמים. כי לאדם על צורתו ומספר אבריו יש סיבה טבעית, כי אין ספר שיש לדבר זה פועל טבעי, ומכל מקום יש לאותה סיבה סיבת אלוקית, שעל סיבת הסיבה אמר (בראשית א כג): ויברא אלוקים את האדם בצלמו בצלם אלוקים ברא אותו

In the Sifsei Chaim (אמונה ובטחון ח"ב דף תמח) Rav Chaim Friedlander explains the Maharal by bringing the דף סז-ט (דעת תבונות) who says that we have an eye in harmony with G-d's Eye of Providence, ears to reflect G-d's listening to our prayers, etc.

5. Judaism & Science – Conflicts and Compatibilities

In his book on religion and science, the great paleontologist Stephen J. Gould stated that there was no tension between the two because they existed on two different planes, or magesteriums, as he called them¹. The magesterium of science deals with the physical word, whereas the magesterium of religion deals with the spiritual and moral plane.

There is a certain truth to this. The Maharal explains that the Sages never attempted to give scientific, medical or biological explanations to things. They were only interested in giving the inner spiritual content of the situation². Scientific laws are explanations for what happens in the world. Behind these explanations of “what” are reasons of why, the underlying spiritual reality of things³. Ultimately, this inner content is not only in complete harmony with the outer, scientific reality, but it is the reason behind the reason⁴. (double of page b4)

At the same time, there is definitely information in the Torah which tells us about the physical world. We know, for example, that the world had a definite beginning, that there were six days of creation, and that after the flood, G-d fixed six seasons. Science also lays claim to interpret these events even if they are not yet sure of all of the facts. Before the Big Bang theory, for example, the 19th century scientific theory of the static universe (claiming that the universe had always existed) was definitely in conflict with the Torah's view that the world was created from scratch⁵. For the same reason, there are definitely things about the theory of evolution as it stands now which contradict the Torah position as is interpreted by the major Meforshim⁶.

¹Stephen J. Gould, Rocks of Ages: Science and Religion in the Fullness of Life.

²מהר"ל, באר הגולה (באר ששי עמ' קו): ח"א באו חכמים לדבר מן הסיבה הטבעית כי קטון ופחות הסיבה הטבעית כי דבר זה יאות לחכמי הטבע או לרופאים או לחכמים. אבל הם ז"ל דברו מן הסיבה שמחייב הטבע

³ר' חיים פרידלנדר, שפתי חיים (אמונה ובטחון ח"ב דף תמט): חכמי הטבע אינה עוסקת בלמה, התחום שבו היא עוסקת הוא המה

⁴מהר"ל (שם סו): שאמרה תורה על אות הקשת (בראשית ט: יד-טז): את קשתי נתתי בענן והיתה לאות ברית ביני ובין הארץ ... והיתה הקשת בענן וראייתה לזכור ברית עולם וחכמי הטבע נתנו סיבה טבעית לקשת כמו שידוע אבל הדבר הוא כך שהסיבה אשר נתנה התורה הוא הסיבה שלכל דבר יש סיבה טבעית המחייב אותו, ועל אותה הסיבה הטבעית יש סיבה אלוקית, והוא סיבת הסיבה, ועל זה דברו חכמים. כי לאדם על צורתו ומספר אבריו יש סיבה טבעית, כי אין ספר שיש לדבר זה פועל טבעי, ומכל מקום יש לאותה סיבה סיבת אלוקית, שעל סיבת הסיבה אמר (בראשית א כג): ויברא אלוקים את האדם בצלמו בצלם אלוקים ברא אותו.

⁵This does not mean that the Big Bang theory solved all contradictions between Judaism and science in this area. But it was agiant step in the right direction.

⁶ What would a Torah-true 'Theory of Evolution' look like? Certainly all the Gedolei Meforshim point out that only three times does the word ברא - a creation ex-nihilo – appear in the Bereishis story, once at the beginning, once at the point of transition from plant to animal life (תנינים), and once with the creation of the soul of man. According to the Ramban and perhaps the Gra, only the first ברא is referring to creation ex-nihilo. The rest of the creation was an evolutionary development from the initial elements, sometimes in several or perhaps many stages. However, to this must be added seven qualifications;

1- That the theory accommodates the fact that some things required a creation ex nihilo.

On the other hand, science has plenty to say about ethical and spiritual issues, as we shall show later. Science posits a secular paradigm and, by its very nature, creates facts on the ground which in turn determine ethical positions on the most major of issues.

So Torah and science do relate and can be in conflict.

Yet, the amazing thing is that while there are definite areas of incompatibility between modern science and Judaism, science has moved very rapidly in the direction of Judaism over the last century. What little incompatibility is left is getting smaller and smaller. This is quite remarkable. A hundred years ago or more, a Jew would have been faced with huge contradictions between Judaism and science. His belief in Torah would have gone against thousands of years of scientific progress. Today, Arachim-like seminars use archaeology, physics, astronomy and other areas of science as outside proofs for the authenticity of the Torah!

Until the twentieth century, scientists thought the world to be completely deterministic, i.e. every effect has a clear cause which in turn is the effect of a previous cause, and so on ad infinitum. As expressed by the nineteenth century Frenchman Laplace, if we could know everything that had happened in the world until now we could predict everything that would happen in the world from now on. The fact that we could not do this, so it was believed, was a function of the impossibility of our knowing all the variables, which was a technical problem rather than something fundamental. This made belief in השגחת הבורא more difficult. For, if everything was predetermined, what place was there for Providence to interfere with the process?

But, with the introduction of quantum physics, probability replaced certainty as the accepted idea in science. We can no longer know for sure what reality is; for example, we can no longer say where an atom is. What we can know are the various options of where it might be and the likelihood (probability) that it indeed might be there. This is not just because we do not have good measuring instruments or because our measuring instruments are somehow faulty. This is because uncertainty is actually built into the universe.

2-That the first day not be regarded as more primitive than subsequent days; on the contrary - it was higher spiritually than the other days.

3-That all evolutionary developments be recognized as only taking place because of G-d's Providential input.

4-That the time taken be reconciled with the literal Biblical text.

5-That the creation process be regarded as the most perfect for the purposes for which the world was made.

Although evolutionary developments can take place after the six days of creation, these represent retrogressive steps. This does not mean that the world was created objectively perfect; on the contrary, there was a certain imperfection built into the creation to allow for free choice and to allow man to partner G-d in completing the creation. But, what it does mean is that the world was completed to perfection for its designated task.

6-That the world and its entire species be regarded as essentially co-operative and not in competition. Even where one species lives off another, the latter is to be regarded as essentially serving the former. This is in opposition to Darwin's principle of the survival of the fittest, even after the many recent modifications to this principle.

It is true that, other than man, at one level, species were produced essentially to reproduce. But this does not require that we evoke a principle of survival of the fittest, which implies that species are in competition and opposition with each other. The *Daas Tevunos* says that the creation with all its species is essentially in co-operation, and all of creation combines to fulfill their common purpose.

A leading micro-biologist, Lynn Margulis has proposed a system of the advancement of organisms by cooperation and symbiosis. Her idea that parts of the cell were once free-living organisms has today won widespread scientific acclaim.

7-That man be regarded as the pinnacle of creation, the purpose for which the creation was made.

In purely evolutionary terms, man may not be the best adapted, i.e. the most successful, to his environment; bacteria do a lot better.

Heisenberg's famous Uncertainty Principle (we can know either the position of an electron or its speed but not both at the same time) was a precursor to this. If all we can say about something is that it exists as a probability, then matter itself is not as solid as we think it is¹.

When the universe was considered to be completely predictable, as scientists thought for thousands of years, there seemed to be no place for G-d's Divine Providence. Perhaps G-d created the world and then withdrew. Today, remarkably, with the collapse of the scientific world of certainty, there is no longer a contradiction between science and G-d's Providence.² The laws of science only represent the range of options which G-d normally uses to run His world. Which specific option He chooses, when He chooses to use the natural order, cannot be pre-determined.

The same is true of our freedom of choice. If the world is pre-determined, our choices are an illusion. But if the world is indeterminate, then there is place for choice.

Let us take this idea of an observer-centered universe a little further (this idea is held by some scientists):

A fascinating experiment in interference was performed by Earnest Young in the seventeenth century. Young sent a band of light through a screen which had two slits onto a second screen. This second screen showed a series of dark and light bands. The dark bands showed where two bands of light **woven** had interfered with each other, arriving at the screen out of step. The light bands showed just the opposite, i.e. where two bands of light reinforced each other. This can only happen if two sets of light are going through both slits simultaneously. But the same results were found even where the light was sent only one photon at a time. The only explanation for this was that each photon was going through both slits at the same time! More amazingly, if someone were to try and measure which slit the photon was going through, the photon landed out going through whichever slit was measured. In some way, the measuring of the slit caused the photon to go through that slit and that slit only. This led scientists to realize that observation actually causes a change in matter.

Many scientists claim that it is the mind itself which causes this change. The fact that I choose to observe one point or the other 'collapses' the particle out of its previous state and causes it to go through this hole and not both holes or the other hole exclusively. This not only opened the way for belief in freedom of choice, a fundamental tenet of Judaism, but also for the idea that our choices actually shape the universe, which is a very Jewish idea as well³. The term "an observer-centered universe" was coined⁴.

¹Heisenberg went on to say that particles do not really have substance, only mathematical form and therefore do not have the quality of being but only a possibility of being or a tendency for being. [Physics and Philosophy, p.60].

Charles W. Petit, *Scientists and the Universe*: The more scientists study the universe, the more preposterous, random ... it becomes. ... [F]or generations they have expected to discover a few simple, elegant rules from which the cosmo's workings spring. But instead of becoming simpler, this new portrait of the universe is an ever more random – seemingly a hodgepodge of apparently unconnected constants, particles, forces, and masses....

²Cressy Morrison, former president of the New York Academy of Sciences: *Seven Reasons Why a Scientist Believes in God*. Reader's Digest: We are still in the dawn of the scientific age, and every increase of light reveals more brightly the handiwork of an intelligent Creator. We have made stupendous discoveries; with a spirit of scientific humility and of faith grounded in knowledge we are approaching ever nearer to an awareness of God....

³A whole sefer, the Nefesh HaChaim, is dedicated to this idea.

⁴Filiz Peach quotes leading physicist David Deutsch in *Philosophy Now*, (December 2000/January 2001) as saying the following:

These are but a few examples of many in the gradual reconciliation of science with what Judaism has been saying for thousands of years.

There is something even more remarkable, however. The progress of science is based on certain beliefs about the world. I call them beliefs because they are not scientifically provable. Yet, they are the underlying bread and butter which provide the direction that propels the fundamental direction in which science is going. For example, scientists have been searching for a theory which will combine all of the basic four forces of matter (the strong, weak, electromagnetic and gravitation forces¹) into one force. There is nothing in science which says that there has to be one force instead of four. There is nothing scientifically wrong with there simply being four forces rather than one. There was no reason for scientists to conduct a search that has involved tens of thousands super-colliders that run in the billions, and a massive effort that has taken most of the century. Why could they not have simply accepted that there were four forces rather than one? However, it is a deep belief of science that the more a theory will give a comprehensive, total explanation for all of nature, i.e. the more unifying it is, the truer the theory is. This is simply a religious belief shared by all scientists and is highly consistent with a belief in an Ultimate Creator². As Timothy Ferris put it, "Science from the beginning incorporated [the] idea that the universe really is a uni-verse, a single system ruled by a single set of laws. And science got that idea from the belief in one G-d³."

The arguments that humans *don't* have a fundamental role in the scheme of things, which used to seem so self-evidently true, have all fallen away. I mean, it is no longer true that human beings are necessarily destined to have a negligible effect on physical events, because there is the possibility that humans will spread and colonize the galaxy. If they do, they will necessarily have to affect its physical constitution in some ways. It is no longer true that the fundamental quantities of nature – forces, energies, pressures – are independent of anything that humans do, because the creation of *knowledge* (or 'adaptation' or 'evolution' and so on) now has to be understood as one of the fundamental processes in nature; that is they are fundamental in the sense that one needs to understand them in order to understand the universe in a fundamental way. So, in this and other ways, 'human' quantities – human considerations, human affairs and so on – *are* fundamental after all.

¹Gravity is the only force which works on the macro-world, the world larger than atoms. The other three forces work on a micro-level. Electromagnetism is well known. The Strong Force holds atoms together. The main expression of the weak force is radiation. Scientists have already combined three of the four forces, i.e. the three micro-forces, to form a Grand Unified Theory, at least at a mathematical level. They are now working on combining these three forces with the fourth force, gravity.

²Though scientists do not readily make that connection.

³Timothy Ferris (author of *The Red Limit - The Search for the Edge of the Universe*, Bantam, 1981) wrote, produced and narrated a PBS science special: "The Creation of the Universe.": The search for, and the belief in the possibility of finding, a unified field theory "testifies to the triumph of the old idea that all creation might be ruled by a single elegantly beautiful principle."

Ferris states: "Religion and science are sometimes depicted as if they were opponents, but science owes a lot to religion. Modern science began with the rediscovery, in the Renaissance, of the old Greek idea that nature is rationally intelligible. But science from the beginning incorporated another idea, equally important, that the universe really is a uni-verse, a single system ruled by a single set of laws. And science got that idea from the belief in one God..."

"The founders of modern science -- Kepler and Copernicus, Isaac Newton and even Galileo, for all of his troubles with the church -- were, by and large, profoundly religious men.

"I'm not saying that you have to believe in God in order to do science. Atheists and agnostics have won Nobel Prizes, as have Christians and Jews, and Hindus, Muslims and Buddhists. But modern scientific research, especially unified theory, testifies to the triumph of the old idea that all creation might be ruled by a single and elegantly beautiful principle" (PBS science special: "The Creation of the Universe")

Few scientists, even those who are investing massive amounts of time, money and effort to unite these forces, ever stop to think that such a belief would only make sense in a Monotheistic world. If there is one G-d Who is the source of everything, then all things ought to be traceable back to a point where they are all one. But if there was no One Creator of everything, what's wrong with four forces rather than one?

The reason that science is getting so close to a Torah viewpoint in our age is because we are in the pre-Messianic era. This is the time when the most powerful Galus ever to exist on earth, Edom, is destined to present the closest, most powerful alternative to Torah, and science is at the center of this.

6. Science is Intrinsically a Secular Paradigm

The German philosopher Karl Jaspers claimed that science failed to give man a comprehensive view of the world¹. While it is true that science never spelled out a philosophy of man, science is based on a very definite worldview, as we shall explain.

Paul Johnson writes in his introduction to The History of the Jews that he came to write about the Jews because he kept on bumping into them in his travels of world history. Indeed, it is difficult not to bump into the Jews on any point in the timeline. But there is more to it than that. World history and Jewish history are one, not merely two overlapping or even interacting histories.

Science itself might have come to the same conclusion, but it did not. Therein lies the greatest source of tension between Judaism and science. Science takes us ever so close to tying up the creation back to the Creator. But just at that point it stops and claims that that is all there is to it. Science separates itself from religion at the very point where it ought to be calling on an understanding of G-d to complete the explanation which it had begun. As such, it is a secular, humanist endeavor.

Science discovers the Big Bang but will then desperately try to avoid saying that that means G-d created the world². Scientists uncover the anthropic principle, that nature seems to have direction and purpose towards life³, but will not say that some Being therefore designed it that way.

¹Cit., 465, Baumer, Modern European Thought, MacMillan.

²See Robert Jastrow's, *God and the Astronomers*, who writes of the fierce resistance of the scientific community to the discovery of the Big Bang, because of its religious implications. But even those who embraced the Big Bang were careful to avoid spelling out its religious implications.

³See Nature's Destiny, by Michael Denton.

Nature turns out to be very exactly tuned - change any law of nature even slightly, or change the initial conditions and it becomes impossible for life to have emerged at all. Denton shows that water, oxygen, minerals and many other things are perfectly suited in multiples of ways for the task for which they fulfill. In fact it is impossible, in each case, to even imagine a theoretical substance which might do a better job.

Critics argue that the universe is bound to look as if it were designed for our existence because we could only be here if the universe were adapted for our existence. That would be a good argument if the cosmos was adapted to some degree for life. But it appears that the cosmos is optimally adapted for life - that every constituent of the cell and every law of nature is uniquely and ideally fashioned to that end.

More than that, it is not only this or that variable that makes this argument so impressive. It is the accumulation of all the variables, all being there in exactly the proportion that they need to be, the lack of any one of them rendering life impossible.

This has led many leading scientists to claim that the world was "designed" for life (e.g. Ernest Sternglass) even if they are careful not to say that G-d was behind that design.

There is no question that the worldview, the paradigm of science, holds that it is unscientific to bring G-d into the picture. Even a religious scientist, and there are lots of them, would not dream of talking about G-d in a scientific paper.

Thomas Kuhn of MIT wrote his famous The Structure of Scientific Revolution about 45 years ago. In it, he claimed that science moves very slowly for long periods of time until there is a sudden revolution during which the scientific community changes paradigms. A paradigm is a way of looking at the world, a way of filtering information. Since facts are always seen through paradigms, there is no such thing as a completely objective fact. When operating in a certain paradigm, the scientific community only sees certain types of questions or unsolved scientific problems as legitimate areas of scientific concern, and therefore they are only going to get certain types of answers. Eventually, someone comes and manages to break out of that paradigm, like Newton and Copernicus did in their day, and as did Einstein, who broke out of Newtonian ways of looking at the world. Usually, this person is very young, not yet set too deeply in the existing paradigm. Very often, the older scientists never fully accept the new paradigm - they simply have to die out to allow for the new paradigm to take root.

The roots of this G-d-exclusion paradigm go back to *Migdal Bavel* and *Dor HaHaflaga*. The people at that time said: *Come, let us build us a city and a tower, whose top may reach to heaven; and let us make us a name, lest we be scattered abroad upon the face of the whole earth*¹. A great city with a great tower in the middle to maintain the unity of the human race! What could be wrong with that? The Meforshim explain, however, that the tower was being built as an instrument to conquer and bring under the control of man every aspect of the creation. Then they would be able to prevent G-d from using the heavens as an instrument for implementing His decrees against the earth². "Remove Divine Providence from the equation," they said, "and we can then use science and medicine to give us a more secure, healthy, wealthy and happy existence." The way the Kabbalists describe such a thing is the attempted separation of the last Sefira, Malchus, through which all Hashpaos from

This includes energy levels of the carbon atom; the rate at which the universe is expanding; the four dimensions of space-time, carbon, DNA, proteins, even the exact distance between stars in our galaxy.

These arguments are not, of course absolute proof that G-d made the world. We could always say that all of this is only by chance. Nevertheless, as more and more exact conditions emerge, this argument does become increasingly more powerful. Even hardcore evolutionists are increasingly subscribing to the anthropic principle. One such person is Conway Morris, professor of evolutionary paleobiology at the University of Cambridge and one of the leading evolutionists in his field. In his book, The Crucible of Creation: The Burgess Shale and the Rise of Animals (Oxford University Press, 1998), he argues that if the tape of life were rerun from the Cambrian time, we would get almost exactly the same outcome as we have today. "I believe it is necessary to argue that within certain limits the outcome of evolutionary processes might be rather predictable." And this for a theory, which started out saying that everything, is a function of random, chance events!

The issue is not whether we can come up with a scientific explanation for what took place. The fact that all these factors are so precise and perfect for the world we need, support the fact that this was a planned and guided event; the fact that this plan followed principles, intelligible to us up to a point, is only to be expected from what we know of how the Almighty made His world.

¹ (יא ד) ויאמרו הבה נבנה לנו עיר ומגדל וראשו בשמים ונעשה לנו שם פן נפוץ על פני כל הארץ:

² גור אריה יא א: לאו כל הימנו וכו' בואו ונעשה עמו מלחמה. פירוש כי זה המגדל היו בונים להיות דבקים עם מערכות עליונים, שהיו עושים בפעולות הידוע להם לבנין ההוא, ובבנין ההוא נכנסו למעלה להיות עם המערכות העליונים, והוא המלחמה שעושים עם העליונים, כי היה כל פעולתם לבטל כמה דברים הבאים בגזירות ה', זה שהיו אומרים לא די שיבור לו העליונים להיות גזירתו על התחתונים גזירות, בואו ונעלה השמים בפעולתנו להתחבר עם מערכות השמים ונעשה עמו מלחמה לבטל מעלינו הגזירות שהם באים על התחתונים:

above must ultimately pass from the other, higher Sefiros in order to control and use the former¹. The discoveries of דור ההפלה and of contemporary science are of tangible benefit to mankind. But, they can also become a Tower of Babel, used as an instrument to lead people astray.

Although the Name אלוהים was consistently used in the story of Noah, the Chumash subsequently changed to use the 4-letter Name of G-d², for the generation of Noah was guilty of moral depravity (theft) and sexual immorality, which are both interpersonal transgressions requiring G-d's attribute of Justice to respond. But, in the case of the Tower of Babel, the problem was in realizing that all forces extended back to G-d's ongoing creative Will and that He cannot be excluded from the running of the world for a moment if it is to survive. Here, it was necessary to mention G-d's ineffable Name, not His attribute of Justice, in order to show that all extends back to Him³. It is G-d's attribute of Justice which defines all the laws of nature, and so it required something above that level to show man that there really was a limit to how far a man-centered universe could go⁴.

Rashi brings another fascinating interpretation to the words דברים אחדים in the story of Dor HaHaflaga: The people of that generation had calculated that the world has a major collapse, as in the case of the flood, every 1656 years. The tower was an attempt to build some kind of an alternative, heavenly system to beat the natural cycle as they perceived it⁵. This second approach amounts to the same thing as the first. As the Ramban explains it, they wished to cut off G-d-connection with the world (לקצץ בנטיעות)⁶ in the belief that this would allow them to discover and harness all the scientific forces that would be needed for them to solve every sort of human misery.

Not naïve to the scope of the job at hand, the people of the Dor HaHaflaga realized that only if there was a United Nations far more powerful than the one we have today was there any hope of bringing the necessary resources to bear in resolving the issues of illness, poverty, war and natural disaster⁷. The idea of a world capital with its gigantic tower, a

¹שעור דעת ח"א עמ' רסח

²רמב"ן, יא ב: והסתכל כי בכל ענין המבול הזכיר אלוהים ובכל ענין הפלגה הזכיר השם המיוחד

³רמב"ן שם: כי המבול עבור השחתת הארץ, והפלגה בעבור שקצצו בנטיעות

⁴שעורי דעת ח"א עמ' רסז: כי בלבול השפה נעשה על ידי ההנהגה היותר עליונה, הנהגת שם הוי', שהיא למעלה משם אלוהים. שם אלוהים מורה על ההנהגה התמידית המסודרת ומגבלת במערכות הטבע. ... בהנהגה התמידית של שם אלוהים נדמה להם כי יש ביכולת בני האדם על ידי כח הבחירה שנתן להם להשתמש בכחות הבריאה שלא כחפץ ההשגחה ... ואמנם הם לא ידעו ולא הבינו כי עצם ההנהגה הוא צמיד בידו של הקב"ה ולא נמסרו מוסרות ההנהגה לכחות הבריאה התחתונים

⁵רש"י יא א: (ודברים אחדים) ס"א דברים חדים) אמרו אחת לאלף ותרנ"ו שנים הרקיע מתמוטט כשם שעשה בימי המבול בואו ונעשה לו סמוכות (ב"ר):

גור אריה יא א: אין צריך לפרש כי על ידי מגדל היו רוצים לעלות השמים, אלא מפני כי המגדל הזה במה שהיה "ראשו בשמים" (פסוק ד) - הוא דוגמא משמים, שהמגדל הוא נבדל מן הארץ בגבהותו כמו השמים - להיות רוצים להתנגד אל השם יתברך, כי האדם ראוי שיהיה למטה והוא יתברך למעלה, וכאשר עשו להם מגדל לדוגמא - היו רוצים בפעולתם הזרות לנוס בדברים השייכים לעליונים בהוראות המגדל הזה שהוא נבדל מן המטה, ודבר זה הוא התנגדות אל השם יתברך, והוא המלחמה:

⁶רמב"ן יא ב: כי היו קוצצים בנטיעות

⁷שעורי דעת ח"א עמ' רסה: עלה בדעתם שצרכים למצא עצות ותחבולות למען תשלט ביניהם אחדות גמורה ושתהיינה כל משפחות הארץ מאורגנות ללחום בכחות משותפות עם פגעי העולם.

monument to human possibility, was just the solution for this challenge¹. Of course, a tower of this size was not just meant to be an empty monument. Its multi-purpose structure would serve as a center of science, a giant lightning rod², and a potential launching pad for future lunar expeditions³.

The truth is, says the Shiurei Daas, that despite the massive advances of contemporary science and its revolutionary impact on us, we have revealed but a drop in the vast ocean that is G-d's world of nature. There may be hundreds of scientific laws which scientists have yet to discover; perhaps far more is hidden than has been revealed. It is possible that had the generation of Dispersion created the mechanisms for long-term, international scientific cooperation, we would have been much further in our progress than we can imagine⁴. This is especially true because those early generations had a much deeper understanding of certain types of forces than we have today⁵. The problem was not in the desire to know more and organize accordingly; it was that when G-d "came down" to look⁶, He saw a rebellion, not a scientific venture⁷.

But here's the rub: the people themselves were not fully conscious of this rebellion. They didn't see themselves as anti-G-d but rather just pro-science, not realizing that the science they proposed made G-d inadmissible. They felt this was for the good of mankind, not seeing that they were seeking a level of control that contradicted G-d's Hashgacha⁸. This, says the Shiurei Daas, is why the verses do not explicitly mention any sin⁹.

This is exactly the same as science today. The secular bias is not deliberate, except for some evolutionists¹⁰. Rather, it exists as the natural framework with which scientific eyes view the world. Because of this, at some stage in the future, perhaps only in the Messianic era, we will require a paradigm change, so that the natural filter for information

¹שעורי דעת ח"א עמ' רסו: הבה נבנה לנו עיר ומגדל וראשו בשמים שישמש להם בתור מרכז וסמל להתאחדות

²ר' בחיי

³יהונתן אייבשיץ, תפארת יהונתן

⁴שעורי דעת שם עמ' רסה: הלא גם בדורות האחרונים ראינו כמה המצאות חדשות שעשו מהפכה ... עד שקודם התגלותם קשה היה לשער ולהאמין כי נמצאים כחות כאלו בטבע, ואמנם כל מה שנתגלתה לנו עתה אין זה אלא טפה מן הים מול סתרי הטבע שעדיין לא נתגלו לנו ולא ידענו אודותם ואלמלא היו בני אדם בכל הדורות באחדות גמורה בשלום ושלוה והיו עובדים כל אחד במנוחה במקצוע שלו לתועלת האדם, מו יודע כמה כחות נפלאות הטמונים בחיק הטבע היו יכולים למצא ולהשתמש עמהם להנאות העולם וכתרים נגד הפורעניות השונים.

⁵שעורי דעת ח"א עמ' רסו

עיין בחזון איש, אמונה ובטחון, שני הפרקים האחרונים

⁶יא (ה) וירד ד' לראת את העיר ואת המגדל אשר בנו בני האדם:

⁷שעורי דעת ח"א עמ' רסו: הבורא ב"ה ראה וידע, שבבקשת האמצעים האלה טמון רגש רע החפץ להשתחרר מההשגחה ושלא להיות מוטל תחת הנהגת ד'

⁸שעורי דעת ח"א עמ' רסו: בבקשת האמצעים האלה טמון רגש רע החפץ להשתחרר מההשגחה ושלא להיות מוטל תחת הנהגת ד' ... אמנם זאת היתה כונה נסתרת שלא נגלתה בבהירות גם להם בעצמם

⁹שעורי דעת שם: ולכן בפשטות הכתובים ספרה לנו התורה המעשה הנגלית כפי שהביעו בדבריהם המפרשים שאמרו "ונעשה לנו שם פן נפוץ על פני כל הארץ".

¹⁰For example: Finally the evolutionary vision is enabling us to discern the lineaments of the new religion that we can be sure will arise to serve the needs of the coming era." (Julian Huxley, 1959)

accommodates G-d. Kuhn points out that the new paradigm may use the same words as the old that often mean something completely different, making the old and new theories non-comparable. A scientist in the post-Messianic paradigm of science will see G-d written in every theory.¹

The truth is that we already had such a scientist - Avraham Avinu. Avraham Avinu did not just look at the world of nature and see G-d. He went much further, harmonizing his entire being with what he saw. This allowed him to intuit all of the Torah and its Mitzvos, since the Torah is but a higher level of the creation-reality² and therefore completely in harmony with the inner logic of creation.

Perceptive scientists throughout the ages have at least achieved Avraham Avinu's basic conclusions. They have marveled at how remarkable it is that higher, more abstract forms of thinking are in harmony with the physical world around us. Carl Gustav Jacobi, the 19th Century Prussian mathematician, remarked that "it is a remarkable fact that when man thinks in a pure system of abstract logic such as mathematics, that logic turns out to be consistent with the logic of the world³." Or, as Plato put it, "G-d ever geometrizes."⁴ These scientists reached the most basic level of a Monotheist, but nowhere do we see that they were able to take these observations and turn them into a personal G-d who makes moral and spiritual demands of them. At most, this represents what Alfred North Whitehead called a "widespread instinctive conviction in the existence of an order of things"⁵. The G-d of the scientist is generally some great cosmic being, and the awe scientists feel when they look a little deeper seems to lead nowhere. A scientist can notice that the number pi, 3.14159..., is not only yielded by the division of the circumference of a circle by its diameter but turns up in equations that describe subatomic particles, light and other quantities that have no obvious connection to circles. He can then conclude, as John Polkinghorne did, that human-invented mathematics somehow tuned into the truths of the cosmos⁶. But, why don't scientists then take the next obvious step, which is to say that the reason there is this harmony between our minds and the world is because they both come from the same Creator-Source and that this Creator has a plan for us?

¹Kuhn subsequently modified his position considerably –'the new Kuhn', in which he questions whether science actually progresses in some objective sense when there is a paradigm changed. What we described above is the Old Kuhn which people usually mean when referring to him.

²עלמא means that the logic of the world is in harmony with the logic of the תורה. Since man was also created from that תורה, the logic of man is similarly in harmony with the logic of the world.

The Maharal's opinion is that it was only Avraham Avinu of the Avos who kept the Torah. He gives two reasons for this:

תפארת ישראל למהר"ל פ"כ:אברהם אבינו היה מיוחד ביותר לקיים כל התורה, כי מעלת אברהם דבקה בחכמה עליונה ... [התורה הוא השכל העליון ועוד ... כי מדת אברהם היא מדת התורה כי התורה נקרא תורת חסד דכתיב (משלי לא) ותורת חסד על לשונה, וזה כי התורה דרכיה דרכי נועם וכל נתיבותיה שלום, ואף כאשר תמצא בתורה מיתות וכריתות אין תכלית התורה רק להעמיד הטוב בעולם שלא יהיה נמצא שום רע.

³Jacobi commented, "The Great Architect of the Universe now appears as a pure mathematician."

⁴Quoted in the Time-Life book on mathematics p. 9

⁵Alfred North Whitehead, Science and the Modern World: "There can be no living science unless there is widespread instinctive conviction in the existence of an order of things"

⁶Newsweek, July 27, 1998

This is not to say that such a conclusion, which is obvious to a frum Jew, is easy to arrive at from the outside. Avraham Avinu, who discovered G-d by looking at nature¹, began his G-d search at the age of 3,² but he was 40 years old (an additional 37 years of total absorption and thought) when he reached a mature understanding and relationship with G-d³. It was only then that Avraham was finally willing to give up all idol-worship⁴. It was another 35 years, when Avraham was 75 years old, that he was first ready for G-d's command of Lech Licha.

To understand what took him so long, one has to look at the context in which Avraham made his discovery. The world that Avraham was born into had become completely idolatrous. The idolaters, praying to intermediaries, were able to show tangible results for their efforts, for they were tuning into real intermediaries used by G-d⁵. This is exactly why

¹רב צדוק הכהן, צדקת הצדיק ס' קפט: ב' מיני השגות אלוקות יש: א - מצד הבריאה מכיר שיש בורא וזה נקרא מעשה בראשית. ב - מצד ההנהגה וזה נקרא מעשה מרכבה איך הש"י רוכב על הברואים. והם ב' מדרגות דראיה וידיעה של אבות ומרע"ה הנזכר בזוהר וארא כג א ע"ש שהאבות השיגו מצד הברואים כמשאז"ל (בר"ר ר"פ לך לך) באברהם אבינו ראה בירה דולקת וכו' והיא נקרא ראייה דאתגליא ולכן נקרא אותו שם אצלם שם בכתוב המורה שאמר לעולמו די דר"ל) חגיגה יב. (ופ' הרבי רב בונים זצ"ל שיש די בבריאה זו להכיר אלוקותו על ידו ... וידיעה הוא בהנהגה כמ"ש הודעני נא דרכיך וגו' ע"ש

²השגת הראב"ד הל' עבודת כוכבים פ' א: א"א יש אגדה בן שלש שנים שנאמר עקב אשר שמע אברהם בקולי מנין עקב. וכן בנדרים לב ע"א: בן ג' שנה הכיר אברהם את בוראו אמנם הרמב"ם כתב שב 40 הכיר את בוראו והכסף משנה על הרמב"ם שם תירץ שבג' התחיל להכיר ובארבעים נשלם הבנתו.

רמב"ם שם הל' ג: כיון שנגמל איתן זה התחיל לשוטט בדעתו והוא קטן והתחיל לחשוב ביום ובלילה והיה תמיה היאך אפשר שיהיה הגלגל הזה נוהג תמיד ולא יהיה לו מנהיג ומי יסבב אותו כי אי אפשר שיסבב את עצמו ולא היה לו מלמד ולא מודיע דבר אלא מושקע באור כשדים בין עובדי כוכבים הטפשים

³רמב"ם הל' עבודת כוכבים פ' א: (ג) ובן ארבעים שנה הכיר אברהם את בוראו

⁴רמב"ם הל' עבודת כוכבים פ' א: (ג) ואביו ואמו וכל העם עובדי כוכבים והוא עובד עמהם ולבו משוטט ומבין עד שהשיג דרך האמת והבין קו הצדק מתבוננתו הנכונה וידע שיש שם אלוה אחד והוא מנהיג הגלגל והוא ברא הכל ואין בכל הנמצא אלוה חוץ ממנו וידע שכל העולם טועים ודבר שגרם להם לטעות זה שעובדים את הכוכבים ואת הצורות עד שאבד האמת מדעתם

⁵רמב"ם הלכות עבודת כוכבים פ' א: (א) בימי אנוש טעו בני האדם טעות גדול ונבערה עצת חכמי אותו הדור ואנוש עצמו מן הטועים היה זה היתה טעותם אמרו הואיל והאלהים ברא כוכבים אלו וגלגלים להנהיג את העולם ונתנם במרום וחלק להם כבוד והם שמשם המשמשים לפניו ראויין הם לשבחם ולפארם ולחלוק להם כבוד וזהו רצון האל ברוך הוא לגדל ולכבד מי שגדלו וכבדו כמו שהמלך רוצה לכבד העומדים לפניו וזהו כבודו של מלך כיון שעלה דבר זה על לבם התחילו לבנות לכוכבים היכלות ולהקריב להן קרבנות ולשבחם ולפארם בדברים ולהשתחוות למולם כדי להשיג רצון הבורא בדעתם הרעה וזה היה עיקר עבודת כוכבים וכך היו אומרים עובדיה היודעים עיקרה לא שהן אומרים שאין שם אלוה אלא כוכב זה הוא שירמיהו אומר מי לא ייראך מלך הגוים כי לך יאתה כי בכל חכמי הגוים ובכל מלכותם מאין כמון ובאחת יבערו ויכסלו מוסר הבלים עץ הוא כלומר הכל יודעים שאתה הוא לבדך אבל טעותם וכסילותם שמדמים שזה ההבל רצונך הוא:

(ב) ואחר שארכו הימים עמדו בבני האדם נביאי שקר ואמרו שהאל צוה ואמר להם עבדו כוכב פלוני או כל הכוכבים והקריבו לו כן וכך ובנו לו היכל ועשו צורתו כדי להשתחוות לו כל העם הנשים והקטנים ושאר עמי הארץ ומודיע להם צורה שבדה מלבו ואומר זו היא צורת הכוכב פלוני שהודיעוהו בנבואתו והתחילו על דרך זו לעשות צורות בהיכלות ותחת האילנות ובראשי ההרים ועל הגבעות ומתקבצין ומשתחווים להם ואומרים לכל העם שזו הצורה מטיבה ומריעה וראוי לעובדה וליראה ממנה וכהניהם אומרים להם שבעבודה זו תרבו ותצליחו ועשו כך כך ואל תעשו כך וכך והתחילו כוזבים אחרים לעמוד ולומר שהכוכב עצמו או הגלגל או המלאך דבר עמהם ואמר להם עבדוני בכך וכך והודיע להם דרך עבודתו ועשו כך ואל תעשו כך ופשוט דבר זה בכל העולם לעבוד את הצורות בעבודות משונות זו מזו ולהקריב להם ולהשתחוות וכיון שארכו הימים נשתכח השם הנכבד והנורא מפי כל היקום ומדעתם ולא הכירוהו ונמצאו כל עם הארץ הנשים והקטנים אינם יודעים אלא הצורה של עץ ושל אבן וההיכל של אבנים שנתחנכו מקטנותם להשתחוות לה ולעבדה ולהשבע בשמה והחכמים שהיו בהם כגון כהניהם וכיוצא בהן מדמין שאין שם אלוה אלא

we turn to science. It delivers again and again. Avraham Avinu himself was brought up as an idolater like all those around him¹. It required enormous courage and a radical breakthrough on his part for Avraham to see the world through different eyes. Perhaps, too, the scientific paradigm of today may require similar courage to break through and see things with different eyes.

Scientific revolutions have happened before. Copernicus and Galileo led one that was rounded off by Newton. Einstein, Plank, Borne and Heisenberg led another scientific revolution in the early part of this century. But, a scientific revolution which allows science to accommodate G-d is a revolution of a different order. It will require a change in the whole order of Western dominance, what we Jews call Edom. This is because science is so hugely dominant in the Western World and through there to the whole world in general.

We know that American culture is exported everywhere (its language, its denim-jeans, its movies and its Coca-Cola). But more than that, America exports the scientific paradigm. It is not capitalism or democracy which bestows the remarkable living standards of today's Westernized countries, although certainly the former is a prerequisite and the latter a great facilitator. Ultimately, it is the ability to be at the cutting edge of modern technology that edges countries out of their millennia of poverty and into this remarkable new order².

So here we are, with a G-d-excluding methodology that appears to produce endless good for mankind (atomic bombs aside). It is no accident that it is just at this time that secular humanism, which places man rather than G-d in the center of things, has become the main source of ethics, law and even meaning. What chance for religion to really challenge that and come up with a better alternative.

When Laplace presented his work to Napoleon, Napoleon reputed to have remarked, "Monsieur Laplace, they tell me that you have written this large work on the system of the universe and you did not even mention its Creator." To this Laplace supposedly responded, "I had no need for that hypothesis."

But the world has come a long way since Laplace and his Napoleonic encounter. Recently, there have been many attempts to reconcile religion with science, not so much because of a change in attitude but because scientific discoveries in the twentieth century seem to point in that direction. Fritjof Capra caused quite a stir when, in The Tao of Physics, he showed the basic harmony that exists between modern physics and Eastern religions. Michael Behe (Darwin's Black Box) has made a powerful case for showing that biochemistry is leading us toward rather than away from the idea of a designer of the universe. These gentlemen have their point, but they miss the larger issue I wish to make here.

It is true, as we show elsewhere, that science is drawing closer to religion in general and Judaism in particular. The idea that matter can turn into pure energy has made it easier to conceive of a purely spiritual world. The indeterminacy of quantum physics allows for freedom of choice and moral responsibility; the Big Bang is a step towards (though not a complete harmonization of) the creation story. But the closeness only consolidates the

הכוכבים והגלגלים שנעשו הצורות האלו בגללם ולדמותן וגו'
וכעין זה פירש הרמב"ן, החינוך, הכוזרי וספר העיקרים.

¹רמב"ם הלכות עבודת כוכבים א ג: ולא היה לו מלמד ולא מודיע דבר אלא מושקע באור כשדים בין עובדי כוכבים הטפשים ואביו ואמו וכל העם עובדי כוכבים והוא עובד עמהם

²It was once possible for an economy to do well based on its natural resources, or on farming. Thus countries like Argentina and South Africa had quite solid economies. But, today emerging economies only exist in countries which are moving into high tech. Although there are seemingly some exceptions to this, most notably China and the oil rich countries, a deeper analysis would show that they really prove the rule.

position of science as the embrace of all reality. It may be, as Robert Jastrow suggests in God and the Astronomers, that the scientist will ultimately get to the top of the cliff and find the theologian sitting there all along. But the scientist has no intention of joining the theologian, sitting side by side. The scientist sees the theologian as an extension of the cliff face which he must climb. He will keep on climbing until he is sitting, as he sees it, on top of the theologian as well. Of course he is gracious to his cliff, and he smiles kindly down on his theologian as well. All are welcome in the ultimate scheme of things.

But there is a different vision of things – one which we will witness in the Messianic era. Although it is possible, I do not envisage the end of science, since I believe that there are enormous secrets still held in nature. I envisage the great scientists (then all non-Jewish) calling the Mashiach¹, telling **them** of a new breakthrough in superconductivity and receiving instruction on what the spiritual implications are and what to do with the discovery. Mashiach's job will not be to teach the Jews – **וְלֹא יִלְמְדוּ עוֹד אִישׁ אֶת רֵעֵהוּ**²; the job of the Mashiach will be to teach non-Jews the Torah they need to know³. Perhaps science will be a part of that Torah.

During the Messianic Era, there will be no distractions from dedicating one's life to spirituality⁴. Every Jew will be capable of understanding the truth by himself⁵ and will be able to understand the Torah at a much deeper level than we are now able to. If that is the case, then, science will also not be a distraction, neither its technical innovations (think of cell phones, the internet, TV – all today questionable additions to the spiritual progress of mankind) nor its more substantive discoveries concerning the beginning of the world, of life and of man, the nature of consciousness, etc. But science will go further: it will actively serve spirituality, it will naturally flow from it, and will provide yet another way of connecting to G-d.

7. Resolution of Conflicts between Judaism & Science

We have talked about the need for a paradigm change in science so that scientific discoveries flow naturally into G-d. However, until that time, we also need to deal with local conflicts – the conflicts of specific scientific theories. The Big Bang may bring us closer to Judaism than its predecessor, the Static Universe, but it still posits an infinitely dense particle of matter. It may mean, as Hawkins and Penrose claim, that time must at least have had a

¹Moshiach himself will have the status of a Melech. Pachad Yitzchak (שבועות לו') states that while דעת on pure Torahdik issues was the domain of the Sanhedrin, it was the King who was in charge of דברי רשות, including הוראת שעה. (But the King, in turn, has to be appointed by the Sanhedrin.) This is why we wrote that the scientists will contact the Moshiach and not the head of the Sanhedrin.

²ירמיהו לא:לג

³שם משמואל) קרח ור"ח תמוז שנת תרע"ב: (עד גמר התיקון שאז נאמר (ירמיהו לא) ולא ילמדו עוד איש את רעהו וגו' לאמור דעו את ד' כי כולם ידעו אותי למקטנם ועד גדולם, ובמדרש (ב"ר פ' צח) אין ישראל צריכין לתלמודו של המלך המשיח דכתיב אליו גוים ידרשו ולא ישראל.

⁴רמב"ם הל' מלכים פ' יב הל' א-ד: (ולא יהיה עס' האדם אלא לדעת את ד' בלבד

⁵ר' פרידלנדר) שם דף קלב: (כיון שלעתיד לבא תהיה עבודת ד' אצלם בטבעם, גם יבינו מצד טבעם מעצמם את האמת. ע"כ זה מה שאמר הנביא (ירמיהו לא לג: (ולא ילמדו עוד איש את רעהו וגו')

beginning¹. But it lends itself just as well to other scenarios. Scientists frankly don't know what happened before then, but certainly many of their speculations do not agree with Judaism². Some have seen in the Punctuated Equilibria an evolutionary theory which is closer to Judaism than the Synthetic Theory, but it is probably closer to classical Darwinism than it is to Judaism. Einstein's theory of relativity makes it easier to reconcile the scientific age of the universe with the Six Days of Creation, but the multiplicity of explanations suggests that this reconciliation is not yet clear. It should also be stated that any resolution needs to be according to the main highway of the Meforshim throughout the ages. This does not mean that no Chiddush is valid. But there is something highly uncomfortable with an approach which requires us to leave aside the Gedolei HaRishonim and Achronim in order to accommodate a scientific theory.

Personally, I would prefer to leave such theories as contradictions. I can live the contradiction (as scientists themselves do with contradictory scientific theories) until one day science changes to reconcile itself with Judaism. The fact is that science is moving closer to Judaism in almost every area, and this lends strength to this patience. The scientific endeavor itself is sufficiently robust that it continues to more closely approximate the truth. Scientists themselves have a healthy attitude towards the almost inevitability of certain theories changing with time. _

Einstein's larger theory of general relativity is one of two macro-theories that describe all of matter. The other one is the quantum theory, which also has considerable theoretical and experimental backup. The theory of relativity describes reality at a macro-level, from the size of an atom up, while quantum theory describes what happens inside an atom.

The problem is that although both theories are accepted, they contradict each other³. Either one or both has to be modified or completely overthrown. As a result, the standard theory of matter is sure to change. Some have already questioned whether Einstein's gravity doesn't change at large distances⁴. Yet, just as sure as scientists know that, they continue to

¹Stephen Hawking and Roger Penrose proved in the 1960s that time cannot extend back indefinitely. As you play cosmic history backward in time, the galaxies all come together to a single infinitesimal point. Each galaxy or its precursor is squeezed down to zero size. Quantities such as density, temperature and spacetime curvature become infinite turning into a singularity. (Gabriele Veneziano, *Scientific American*, May 2004)

²See Gabriele Veneziano, *Scientific American*, May 2004.

³Quantum theory radicalizes our assumptions about the relationship between observer and observed but pretty much buys into Newton's ideas of space and time. General relativity changes our notions of space and time but accepts Newton's view of observer and observed. This situation is deemed unacceptable by most physicists, and the solution is thought to lie in a unifying theory of quantum gravity, sometimes called a Theory of Everything. The idea is that ultimately everything, space and time, like matter and energy, come in quantized, indivisible units and that relationships, rather than things, are the fundamental elements of reality

⁴See George Musser, *Four Keys to Cosmology* in *Scientific American*, February 2004.

Dennis Overbye, *Some Scientists Suggest Relativity May Be, Well, Relative*: In science, no truth is forever, not even perhaps Einstein's theory of relativity, the pillar of modernity that gave us $E=mc^2$. Relativity declares that the laws of physics, and in particular the speed of light — 186,000 miles per second — are the same no matter where you are or how fast you are moving. A few physicists now say that relativity may have limits and will someday have to be revised.... Any hint of breakage of relativity, scientists say, could yield a clue to finding the holy grail of contemporary physics — a "theory of everything" that would marry Einstein's general theory of relativity, which describes how gravity shapes the universe, to quantum mechanics, the strange rules that govern energy and matter on subatomic scales. ...

find proofs which confirm both theories¹! For the time being, scientists are happy to regard both as true. Scientists comfortably live this contradiction as they do many others.

It is the layman more than the scientist that gives science an aura of infallibility and makes the problem of any contradiction larger than it really is.

Few scientists would agree with Paul Feyerabend², a noted physicist, who claims that non-rational factors are dominant in science. But they do agree that the theories they propose are not meant to be claims of absolute truths about the world. What scientists purport to do is to provide theories which are the best explanation, amongst competing explanations, of the facts at hand. Scientists never claim that a particular theory is the final explanation of things (although they may dream of such a thing³), even where the theory is supported by experimental evidence.

Newtonian physics is a classic example. Today, we know that Newtonian physics is wrong. It has been replaced by Einstein's theory of relativity. Einstein proposed three proofs to decide between his theory and Newton's. One of them was how much light would be bent by a large object. One of the world's greatest astronomers of the time, Sir Arthur Eddington, went out on a boat on a full solar ellipse to measure how much the starlight coming from

Taking a Shot at Einstein: Joao Magueijo ... taking on Einstein. Magueijo isn't proposing to throw relativity out the window. If relativity is wrong, it is wrong by such tiny amounts or in such particular circumstances that you have to go to great lengths to find the error. By studying light from the distant universe, researches may soon be able to measure such smaller-than-nano deviations. They may need to find them, if they are ever to create a unified theory of all the forces of nature to fulfill that dream. They may have to bend his best known principle: the one that says the speed of light is an absolute.

Einstein postulates, first, that the laws of physics don't prefer one reference frame over another, as long as each is moving at a constant velocity. Second, he says that c , the speed of light, will appear exactly the same to every observer, in every frame of reference.

A century later, the second postulate still defines common sense. It says that if you're driving down the hallway at a quarter the speed of light, you'll still see the photons from your headlights racing ahead of you at light speed-not three quarters light speed. If I'm coming from the opposite direction at half light speed, I'll see you photons approaching at c – not 1.5 times c . Since speed is just a pace decided by time, and we both agree about the speed of light, we can't possibly agree about space and time. You say my clock is too slow and my yardstick has shrunk (not to mention my whole care). Maddeningly, I say the same about you. The one thing we agree on, aside from c itself, is the weird new reference frame of four – dimensional spacetime.

¹Quantum physics not only has many proofs, but we have many practical instruments based on this theory. The theory of relativity has been tougher to prove, though Einstein initially set out three tests, all of which relativity passed. The contraction and expansion of time is used in a practical way in GPSs, which if they were not refactored for the influences of gravity and speed, would be off by as much as seven feet a day.

Even Einstein's so-called fudge factor is turning out to be right. When Einstein first applied his general theory of relativity to the universe, he made a dramatic simplifying assumption: the universe, on average, was homogeneous (it had no lumps) and isotropic (it looked the same in all directions). He called this assumption the cosmological principle, and it underlies all modern scientific models of the universe. (See Michael A. Strauss, *Reading the Blueprints of Creation*, in *Scientific American*, February 2004)

²*Against Method*

³In 1996, John Horgan, created quite a stir when he wrote *The End of Science* (Broadway Books, 1996), claiming that science was about to solve all the major issues and after that there would be only riddles. However, most scientists agree that Horgan's exceptional optimism has not panned out. Many argued that his idea that certain major discoveries would resolve all the major issues of science was flawed to begin with.

behind the sun was bent by it on its way to earth. The amount of refraction turned out to be exactly as Einstein predicted.

But school children still learn more about Newton than Einstein. And every bridge, skyscraper and jet plane is built on the principles that Newton expounded. How can this be if Newton is known to be wrong? However, Newton is accurate enough that on small scales like skyscrapers, the margin of error does not matter. We might say that Newton is right enough for us. And that is why it took 300 years to show that there is a better theory which may, in turn, approximate reality just a little better.

One of the things which Einstein's general theory predicts is a new way of understanding gravity as curvatures in space rather than as a force which objects exert on each other. The attempt to prove Einsteinian gravity goes on to this day. Although all experiments have been in favor, scientists are always discovering more accurate ways of proving the theory. Yet, as we pointed out above, Einstein's underlying theory of relativity may well have to go¹.

When a theory is first proposed, it is usually competing with many others. Often, different scientists will cling to different theories. Even if scientists will do an experiment to prove one of these theories, it will usually not be decisive.

However, after experimental evidence builds up, there does come a certain point at which the scientific community accepts a particular scientific theory. Such is the case of the Big Bang. For 60 years after it was first discovered in the 1920's, the Big Bang was a disputed theory. A lot of scientists believed it, but others had good reason to believe that the world had always existed. By the 1980's, however, there were more than 6 proofs, coming from different areas, for the theory². At that stage, no self respecting scientist, even those who were frightened of the religious implications of the Big Bang, disputed the theory. The Big Bang is therefore now a strong theory, but it is not invincible. And it is, in fact, undergoing modifications all the time.

Einstein's theory of relativity seems as sure and confirmed as a theory. There are many proofs for and applications based on this theory. Yet, most scientists don't expect it to be around in the next century unless it can be modified and reconciled with quantum physics.

The truth is that one can always come up with competing theories to explain any set of phenomena. Scientists try to choose a theory that best fits the facts at hand. This theory may later be proven to be wrong, and it may even now contradict other accepted theories. But, scientists are not bothered by this because they have a great belief in their method. They are sure that the scientific method will ultimately prove which theories have to be abandoned or modified. This process, however, usually continues on an open-ended basis, as theories are

¹In a choice between the correctness of Quantum Physics vs. Relativity, I believe most physicists today would vote for Quantum Physics

²Proofs came from:

- a- The Red Shift (the Doppler Effect);
- b-Radio waves which showed changes in universe;
- c-Cosmic Background Radiation;
- d-COBE, the satellite which confirmed much of the above
- e-Entropy, which should have led to increasing disorder in the universe. Since the universe is still highly ordered and was even more ordered in the past, it follows that the universe could not have existed for ever: otherwise it would have reached its state of maximum entropy a long time ago.
- f-The composition of the Universe: Atom smashers which push subatomic particles to extremely high energies, produced results that allowed researchers to calculate that the early universe should have been about three-quarters hydrogen and one-quarter helium. When astronomers inspect the oldest stars and nebulae, they find them composed of almost exactly that mix.

never finally proven. As Sir Karl Popper put it, theories can only claim that they have not yet been disproven.

Many people are under the mistaken impression that in at least one area, mathematics, a rigorous notion of proof does apply. Mathematics, after all, lends itself to a progression of logic, starting from assumptions and arriving at a conclusion. If the chain is correct, the proof is true. If not, it is wrong¹.

But even a mathematics proof is sometimes a fuzzy concept, subject to whim and personality. Almost no published proof contains every step; there are just too many. Reviewers rarely check every step, instead focusing mostly on the major points. In the end, they either believe the proof or not.

"It's like osmosis," said Dr. Akihiro Kanamori, a mathematics professor at Boston University who writes about the history of mathematics. "More and more people say it's a proof and you believe them."

Let us take as an example one of the longest-standing problems in the field — the most efficient way to pack oranges.

The packing problem dates at least to the 1590's, when Sir Walter Raleigh, stocking his ship for an expedition, wondered if there was a quick way to calculate the number of cannonballs in a stack based on its height. His assistant, Thomas Harriot, came up with the requested equation.

Years later, Harriot mentioned the problem to Johannes Kepler, the astronomer who had deduced the movement of planets. Kepler concluded that the pyramid was most efficient. The pyramid set-up allowed each layer of oranges to sit lower, in the hollows of the layer below, and take up less space than if the oranges sat directly on top of each other². Kepler, though, offered no proof.

In 2002, Dr. Wu-Yi Hsiang of the University of California at Berkeley claimed that he had a proof³. But, because his earlier versions contained holes of logic that other scientists felt Dr. Hsiang could not fill, few bothered to even read, let alone check, Dr. Hsiang's thesis⁴. Dr. Hsiang's thesis may well be true but we will probably never know this⁵.

In the belief that too much emphasis on details stifles creativity, mathematicians continue to debate how much rigor a proof requires. Major mathematical fields of the 1700's and 1800's like calculus and topology developed without rigorous proofs. "For quite some time in mathematics, arguments were basically descriptive," Dr. Kanamori said. "People would give what we would now call informal arguments."

In 1998, Dr. Thomas C. Hales, a professor of mathematics at the University of Pittsburgh, offered a proof for Kepler's proposal comprising hundreds of pages. But, Dr. Hales' proof of the problem, known as the Kepler Conjecture, hinges on a complex series of computer calculations.

¹This and the following paragraphs concerning mathematical theories was adapted from a NY Times article, *In Math, Computers Don't Lie. Or Do They?* By Kenneth Chang, April 6, 2004

²An alternative arrangement, with each layer of spheres laid out in a honeycomb pattern, is equally efficient, but not better.

³It appeared as a book (rather than in a peer-reviewed journal).

⁴"Hsiang has not such a good track record," said Dr. Frank Quinn, a mathematics professor at Virginia Tech. "I don't want to spend time proving its wrong." Dr. Hsiang counters that his proof offers deeper insight and that others' understanding of his techniques is inadequate.

⁵Scientists justify this approach by saying that they do not have the time or the inclination to spend time disproving something they think is wrong.

The first group recruited to review the proof spent six years on it, but gave up, exhausted¹. Yet, the proof was accepted by the mathematics community anyhow². This requires faith that the computer performed the calculations flawlessly, without any programming bugs³. Untested computer techniques are becoming more common in mathematics⁴, further lowering the old barrier of checking everything before accepting a theorem as true⁵.

When one gets to something like evolution, the barrier is lowered even further. The very nature of the proof which is being attempted, something which happened in the past, requires a weaker standard. But critiquing evolution does not mean that, as a scientist, one ought to reject it as a theory. It may have lots of problems and still be the best theory around. Either paleontologists will plug the holes one day by modifying the theory or finding more evidence, or they will have to reject the theory altogether. For the time being, however, it is scientifically valid to accept evolution as the reigning theory. Laymen tend to ask, "How can there be so much wrong with evolution and yet the scientific establishment still hold on to it? It must be because of a radical, secular bias." And then they say, "And how can they believe in something just because they don't have something better to believe in?" This misses the point of how scientific theories work. We can say that evolution is a weak theory or a strong theory; we can look at Lynn Margolis⁶ for some competing theory. But, as things stand today,

¹Everything checked by the reviewers, led by Dr. Gabor Fejes Toth of the Hungarian Academy of Sciences, turned out to be correct. But the prospect of reviewing every calculation proved too daunting.

²Eventually, the prestigious Annals of Mathematics Journal published only the theoretical parts of the proof, which were checked by hand. A more specialized journal, Discrete and Computational Geometry, published the computer sections.

³In 1976, Dr. Wolfgang Haken and Dr. Kenneth Appel of the University of Illinois used computer calculations in a proof of the four-color theorem, which states that any map needs only four colors to ensure that no adjacent regions are the same color.

The work was published — and mathematicians began finding mistakes in it. In each case, Dr. Haken and Dr. Appel quickly fixed the error.

⁴Mathematicians like Dr. Larry Wos of Argonne National Laboratory use "automated reasoning" computer programs: they enter axioms and the computer sifts through logical possibilities in search of a proof. Because of the huge number of possibilities, a human still needs to tell the computer where to search.

"The human mind will never be replaced," Dr. Wos said, but the advantage of computers is their lack of preconceptions. "They can follow paths that are totally counterintuitive," he said.

The software also fills in the tedious work giving the mathematician more time to contemplate other problems, and it generates as much or as little detail as a mathematician desires, telling you how each step was obtained. In 1996, Dr. Wos and a colleague, Dr. William McCune, used the software to prove a previously unsolved problem known as the Robbins Conjecture.

In a 2003 book, "Automated Reasoning and the Discovery of Missing and Elegant Proofs," Dr. Wos described new proofs and more elegant versions of known proofs discovered by computers.

Intel, the microchip giant, uses proof-checking software to check algorithms in its chips, in the hope of avoiding glitches like one in the original 1994 Pentium that caused numbers to divide incorrectly. Current software, however cannot handle anything nearly as complex as the Kepler Conjecture.

⁵The Annals has decided that computer-assisted proofs have merit, but the journal will accord them a lower status than traditional proofs, regarding them more like laboratory experiments that provide supporting evidence

The above paragraphs, concerning mathematical theories was adapted from a NY Times article, In Math, Computers Don't Lie. Or Do They? By Kenneth Chang, April 6, 2004

⁶Lynn Margolis' proposal is that organism's operate in holistic and cooperative fashions.

if we do not believe in evolution it is because it contradicts elements of the Torah and not because it is scientifically invalid.

Sometimes there are as many as ten or twenty competing theories, all of them with some problems and all of them with some proof. Take superconductivity, for example. Superconductivity means that a material conducts electricity without resistance. Almost all of the electricity is passed through the material and almost none is lost in the form of heat. But, superconductivity requires very cold temperatures well below zero to work. Scientists believe that this is because at these temperatures the electrons all align in neat rows and therefore do not bounce around. Superconductivity, however, has also been discovered in ceramics at much higher temperatures. No one theory conclusively explains why this is; there are tens of competing explanations as to why superconductivity works in this way. Perhaps one day, one of these theories will emerge as the accepted one amongst scientists, but for the time being, you can take your pick.

Up until now we have been suggesting that it is the amount of proof which is the determinant of how accepted a theory is. But proof, though important, is not the only thing that determines the acceptability of a theory. There are also things like the unity which the theory brings, its mathematical beauty and its simplicity. To say that the more beautiful (mathematically) a theory is the truer it is, is an axiom of science and cannot be proven. Yet, there is no question that these kinds of criteria play a significant role in determining which theory gets the chop and which gets the final nod of approval.

Quantum physics gave a boost to this belief. In his book The Tao of Physics, physicist Fritjof Capra wrote:

*Subatomic particles [in fact] have no meaning as isolated entities ... Quantum theory thus reveals a basic oneness of the universe. ... We cannot decompose the world into independently existing smallest units. ... Nature does not show us any isolated 'basic building blocks', but rather appears as a complicated web of relations between the various parts of the whole."*¹

Another one of the beliefs of science, closely linked to the first, is the fact that, "as we examine nature on deeper and deeper levels, she appears ever more beautiful, revealing hidden symmetries where none were imagined to exist²; why should that be?"³ Physicists don't just notice a correlation; they use beauty as an active criterion to measure truth. H. Bondi describes Einstein's attitude to an 'ugly' equation:

*"What I remember most clearly was that when I put down a suggestion that was most cogent and reasonable, Einstein did not in the least contest this, but he only said, 'Oh, how ugly'." As soon as an equation seemed to him to be ugly, he rather lost interest in it and could not understand why somebody else was willing to spend much time on it. He was quite convinced that beauty was a guiding principle in the search for important results in theoretical physics*⁴.

¹page 78

²Simple symmetries are seen everywhere in nature. Anything which is shaped in a circle or a square, snowflakes, reflections are all symmetrical. But, it was the discovery of deeper symmetries in nature which helped to unlock many of the secrets of higher physics.

³A Zee, *Fearful Symmetry*

⁴In A Zee, Fearful Symmetry, p. 3

This is almost a mystical approach to things. Whereas we can understand why scientists associate truth with unity, it is harder to understand how a theory can be accepted based on how beautiful it is. Although man has always tried to connect truth with beauty, from a purely secular point of view scientific theories might just as soon be ugly as beautiful. It would be nice if they were beautiful as well, but to say, as Paul Dirac often did, that, "It is more important to have beauty in one's equations than to have them fit the experiment¹," is to go very far indeed. It is to use aesthetics as a driving force; to presume that not only is nature, at the fundamental level, beautifully designed, but that *aesthetic imperatives of contemporary physics make up a system of aesthetics that can be rigorously formulated*².

Science has never proven that truth is dependent on beauty. This, too, is a part of the religion of science. The physicist A Zee calls a spade a spade when he declares:

Some physics equations are so ugly that we cannot bear to look at them, let alone write them down. Certainly the Ultimate Designer would use only beautiful equations in designing the universe! We proclaim: Let us worry about beauty first and truth will take care of itself.

Paul Davies goes even further: "Forces are simply nature's attempt to maintain various abstract symmetries in the world."³

¹Paul Davies, Superforce, pg. 54

²A Zee, Fearful Symmetry, p. 3 – 5

³Superforce, Davies, p. 7; see also p. 112-116)

The discovery of these hidden symmetries is that it is all the more remarkable given that, on the surface, everything in nature seems to demand the opposite, that things be slightly asymmetrical. ... A perfect Creation, with its symmetry untainted, would have led to matter and antimatter in precise balance and a mutual annihilation when in the very next instant they recombined: a precisely symmetrical universe would have vanished as soon as it had appeared. Such a uniform cosmic soup could hardly have led to the asymmetrical universe that we are a part of today where antimatter appears to be all but absent.

However, another theory states that the two were indeed made equally in the Creation. Soon afterwards something interceded; the symmetry between matter and antimatter was slightly lost, with the result that after the great annihilation, a small proportion of the matter was left over. Those remnants are what have formed us and everything around us as far as we can see. We are the material rump of what must have been an even grander Creation.

Scientists also see the need for asymmetry in the four forces [and] in the atoms, the building blocks of all of life. Life appears to thrive on mirror asymmetry The deeper one looks, the more asymmetry becomes apparent and seemingly necessary for anything 'useful' to have emerged. And yet, seemingly deeper still, everything emerges symmetrical once more.

The focus of much current research is to understand how nature hides symmetry, producing structured patterns out of underlying uniformity.

Scientific American, July 2002 *Uncovering Supersymmetry*, By Jan Jolie:

Symmetry principles occur through physics, often in ways that one wouldn't expect. For example, the law of conservation of energy can be derived from a symmetry principle involving the flow of time. The equations governing elementary particle physics are fundamentally based on symmetries.

Einstein's theory of special relativity is a theory of the symmetries of empty space and time. Effects such as length contraction and time dilations, which flatten fast-moving clocks and make them run slow, are operations of the symmetry group, similar to rotating your point of view in space, but with time as par of the "rotations." The fundamental forces are dictated by symmetries called gauge symmetries. Conservation of electric charge is a consequence of yet another symmetry.

Supersymmetry is a remarkable symmetry. In elementary particle physics, it interchanges particles of completely dissimilar types, the kind called fermions (such as electrons, protons and neutron), which

Simplicity is another way of measuring truth. For practical reasons, scientists are always looking to explain things according to the simplest formula possible. This allows complex things with many variables to become easily manageable and usable. In fact, Newton and Einstein came up with formulae that are less than half a line long and can be taught to a schoolchild. The greatness of their theories included the fact that they were so elegant and simple.

However, there is no reason to expect that everything in the universe can be reduced to simple formulae and that because one scientific theory is simpler than another it is therefore more true. From a purely scientific point of view, there is no rational reason why the world should be explained according to simpler rather than more complicated formulae. Yet, scientists believe just that.

In the time of the great astronomer Copernicus, there was a great showdown between him, as a scientist, and the church, which sought to silence his views as being contradictory to church doctrine.¹ Up until then, the Church had accepted Ptolemy's ingenious but very complicated system of calculating planetary motion², which was presumed to be circular. Copernicus had proposed a much simpler heliocentric system of planetary motion. In response to Copernicus, the Church argued with Copernicus that the fact that his theory was simpler (and more elegant) was no indication that it was more true. But the belief of the scientific community in the principle of simplicity won out in the end over that of the church.

Beauty, unity and simplicity all represent underlying beliefs or axioms of science. "Science", said the mathematician-philosopher Bertrand Russell, "has never cared to justify

make up the material world, and those called bosons (such as photons), which generate the forces of nature. In quantum physics particles are divided into bosons and fermions.

.... Fermions are inherently the individualists and loners of the quantum particle world: no two fermions ever occupy the same quantum state. Their aversion to close company is strong enough to hold up a neutron star against collapse even when the crushing weight of gravity has overcome every other force of nature. Bosons, in contrast, are convivial copycats and readily gather in identical states. Every boson in a particular state encourages more of its species to emulate it. Under the right conditions, bosons form regimented armies of clones, such as the photons in a laser beam or the atoms in superfluid helium 4.

In the mirror of supersymmetry, standoffish fermions look magically like sociable bosons, and vice versa. Figuratively, you might say it is a symmetry that lets you compare apples and oranges. Hold up an apple to the supersymmetry mirror, and its reflection looks and tastes like an orange.

In the 1980s nuclear theorists predicted that a different form of supersymmetry could exist in certain atomic nuclei. Nuclei with even numbers of protons and neutrons and those with odd numbers.

Supersymmetry opens up a new class of possible relations among particles. These relations result in far greater computational power for analyzing or predicting a system's behavior.

¹There was widespread opposition to Copernicus in Judaism too. Chacham David Nieto, a leading Torah scholar in London, felt that while Copernicus' view of the solar system was entirely logical, it was nevertheless unacceptable, because it contradicted the simple meaning of the verse in Yehoshua 10:12 which spoke of the sun miraculously standing still. Maharal disparages Copernicus' assertions as having no authority. His student, Rabbi David Ganz, speaks glowingly of Copernicus but nevertheless rejects the heliocentric system. Tuviah Katz in Maaseh Tuviah rejects Copernicus on the grounds that his proofs are contrary to the Torah and calls him the "firstborn of Satan." Rabbi Yonason Eybeshitz refers to the folly and falsehood of Copernicus, and notes that "the world stands forever." The opposition was certainly more muted than that of the church, but ... don't know of any Torah authorities who welcomed Copernicus.

²It involved a system of circles and sub-circles, with different radii, tilts and different amounts and directions of eccentricity.

its faith or explain its meaning³.” The enormous success of science over the last 150 years has emboldened the scientist to believe that his creed is truly correct.

8. Science as the New Ethics

We are much beholden to Machiavelli...that if something has been invented then we must use it. We don't stop to think of the possible consequence of its use.¹

Scientists exceed their mandate, and can even be dangerous, when they try to deal with the question why². Firstly, science, by its very nature, lacks a certain perspective. As Will Durant put it: “The scientist is as interested in the leg of the flea as the creative throes of a genius....” Scientifically speaking, they may be of equal interest. In human values, they are worlds apart.

Yet, the very pace of science has meant that by default, science has become the great moral arbiter of its own discoveries. 20th century science charged ahead so quickly that its de facto control created a sort of de jure reality. It operated on the assumption that since science meant progress, every discovery was automatically for the good of mankind. It was dead wrong³. The moral and ethical issues which emerged from the new science were rarely anticipated. They were almost always only brought up after the fact. To their credit, in the last twenty years many American colleges have introduced medical and other ethical courses. Many hospitals now have an ethics committee. However, these are limited to responses to given realities; science, with virtually no constraints, first discovers a particular area and only then does the ethicist deal with it.

Take the atom bomb, for example. The dropping of the bomb led to much discussion about whether nuclear power for military ends is good or bad. Some of the most eloquent and vociferous opponents of the atom bomb became those who were involved in the Manhattan project (the American WW2 initiative to make the atomic bomb) to begin with, including Robert Oppenheimer who headed the project. It was he who said in retrospect, “The physicists have known sin; and this is a knowledge which they cannot lose”⁴. At the time of its development, however, a certain dynamic was taking place, a dynamic which is insightful about the momentum of science in general.

Victor Weiskopf writes of his participation in the Manhattan Project: “Today, I am not quite sure whether my decision to participate in this awesome and awful enterprise was solely based on the fear of the Nazis beating us to it. It may have been more simply an urge to

³The Will to Doubt, p. 65

¹ J.B. Priestley

²שפתי חיים שם: אוי ואבוי הוא כאשר חכמי הטבע חורגים מגבולות וממגבלות חכמתם, ומנסים להסביר את הלמה, כי אז הם בודאי שוגים, וטועים, מפני שהלמה - סיבת הסיבה היא רוחנית

³R.G. Collingwood (Autobiography): “The gigantic increase in man's power to control nature had not been accompanied by a corresponding increase in his power to control human situations” (Baumer, *Modern European Thought*, pg. 466)

Aldous Huxley felt that science actually made things worse: “Man's very victory over nature constituted an important causative factor - in the progressive centralization of power and oppression and in the corresponding decline of liberty during the twentieth century.” (Above Cit.)

⁴ In a lecture, 1947

participate in the important work my friends and colleagues were doing. There was certainly a feeling of pride in being a part of a unique and sensational enterprise. Also this was a chance to show the world how powerful, important and pragmatic the esoteric science of nuclear physics could be."

After the defeat of Germany, the single, most powerful reason for working on the bomb had been removed. But work continued because, "By then we were too involved in the work, too deeply interested in its progress, and too dedicated to overcoming its many difficulties ... the thought of quitting did not even cross my mind." (After the war, Weiskopf did quit working on the project.)¹

It has become popular to talk of the twentieth century scientific revolution as having been concentrated in the first decades of the century. Enter quantum physics, enter relativity, enter most of the major practical innovations which affect our lives so greatly today. The truth be told, science has increased its revolutionary momentum over time. The whole area of biochemistry, for example, only really took off from the 50's onward.

Until that time, there was precious little understanding of how organs of the body worked at a chemical level, let alone of whole organisms. To explain the exact transmission of vision, for example, from the time a photon first hits the eye to the time when the fired nerve returns to its normal state, was something that early 20th century science did not even dream of being able to do. In fact, the tendency was to grossly underestimate the complexity of all living organisms. The questions were not even asked. Very small creatures were not even thought to have discreet internal structures. We might say that in this regard there has been a paradigm shift of sorts. We now expect to find complexity; we ask the right sort of questions and we therefore get the right sort of answers. But the ethical implications of all this has barely been touched.

Perhaps most dramatic is our assault on both ends of life. It is not always realized that the American average life span of 78 for men and 80 for women is as much a function of the lives we save of people in their first year on this earth as it is of people in their 70th or 90th year. It is estimated that over 80% of all medically related costs (especially including research) goes into these extremities.

The attempts of ethicists to keep pace with these events have been hopeless. As science reached toward the top of any hill, ethicists only began climbing from the bottom. This is not because of any failure on their part. More recently, the reaction time to issues has gotten faster. The U.S. made great strides when it reacted promptly to the recent cloning in Scotland. But, cloning has been around for ages; scientists just happened to get it right at a much earlier age, something they were bound to do sooner or later. In other words, it was only when science was again at the top of the hill that such responses were forthcoming.

Not only are responses by the non-scientific community reactive rather than proactive, but such responses are to the credit of big government and not to the world of philosophers and thinkers. However, democratic, capitalist governments will at best act as honest brokers guiding processes that ultimately must be controlled and directed by others. At best, bodies like the NIH are scientists monitoring other scientists to create acceptable, not ideal standards. Any suggestion of a "non-professional" monitoring the corporate body of science, even in essentially non-scientific ethical areas, such as criteria for publishing results or preventing fraudulent claims, is fiercely and successfully resisted by the scientific community.

The situation that has emerged is aptly described by the Jewish medical ethicist and biologist Rabbi Dr. Moses Tendler: "By default, society has assigned the physician the role of theologian and moralist - a role for which he has no competence. The fear of sickness and

¹The Joy of Insight, Passions of a Physicist, Basic Books.

death, aided by the intentionally cultivated aura of mystery and the deep respect of the laity for scientific achievement, has resulted in this unwritten election of the medical community as arbiter of the most fundamental truths of Torah morality and of Western Civilization."¹

In truth, a doctor is as qualified to pass judgment on when life begins and ends as a chef is on which foods are carcinogenic or a computer programmer about which way the PC market is about to go. All are likely to sound intelligent; none have more than an educated layman's chance of being right.

Thinking rigorously ethically is a highly specialized business. A great posek invariably spends 40 to 50 years of his life preparing for just this. He has focused on a body of Divinely given information, the Torah, which anticipates all these questions to begin with. One has only to page through an Igros Moshe to see that all the new ethical issues have already been in the Torah, in principle form, from the outset. A posek prepares himself personally to reflect the values he adheres to at the highest of levels.

A posek is aware of every variable that impacts his decision. He knows that what he thinks about the centrality of the family, the value and the purpose of life, the right to self-determination and G-d are not only going to influence his answers but will determine the very questions that get asked. And those questions will already point us toward a particular answer. As the Sages put it, 'The question of a wise man is half the answer.'

Even if we ignore the fundamental difference of a Torah answer to a man-given one, the average medical ethicist has but a fraction of the preparation that we are talking about. For many, this is comprised of one under-graduate course, and that's it. And therefore, in the main, these people are lightweights against the inexorable march of scientific progress. There is not a single one who can claim a towering moral prowess which will prompt any major scientist to consult with him in advance to set the parameters of research and anticipate its ethical implications.

The idea that the moral implications of science be dictated by the fact of science is a fundamental flaw of Western reality. The classic view of science as a morally neutral force is simply no longer tenable. Fifty odd years ago, Will Durant was able to say that "science tells us how to heal and how to kill; it reduces the death rate in retail and then kills us wholesale in war; but only wisdom...can tell us when to heal and when to kill."² But science did not wait for wisdom to inform it.

What this leads to is a sort of trance of action inherent in the nature of scientific progress. "We are much beholden to Machievelli," J.B. Priestley said, "...that if something has been invented then we must use it. We do not stop to think of the possible consequences of its use."

Of course, many Western scientists, together with the politicians, were aghast at some of the more morally repugnant uses to which Nazis and Communists had applied the new technology. Scientists as a whole are interested in doing the right thing. But this misses the point. The real issue was that "the gigantic increase in man's power to control nature had not been accompanied by a corresponding increase in his power to control human situations,"³ nor to act more morally. Alduous Huxley pointed out that man's very victory over nature constituted an important causative factor in the progressive centralization of power and oppression and in the corresponding decline of liberty during the twentieth century.⁴

And there things lay. On the one hand, we never expected, and therefore never demanded, that science deal with the whole world of feelings, purpose and values⁵. But nor

¹Challenge, Feldheim

² A History of Philosophy

³ Baumer, Modern European Thought, MacMillan, 466, quoting R.G. Collingwood, Autobiography

⁴ Above cit.

did we expect its de facto dictation of these very things with which it claimed to have nothing to do.

We are not suggesting a conspiracy of scientists making a takeover bid of the world. It is the scientific endeavor per se which imposes this reality. For example, the ability to end an individual life has never required much help from the scientific establishment. We have always known how to insert poisons into living bodies, turning people into just so much rotting flesh. It is hardly cutting edge technology to put up a drip and engage in an act of euthanasia a la Kevorkian. It requires infinitely greater expertise to save the life of someone in critical condition rather than to end it. We can therefore expect that the medical establishment would move in the direction of saving lives rather than ending lives. Ending the life of fetus in a way that is painless and relatively dignified for both mother and fetus is more medically challenging than ending the life of a critically ill adult, especially an adult that is on life-sustaining machinery. Therefore, the medical establishment is more likely to invest in learning how to do abortions than how to do euthanasia. That the medical challenge rather than the ethical prioritization should determine these goals is inherent in the nature of the scientific enterprise. Even where humanitarian efforts are undertaken in areas such as finding a cure for AIDS, it is a function of the occasional successes of forces outside the scientific community indicating a priority.

The medical establishment is certainly not morally neutral. It does distinguish the ethical difference between conducting an abortion vs. conducting euthanasia. This is why abortionists still retain their medical licenses while Dr. Kevorkian had his license revoked. But this moral sensitivity is a secondary and not a primary determinant of research and other priorities.

Outside of medicine, conventional wisdom has it that the scientific endeavor is essentially morally neutral. Atomic power can light up dark homes or flatten and darken 100,000 lit ones. Society decides whether evil ends or good ones are what is in mind. I have tried to show that this is not so. The scientific exercise produces moral facts on the ground, facts which would require an exceptional effort on the part of society to counter.

⁵ Based on Sir Arthur Eddington: "Physics dealt, by choice, only with measurable quantities. But there was the whole world of feelings, purpose and values." (Above Cit. 471)

Appendix 1: THE METHODOLOGY OF MODERN PHYSICS: THEORY VS. PRACTICE

- i - Observation And Recording Of All Facts**
- ii - Analysis And Classification**
- iii - Forming Theories And Laws**
- iv - Prediction And Verification**
- v - Peer Review And Replication**
- vi - Replacement Of Previous Theory**
- vii- Scientific Misconduct**

APPENDIX 1: THE METHODOLOGY OF MODERN PHYSICS - THEORY VS. PRACTICE

When Thomas Edison was trying to figure out how to get a small amount of current through a thin wire to light up multiple light bulbs at once, he was really trying to apply Ohm's law. Yet he said later, "At the time I experimented I did not understand Ohm's law. Moreover, I do not want to understand Ohm's law. It would stop me experimenting."

Most laymen underestimate the role of creativity in the progress of science. It is important to understand the underlying beliefs of science not only to understand what goes into a scientific theory but also because it is essential when talking about proofs for G-d, the Divine Origin of the Torah, the existence and accuracy of the Oral Law or the Chosen People¹. Audiences in Discovery and similar seminars often respond to a proof by saying, "But you don't have to say it like that; you could say such and such." This reflects a misunderstanding of what is meant by the word proof. In any attempted "proof" for anything, what is meant is not absolute proof so that no other possibility can ever be suggested. Human beings are not capable of that kind of knowledge. What is meant is that, on balance, this is the best possible alternative amongst all the possibilities conceivable. (For this reason, Rabbi Dovid Gottlieb does not use the word "proofs". Rather, he talks about "the historical verification of the Torah" and the like. Torah proofs are exactly of the same order as the scientific proofs. They, too, are not coming to provide the only possible explanation but the best possible explanation. The layman, however, often does not understand this. He assumes that scientific proofs are certain (after all, he sees the technological results of science all around him) and he therefore wants Torah proofs to be absolute as well. We have already shown that scientific theories are simply the best explanations, usually amongst many, for a set of phenomena. We have also seen how science operates according to an underlying set of beliefs, which influences what kinds of theories the scientist is likely to formulate to begin with. Here we will show many examples of how scientists deviate from the idealized way in which a theory is supposed to be formulated. These deviations are not a bad thing. On the contrary, they are, as we shall see, responsible for many great scientific discoveries.

Ideal science is supposed to unfold according to the following steps:

- i - Observation and recording of all facts*
- ii - Analysis and classification*
- iii - Forming theories and laws*
- iv - Prediction and verification*
- v - Peer review and replication*
- vi - Replacement of previous theory*
- vii - Scientific misconduct*

However, science very rarely operates in this way. Steps are either followed improperly, avoided on occasion or performed in the wrong order. This is not to fault the scientific endeavor in any way. For, scientists themselves never claimed that this was the way they did business, and, on the contrary, would discover a lot less if they were constrained by this process. The idealization of the scientific process exists only as a school textbook.

Below, we take a look at each one of these steps and put it in its correct context.

¹See the Ner LeElef Book on **Proofs**

i-Observation and recording of all facts

Observation is limited by the following factors:

1- It is impossible to observe all the facts that may be relevant to any scientific theory. For this, we would have to wait until end of the world.

Even all the facts up to now are infinite. For example, if I were investigating what contributes to room temperature, I might consider the following things:

The outside temperature; the wind; the heat of lighting systems or any other cooling, heating, gas, water or other systems passing through the room; the number of people in the room and their body temperature; any other animals such as mosquitoes, flies, etc. that may be in the room; the reflective and absorptive capacity of the various materials with which the room is made and which are in the room; the interaction of these articles with outside sources of heat (such as the temperature of the couch after someone has sat on it), etc.

This list could be expanded to hundreds of other items, making the final calculation nearly impossible. What the scientist does in practice, therefore, is never to simply collect information but rather to filter information through some theoretical framework in order to reduce it to manageable proportions. Any data collection then usually presupposes a theory of some sort and does not, as is presumed, precede it.

Sir Arthur Eddington: The mind selects for study certain patterns of nature rather than others. "The things which we might have built and did not, are there in nature just as much as those we did build."

2- A second factor which renders information not completely objective is that most scientific "facts" are only as objective as the instrumentation through which they are preserved on theory. (In the social sciences, such as psychological testing, this filtering can be quite significant.)¹

¹The following, based on an article in the N.Y. Times Science section, gives an idea of the accuracy of various different types of scientific studies.

LABORATORY EXPERIMENTS

Definitions:

in vitro – carried out on cells or tissue samples in a test tube

in vivo - carried out on laboratory animals (e.g. mice or guinea pigs)

Advantages: These studies can be tightly controlled, e.g. scientists can ensure that comparison groups and conditions are identical.

Disadvantages: There is a big difference between human and the test tube or laboratory animals. Not all that applies to them would apply to us.

EPIDEMIOLOGICAL RESEARCH

Definition – Observational studies:

Case-control studies – Comparing factors found among one group with a certain condition to factors found among a comparable group without that condition

Cohort studies – *Large groups of people are followed for a long time. Researchers try to identify factors – possible causes and preventatives – associated with illnesses that develop over time.*

Advantages: Researchers can often zero in on important associations by adjusting their data statistically to account for the influence of extraneous factors. Disadvantages: Only more reliable when study is larger and carried out longer. Cannot establish cause and effect – can only suggest a relationship between two factors. Often produce contradictory results.

CLINICAL TRIALS

Definition: Studies that randomly assign people to two treatment groups, with neither the researcher nor the participants knowing which group is which until the study is completed.

Disadvantages: Not every suspected association can be subjected to a clinical trial. (e.g. it would be unethical to assign one group to smoke and another to never smoke just to prove that smoking causes cancer.)

Our senses alone are rarely accurate enough to give us the information we need. Thus Tycho Brahe, living in a pre-telescope era, rejected the Copernican idea that the earth moves around the sun. If Copernicus were right, he reasoned, the position of the stars at the same time on different nights should change.

Ernst Mach wrote that since sub-atomic physics goes beyond our senses, the atomic theory can be regarded as a mathematical representation of certain facts, but no physical "reality" could be claimed for atoms or molecules.

Einstein in a letter to Heisenberg, 1927: "But on principle it is quite wrong to try and found a theory on observable magnitudes alone. In reality, the very opposite happens. It is the theory which decides what we can observe."

3- Some information is just too inaccessible either because the events happened too long ago or are too far away. As Michael Philips wrote¹:

We have developed a technology that enables us to observe events in galaxies billions of light-years away. The Big Bang Theory is based on these observations. So is our knowledge of what the universe was like in the first 10^{-35} second of its existence.

But how confident can we really be that our instruments are accurate at these distances?

The answer is that we do not know...we assume that our sample is representative, i.e., that the laws of nature we have discovered here, in our sector of the universe, hold everywhere...It is reasonable for us to act on this assumption [but that] does not mean that this assumption is true.

[We are right to] assume that there are general laws governing the universe...But if... can we assume that we have now discovered them or that we are anywhere close to doing so? If the universe really is diverse...we may be trying to understand the whole in terms of laws and theories that **hove** for a very minute part.

ii-Analysis and Classification

Ideally, we would take raw data and begin to classify it, e.g. in the case of humans by race, gender, age, health, wealth, intelligence, etc. (same as **a** above). Actually, however, scientists have come to learn that classification is often so biased that it can lead to very wrong science. A famous example was that of Samuel Morton, who classified 1000 skulls by race in the 1830-50's.²

Furthermore, classification may be based on assumptions (called secondary hypotheses) that are simply wrong. For example, scientific theories are often based on a presumption that things have been constant in nature over a long period of time even though there may not be any special reason to believe this. To illustrate, carbon dating is based on measuring the ratio of C12 to C14 in a once-living organism relative to the environment. But it is based on the presumption that the amount of both that we find in the environment today has been constant for tens of thousand of years. In fact, there is much evidence to challenge this.

¹Philosophy Now, October/November 2000

²See Stephen Gould, The Mismeasure of Man

iii-Forming Theories and Laws

"Scientific laws and theories are not derived from observed facts, but invented in order to account for them. They constitute guesses (and)...require great ingenuity." (Carl G. Hempel, Philosophy of Natural Science, p. 17)¹

"Progress would do much better to glorify problems than theories. It is problems that are inherently wonderful; solutions are merely useful. I even sometimes say, only half jokingly, that theories ought to be renamed 'misconceptions', and that progress consists of moving from one misconception to a preferable misconception. That is, from a misconception that contains a great deal of falsehood to one that contains less falsehood." (leading physicist David Deutsch in Philosophy Now, 2000)

"The logical progression comes only right at the end, and it is in fact quite tiresome to check that all the details really work. Before that, you have to fit everything together by a lot of experimentation, guesswork and intuition." (Richard Borchers, one of the world's leading mathematicians in Scientific American, Nov. '98, pg. 21)

Einstein's Theory of Relativity was first conceived and then tested (Einstein himself devised three experiments to prove or disprove his theory), and so was Quantum Theory, some elements of which have only been proven recently. For example, Max Planck proposed a measure of the amounts or quanta of energy that atoms can absorb or emit (Planck's Constant). Science magazine (Feb. 8, 1991) reported that many physicists were so used to using Planck's Constant that they did not even realize that it had never been accurately checked. It was only in 1991 that physicists at the Los Alamos National Laboratory confirmed that the constant is in fact correct (Physical Review Letters, Jan 21).

¹Many scientific theories are purely mathematical constructs. They are merely projections as to what some aspect of the micro or the macro world would look like if we could ever see it. Certainly, there is good reason to operate this way. Often the mathematical projections have later been shown to be true. This, despite the fact that many do not regard mathematics itself as existing in the real world. Richard Borchers, leading mathematician, takes a middle view (in Scientific American, Nov. '98, pg. 21): "Some mathematics clearly is a human invention" most notably anything that depends on the fact that we use a 10-digit numbering system. "But I think some mathematics does exist before discovery. Take the Pythagorean theorem. That has been independently rediscovered several times by various civilizations. It's really there. Presumably if there were small furry creatures doing mathematics on Alpha Centauri prime, they would also have some version of the Pythagorean theorem."

Stephen Jay Gould in *"Questioning the Millennium"* (1997), wrote the following:

Galileo described the Cosmos as "a grand book written in the language of mathematics, and its characters are triangles, circles and other geometric figures." The Scottish biologist D'arcy Thompson, one of my earliest intellectual heroes and author of the incomparably well-written *Growth and Form*, (first published in 1917 and still in print) stated that "the harmony of the world is made manifest in Form and Number, and the heart and soul and all the poetry of Natural Philosophy are embodied in the concept of mathematical beauty."

Many scientists have invoked this mathematical regularity to argue, speaking metaphorically at least, that any creating God must be a mathematician of the Pythagorean school. For example, the celebrated physicist James Jeans wrote: "From the intrinsic evidence of his creation, the Great Architect of the Universe now begins to appear as a pure mathematician." This impression has also seeped into popular thought and artistic proclamation. In a lecture delivered in 1930, James Joyce defined the universe as "pure thought, the thought of what, for want of a better term, we must describe as a mathematical thinker."

Some corners of truly stunning mathematical regularity grace the cosmos in domains both large and small. The cells of a honeybee's hive, the basalt pillars of the Giant's Causeway in Northern Ireland make pretty fair and regular hexagons. Many "laws" of nature can be written in an astonishingly simple and elegant mathematical form. Who would have thought that $E=mc^2$ could describe the unleashing of the prodigious energy in an atom?

But we have been oversold on nature's mathematical regularity If anything, nature is infinitely diverse and constantly surprising — in J.B.S. Haldane's famous words, "not only queerer than we suppose, but queerer than we can suppose."

Steven Weinberg, after trying for a long time to apply the Higgs phenomenon to the strong interaction, suddenly realized, while driving to his office one day, that he had been applying the right ideas (the Higgs phenomenon) to the wrong problem (to the strong instead of the weak force).

Fred Hoyle in 1953 predicted the existence of a previously unknown isotope of Carbon 12 based on theories of how stars generate heavy elements. Only afterward was this confirmed by experiment.

Kepler's inspiration for a sun-centered solar system was in part based on certain solar deification in which he believed (Burt - *Metaphysical Foundations of Modern Science*). His study of planetary motion was inspired by his interest in a mystical doctrine about numbers and a passion to demonstrate the music of spheres (Hempel, Philosophy of Natural Science, p. 16).

The chemist Kekule had long been trying to devise a structural formula for the benzene molecule when, one evening in 1865, he found a solution while dozing in front of his fireplace. Gazing into the flames, he saw snake-like patterns. Suddenly, one of the flames seemed to hold onto its tale. Kekule woke in a flash: he had hit upon the now famous and familiar idea of representing the benzene structure by a hexagonal ring (Hempel, pg. 16).

Murray Gell-Mann (A leading physicist) "We are driven by the insatiable curiosity of the scientist, and our work is a delightful game. I am frequently astonished that it so often results in correct predictions of experimental results."

The following by David Goodstein in the NY Times, October 2000, is a good example of how theory can lend credibility to ideas even when they remain unproven:

In June 1969, at a scientific meeting in Cincinnati, Joseph Weber, a physicist from the University of Maryland, announced the first detection of gravitational waves. His statement was greeted with enormous excitement among scientists and in the press. However, other scientists were unable to reproduce Weber's results, and so his claims were eventually discredited. The story brings to mind the more recent announcement by two scientists in Utah that they had discovered "cold fusion." But unlike cold fusion, which has been cast out of the house of science in spite of persistent claims by others of having detected the effect, the search for gravitational waves has grown into a global scientific industry even though no one has recorded so much as a blip. The difference is that cold fusion violates fundamental principles of theoretical physics while gravity waves were predicted by Albert Einstein. Weber, who died while I was working on this review, is regarded by all as the father of the field of gravity wave detection.

iv-Prediction and Verification

According to the classic perfect abstract conception of how science works, the following principles apply:

1- Any body of knowledge could be explained by any number of theories.

2- "Any physical theory is always provisional, in the sense that it is only a hypothesis: you can never prove it. No matter how many times the results of experiments agree with some theory, you can never be sure that the next time the result will not contradict the theory. On

the other hand, you can disprove a theory by finding even a single observation that disagrees with predictions of the theory." (Stephen Hawking, A Brief History of Time, pg. 10)

A classic example of this was the discovery of Neptune. Irregularities in the motion of Uranus led to the prediction that there must be another planet, and where that planet should be. Scientists trained their telescopes on the predicted spot where the planet should be seen, and presto! Neptune was discovered.¹ The trouble with all of this is that it was done using Newtonian physics, and we know today that Newtonian physics is not true!

In most scientific studies involving people, we are dealing with statistically relevant samples. This allows for considerable judgment as to when an experiment with negative results should be repeated (or even reported), and whether a sub-group which shows positive results is random or significant².

¹Irregularities in motion of Mercury failed to produce Vulcan, due to point 1 above, that many theories can explain a single phenomena.

²Adapted from Gina Kolata in the NY Times, July '02: Most experiments done in science fail and the hypotheses that seduced researchers turn out not to be true or, at least, the studies provide no evidence that they are true.

Generally, if the negative studies are large and the hypotheses well known, they will be published. That happened, for example, with studies of thousands of cellphone users finding no evidence that cellphone radiation predisposes to brain cancer. It also happened with a study published last month finding no evidence that men who had vasectomies are more likely to get prostate cancer.

But if the studies are small — just some professor's good idea proved wrong — the findings often are never published, leading future researchers to waste time and money going down the same blind alley. Or, if a study that fails to support a popularly held idea — that stress causes ulcers, for instance — goes unpublished, people may continue to believe in an association that has never actually been proven.

A few new journals have begun soliciting and publishing negative studies — ostensibly to prevent repetition and waste, and to acknowledge that even negative results add value to our collective knowledge bank. It's a tough sell. The tendency for science to overlook most of the vast backwash of failed experiments isn't accidental. Money, pride, politics and good old competition all play a role. And even when major negative studies are published, it may not have the effect of moving researchers on to other topics.

The journals aren't entirely to blame. Some negative data are not published, he suggests, because those conducting the studies do not want to share them.

One reason is because scientists do not want to give their competitors an advantage.

"They now know something they're not going to do again and their competitor does not," Dr. Kern said.

In an ideal world, said Dr. Leon Gordis, a professor of epidemiology at Johns Hopkins, all studies, positive or negative, would be judged by whether they were well done and whether they were interesting. "I don't think there should be a journal of not finding associations," Dr. Gordis said. "If you have a good study, it should be entered into a prestigious medical journal."

"On certain controversial or emotionally charged issues, when do we decide that no further studies are needed?" Dr. Gordis asked.

With cellphones, some scientists are continuing to look for evidence of danger. Now, Finnish scientists have announced that they will be reporting on laboratory experiments that suggest that cellphone radiation alters the blood-brain barrier, allowing chemicals into the brain that should be kept out. There is, of course, no evidence that any such thing is happening in humans. But the very effort shows that the cellphone issue remains alive.

Another way to keep an issue alive is to look for subgroups of people in large negative studies whose experience seems to support a given hypothesis. You can always find such subgroups if you slice the data, said Dr. Barnett Kramer, editor of The Journal of the National Cancer Institute. They will appear simply by chance, he said, adding that since the total effect is null, for every subgroup with a positive effect, there is another with a negative effect. That does not mean that the effect in any subgroup is real — to find out you need to do another study just with them. Should you? Or should a study that enrolled mostly men be repeated with women? Should one involving whites be done again to see if the results are the same with blacks?

3- In order to test a theory, the theory must make clear predictions. This is what makes Einstein good science and evolution bad science. Evolution makes no testable prediction whereas Einstein gave three clear instances whereby his theory could be tested. One of these had to do with how much the sun would bend light passing close by it. Einstein's measurements differed from those of Newton. On the night of a solar eclipse, Sir Arthur Eddington went out on a boat off the coast of Africa and made measurements that confirmed Einstein's predictions. (Interestingly, Eddington actually made an error in his measurements, but the theory proved to be correct anyhow.)

Every scientist knows that science rarely works out this way. At best, a scientific theory gradually accumulates evidence in its favor, becoming stronger and stronger over time¹. A good example of this is quantum physics, which, although it still has many puzzles,

"There's no shortage of issues that can be raised," Dr. Gordis said. Often, he added, there is money to be found to re-do the studies with a different emphasis.

So what should a scientist do? "I'm not aware of anyone refusing money," Dr. Gordis said. "That's the acid test."

¹The following article by a leading cosmologist, James Peebles in *Scientific American*, January, 2001, is an example of the graded hierarchy of theories according to the amount of evidence to back them: This is an exciting time for cosmologists: findings are pouring in, ideas are bubbling up, and research to test those ideas is simmering away. But it is also a confusing time. All the ideas under discussion cannot possibly be right; they are not even consistent with one another. ...

I compare the process of establishing such compelling results, in cosmology or any other science, to the assembly of a framework. We seek to reinforce each piece of evidence by adding cross bracing from diverse measurements. Our framework for the expansion of the universe is braced tightly enough to be solid. The big bang theory is no longer seriously questioned; it fits together too well. Even the most radical alternative--the latest incarnation of the steady state theory -does not dispute that the universe is expanding and cooling. You still hear differences of opinion in cosmology, to be sure, but they concern additions to the solid part.

For example, we do not know what the universe was doing before it was expanding. A leading theory, inflation, is an attractive addition to the framework, but it lacks cross bracing. That is precisely what cosmologists are now seeking. If measurements in progress agree with the unique signatures of inflation, then we will count them as a persuasive argument for this theory. But until that time, I would not settle any bets on whether inflation really happened. I am not criticizing the theory; I simply mean that this is brave, pioneering work still to be tested.

More solid is the evidence that most of the mass of the universe consists of dark matter clumped around the outer parts of galaxies. We also have a reasonable case for Einstein's infamous cosmological constant or something similar; it would be the agent of the acceleration that the universe now seems to be undergoing. A decade ago cosmologists generally welcomed dark matter as an elegant way to account for the motions of stars and gas within galaxies. Most researchers, however, had a real distaste for the cosmological constant. Now the majority accept it, or its allied concept, quintessence. Particle physicists have come to welcome the challenge that the cosmological constant poses for quantum theory. This shift in opinion is not a reflection of some inherent weakness; rather it shows the subject in a healthy state of chaos around a slowly growing fixed framework. We are students of nature, and we adjust our concepts as the lessons continue.

The lessons, in this case, include the signs that cosmic expansion is accelerating: the brightness of supernovae near and far; the ages of the oldest stars; the bending of light around distant masses; and the fluctuations of the temperature of the thermal radiation across the sky. The evidence is impressive, but I am still uneasy about details of the case for the cosmological constant, including possible contradictions with the evolution of galaxies and their spatial distribution. The theory of the accelerating universe is a work in progress. I admire the architecture, but I would not want to move in just yet.

How might one judge reports in the media on the progress of cosmology? I feel uneasy about articles based on an interview with just one person. Research is a complex and messy business. Even the most experienced scientist finds it hard to keep everything in perspective. How do I know that this individual has managed it well? An entire community of scientists can head off in the wrong direction, too, but it happens less often. That is why I feel better when I can see that the journalist has consulted a cross section of the community and has found agreement that a certain result is worth considering.

is gradually becoming more and more proven. A classic example of how science often works is Einstein's Special Theory of Relativity. Einstein published his paper on the Special Theory of Relativity in 1905. The first reference to it in the scientific literature was a paper from a very reputable laboratory that had tested one of the predictions of the paper and found that it disagreed with the laboratory's experimental result. According to the Feynman doctrine, quoted approvingly by Gribbin, Einstein's theory must have been wrong, and he should have gone back to the drawing board. But that is not at all what Einstein did. He knew that what mattered in his theory was its power and consistency. Given everything the theory did explain, he was sure that the experiment was wrong—which it was, although it took nearly a decade to sort it out. Indeed, when Feynman and Murry Gell-Mann created their theory of weak interactions (the kind that cause many particles to be unstable) they ignored a set of experiments that disagreed with the theory, and which, it turned out, were also wrong. Doing science at this level is not like looking up the correct spelling of words in a dictionary. It is more like a continual colloquy in which there are times when theorists are guided by experiment and many times when the opposite is true. The great scientists have an intuition that guides them through this most uncertain terrain. (Jeremy Bernstein in *The American Scholar*, March 2000) (See **Chapter F ii – Beauty** below for further examples.)

v- Peer Review and Replication

When a scientist makes a scientific claim, two things happen:

1-Peer Review

He must submit his paper to a scientific journal. Before a reputable journal will publish his paper it must undergo a peer review by about three other reputable scientists. They will consider not only whether the paper has any significance but also whether it is rigorous enough to be considered good science.

In the main, this system works well. There are some qualifications to this, however. In particular, there is a constant huge pressure on the career scientist (including doctors) to publish papers. One needs a certain number of papers to become an associate, assistant and then full professor, and after that it still requires a certain amount of papers per year to maintain that status. On the other side, all but the top journals are under huge pressure to find articles (there are over 8000 medical journals alone!). These journals are not subject to market forces, i.e. they are not dependent on subscriptions for their survival. Rather, their money is earned through payments made by those submitting articles. In general, scientists can get the credit they need no matter which journal they publish in. Therefore, although the peer review system works well for top journals, it is far weaker for all the journals below this standard.

2-Replication

The result becomes more interesting when others reproduce it. It starts to become convincing when independent lines of evidence point to the same conclusion. To my mind, the best media reports on science describe not only the latest discoveries and ideas but also the essential, if sometimes tedious, process of testing and installing the cross bracing.

Over time, inflation, quintessence and other concepts now under debate either will be solidly integrated into the central framework or will be abandoned and replaced by something better. In a sense, we are working ourselves out of a job. But the universe is a complicated place, to put it mildly, and it is silly to think we will run out of productive lines of research anytime soon. Confusion is a sign that we are doing something right: it is the fertile commotion of a construction site.

In addition, if the discovery is of some significance, other scientists will attempt to replicate the experiment.

Replication only takes place for top discoveries. The motivation to reproduce is low. Prizes go for originality. There is little credit given to the scientist who merely replicates the experiments of others (unless he plans on adding additional elements) and most scientific papers are not only never replicated but are never even quoted again in another scientific paper. (It is interesting to note that colleagues of Galileo failed to reproduce his results.)

Raw data is usually not available in full to others, even upon special request (although the American scientific establishment is moving towards requiring this). Therefore, statistical and other errors of basic interpretation cannot usually be picked up.

The published details of an experiment usually leave out little details of practical technique (very often, a researcher does this to have the field to himself a little longer).

If another researcher does attempt to replicate an experiment and fails to do so, this is also problematic for the one submitting his discovery. "A chef cannot develop a reputation for himself by demonstrating bad recipes" (William Broad and Nicholas Wade, Betrayers of the Truth, pg. 77). Often, this failure is attributed to less prestigious replicators' lower expertise. For example, Mark Spector, who had actually forged his results in cancer research, was not caught out even though others failed to replicate his work. Their failure was attributed to Spector's superior technical expertise at purifying kinase reagents.

Sometimes, the very prestige of the scientist appears to obviate the need to replicate. Such was the case of Sir Cyril Burt whose research on identical twins was accepted for decades until it was finally revealed that he, too, had forged the results.

vi-Replacement of previous theory

It is presumed that when results seem to contradict a previous theory and to support a new one, the old theory would be immediately replaced. This is not always the case. A theory may be maintained because it continues to be useful even if it is not ultimately accurate. The most famous example of this is Newtonian physics. Today we accept that Newtonian physics is wrong and that it has been replaced by Einsteinian physics. But, we continue to use Newtonian physics in everyday life such as in building bridges and buildings because it is accurate enough to serve our needs in these areas and is much simpler to use than Einsteinian formulae.

Another example is in the area of light, where Einstein's theory of light quanta overturned the previous theory of light as a form of electromagnetic waves. Despite this, we still use the electromagnetic wave theory of light for refraction, reflection and polarization of light. Einstein himself predicted that the former's greater simplicity of use would lead to its continued usage.

Sometimes, a theory may be kept even after it has been disproven simply because there is no new one to replace the old one. A dramatic example of this occurred in 1925 when D.C. Miller, then President of American Physical Society, announced that he had evidence contradicting the special theory of relativity. The scientific community simply ignored this dramatic development, believing that the contradiction would somehow be resolved. In this case they were indeed correct. (Paul Davies, Superforce, pg. 59)

vii-Scientific Misconduct

Although there have been some famous cases of absolute scientific fraud, this is quite rare - usually about one major case once every two years or so. These became highlighted

when the American Congress conducted an inquiry into scientific misconduct. What is more common is the urge of the scientist to improve on his existing results by rounding off his statistical data, plagiarism, redundant publication and conflict of interest between reviewers and authors. A survey done by the New Scientist of research scientists found that 93% of respondents personally knew of cases of cheating of this sort. The *NY Science Times* (June 9, 1998) quoted the editor of the British Medical Journal, Dr. Richard Smith, as saying that scientific misconduct was a bigger problem than scientists were willing to admit and called for a national body with powers to investigate researchers without warning.¹

Newton added a fudge factor (an artificial or unexplained correction attached to his formula), and Einstein did the same in an attempt to reconcile his theory with the static universe model. (Ironically, Einstein may have been correct for the wrong reasons.) Gregor Mendel, discoverer of genetics, tidied up his statistics. John Milliken (who won the Nobel Prize for discovering the electrical charge of the atom) was also found to have made his results seem more convincing.

In some cases, the scientific researcher appears to have deceived himself, finding what he expected to find even though it was not there. The most famous case of this was the horse Clever Hans, who appeared to understand language but was in fact merely responding to unwitting cues. Piltdown Man, a complete fake, fooled the scientific community for decades. Some feel that this was because the British scientists who had the primary access to Piltdown Man were suffering from nationalistic pride that a fossil of such importance had been discovered in Britain.

In September 2002, it was reported that a series of extraordinary advances in physics claimed by scientists at Bell Labs relied on fraudulent data. A total of 17 papers between 1998 and 2001 that had been promoted as major breakthroughs in physics, including claims that Bell Labs had created molecular-scale transistors, had been improperly manipulated or even fabricated². Primary blame for the deceit was placed on one Bell Labs scientist, Dr. J.

¹ A lower level, below actual misconduct, is bias.

NY Times, 10 Aug. 2000:

Human bias has a long, unhappy history in scientific research. In retrospect, some of Gregor Mendel's data on heritable traits was probably too good to be true, but the great Austrian geneticist knew what he was seeing and may simply have discarded some data that did not fit.

Sir Arthur Eddington, the British astrophysicist, probably did the same thing with his team's measurements of the deflection of starlight over the edge of the sun in 1919. But his results fit the predictions from Einstein's theory of relativity, which Sir Arthur was championing at the time and which turned out to be correct.

Scientists who are either less skilled or less lucky have had harsher experiences with bias. In the 1980's, scientists at the Organization for Heavy-Ion Research in Darmstadt, Germany, convinced themselves that they had established to a statistical certainty of 99.9999 percent that they had discovered either a bizarre new particle or some other unpredicted event. But the particle evaporated when physicists tried to find it in other laboratories.

"If you think there's something there and you're very committed to looking for it, you may lull yourself into saying, 'Gee, I've found it,'" said Dr. Michael S. Lubell, chairman of the physics department at City College of New York, who searched for the particle in experiments at Brookhaven National Laboratory. As a result, many physicists have learned to take precautions, especially when searching for rare events amid the confusion of a much greater number of ordinary processes. In such cases, it is only by carefully subtracting events with, say, the wrong energy or mass or decay products that the few golden events emerge. Mistakes or biases in the subtraction can either erase those events or fail to remove all of the meaningless background.

Hendrik Schon, but the papers tarnished co-authors who noticed nothing amiss¹, Dr. Bertram Batlogg, the former director of solid state physics research at Bell Labs and senior author of several of the papers², and the scientific journals that critics say moved too quickly to publish the sensational findings.

The case also raises questions about the core of the scientific process in which scientists critique each other's work for errors but rely on trust that the data is honest. If the panel is correct, Dr. Schon pursued his fabrications in one of the hottest areas of research, molecular electronics, i.e. one where lots of co-scientists were looking closely at what he was doing. Yet, he still managed to continue the charade for several years. On the other hand, it is a credit to the scientific process that the fabrications were revealed after a few years and not decades or centuries later.

It became clear that when fraud occurs the best scientists can be fooled by their own colleagues. Often, the senior scientist is the one caught unaware. In 1991, Mitchell Rosner, a graduate student at Georgetown University, fraudulently reported that he had found a protein that signals a fertilized egg to start developing into an embryo. His co-authors retracted their paper and apologized.

In 1981, at Cornell University, Dr. Efraim Racker, one of the grand old men of biochemistry, was taken in by a graduate student. Other scientists grew suspicious about the too-perfect data but Dr. Racker first defended the papers he had published with his student.

In 1986, the Nobel laureate David Baltimore found himself caught in a bitter dispute after his colleague, Dr. Thereza Imanishi-Kari, was wrongly accused of faking data. For five years, Dr. Baltimore defended her vigorously before submitting an apology. As it turned out, after a long, bitter inquiry by the federal government, Dr. Imanishi-Kari was exonerated in 1996, attributing the errors in her work to sloppiness rather than fraud.

Acts of scientific fraud have not been so numerous as to prevent science's having become the most successful enterprise that human beings have ever engaged in. More often, results were fudged to give better results. Segregation ratios (3:1; 9:3:3:1), as reported by Gregor Mendel in his plant breeding experiments, conformed far too closely to theoretical expectations to be plausible. Often, a scientist, convinced that he found the truth, felt that colleagues would not believe him unless the results were overwhelmingly supportive of them.

Sir Cyril Burt pulled one of the greatest acts of fraud in his measurement of the IQs of twins. There was no effective check of Burt's findings because he told the IQ boys exactly what they wanted to hear. A graduate student of Iowa State University, Leroy Wolins, wrote to 37 authors of papers published in psychology journals asking for the raw data on which the papers were based. No fewer than 28 reported that their data had been misplaced, lost, or inadvertently destroyed. Of the seven that arrived in time to be analyzed, three contained 'gross errors' in their statistics.

Scientific American, December 2002 (*In Science We Trust*), expressed the opinions of most scientists when it stated that fraud could never become a major problem for science: "As a year for science, 2002 was marked by many wonderful accomplishments. But the year for blemishes on the scientific record: prominently among them, the fraud of a physicist working on semiconductor technology, the withdrawn discovery of element 118, a reversal on the wisdom of hormone replacement therapy for many postmenopausal women, and conflicting recommendations about dietary fat."

¹With one exception, none of his collaborators ever witnessed any of the experiments. Typically, organic crystals were grown by Dr. Schon's collaborators, and he then assembled them into electronic devices.

²Most of Dr. Schon's disputed experiments, it turned out, were not even performed at Bell Labs in Murray Hill, N.J., but at the University of Konstanz in Germany.

“Over time, however, science rises above narrow interests and corrects itself more reliably than any other institution through such practices as the open publication of results and methods. Some recantations will be unavoidable. This is not a weakness of science; this is its glory. No endeavor rivals science in its incremental progress toward a more complete understanding of the observable world.”

“Announcements of discoveries in professional journals also qualify and quantify their certainty; announcement in the general media often do not, because non-specialists usually lack the background to interpret them.”

“The greatest mistake is to wait for 100 percent scientific certainty or agreement, because it will never materialize. Conclusions vetted by the professional community might turn out to be wrong, but they generally represent the best-supported views currently available.”

(See examples of the non-existent heavy neutrino and cold fusion in **Appendix H iii.**)

Appendix 2: UNDERLYING BELIEFS OF SCIENCE

i-Unity

ii-Beauty

iii-Simplicity

iv-Paradigms

APPENDIX 2: UNDERLYING BELIEFS OF SCIENCE

Physicist Gerald Holton: “A few simple themes-unspoken assumptions and intuitively held prejudices that originate outside science, underlie all scientific thought.”

There are numerous principles, enumerated below, which represent the underlying principles to which all members of the scientific community adhere. These are not scientific principles per se. They represent the underlying deep beliefs held by scientists that there is order and harmony in the universe. They constitute the religion of science.

“In judging a physical theory... Einstein would ask himself if he would have made the universe in that particular way, were he G-d.” (A Zee, p. 6)

“I want to know how G-d created the world. I am not interested in this or that phenomenon, in the spectrum of this or that element. I want to know His thoughts; the rest are details.” (A. Einstein in A. Zee p. 8)

“The scientific creator, like every other, is apt to be inspired by passions to which he gives an intellectual explanation amounting to an undemonstrated faith without which he would probably achieve little.” (Bertrand Russel, The Will to Doubt, The Wisdom Library, pg. 61)

“The scientific credo: the system of beliefs and emotions which lead a person to become a great scientific discoverer.” (Bertrand Russel, The Will to Doubt, pg. 62)

In 2002, Science Writer Corey S. Powell wrote a book called G-d in the Equation: How Einstein Became a Prophet of the New Religious Era. By new religion, Powell means science. Science, he says, “offers a positive and immensely appealing alternative way of looking at the world, a religion of rational hope.”

i-Unity

Above we described how scientists are attempting to combine the four basic forces of nature into one force (see **Appendix B v** for greater detail). There is no reason why scientists should feel that all forces are really one force. There is nothing scientifically wrong with there simply being four forces rather than one. There was no reason for scientists to conduct a search that has involved tens of thousands super-colliders that run in the billions and a massive effort that has taken most of the century. Why could they not have simply accepted that there were four forces rather than one? However, it is a deep belief of science that the more a theory will give a comprehensive, total explanation for all of nature, i.e. the more unifying it is, the truer the theory is. This is simply a religious belief shared by all scientists and is highly consistent with a belief in an Ultimate Creator (though scientists do not readily make that connection).¹

¹Timothy Ferris (author of *The Red Limit - The Search for the Edge of the Universe*, Bantam, 1981) wrote, produced and narrated a PBS science special: "The Creation of the Universe": The search for, and the belief in the possibility of finding, a unified field theory "testifies to the triumph of the old idea that all creation might be ruled by a single elegantly beautiful principle."

In general, science has as its goal a total explanation of all aspects of reality (in the last two decades, an area called chaos theory has attempted to provide explanations even for those phenomena, like the weather, which previously appeared to defy scientific explanation).

The Tao of Physics, Fritjof Capra:

“Subatomic particles [in fact] have no meaning as isolated entities ... Quantum theory thus reveals a basic oneness of the universe. ... We cannot decompose the world into independently existing smallest units. ... Nature does not show us any isolated 'basic building blocks', but rather appears as a complicated web of relations between the various parts of the whole.” (page 78)

ii-Beauty

“What I remember most clearly was that when I put down a suggestion that was most cogent and reasonable, Einstein did not in the least contest this, but he only said, ‘Oh, how ugly’. As soon as an equations seemed to him to be ugly, he rather lost interest in it and could not understand why somebody else was willing to spend much time on it. He was quite convinced that beauty was a guiding principle in the search for important results in theoretical physics.” (H Bondi in A Zee, p. 3)¹

There is no reason why a scientist should presume that the world and the theories which describe that world (including some very abstract mathematical ones) should be beautiful. From a purely secular point of view, scientific theories might just as soon be ugly as beautiful. Again this is a part of the religion of science.

Paul Dirac: “It is more important to have beauty in one's equations than to have them fit the experiment.” (Paul Davies, Superforce, pg. 54)

A Zee (p. 3):

Some physics equations are so ugly that we cannot bear to look at them, let alone write them down. Certainly the Ultimate Designer would use only beautiful equations in designing the universe! We proclaim:

Let us worry about beauty first and truth will take care of itself.

Ferris states: "Religion and science are sometimes depicted as if they were opponents, but science owes a lot to religion. Modern science began with the rediscovery, in the Renaissance, of the old Greek idea that nature is rationally intelligible. But science from the beginning incorporated another idea, equally important, that the universe really is a uni-verse, a single system ruled by a single set of laws. And science got that idea from the belief in one God...

"The founders of modern science -- Kepler and Copernicus, Isaac Newton and even Galileo, for all of his troubles with the church -- were, by and large, profoundly religious men.

"I'm not saying that you have to believe in God in order to do science. Atheists and agnostics have won Nobel Prizes, as have Christians and Jews, and Hindus, Muslims and Buddhists. But modern scientific research, especially unified theory, testifies to the triumph of the old idea that all creation might be ruled by a single and elegantly beautiful principle" (PBS science special: "The Creation of the Universe")

¹Einstein's general theory of relativity, as it was known, described gravity as warped space-time. It had no fudge factors — no dials to twiddle. When the calculation nailed Mercury's orbit Einstein had heart palpitations. Something inside him snapped, he later reported, and whatever doubt he had harbored about his theory was transformed into what a friend called "savage certainty." He later told a student that it would have been "too bad for God," if the theory had been subsequently disproved.

...Rare indeed is the scientist who has not at one point or other been seduced by the beauty of his own equations and dumbfounded by what the physicist Dr. Eugene Wigner of Princeton once called the "unreasonable effectiveness of mathematics" in describing the world.

Aesthetics has become a driving force in contemporary physics.

Physicists have discovered something of wonder: nature, at the fundamental level, is beautifully designed.

(p. 4):

Aesthetic imperatives of contemporary physics make up a system of aesthetics that can be rigorously formulated.

As we examine nature on deeper and deeper levels, she appears ever more beautiful; Why should that be?

See also Paul Davies, Superforce, p. 68, last paragraph.

Symmetry

Simple symmetries are seen everywhere in nature. Things shaped in a circle or a square, snowflakes, reflections, etc. are all symmetrical. It was the discovery of deeper symmetries in nature which helped unlock many of the secrets of higher physics. As Paul Davies put it, "Forces are simply nature's attempt to maintain various abstract symmetries in the world." (*Superforce*, Davies, p. 7; see also p. 112-116)¹

¹The discovery of these hidden symmetries is that it is all the more remarkable given that, on the surface, everything in nature seems to demand the opposite, that things be slightly asymmetrical. In *Lucifer's Legacy*, Frank Close writes that if Creation had been perfect and its symmetry had remained unblemished, nothing that we now know would ever have been. The world is comprised of matter and antimatter. Antimatter, is the exact opposite of matter, its mirror, symmetrical particle. When any particle of matter meets its mirror antiparticle, mutual annihilation occurs. Physicists at CERN, the European Centre for Particle Physics in Geneva, can even watch this happen, as well as the converse, where a large enough concentration of energy can coagulate into the two forms of substance: matter, as we know it, and its mirror image, antimatter.

A perfect Creation, with its symmetry untainted, would have led to matter and antimatter in precise balance and a mutual annihilation when in the very next instant they recombined: a precisely symmetrical universe would have vanished as soon as it had appeared. Such a uniform cosmic soup could hardly have led to the asymmetrical universe that we are a part of today where antimatter appears to be all but absent.

However, another theory states that the two were indeed made equally in the Creation. Soon afterwards something interceded, the symmetry between matter and antimatter was slightly lost, with the result that after the great annihilation, a small proportion of the matter was left over. Those remnants are what have formed us and everything around us as far as we can see. We are the material rump of what must have been an even grander Creation.

Scientists also see the need for asymmetry in the four forces. Each one of the four forces is of a very different strength, and just as well. For example, we needed a weak gravitational force to coalesce matters into the sun. But the warmth from the sun comes from a much stronger, electromagnetic force, whereas the force involved in the transmutation of hydrogen in the sun is much weaker than that of the electromagnetic force. Had the force driving the solar furnace been as powerful as the electromagnetic force, all of the solar fuel would have been exhausted within five hundred thousand years—far too brief a time for life on earth, or anywhere, to have emerged. This separation of the electromagnetic force and its aptly named 'weak' force is but one of the critical asymmetries that has been necessary for our existence.

So too, the asymmetry in the atoms, the building blocks of all of life. In the atoms, it is the tiny electrons that mover around rapidly, cross over to other electrons and radiate energy. The middle of the atom comprises the positively charged nucleus. All but one of the two thousand parts of the mass of an atom resides in this central nucleus. The positives, too heavy to be easily stirred, tend to stay at home and form the templates of solidity. This asymmetry in mass is crucial for the structure of materials.

Life appears to thrive on mirror asymmetry, a distinction between left and right in the basic structures of organic molecules. Water proteins and DNA all have shapes that differ from their mirror images. Superficially identical in all respects but for the interchange of left and right, one might have reasonably expected that both forms would be equally abundant in nature. However, it is not so; life is mirror asymmetric. This is not simply a matter of there being more right handers than left, or even of our heart and stomach being found, usually, on our left side. The amino acids and molecules of life in one form have the ability to know that they exist and to be cogniscent of the universe; their mirror images are inorganic, lifeless. Life chooses one form while the mirror image is rejected.

The deeper one looks, the more asymmetry becomes apparent and seemingly necessary for anything 'useful' to have emerged. And yet, seemingly deeper still, everything emerges symmetrical once more. The focus of much current research is to understand how nature hides symmetry, producing structured patterns out of underlying uniformity.

iii-Simplicity

For practical reasons, scientists are always looking to explain things according to the most simple formula possible. This allows complex things with many variables to become easily manageable and usable. But, there is no reason to expect that everything in the universe can be so reduced and that because a scientific theory is simpler than another it is therefore more true. Yet, scientists believe just that. From a purely scientific point of view, there is no rational reason why the world should be explained according to simpler rather than more complicated formula. Ironically, in fact, the Church argued with Copernicus that the fact that his theory was simpler (and more elegant) was no indication that it was more true. (Copernicus had proposed a heliocentric system of planetary motion in contrast to the

Scientific American July 2002 Uncovering Supersymmetry, By Jan Jolie:

Symmetry principles occur through physics, often in ways that one wouldn't expect. For example, the law of conservation of energy can be derived from a symmetry principle involving the flow of time. The equations governing elementary particle physics are fundamentally based on symmetries.

Einstein's theory of special relativity is a theory of the symmetries of empty space and time. Effects such as length contraction and time dilations, which flatten fast-moving clocks and make them run slow, are operations of the symmetry group, similar to rotating your point of view in space, but with time as part of the "rotations." The fundamental forces are dictated by symmetries called gauge symmetries. Conservation of electric charge is a consequence of yet another symmetry.

Supersymmetry is a remarkable symmetry. In elementary particle physics, it interchanges particles of completely dissimilar types, the kind called fermions (such as electrons, protons and neutrons), which make up the material world, and those called bosons (such as photons), which generate the forces of nature. In quantum physics particles are divided into bosons and fermions. The underlying difference between bosons and fermions is this: in a collection of particles, if two identical fermions are swapped (for instance, switch two electrons), the total quantum state of the collection is inverted. (Imagine crests and troughs of a wave being interchanged.) Swapping two identical bosons, in contrast, leaves the total state unaltered. Those characteristics lead to the Pauli exclusion principle, which prevents two fermions from occupying the same state, and to bosons' propensity to collect together in a common state, as in laser beams and Bose-Einstein condensates. Bosons, in contrast, prefer to collect in identical states, as demonstrated by helium 4 atoms in a superfluid. Another way of saying this is as follows: Fermions are inherently the individualists and loners of the quantum particle world: no two fermions ever occupy the same quantum state. Their aversion to close company is strong enough to hold up a neutron star against collapse even when the crushing weight of gravity has overcome every other force of nature. Bosons, in contrast, are convivial copycats and readily gather in identical states. Every boson in a particular state encourages more of its species to emulate it. Under the right conditions, bosons form regimented armies of clones, such as the photons in a laser beam or the atoms in superfluid helium 4.

Yet somehow in the mirror of supersymmetry, standoffish fermions look magically like sociable bosons, and vice versa. Figuratively, you might say it is a symmetry that lets you compare apples and oranges. Hold up an apple to the supersymmetry mirror, and its reflection looks and tastes like an orange.

In the 1980s nuclear theorists predicted that a different form of supersymmetry could exist in certain atomic nuclei. Nuclei with even numbers of protons and neutrons and those with odd numbers.

By mapping bosons onto fermions, and vice versa, supersymmetry opens up a new class of possible relations among particles. These relations result in far greater computational power for analyzing or predicting a system's behavior.

The symmetries predicted are of a special type known as dynamical symmetries. Ordinary symmetries look the same when viewed in a mirror. Your left hand is approximately the mirror image of your right hand. Dynamical symmetries, in contrast, relate not to the objects themselves but to the equations that govern the dynamics of the objects.

For the known particles to obey supersymmetry, they must each have a "superpartner" – every boson must have a fermionic counterpart, and vice versa. The known particles do not have the right properties to be one another's partners, so new particles are predicted. The Standard Model is extended to the supersymmetric standard model. The postulated fermionic partners go by the names photino, gluino, Wino, Zino, gravitino and higgsino. The bosonic partners have an "s" added to their names: selectron, smuon, sneutrino, squark and so on. None of these particles have yet been

Church-accepted doctrine of Ptolemy's ingenious and accurate but very complicated system of circles and sub-circles, with different radii, tilts and different amounts and directions of eccentricity.)

iv-Paradigms

In E vi above, we showed that sometimes an old theory continues to be used even when it has been disproven either because it continues to be accurate enough and simpler than the newer theory (Newtonian physics), because a newer theory has yet to be found, or because the scientific community has such faith in the theory that it ignores the challenges to that theory and believes that the challenge will somehow be answered at some future date. In addition to all of this we have shown that science uses certain beliefs (unity, simplicity and beauty) which are simply unproven axioms. "Science repudiates philosophy. In other words, it has never cared to justify its faith or explain its meaning."¹

All of this goes into what Thomas Kuhn calls the paradigm of science. Within quiet periods, only certain types of questions are considered legitimate within the scientific community and therefore only certain types of answers are going to be given. Kuhn states that these are essentially puzzles, problems that do not bring the overall paradigm into question. A paradigm is therefore not simply a scientific theory or set of theories; it is rather a whole way of looking at the world. It is sometimes very difficult for scientists to imagine anything outside of their paradigm. Thus in 1894 Albert Michelsen, the great physicist who first determined the speed of light, stated: "the more fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is extremely remote. Our future discoveries must be looked for in the sixth place of decimals." Within 30 years of his statement, almost every major scientific theory which he held dear had been overturned. A specific paradigm continues until anomalies within the paradigm build up and a revolutionary paradigm, like Einstein's theory of relativity, is proposed. The old paradigm is not just discarded. The new paradigm has to battle the old, and in fact, a correct theory may initially be rejected by the majority of the scientific community who find it too radical for the thinking of the time. Examples of such new theories include Thomas Young's wave theory of light; Pasteur's fermentation; Mendel's theory of genetics; Louis Pasteur's germ theory of disease; Joseph Lister's discovery of antiseptis; Ignaz Semmelweis' washing hands before examining patients!

Young scientists usually propose and accept the new paradigm while older ones adhere to the old paradigm. Max Planck, one of the discoverers of quantum theory, claimed that the old ideas die only with those who hold them.

(Paul Feyerabend (Against Method) has taken this even further, claiming that non-rational factors are dominant in science. However, most scientists do not agree with this radical approach. See Appendix H iii for further discussion.)

Joao Maguijo wrote the following article in Scientific American January 2001, *Plan B for the Cosmos*:

...Dethroning the constancy of G has been exquisitely fashionable. In contrast, the speed of light, c , has remained inviolate. The reason is clear: the constancy of c and its status as a universal speed limit are the foundations of the theory of relativity. And relativity's spell detected.

¹Bertrand Russel, *The Will to Doubt*, p. 65

is so strong that the constancy of c is now woven into all the mathematical tools available to the physicist. “Varying c ” is not even a swear word; it is simply not present in the vocabulary of physics.

Inflation...Its key insight is that for a light wave in an expanding universe, the distance from the starting point is greater than the distance traveled. The reason is that expansion keeps stretching the space already covered...Seemingly disjointed regions could thus have communicated with one another and reached a common temperature and density. When the inflationary expansion ended, these regions began to fall out of touch.

The same thing could have been achieved if light had simply traveled faster in the early universe than it does today. As the speed of light slowed, those regions would have fallen out of contact.

APPENDIX 3: THE BIG BANG

i-The State of Cosmology Today

ii-Description

iii-Proofs for the Big Bang theory

a-Red Shift - Dopler Effect

b-Radio Waves showed changes in universe

c-Cosmic Background Radiation

d-COBE

e-Entropy

f-Composition of the Universe

iv-Reactions to the Discovery of the Big Bang.

v-Inflationary Theory

vi-What happened before the Big Bang?

vii-What happened after the Big Bang?

viii-A Narrative Description of the Discovery of the Big Bang

ix-Is the Universe still expanding and how will it end?

APPENDIX 3: THE BIG BANG

i-The State of Cosmology Today

Reflecting on the state of cosmology today, Dennis Overbye¹ made the following comment: *“Until the 21st Century it was easy to make fun of cosmologists, pronouncing judgment on the fate of the universe or the behavior of galaxies billions of light-years away, with only a few scraps of light as evidence.*

“In the last few years, blessed with new instruments like the Hubble Space Telescope and other space-based observatories, a new generation of their giant cousins on the ground and ever-faster computer networks, cosmology is entering ‘a golden age’ in which data are finally outrunning speculation.

“As a result, cosmologists are beginning to converge on what they call a ‘standard model’ of the universe that is towering in its ambition. It purports to trace, at least in broad strokes, cosmic history from the millisecond after time began, when the universe was a boiling stew of energy and subatomic particles, through the formation of atoms, stars, galaxies and planets to the vast, dilute, dark future in which all of these will have died.

“The universe, the cosmologists say, was born 14 billion years ago² in the Big Bang. Most of its material remains reside in huge clouds of invisible so-called dark matter³, not yet identified.

“A good case can be made, scientists now agree, that the universe will go on expanding forever and may even be speeding up over time, under the influence of a ‘dark energy’ even more mysterious than dark matter.”

Cosmologists now appear to be answering some of the major questions that they have had since the 1920's. On the other hand, as recently as July 2002, Dr. Marc Davis, a cosmologist at the University of California at Berkeley, called it *“a universe chock full of exotics that don't make sense to anybody.”*

Moreover, there are some questions that scientists still do not know how to ask, let alone answer, scientifically. Was there anything before the Big Bang? Is there a role for life in the cosmos? Why is there something rather than nothing at all? Will we ever know?

“We know much, but we still understand very little,” said Dr. Michael Turner, a cosmologist at the University of Chicago.

¹NY Times, July, '02

²Recently, a group of astronomers led by Dr. William Percival at the University of Edinburgh is 13.89 billion years old, plus or minus half a billion years

³Only 4.8 percent of it is made of ordinary matter. Matter of all types, known and unknown, luminous and dark, accounts for just 27.5 percent. The rest of creation, 72.5 percent, is the mysterious dark energy.

ii-Description

This theory postulates that all matter exploded outwards from a super hot point at the beginning of measurable time¹. Within seconds, this process slowed and matter began to cool², but the universe continues to expand to this day.

Prior to the Big Bang Theory, the accepted scientific theory was the Steady-State Theory, which held that the world had always existed.

“The Big Bang...was not an event which occurred within the universe; it was the coming-into-being of the universe, in its entirety, from literally nothing”³. Everything (all matter, energy, space and time) came into being at that precise instant. Scientists think they can describe what the detailed conditions of the early universe were, instant by instant, from when it was 10^{-35} seconds old. They cannot explain (although there have been some attempts) what happened before then, and especially how matter, energy, space and time could come out of nothing.

The Big Bang Theory does not mean that we can identify a center of the universe. This would only be so if there was something akin to an explosion into an already existing void. But there was no such void. Space itself was created by the Big Bang. Therefore, the universe expands equally in every place, with no identifiable center.

The universe may expand forever, in which case all the galaxies and stars will eventually grow dark and cold. The alternative to this big chill is a big crunch. If the mass of the universe is large enough, gravity will eventually reverse the expansion, and all matter and energy will be reunited. During the next decade, as researchers improve techniques for measuring the mass of the universe, we may learn whether the present expansion is headed toward a big chill or a big crunch⁴.

iii-Proofs for the Big Bang Theory

¹Fred Hoyle, an English cosmologist, was the first to call this process the big bang. Hoyle intended to disparage the theory, but the name was so catchy it gained popularity. It is somewhat misleading, however, to describe the expansion as some type of explosion of matter away from some particular point in space. Rather, what is happening is the unfolding of space itself. The expansion is similar to a rising loaf of raisin bread. The dough is analogous to space, and the raisins, to clusters of galaxies. As the dough expands, the raisins move apart. Moreover, the speed with which any two raisins move apart is directly and positively related to the amount of dough separating them.

²At a particular instant roughly 12 billion years ago, all the matter and energy we can observe, concentrated in a region smaller than a dime, began to expand and cool at an incredibly rapid rate. By the time the temperature had dropped to 100 million times that of the sun's core, the forces of nature assumed their present properties, and the elementary particles known as quarks roamed freely in a sea of energy. When the universe had expanded an additional 1,000 times, all the matter we can measure filled a region the size of the solar system.

At that time, the free quarks became confined in neutrons and protons. After the universe had grown by another factor of 1,000, protons and neutrons combined to form atomic nuclei, including most of the helium and deuterium present today. All of this occurred within the first minute of the expansion. Conditions were still too hot, however, for atomic nuclei to capture electrons. Neutral atoms appeared in abundance only after the expansion had continued for 300,000 years and the universe was 1,000 times smaller than it is now. The neutral atoms then began to coalesce into gas clouds, which later evolved into stars. By the time the universe had expanded to one fifth its present size, the stars had formed groups recognizable as young galaxies. When the universe was half its present size, nuclear reactions in stars had produced most of the heavy elements from which terrestrial planets were made. Our solar system is relatively young: it formed five billion years ago, when the universe was two thirds its present size.

³Davies-Superforce, pg. 16

James Peebles, a leading cosmologist, wrote the following in *Scientific American*¹ as part of a larger article:

“Over the past 70 years, we have gathered abundant evidence that our universe is expanding and cooling. First, the light from distant galaxies is shifted toward the red, as it should be if space is expanding and galaxies are pulled away from one another. Second, a sea of thermal radiation fills space, as it should if space used to be denser and hotter. Third, the universe contains large amounts of deuterium and helium, as it should if temperatures were once much higher. Fourth, galaxies billions of years ago look distinctly younger, as they should if they are closer to the time when no galaxies existed. Finally, the curvature of space-time seems to be related to the material content of the universe, as it should be if the universe is expanding according to the predictions of Einstein's gravity theory, the general theory of relativity.

“That the universe is expanding and cooling is the essence of the big bang theory. You will notice I have said nothing about an ‘explosion’--the big bang theory describes how our universe is evolving, not how it began.

“Cosmologists are still scratching their heads as evidence continues to mount that our universe is unlike anything we imagined only a few years ago: The universal expansion is accelerating rather than slowing down. Some mysterious, repulsive ‘dark energy’ seems to fuel the acceleration, overpowering the tendency of the expansion to decelerate. But scientists are not sure what is this dark energy is.”

a-Red Shift - Doppler Effect

From 1913-1925, Vesto Slipher began to discover that many galaxies in the universe are expanding away from us at great speeds. In 1923, Edwin Hubble showed that the whole universe is expanding in every direction at a uniform rate (which is now known as the Hubble Constant)². The further away from us a star is, the faster it is speeding away from us. This means that at some stage in the past all of the universe must have been contracted together.

¹January, 2001

²Hubble's measurements indicated that the redshift of a distant galaxy is greater than that of one closer to Earth. This relation, now known as Hubble's law, is just what one would expect in a uniformly expanding universe. Hubble's law says the recession velocity of a galaxy is equal to its distance multiplied by a quantity called Hubble's constant. The redshift effect in nearby galaxies is relatively subtle, requiring good instrumentation to detect it. In contrast, the redshift of very distant objects--radio galaxies and quasars--is an awesome phenomenon; some appear to be moving away at greater than 90 percent of the speed of light.

Hubble contributed to another crucial part of the picture. He counted the number of visible galaxies in different directions in the sky and found that they appear to be rather uniformly distributed. The value of Hubble's constant seemed to be the same in all directions, a necessary consequence of uniform expansion. Modern surveys confirm the fundamental tenet that the universe is homogeneous on large scales. Although maps of the distribution of the nearby galaxies display clumpiness, deeper surveys reveal considerable uniformity.

The Milky Way, for instance, resides in a knot of two dozen galaxies; these in turn are part of a complex of galaxies that protrudes from the so-called local supercluster. The hierarchy of clustering has been traced up to dimensions of about 500 million light-years. The fluctuations in the average density of matter diminish as the scale of the structure being investigated increases. In maps that cover distances that reach close to the observable limit, the average density of matter changes by less than a tenth of a percent.

To test Hubble's law, astronomers need to measure distances to galaxies. One method for gauging distance is to observe the apparent brightness of a galaxy. If one galaxy is four times fainter than an otherwise comparable galaxy, then it can be estimated to be twice as far away. This expectation has now been tested over the whole of the visible range of distances.

The movement of stars away from the earth causes them to have a reddish color (they shift towards the red side of the color spectrum). The farther away a star is from the earth the faster it is moving away, and thus the greater the Red Shift. This is similar to the pitch of a siren, as it gets higher as it approaches us and lower after it passes us. As the sound wave must travel farther to reach us, each subsequent wavelength of the sound gets longer. Similarly, with light, the wavelength of light from a galaxy which is moving away from us is stretched towards the longest or reddest wavelength.

b-Radio waves showed changes in universe

In the early 60's, Martin Ryle and his colleagues at Cambridge found that there were many more sources of radio waves far away than nearby. According to the astronomers' way of measuring time, radio waves from these distant objects had taken billions of years to reach us. They were therefore emitted from their source when the universe was at a much earlier stage, giving us a picture of what the universe looked like at that time. The fact that the universe then looked so different from the way it looks to us today ran counter to a Steady State theory.

c-Cosmic Background Radiation

In 1965, Arno Penzias and Robert Wilson of Bell Labs discovered a continuous, faint afterglow radiation of 3 degrees above absolute zero from the intensely hot Big Bang spread evenly over the entire universe.

Penzias and Wilson made this discovery completely by accident: The measurements showed that the earth itself could not be the source of this radiation, nor could the radiation be coming from the direction of the moon, the sun or any other particular object in the sky. The entire universe appeared to be the source. The radiation that Penzias and Wilson discovered has exactly the wavelengths expected for the light and heat produced in a great explosion.

Recent satellite readings of the background radiation (see COBE below) fall within better than 99.9 percent of what the theory predicts.

This radiation is known as the cosmic microwave background (CMB) radiation. Because this radiation was emitted nearly 15 billion years ago and has not interacted significantly with anything since then, getting a clear picture of the CMB is equivalent to drawing a map of the early universe¹.

Some critics of the theory have pointed out that a galaxy that appears to be smaller and fainter might not actually be more distant. Fortunately, there is a direct indication that objects whose redshifts are larger really are more distant. The evidence comes from observations of an effect known as gravitational lensing [see illustration on opposite page]. An object as massive and compact as a galaxy can act as a crude lens, producing a distorted, magnified image (or even many images) of any background radiation source that lies behind it. Such an object does so by bending the paths of light rays and other electromagnetic radiation. So if a galaxy sits in the line of sight between Earth and some distant object, it will bend the light rays from the object so that they are observable [see "Gravitational Lenses," by Edwin L. Turner; Scientific American, July 1988]. During the past decade, astronomers have discovered about two dozen gravitational lenses. The object behind the lens is always found to have a higher redshift than the lens itself, confirming the qualitative prediction of Hubble's law.

d-COBE

The signal of the cosmic microwave background (CMB) looks almost identical in every direction. The ubiquity and constancy of the CMB is a sign that it comes from a simpler past, long before structures such as planets, stars and galaxies formed

The discovery of Cosmic Background Radiation spurred astronomers to obtain two crucial sets of observations that would reveal some of the basic details of how the universe was born. The first goal was to measure the spectrum of the cosmic radiation to determine whether it matched the ideal-radiator shape predicted by nearly all cosmological theories. The second goal, even more challenging, was to find small amounts of radiation arriving from different directions in space. These differences would have arisen from tiny local inequalities in the density of matter during the period when photons separated from each other and atoms began to form. Theorists believed such variations were the “seeds” that led to the formation of galaxies. To test these theories, the COBE (Cosmic Background Explorer) was launched in 1989.

COBE detected slight variations (at the level of one part in 100,000) in the temperature of the CMB from place to place in the sky, the key to understanding the origin of structure in the universe: how the primordial plasma evolved into galaxies, stars and planets. These variations provide evidence of small lumps and bumps in the primordial plasma. These later evolved into the large-scale structures of the cosmos: the galaxies and galaxy clusters that exist today.

By 1992, COBE had confirmed both observations, leading one of the collaborators, George Smoot, to say about the differences in intensity of radiation, “If you're religious, it's like looking at G-d.”¹

Another satellite, the Wilkinson Microwave Anisotropy Probe (WMAP), launched in 2001, travels around the sun in an orbit 1.5 million kilometers beyond Earth's orbit. The results from WMAP reveal that the CMB temperature variations follow a distinctive pattern predicted by cosmological theory: the hot and cold spots in the radiation fall into characteristic sizes. What is more, researchers have been able to use this data to precisely estimate the age, composition and geometry of the universe. The process is analogous to determining the construction of a musical instrument by carefully listening to its notes².

In the late 1990s, several ground-based and balloon-borne detectors observed the CMB with much finer angular resolution than COBE did. The observations are also consistent with the theory of inflation, according to which there was a period of phenomenally rapid expansion in the first few moments after the big bang (10^{-38} of a second)³. **This year, the National Aeronautics and Space Administration plans to launch** the Microwave

¹Scientific American, March '97, pg. 110-112

²The above 3 paragraphs are based on Wayne Hu and Martin White, The Cosmic Symphony in Scientific American, February 2004

³The strongest evidence for inflation would be the observation of inflationary gravitational waves. In 1918 Albert Einstein predicted the existence of gravitational waves as a consequence of his theory of general relativity. Just as x-rays allow doctors to peer through substances that visible light cannot penetrate, gravitational waves should allow researchers to view astrophysical phenomena that cannot be seen otherwise. Gravitational waves have never been directly detected. The plasma that filled the universe during its first 500,000 years was opaque to electromagnetic radiation, because any emitted photons were immediately scattered in the soup of subatomic particles. Therefore, astronomers cannot observe any electromagnetic signals dating from before the CMB. In contrast, gravitational waves could propagate through the plasma.

Anisotropy Probe (MAP), which will extend the precise observations of the CMB to the entire sky. The European Space Agency's Planck spacecraft, scheduled for launch in 2007, will conduct an even more detailed mapping¹.

e-Entropy

Clausius' second law of thermodynamics is the law of entropy, i.e. that every day the universe becomes more and more disordered. This is considered an irreversible process. Although we may see some things, like plants, developing into a high state of order, that is only at the expense of the universe as a whole.

If one would put some chemicals in a closed jar, some of the chemicals may react, some heat may be produced, some of the chemicals may change into others, etc. Eventually, the contents of the jar settle down at a uniform temperature and nothing further happens. The jar has now reached its state of maximum entropy (known as thermodynamic equilibrium).

Since the universe is still highly ordered and was even more ordered in the past, it follows that the universe could not have existed forever; otherwise, it would have reached its state of maximum entropy a long time ago. It follows, then, that at some time in the past the universe must have been fully wound up, which was probably at the time of the Big Bang.

Scientists presume as a matter of course that all laws apply all over the universe and, in fact, this has generally shown to be true. Therefore, it is presumed that gravity will work the same way on the opposite side of the cosmos as it does here. Thus it is a curious fact that entropy, although it was known since Newton's time, was never applied in this way until many other proofs for the Big Bang had been supplied. If scientists would have admitted, in

¹A telescope in eastern Australia has seen what appear to be the faint imprint of waves, much like sound waves, that may have rippled through the gases of the young universe. Scientists have long theorized such waves were the seeds for all structures glittering in the heavens today.

The imprints were revealed within the clumps and filamentary patterns formed by tens of thousands of galaxies that the telescope observed in Earth's cosmic neighborhood. The findings ... have emerged from the largest and most detailed mapping of galaxies ever made, including the positions of nearly 170,000 galaxies.

Scientists found that hidden in the irregular clumps and filaments were imprints of waves of particular sizes, or wavelengths, that cosmologists believe were generated in the explosive birth of the universe. The waves are thought to have seeded the primordial gases with slight irregularities that later grew into galaxies and clusters.

If confirmed, the observations would be scientists' first direct glimpse of what amounts to a blueprint for the structure of the universe.

A much larger survey now in progress, called the Sloan Digital Sky Survey and involving the United States, Germany and Japan, would among other things determine about a million galaxy positions over the next several years.

The problem of how structures like galaxies and galaxy clusters could have formed has persistently bedeviled scientists working out the theory of the Big Bang, the great explosion in which the universe apparently began. Early measurements of the cosmic background radiation, emitted from the hot gases of the young universe, seemed to show that it was nearly smooth and featureless, with no irregularities that could have spawned lumpy structures like galaxies.

But in 1992, a NASA satellite called the Cosmic Background Explorer satellite, or COBE, made highly sensitive measurements of the radiation and saw minute temperature variations suggesting the existence of so-called acoustic waves sloshing in the early universe.

Subsequently, measurements of the radiation have turned up a series of discrete "tones," or wavelengths, that theorists have predicted should have been generated in the explosion. But while those waves are thought to have been the seeds that allowed galaxies and other structures to coalesce, no direct evidence for the waves had until this point turned up in the confusion of the present-day heavens. (Based on an article in the NY Times, May, 2001)

defiance of the law of entropy, that the universe was wound up at some stage, the next logical question would then have been who or what wound it up.

f-Composition of the Universe

Atom smashers which push subatomic particles to extremely high energies produced results that allowed researchers to calculate that the early universe should have been about three-quarters hydrogen and one-quarter helium. When astronomers inspect the oldest stars and nebulae, they find them composed of almost exactly that mix.

On January 9, 2003, astronomers reported seeing what they think are some of the earliest known objects in the universe, including the most distant quasar ever detected.

The faint light of 26 young galaxies and three quasars, objects thought to be powered by super-massive black holes, were observed at a distance of some 13 billion light-years, at the time the universe was less than a billion years old and apparently just emerging from an epoch of utter darkness.

The observations were made by two groups of astronomers, one using infrared images from the Sloan Digital Sky Survey and the other analyzing new photographs from the Hubble Space Telescope.

In current theory, after its creation in the Big Bang about 14 billion years ago, the expanding universe cooled down and became opaque. No light could beam through the omnipresent neutral hydrogen. Sometime during that dark age (the timing is one of cosmology's big mysteries), stars and galaxies began forming and their ultraviolet light eventually cleared away the neutral hydrogen and the opacity. It was the beginning of a universe of starry nights.

iv-Reactions to the Discovery of the Big Bang

Robert Jastrow, a famous astronomer who claims to be an agnostic, describes how resistant the scientific community was to accepting the Big Bang because it seemed to point to a creation by G-d: "... the reaction from the astronomical community ranged from skeptical to hostile."¹

This huge initial resistance to the theory was based purely on the dominant secular biases of the time. (See L. Kelemen, Permission to Believe, the Cosmological approach.) One such skeptic was Einstein himself. Willem de Sitter and Alexander Friedmann showed two separate solutions from Einstein's Theory of General Relativity predicting an exploding universe. Einstein, however, objected to both of them, making two very basic, totally uncharacteristic errors in mathematics in doing so. He ignored Friedmann's letter to him proving Friedmann's assertion and responded to the scientific journal that published Friedmann's result, saying that these results were suspicious. Einstein was later forced to admit his error, and after Edwin Hubble had proven the issue quite decisively (see below), he accepted the expanding universe as true. Nevertheless, he was still to write to de Sitter, "This circumstance [of an expanding Universe] irritates me." In another letter he stated, "To admit such a possibility seems senseless."

¹G-d and the Astronomers, pg. 17

On this, Jastrow¹ comments: "This is curiously emotional language for a discussion of some mathematical formulas. I suppose the idea of a beginning in time annoyed Einstein because of its theological implications. We know he has a well-defined feeling about G-d, but not as the Creator or the Prime Mover. ... When Einstein came to New York in 1921, a Rabbi sent him a telegram asking, 'Do you believe in G-d?' and Einstein replied, 'I believe in Spinoza's G-d, who reveals himself in the orderly universe of what exists.'"

Still others held onto the steady-state theory until the 1960's, when the evidence for the Big Bang theory became overwhelming. Today, all scientists accept some version of the theory.

One of the world's leading astronomers, Allan Sandage, stated that contemplating the majesty of the Big Bang helped make him a believer in G-d, willing to accept that Creation could only be explained as a miracle. (U.S. News & World Report, July 20, 1998)²

v-Inflationary Theory

The newer Inflationary Theory is a modification of the Big Bang Theory. The Theory of Inflation was first proposed by Alan H. Guth of Stanford³ in 1979 and is quite widely supported by scientists today. Inflation states that there was a time, very soon after the Big Bang, when gravity, instead of attracting objects to each other, reversed itself and repulsed objects from each other instead. This caused the universe to undergo a stupendous growth spurt for a brief period before gravity reversed itself again and the universe settled down into the type of expansion we see today⁴. The result of these gravity reversals is that the world does not always expand at an even rate. There was, in the beginning, a period of very rapid expansion due to what is called a negative vacuum. A vacuum creates energy which pushes outwards and counteracts any gravity which pulls in the opposite direction. At a later stage,

¹pg. 29

²In the PBS science special: "The Creation of the Universe", Sandage, who was once a student of Hubble and continued most of his career at the Mt. Palomar Observatory continuing Hubble's work was interviewed. Commenting on the scientific fact of the "Big Bang," the beginning of the expansion, he said, "As astronomers, you can't say anything except, 'Here is a miracle, what seems -- what seems almost supernatural -- an event which has come across the horizon into science, through the Big Bang.' Can you go the other way back, outside the barrier? Can you finally find the answer [to the question] 'Why is there something and not nothing?' No, you cannot, not from within science. But it still remains an incredible mystery: Why is there something instead of nothing?"

³Now at MIT

⁴A way to understand this is to consider water as it freezes. Under some circumstances, a glass of water can stay liquid as the temperature falls below 32 degrees, until it is disturbed, at which point it will rapidly freeze, releasing latent heat in the process. Similarly, the universe could "supercool" and stay in a unified state too long. In that case, space itself would become temporarily imbued with a mysterious kind of latent heat, or energy.

Inserted into Einstein's equations, the latent energy would act as a kind of antigravity, and the universe would blow itself apart, Dr. Guth discovered in a calculation in 1979.

In far less than the blink of an eye, 10⁻³⁷ second, a speck much smaller than a proton would have swollen to the size of a grapefruit and then resumed its more stately expansion, with all of normal cosmic history before it, resulting in today's observable universe — a patch of sky and stars 14 billion light-years across. All, by the magical-seeming logic of Einstein's equations, from about an ounce of primordial stuff.

"The universe," Dr. Guth liked to say, "might be the ultimate free lunch."

Dr. Guth called his theory inflation. Inflation, as Dr. Guth pointed out, explains why the universe is expanding. Dr. Turner of the University of Chicago referred to it as "the dynamite behind the Big Bang." (Dennis Overbye, NY Times, July, '02)

this vacuum energy was used up and the world slowed down to the type of expansion we see today.

Inflation explained many problems which the standard Big Bang model cannot, including the uniformity of the afterglow of the universes, the fact that space is relatively flat instead of curved¹ and why the universe contains lumps of matter in the form of stars and galaxies².

Inflation has some problems and therefore there are a number of different inflation theories, none of which has emerged as the decisive one.³

vi-What Happened before the Big Bang?

The Big Bang presumes that there was an explosion from an infinitely dense particle. Where, however, did that first particle come from?

Robert Jastrow writes as follows⁴:

“A few scientists bit the bullet and dared to ask, ‘What came before the beginning?’ Edmund Whittaker, a British physicist, wrote a book on religion and the new astronomy called The Beginning and End of the World, in which he said, ‘There is no ground for supposing that matter and energy existed before and was suddenly galvanized into action. For what could distinguish that moment from all other moments in eternity?’ Whittaker concluded, ‘It is simpler to postulate creation ex nihilo - Divine Will constituting Nature from nothingness.’ Some scientists were even bolder and asked, ‘Who was the Prime Mover?’ The British theorist Edward Milne wrote a mathematical treatise on relativity which concluded by saying, ‘As to the first cause of the Universe, in the context of expansion, that is left for the reader to insert, but our picture is incomplete without Him.’

“But the views of most physicists and astronomers were closer to that of St. Augustine, who, asking himself what G-d was doing before He made Heaven and Earth, gave the reply, ‘He was creating Hell for people who asked questions like that.’ In fact, some prominent scientists began to feel the same irritation over the expanding Universe that Einstein had expressed earlier. Eddington wrote in 1931, ‘I have no ax to grind in this discussion,’ but ‘the notion of a beginning is repugnant to me ... I simply do not believe that the present order of things started off with a bang ...the expanding Universe, is preposterous ... incredible ... it leaves me cold.’ The German chemist, Walter Nernst, wrote, ‘to deny the infinite duration of time would be to betray the very foundations of science.’

¹If the inflationary theorists are right, the universe we see, the 14 billion light-years, is just a tiny piece of a much vaster universe, or even a whole ensemble of them, forever out of our view. According to the theory, therefore, our own little patch of the cosmos should appear geometrically “flat,” the way a section of a balloon looks flat when viewed close up. This was the universe long thought to be the most beautiful and simple.

²The universe does need a tiny bit of lumpiness for matter to gather around and form stars and planets, etc. However, the evenness of the universe is only at a macro level. On the smallest scales, according to quantum theory, nature is lumpy, emitting even energy in little bits and subject to an irreducible randomness. As a result, so-called quantum fluctuations would leave faint lumps in the early universe. These would serve as the gravitational seeds for future galaxies and other cosmic structures.

In 1992, the Cosmic Background Explorer, or COBE, satellite discerned faint blotches in the primordial cosmic radio glow. This was later confirmed by the Hubble Telescope. These were the seeds from which, inflation predicted, large cosmic structures would eventually grow.

“If you’re religious, it’s like seeing God,” said Dr. George Smoot, a physicist from the Lawrence Berkeley National Laboratory who led the COBE team.

³ Scientific American, June 1997, pg. 15 & 16

⁴ pg. 121-5

More recently, Phillip Morrison of MIT said in a BBC film on cosmology, 'I find it hard to accept the Big Bang theory; I would like to reject it.' And Allan Sandage of Palomar Observatory, who established the uniformity of the expansion of the Universe out to nearly ten billion light years, said, 'It is such a strange conclusion ... it cannot really be true.'

"There is a strange ring of feeling and emotion in these reactions. They come from the heart, whereas you would expect the judgments to come from the brain. Why?"

"I think part of the answer is that scientists cannot bear the thought of a natural phenomenon which cannot be explained, even with unlimited time and money. There is a kind of religion in science; it is the religion of someone who believes there is order and harmony in the Universe. Every event can be explained in a rational way as the product of some previous event: every event must have its cause: there is no First Cause. Einstein wrote that the scientist is possessed by the sense of universal causation. This religious faith of the scientist is violated by the discovery that the world had a beginning under conditions in which the known laws of physics are not valid and as a product of forces or circumstance we cannot discover. When that happens, the scientist has lost control. If he really examined the implications, he would be traumatized. As usual when faced with trauma, the mind reacts by ignoring the implications - in science this is known as "refusing to speculate" - or trivializing the origin of the world by calling it the Big Bang, as if the Universe were a firecracker.

"Consider the enormity of the problem. Science has proven that the Universe exploded into being at a certain moment. It asks: What cause produced this effect? Who or what put the matter and energy into the Universe? Was the Universe created out of nothing or was it gathered together out of pre-existing material? And science cannot answer these questions, because, according to the astronomers, in the first moments of its existence, the Universe was compressed to an extraordinary degree and consumed by the heat of a fire beyond human imagination. The shock of that moment must have destroyed every particle of evidence that could have yielded a clue to the cause of the great explosion. An entire world, rich in structure and history, may have existed before our Universe appeared; but if it did, science cannot tell what kind of a world it was. A sound explanation may exist for the explosive birth of our Universe; but if it does, science cannot find out what the explanation is. The scientist's past ends at the moment of creation.

"... For the scientist who has lived by his faith in the power of reason, the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak, as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries."

Since Robert Jastrow wrote these words, the Big Bang has become a part of scientific orthodoxy and scientists have begun to ask themselves what happened before the Big Bang. The more fundamental question of why there is something at all evokes wild theorizing (and a lot of poor philosophizing) on the part of physicists who are clearly not trained to think rigorously on these issues, and, as Jastrow points out, poorly equipped emotionally. But even the simpler issue of just how things came about originally is highly problematic for the scientific community.

Some scientists have stated that since the first particle was a singularity (see **Appendix F-ii Black Holes**), all the laws of physics break down and it is therefore beyond the parameters of science. Yet others claim that the Big Bang detonation itself destroyed all possible information about the prior state of the universe, and therefore the question of what came before was moot. Hence Astronomer Royal, Martin Rees of Cambridge University: "I am relatively confident science can understand what happened after the first millisecond of creation, because we see the fossils, such as the amount of helium in the universe, and these

fossils are roughly what theories predict. But before one millisecond there is a barrier to understanding, where we understand little about what the relevant physics might have been.”¹

Cosmologist Allan Sandage (whom Jastrow quotes): “The most amazing thing to me is existence itself. Why is there something instead of nothing?” This impenetrable mystery, he said, drove him to be a believer. “How is it that inanimate matter can organize itself to contemplate itself? That's outside of any science I know.”

To this Stephen Hawking responds: “Some people feel that ... the question of the initial situation (is) a matter for metaphysics or religion. They would say that G-d, being Omnipotent, could have started the universe off any way He wanted. That may be so, but in that case He also could have made it develop in a completely arbitrary way. Yet it appears that He chose to make it evolve in a very regular way according to certain laws. It therefore seems equally reasonable to suppose that there are also laws governing the initial state”².

Many scientists have made elaborate theories which show how the universe could have produced something out of nothing. None of these theories have a shred of evidence, the scientists themselves admitting that they are engaged in pure speculation.

Stephen Hawking has proposed a “no-boundary universe”, i.e. a universe which is closed in the shape of a sphere only in four dimensions. Such a sphere would be finite³ (being

¹U.S. News and World Report July 20, 1998

²A Brief History of Time, pg. 11

a sphere, it meets up with itself instead of just spreading out further and further). However, to get over current evidence which seems to point to an open universe, Hawking had to say that the universe is both a sphere and a horn shape simultaneously, depending on one's point of view (i.e. at what point he took a slice of the universe). All Hawking gains with this complicated model, however, is the ability to explain how the laws of physics as we know them today could have applied to the universe from the very beginning. It still does not explain how the first matter got there.

Some theorists let their imagination go further, claiming that there is a concept called a "Mother Universe", a timeless dimension that has always existed and always will, bearing daughter universes down an endless corridor of time. One attempt to do this invokes the inflationary model of the Big Bang. According to this, the inflationary period of the Big Bang came as a result of a (negative) vacuum and the pressure of this vacuum produced the enormous energy which led to the Big Bang (see iv above - Inflationary Theory). These theorists use the fact that particles (called virtual particles) often appear to pop out of nowhere in empty space, as well as the similarly non-understandable idea of quantum fluctuations. But, this just ends up explaining one thing we do not understand (what happened before the Big Bang) with another thing we do not understand. Anything to avoid invoking G-d! Besides which, sudden virtual particles are always tiny and fleeting - hardly the stuff of which Big Bangs are made.

vii-What Happened After the Big Bang?

Scientists propose that the timeline after the Big Bang reads as follows (in years):

10^{-51}	Space and time disentangle
10^{-44}	Cosmic inflation
10^{-18}	Electromagnetism emerges
10^{-5}	Atomic nuclei created
10^6	First stars form

The great mystery for cosmologists is the series of events that occurred less than one millisecond after the Big Bang, when the universe was extraordinarily small, hot and dense. The laws of physics that we are familiar with offer little guidance for explaining what happened during this critical period. But to comprehend why the universe was set up this way, we must probe further back, to the very first tiny fraction of a microsecond. Such an effort will require ... [that] physicists find a way to relate Einstein's theory of general relativity, which governs large-scale interactions in the cosmos, with the quantum principles which apply at very short distances.¹

¹Martin Rees, Scientific American, Dec. 1999, pg. 47.

In the recent creation of a quark plasma (described below) scientists have come another step closer to mimicking the Big Bang:

Scientific American April 2000, *Fireballs of Free Quarks*, p. 8:

A quark-gluon plasma (QGP), in which hundreds of ordinary protons and neutrons melt together and form a fiery soup of free-roaming quarks and gluons. The universe consisted of such a quark stew 10 microseconds after the big bang, about 15 billion years ago.

Seven experiments...for the past six years at CERN...use lead nuclei...hurled at almost the speed of light at a thin foil...

Ordinarily, quarks are locked away inside their parent particles...Separating the component quarks of a particle takes a large amount of energy.

At sufficiently high energy densities...Instead of being a hot swarm of numerous hadrons colliding together and reacting, the fireball becomes one large cloud of quarks and gluons. The tremendous energy and pressure of the quark-gluon plasma causes it to explode outward. The temperature and density fall and soon become too low to sustain the plasma state. The quarks then rapidly pair off

About half a million years after the Big Bang, the universe cooled and entered the dark ages, which lasted for hundreds of millions of years and ended only when enough stars and galaxies formed so that their light dissipated the fog¹.

In August 2001, a team of astronomers announced that it had found what it called the cosmic renaissance, the epoch in which starlight first began streaming freely through the universe. The announcement was made a few days after another team reported that it had discovered the cosmic dark ages, a time before stars and galaxies began shining².

What will happen in the future?

In 1998, two competing teams of astronomers startled the scientific world with the news that the expansion of the universe seemed to be speeding up under the influence of a mysterious antigravity that seems embedded in space itself³. The scientists, unable to account for the phenomena, called it "Dark energy." Dark energy, instead of attracting particles like gravity does, would actually repel them⁴.

If dark energy is real and the acceleration continues, the galaxies will eventually speed away from one another so quickly that they couldn't see one another. The universe would become cold and empty as the continued acceleration sucked away the energy needed for life and thought⁵.

Whether the universe will continue expanding indefinitely or whether it will eventually change course and collapse (the big crunch) depends on the total amount of dark

again, forming colorless hadrons. The fireball, now composed of hadrons, continues expanding and cooling, and ultimately the hadrons fly on to the detectors. The process...mimics what happened during the big bang.

¹Or, in technical terms, ionized the hydrogen gas pervading the universe

²Both sets of measurements were made by observing parts of the universe whose light is now observable from earth. The Sloan observations looked at that fog in the light of the most distant known object in the universe, a quasar, or cosmic beacon with a brightness equivalent to billions of suns. The quasar seems to have been shining just as the dark ages were ending. By contrast, Dr. Djorgovski's team examined a quasar that is slightly less distant and therefore emitted its light a little more than a hundred million years more recently, after the dark ages apparently ended. Like two distant streetlights, one inside a fog bank and one outside, the quasars appear different when observed with powerful telescopes, apparently confirming that the universe went through a major change when it was about 900 million years old.

³This is hauntingly reminiscent of Einstein's old, presumably discredited, cosmological constant.

⁴According to the uncertainty principle, a pillar of quantum theory, empty space was not empty, but rather foaming with the energy of so-called virtual particles as they flashed in and out of existence on borrowed energy. This so-called vacuum energy could repel, just like Einstein's old cosmological constant, or attract.

The case for dark energy got even stronger a year later, when the cosmic background observations reported evidence of a flat universe. Because astronomers had been able to find only about a third as much matter, both dark and luminous, as was needed by Einstein's laws to create a flat geometry, something else had to be adding to it.

What is dark energy? The question now hangs over the universe.

Is it really Einstein's old fudge factor returned to haunt his children? In that case, as the universe expands and the volume of space increases, astronomers say, the push because of dark energy will also increase, accelerating the galaxies away from one another faster and faster, leading to a dire dark future. (Dennis Overbye, NY Times, July, '02)

⁵Dennis Overbye, NY Times, July, '02

(hidden or unidentifiable) matter¹ (which would pull the universe in) and dark energy (which would pull the universe out) that exists in the universe and the gravity it exerts. There are several indications that dark matter exists². Many galaxies, for example, are rotating so fast that they would fly apart unless they were being reined in by the gravity of halos of dark matter. Since this matter is unknown and unaccounted for, scientists cannot give a final answer on this.

In a high-density universe, space would be curved or warped around on itself like a ball. Such a universe would eventually stop expanding and fall back together in a big crunch that would extinguish space and time, as well as the galaxies and stars that inhabit them. A low-density universe, on the other hand, would have an opposite or "open" curvature like a saddle, harder to envision, and would expand forever.

In between with no overall warpage at all was a "Goldilocks" universe with just the right density to expand forever but more and more slowly, so that after an infinite time it would coast to a stop. This was a "flat" universe in the cosmological parlance, and to many theorists the simplest and most mathematically beautiful solution of all³.

Current estimates are that the universe contains only about 30% of the matter that would be needed to stop the expansion. In fact, recent observations of supernovae indicated that the expansion was actually speeding up. Some astronomers say that the observations are

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But what is the dark matter? While some of it is gas or dark dim objects like stars and planets, cosmologists speculate that most of it is subatomic particles left over from the Big Bang.

Many varieties of these particles are predicted by theories of high-energy physics. But their existence has not been confirmed or detected in particle accelerators.

"We theorists can invent all sorts of garbage to fill the universe," Dr. Sheldon Glashow, a Harvard physicist and Nobel laureate, told a gathering on dark matter in 1981.

Collectively known as WIMP's, for weakly interacting massive particles, such particles would not respond to electromagnetism, the force responsible for light, and thus would be unable to radiate or reflect light. They would also be relatively slow-moving, or "cold" in physics jargon, and thus also go by the name of cold dark matter. (Dennis Overbye, NY Times, July '02)

²As Earth in its travels passed through the dark-matter cloud that presumably envelops the Milky Way, the particles would shoot through our bodies, rarely leaving a trace, like moonlight through a window. But the collective gravity of such particles, cosmologists say, would shape the cosmos and its contents.

Gathering along the fault lines laid down by random perturbations of density in the early universe, dark matter would congeal into clouds with about the mass of 100,000 Suns. The ordinary matter that was mixed in with it would cool and fall to the centers of the clouds and light up as stars.

The clouds would then attract other clouds. Through a series of mergers over billions of years, smaller clouds would assemble into galaxies, and the galaxies would then assemble themselves into clusters of thousands of galaxies, and so forth.

Using the Hubble and other telescopes as time machines — light travels at a finite speed, so the farther out astronomers look the farther back in time they see — cosmologists have begun to confirm that the universe did assemble itself from the "bottom up," as the dark matter model predicts.

Last year, two teams of astronomers reported seeing the first stars burning their way out of the cloudy aftermath of the Big Bang, when the universe was only 900 million years old. The bulk of galaxy formation occurred when the universe was a half to a quarter its present age, cosmologists say. ...

Yet there are still many questions that the cold dark matter model does not answer. Astronomers still do not know, for example, how the first stars formed or why the models of dark matter distribution don't quite fit in the cores of some kinds of galaxies. Nor have the dark matter particles themselves been unambiguously detected or identified, despite continuing experiments. (Dennis Overbye, NY Times, July, '02)

³Dennis Overbye, NY Times, July '02

evidence of an extra repulsive force that overwhelms gravity on cosmic scales – what Albert Einstein called the cosmological constant.¹

One physicist, Dr. Linde,² has argued that inflation can occur over and over, spawning an endless chain of universes out of one another, like bubbles within bubbles. "The universe inflates on top of itself," Dr. Linde told a physics conference recently. "It's happening right now." Of course, all of this is nothing more than intelligent speculation.

Other physicists, however, have pointed out that the theories of modern physics are replete with mysterious force fields, collectively called "quintessence," that might or might not exist, but that could temporarily produce negative gravity and mimic the action of a cosmological constant. In that case, all bets on the future are off. The universe could accelerate and then decelerate, or vice versa, as the dark energy fields rose or fell.

A third possibility is that dark energy does not exist at all, in which case not just the future, but the whole carefully constructed jigsaw puzzle of cosmology, might be in doubt. The effects of cosmic acceleration could be mimicked, astronomers say, by unusual dust in the far universe or by unsuspected changes in the characteristics of supernovas over cosmic time. As a result, more groups are joining the original two teams in the hunt for new supernovas and other ways to measure the effects of dark energy on the history of the universe³.

For all the new answers being harvested, some old questions linger, and they have now been joined by new ones.

A flat universe is the most mathematically appealing solution of Einstein's equations, cosmologists agree. But they are puzzled by the specific recipe, large helpings of dark matter and dark energy, that nature has chosen. Dr. Turner called it "a preposterous universe."

But Dr. Martin Rees, a Cambridge University cosmologist, said that the discovery of a deeper principle governing the universe and, perhaps, life, may alter our view of what is fundamental. Some features of the universe that are now considered fundamental — like the exact mixture of dark matter, dark energy and regular stuff in the cosmos — may turn out to be mere accidents of evolution in one out of the many, many universes allowed by eternal inflation.

"If we had a theory, then we would know whether there were many big bangs or one," Dr. Rees said. The answers to these and other questions, many scientists suspect, have to await the final unification of physics, a theory that reconciles Einstein's relativity, which describes the shape of the universe, to the quantum chaos that lives inside it.

Such a theory, quantum gravity, is needed to describe the first few moments of the universe when it was so small that even space and time should become fuzzy and discontinuous.

For two decades, many physicists have placed their bets for quantum gravity on string theory, which posits that elementary particles are tiny strings vibrating in a 10- or 11-dimensional space. Each kind of particle, in a sense, corresponds to a different note on the string.

In principle, string theory can explain all the forces of nature. But even its adherents concede that their equations are just approximations to an unknown theory that they call M-theory, with "M" standing for matrix, magic, mystery or even mother, as in "mother of all theories." Moreover, the effects of "stringy physics" are only evident at energies forever beyond the limits of particle accelerators.

¹Martin Rees, Scientific American, Dec. 1999, pg. 46

²Dr.Linde is the proponent of a new theory of Inflation, called "chaotic inflation."

³Dennis Overbye, NY Times, July, '02

Some string theorists have ventured into cosmology, hoping to discover some effect that would show up in the poor man's particle accelerator, the sky.

In addition to strings, the theory also includes membranes, or "branes," of various dimensions. Our universe can be envisioned as such a brane floating in higher-dimensional space like a leaf in a fish tank, perhaps with other brane universes nearby. These branes could interact gravitationally or even collide, setting off the Big Bang.

In one version suggested last year by four cosmologists led by Dr. Steinhardt of Princeton, another brane would repeatedly collide with our own. They pass back and forth through each other, causing our universe to undergo an eternal chain of big bangs.

Such notions are probably the future for those who are paid to wonder about the universe.

And the fruits of this work could yet cause cosmologists to reconsider their new consensus, warned Dr. Peebles of Princeton, who has often acted as the conscience of the cosmological community, trying to put the brakes on faddish trends.

He wonders whether the situation today can be compared to another historical era, around 1900, when many people thought that physics was essentially finished and when the English physicist Lord Kelvin said that just a couple of "clouds" remained to be dealt with.

"A few annoying tidbits, which turned out to be relativity and quantum theory," the twin revolutions of 20th-century science, Dr. Peebles said. Likewise, there are a few clouds today like what he called "the dark sector," which could have more complicated physics than cosmologists think.

As for the fate of the universe, we will never have a firm answer, said Dr. Sandage, who was Hubble's protégé and has seen it all. "It's like asking, 'Does God exist?'" he said¹.

viii-A Narrative Description of the Discovery of the Big Bang

By Tanya Weissman, Moreshet:

In 1913, at the Lowell Observatory in Flagstaff, Arizona, Vesto Melvin Slipher, a P.H.D. in astronomy, was investigating what seemed to be another ordinary galaxy coming into existence. But instead of the stars moving in the regular rotating pattern found in all new forming galaxies, he found that the stars were moving away from earth at speeds ranging up to one million miles per hour. Upon further investigation, Slipher discovered other galaxies in the same vicinity all moving away from earth at amazingly high speeds. By 1925, Slipher had discovered 42 galaxies all moving away from earth at tremendously high speeds. He reported his findings at the 1914 American Astronomical Society meeting and received a standing ovation. Although the astronomers present weren't exactly sure what Slipher's discoveries meant, they realized it was instrumental in the understanding of the world's beginnings.

In 1916, on the other side of the Atlantic, a young scientist named Albert Einstein published his General Theory of Relativity. These equations solved many science problems of that era. He sent his paper to a Dutch mathematician, Willem de Sitter, who said that the only way Einstein's theory could work was if the universe exploded and all the galaxies were moving away from a center point at immense speeds. De Sitter wrote to Einstein of his discovery but received no response. In 1922, a Russian mathematician, Alexander Friedmann, arrived at the same expanding-universe conclusion after studying Einstein's equations and finding a simple mathematical error. Friedmann contacted Einstein about his mistake, but Einstein ignored this letter, too.

Because of communication interruptions due to World War I, neither de Sitter nor Friedmann knew of Vesto Slipher's discovery of the dozens of receding galaxies at the

¹All the text in italics is edited text from Dennis Overbye, NY Times, July '02

Flagstaff Observatory. After the war, however, Slipher, de Sitter and Friedmann all shared their findings with Einstein. Einstein resisted their hypothesis of a non-static universe. He said, "This circumstance of an expanding universe is irritating. To admit such possibilities seems senseless to me."¹ If it would be found that the universe is expanding, it could also be discovered that the energy of the original explosion would never be slowed down by the gravitational pull between expanding stars and planets, proving the expanding model to be true. This would in essence be admitting the existence of a supernatural creative force.

Friedmann continued to pursue the matter and published his findings in the science journal *Zeitschrift für Physik*. When he succeeded in proving Einstein's error, Einstein finally conceded and stated that Slipher, de Sitter and Friedmann were probably right. Nevertheless, since nothing had yet been proven absolutely, Einstein said "I have not yet fallen in the hands of priests."²

At the Mount Wilson Observatory in California in 1925, two astronomers, Edwin Hubble and Milton Humason, discovered that all galaxies within the distance of 100 million light-years were all moving away from earth. This was enough to finally prove that the static theory of the universe was incorrect. In 1929, Hubble formulated what was later to be known as Hubble's Law: the farther away a galaxy is, the faster it moves. This was actually one of the ideas predicted by Einstein's theory of relativity. Now both theory and observation pointed to an expanding universe. But again, probably because of its theological implications, Einstein remained stubborn in his belief against a non-static universe. In 1930, Einstein visited Hubble to study his discoveries himself. At the conclusion of the meeting, Einstein reluctantly admitted, "New observations by Hubble and Humason... make it appear likely that the general structure of the universe is not static."³ Despite all of this, at the time of his death in 1955, Einstein was not completely sold on the idea of an expanding universe.

In 1965, two employees of Bell Telephone Laboratories, Arno Penzias and Robert Wilson, were working on a problem with a specific ultra-sensitive radio detector. It seemed that no matter which way they pointed the detector, a strange background noise was picked up. After looking into all possibilities, they made a final attempt to fix the problem. They dismantled the whole system and reassembled it, but the same noise, a 3 degree Kelvin hum ("3K hum"), continued. Penzias and Wilson began an investigation into this unexplainable "3K" interference. They discovered that this 3K hum can be found in every part of the observable universe, which corroborated what was written in an essay published by a student of Friedmann's student. The essay said that echoes of the universe's most recent explosion in the cycle of expansion-contraction should be detectable in a weak form of radiation at about 5 degrees Kelvin. Upon further study they found a mathematical error and realized that the echo should really be at 3 degrees Kelvin. For discovering the echo of the universe's biggest explosion, The Big Bang, Penzias and Wilson were later awarded the Nobel Prize.

As a result of the 3K hum discovery, more research on Big Bang theories was conducted. Another hypothesis based on general relativity was that the extra hot temperatures of the universe moments after the Big Bang should have produced a universe made up of 75 percent hydrogen and 25 percent helium. This prediction, too, was confirmed. It was at this point that the static model of the universe officially collapsed. There were two possible remaining descriptions of the nature of the universe: the oscillating model and the expanding model. The deciding factor is the relationship between the gravitational force between

¹Jastrow, "Have Astronomers Found God?" p. 29. New York Times Magazine, June 25 1978.

²Stanley L. Jaki, "From Scientific Cosmology to a Created Universe," in *Intellectuals Speak Out About God*, Roy Varghese, p.76.

³Jastrow, "Have Astronomers Found God?" p. 55. New York Times Magazine, June 25 1978

receding planets and stars (G) and the force of the initial explosion's energy (E). If G is found to be greater than E, the oscillating model is proven. If G is found to be less than E, the expanding model is correct, indicating the involvement of a supernatural creative force.

Scientists have derived that the key to this question lies in the degree of density of the universe. If the universe contains about one hydrogen atom per ten cubic feet of space, that would mean that the (G) is great enough to overcome the explosion's energy and eventually cause a contraction of the universe. But if it is found that there is less than that amount, then (G) is not great enough to overcome (E), indicating that the universe will expand until it eventually burns out.

Between 1965 and 1978 much research was done to measure the density of the universe, all producing the same results: there are not enough hydrogen atoms per ten cubic feet in the universe to create an eventual contraction, the number of missing atoms being in the thousands.

In 1978, Dr. Robert Jastrow, director of the National Aeronautics and Space Administration's Goddard Center for Space Studies, wrote an article in The New York Times Magazine called "Have Astronomers Found God?". After researching and investigating all possibilities of where the 'missing' atoms could be, he came to a conclusion quite shocking for a self-claimed agnostic: that the expanding model was probably correct. He explained that the total weight of the universe was "still more than ten times too small to bring the expansion...to a halt."¹ He describes the frustration of scientists upon studying the latest discoveries:

"For the scientist who has lived by his faith in the power of reason, the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries."²

After his essay was published, Jastrow disappeared from the science scene. He had become a devout Christian.

Confirmations of Jastrow's discovery followed: first in 1983 by Dr. James Trefil, a physicist at University of Virginia, then in 1986 by Dr. John Barrow, an astronomer at the University of Sussex, and Dr. Frank Tipler, a mathematician and physicist at Tulane University. In 1988, Dr. Stephen Hawking, a mathematician and theoretical physicist at Cambridge University, made the same confirmation and said: "Many people do not like the idea that time has a beginning, probably because it smacks of divine intervention." He continued: "The present evidence suggests that the universe will probably expand forever."³ Tipler, too, became religiously inclined and formed his own religion in which he proved the afterlife through physics. At the 1990 meeting of the American Astronomical Society, Prof. John Mather, an astrophysicist of Colombia University, made a presentation making staggering comparisons between cosmology and the book of Genesis. He received a standing ovation for his work and it was called "the most dramatic support ever"⁴ in favor of the expanding universe. The chairman of the A.A.S. meeting, Dr. Geoffrey Burbidge, said about

¹Jastrow, "Have Astronomers Found God?" p. 55. New York Times Magazine, June 25 1978 p.132.

²Jastrow, "Have Astronomers Found God?" p. 55. New York Times Magazine, June 25 1978 p.29

³Stephen Hawking, A Brief History of Time, p. 46. N.Y. Bantam Books, 1988.

⁴David Chandler, "Satellite's New Data Smoothly Supports Big Bang Theory," Boston Sunday Globe, January 14, 1990.

Mather's presentation: "It seems clear that the audience is in favor of the book of Genesis – at least the first verse or so, which seems to have been confirmed."¹

In 1998, Allan Sandage, a leading astronomer of our day, said that after contemplating the depth of the Big Bang, he realized that creation is a miracle and became a believer in G-d.

As a result of this century's cosmological advances, we see how the once-clear lines between science and religion have been blurred. Jastrow, Tipler and Sandage are only a few examples of scientific figures who have crossed these lines. Not only can it be said that science and religion no longer need to oppose one another, but we can even say that they work together with each other. Science is a means by which to discover G-d.

The irony of this 20th century breakthrough is that the Jewish People have understood this all along. For example, the very first instruction given to the Jewish people by G-d was the sanctification of the new lunar month: "This month shall be for you the beginning of the months."² The sanctification of the month requires intricate knowledge of the relationship between the solar and lunar calendars. Jews were thus required to have deep understanding in this scientific area in order to set the Jewish calendar which is the foundation of the Jewish religion.

Jews were taught by G-d that science is part of being religious. For the Jewish people, science is a way of discovering, understanding and relating to G-d. Science is how we see G-d in this world and come closer to Him. After centuries of the Jews knowing this, the world seems to be catching on.

¹Ibid.

²Exodus 12:2 6

ix – Is the Universe still expanding and how will it end?¹

General relativity predicted that the very high temperatures moments after the Big Bang should have produced mass amounts of certain elements. The universe should be made up of 75 percent hydrogen and 25 percent helium.

This prediction, too, was confirmed. It was at this point that the static model of the universe officially collapsed. There were two possible descriptions of the nature of the universe left, the oscillating model and the expanding model². Scientists have derived that the key to this question lies in the degree of density of the universe³. Fifteen years of this research produced the same results: there are not enough hydrogen atoms in the universe to create an eventual contraction.⁴ In 1978, Dr. Robert Jastrow, director of the National Aeronautics and Space Administration's Goddard Center for Space Studies, wrote an article in The New York Times Magazine called "Have Astronomers Found God?" After researching and investigating all possibilities of where the 'missing' atoms could be, he came to a conclusion quite shocking for a self-claimed agnostic. He said that it seemed to him that

¹Before the discovery of the Big Bang the following scenarios about the unfolding of the universe were possible:

1. The static model states that all stars and planets basically sit still in space, or at least don't follow a specific orbiting pattern. According to this theory, such a universe could have existed forever, without the involvement of God, or it could just as well have been created by God at some point in history.

2. The oscillating model states that the universe maintains a cycle of expansion and contraction. The cycle begins with a ball containing all matter and energy exploding causing the universe to expand. Eventually, the gravitational pull between the receding stars and planets begins to slow down the force of the explosion, causing the stars and planets to contract back to the center. This leads to what physicists call "the Big Crunch". History might end there or it may lead to the next explosion. In the latter case the universe may continue expanding and contracting infinitely. We might also say that this process has always been going on, back to infinity. An infinite process has neither an end point nor a beginning point. Therefore, we can conclude that such a universe always existed, excluding the hand of God.

3. The Expanding Model describes the universe as having exploded from a ball containing all matter and energy, as in the oscillating model above. In this model, however, the energy of the gravitational pull between receding stars and planets (G) never overpowers the energy released by the initial explosion (E) to slow it down and cause a contraction. Therefore, the universe will be in a constant state of expansion until eventually, the stars will burn out and there is no next explosion to restart the universe. However, there is a problem that arises due to the nature of the model. How could a ball of all matter and energy sitting peacefully in space suddenly explode? The Law of Inertia clearly states that something at rest will remain at rest unless acted upon by an outside force. Since everything is contained within this ball of matter, something outside the ball had to have acted upon the ball in order to cause it to explode. In order for this description of the universe to be true, we are forced to say that there must be some sort of supernatural creative force.

²The deciding factor between the two theories is the relationship between the gravitational force between receding planets and stars (G) and the force of the initial explosion's energy (E). If G is found to be greater than E, then the oscillating model is proven. If G is found to be less than E, then the expanding model is proven indicating the involvement of a supernatural creative force.

³If the universe contains about one hydrogen atom per ten cubic feet of space, then that would mean that the (G) is great enough to overcome the explosion's energy and eventually cause a contraction of the universe. But if, however, it is found that there is less than that amount, then (G) is not great enough to overcome (E), which means that the universe will expand until it burns out. Between 1965 and 1978, much research was done to measure the universe's density.

⁴In 1997, at the American Astronomical Society meeting, an astronomer from Princeton University, Ruth Daly, announced that while conducting a spectral analysis of the stars, she discovered with 97.5% accuracy that E is greater than G. Therefore there is no chance the universe will ever fall back on itself.

the expanding model was probably correct. He explained that the total weight of the universe was "still more than ten times too small to bring the expansion...to a halt." He described the frustration of scientists upon studying the latest discoveries: "For the scientist who has lived by his faith in the power of reason the story ends like a bad dream. He has scaled the mountains of ignorance; he is about to conquer the highest peak; as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries."¹

After his essay was published, Jastrow disappeared from the science scene. He had become a devout Christian. Confirmations of Jastrow's discovery followed². (double of page 76)

In 1988, Dr. Stephen Hawking, a mathematician and theoretical physicist at Cambridge University, made the same confirmation and said, "Many people do not like the idea that time has a beginning, probably because it smacks of divine intervention." He continued, "The present evidence suggests that the universe will probably expand forever." At the 1990 meeting of the American Astronomical Society, Prof. John Mather, an astrophysicist of Colombia University, made a presentation making staggering comparisons between cosmology and the book of Genesis. He received a standing ovation for his performance and it was called "the most dramatic support ever" in favor of the expanding universe. The chairman of the A.A.S. meeting, Dr. Geoffrey Burbidge, said about Mather's presentation, "It seems clear that the audience is in favor of the book of Genesis - at least the first verse or so, which seems to have been confirmed."³ (double)

But there were more surprises to come for it turned out that the universe is even emptier than expected. As a result of this, the universe is not only not slowing down; in fact, recent measurements indicate that it may be speeding up. Cosmologists currently think that the world will expand forever rather than, as scientists once thought, expand to a maximum and then begin to shrink, ending in a big crunch.⁴

¹Jastrow, "Have Astronomers Found God?" p 29. New York Times Magazine, June 25 1978

²First in 1983, by Dr. James Trefil a physicist at University of Virginia, then in 1986 by Dr. John Barrow, an astronomer at the University of Sussex and Dr. Frank Tipler, a mathematician and physicist at Tulane University. Tipler, too, became religiously inclined and formed his own religion in which he proved afterlife through physics.

³David Chandler, "Satellite's New Data Smoothly Supports Big Bang Theory," Boston Sunday Globe, January 14, 1990.

With a series of discoveries,¹ the year 2001 went a long way toward settling the question once and for all². One of the implications of these discoveries is that the universe is pervaded with a strange sort of "antigravity," a concept originally proposed by and later abandoned by Einstein as the greatest blunder of his life. This force, which has been dubbed "dark energy," isn't just keeping the expansion from slowing down; it's making the universe fly apart faster and faster all the time, like a rocket ship with the throttle wide open.

Furthermore, not only does dark energy swamp ordinary gravity, but an invisible substance known to scientists as "dark matter" also seems to outweigh the ordinary stuff of stars, planets and people by a factor of 10 to 1. "Not only are we not at the center of the universe," University of California, Santa Cruz, astrophysical theorist Joel Primack has commented, "we aren't even made of the same stuff the universe is."

These mind-bending discoveries raise more questions than they answer. For example, just because scientists know dark matter is there doesn't mean they understand what it really is. Same goes for dark energy. "If you thought the universe was hard to comprehend before," says University of Chicago astrophysicist Michael Turner, "then you'd better take some smart pills, because it's only going to get worse."

It was noted as early as the 1930s that something lurked out there besides the glowing stars and gases that astronomers could see. Galaxies in clusters were orbiting one another too fast; they should, by rights, be flying off into space like untethered children flung from a fast-twirling merry-go-round. Individual galaxies were spinning about their centers too quickly too; they should long since have flown apart. The only possibility: some form of invisible dark matter was holding things together, and while one could infer the mass of dark matter in and around galaxies, nobody knew if it also filled the dark voids of space where its effects would not be detectable.

By 1998, scientists knew that something very weird was happening. The cosmic expansion should have been slowing down a lot or a little, depending on whether it contained a lot of matter or a little—an effect that should have shown up as distant supernovas, looking brighter than one would expect compared with closer ones. But, in fact, they were dimmer—meaning that the expansion was speeding up. This suggested that some sort of powerful antigravity force was at work, forcing the galaxies to fly apart even as ordinary gravity was trying to draw them together³.

¹What appears below *How the Universe Will End* modified from an article by Michale D. Lemonick, *Time Magazine*, June, 20001

²The particulars of these discoveries also bolster the theory of inflation: the notion that the universe went through a period of turbocharged expansion before it was a trillionth of a second old, flying apart (in apparent, but not actual, contradiction of Albert Einstein's theories of relativity) faster than the speed of light.

³For all its seeming strangeness, antigravity did have a history, one dating back to Einstein's 1916 theory of general relativity. The theory's equations suggest that the universe must be either expanding or contracting; it couldn't simply sit there. Yet the astronomers of the day, armed with relatively feeble telescopes, insisted that it was doing just that. Grumbling about having to mar the elegance of his beloved mathematics, Einstein added an extra term to the equations of relativity. Called the cosmological constant, it amounted to a force that opposed gravity and propped up the universe. A decade later, though, Edwin Hubble discovered that the universe was expanding after all. Einstein immediately and with great relief discarded the cosmological constant, declaring it to be the biggest blunder of his life. (If he had stuck to his guns, he might have nabbed another Nobel.)

This was supported by theoretical equations of quantum physics that suggested that the seemingly empty vacuum of space should be seething with a form of energy that would act just like Einstein's disowned antigravity¹, and it was supported by the discovery of a new supernova existing closer to the time of the Big Bang than anything which had existed before².

An entirely different kind of observation—the long-standing search for lumpiness in the cosmic background radiation—now suggests independently that dark energy is real. Matter isn't spread evenly through the modern universe. Galaxies tend to huddle relatively close to one another, dozens or even hundreds of them, in clumps known as clusters and superclusters. In between, there is essentially nothing at all.

That lumpiness, reasoned theorists, must have evolved from some original lumpiness in the primordial cloud of matter that gave rise to the background radiation. Slightly denser knots of matter within the cloud—forerunners of today's superclusters, should have been a bit hotter than average. Scientists therefore began looking for subtle hot spots. The lumps themselves were first detected about a decade ago, thanks to the Cosmic Background Explorer satellite. At the time, astrophysicist and COBE spokesman George Smoot declared that "if you're religious, it's like seeing G-d." More recently, sharper images have confirmed this result³, making it clearer than ever that galaxies cluster together into huge clumps that reflect conditions that existed soon after the Big Bang.

A statistical analysis shows that the early lumps—actually patches of slightly warmer or cooler radiation—don't come at random but rather at certain fixed sizes.

¹Problem was, this force would have been so powerful that it would have blown the universe apart before atoms could form, let alone galaxies—which it clearly did not. "The value particle physicists predict for the cosmological constant," admits Chicago's Turner, "is the most embarrassing number in physics."

There were other problems. Maybe the observers didn't really have the supernovas' brightness right; perhaps the light from faraway stellar explosions was dimmed by some sort of dust. The unique properties of a cosmological constant, moreover, would make the universe slow down early on, then accelerate. That's because dark energy grows as a function of space. There wasn't much space in the young, small universe, so back then the braking force of gravity would have reigned supreme. More recently, the force of gravity fell off as the distance between galaxies grew and that same increase made for more dark energy. Nobody had probed deeply enough to find out what was really going on in the distant past.

²In 1998 a new supernova was discovered. It was some 50% closer to the beginning of the universe than any supernova known before, was far brighter than had been predicted. The level of brightness signaled that this supernova was shining when the expansion of the cosmos was still slowing down. That neatly eliminated the idea of dust, since a more distant star should have been even more dust-dimmed than nearer ones. "Usually," says Riess, "we see weird things and try to make our models of the universe fit. This time we put up a hoop for the observations to jump through in advance, and they did—which makes it a lot more convincing."

³The original COBE satellite saw lumps but couldn't determine much about them. In April, 2001, though, scientists offered up much sharper images from a balloon-borne experiment called boomerang (Balloon Observations of Millimetric Extragalactic Radiation and Geophysics), which lofted instruments into the Antarctic stratosphere; from another named maxima (Millimeter Anisotropy Experiment Imaging Array, which did the same over the U.S.); and from a microwave telescope on the ground at the South Pole, called *dasi* (Degree Angular Scale Interferometer).

All these measurements pretty much agreed with one another, confirming that the lumps scientists saw were real, not some malfunction in the telescopes. In June, 2001, astronomers from the Sloan Digital Sky Survey confirmed that this primordial lumpiness has carried over into modern times. The five-year mission of the survey, to make a 3-D map of the cosmos, will be completed in 2006.

Using this information, physicists have concluded that ordinary matter makes up only about 5% of the so-called critical density—what it would take to bring the cosmic expansion essentially to a halt by means of gravity¹. An additional 35% of the needed matter most likely comes in the form of mysterious particles that have been identified only in theory, never directly observed—particles with quirky names like neutralino and axion. These are the mysterious dark matter². The remaining 60% is comprised of dark energy.

This means that the 100 billion or so galaxies we can now see through our telescopes will zip out of range one by one. Tens of billions of years from now, the Milky Way will be the only galaxy we're directly aware of (other nearby galaxies, including the Large Magellanic Cloud and the Andromeda galaxy, will have drifted into, and merged with, the Milky Way).

¹from the equations of nuclear physics and from measurements of the relative amounts of hydrogen, helium and lithium in the universe, that protons, neutrons and electrons (the building blocks of every atom in the cosmos)

Same goes for the universe, but with one more dimension. According to Einstein, the whole thing could be positively or negatively curved or flat (but don't try to imagine in what direction it might be curved; it's quite impossible to visualize). "What the new measurements tell us," says Turner, "is that the universe is in fact flat. Draw a triangle that reaches all the way across the cosmos, and the angles will always add up to 180° ."

[illegible]

that will be left in the cosmos will be black holes, the burnt-out cinders of stars and the dead husks of planets. The universe will be cold and black. University of Michigan astrophysicist Fred Adams predicts that all this dead matter will eventually collapse into black holes. By the time the universe is 1 trillion trillion trillion trillion trillion years old, the black holes themselves will disintegrate into stray particles, which will bind loosely to form individual "atoms" larger than the size of today's universe. Eventually even these will decay, leaving a featureless, infinitely large void. And that will be that—unless, of course, whatever inconceivable event that launched the original Big Bang should recur, and the ultimate free lunch is served once more.

None of the discoveries about dark matter, dark energy and the flatness of space-time have been confirmed to the point where scientists will accept this picture without reservation. "We're really living dangerously," says Chicago's Turner. There could be surprises to come: an Einstein-style cosmological constant, for example, is the leading candidate for dark energy, but it could in principle be something subtly different—a force that could even change directions someday, to reinforce rather than oppose gravity.

APPENDIX 4: THE FOUR FORCES AND THE ATTEMPT TO UNIFY THEM

i-Gravity

ii-The Electromagnetic Force

iii-The Strong Force

iv-The Weak Force

v-One force from four

vi-A Fifth Force

APPENDIX 4: THE FOUR FORCES AND THE ATTEMPT TO UNIFY THEM

There are four fundamental forces in the world which account for all of physical reality:

- **Gravity**
- **Electromagnetism**
- **The Strong Force which holds atoms together**
- **The Weak Force, the main expression of which is radiation**

These forces are constants. However, in August 2001 an international team of astrophysicists reported that the basic laws of nature as understood today may be changing slightly as the universe ages, a surprising finding that could rewrite physics textbooks and challenge fundamental assumptions about the workings of the cosmos¹.

If confirmed, the finding could mean that other constants regarded as immutable, like the speed of light, might also have changed over the history of the cosmos².

¹The researchers used the world's largest single telescope to study the behavior of metallic atoms in gas clouds as far away from Earth as 12 billion light years. The observations revealed patterns of light absorption that the team could not explain without assuming a change in a basic constant of nature involving the strength of the attraction between electrically charged particles.

i-Gravity

Although we are most familiar with gravity, it is actually the weakest of the four forces, too weak in fact to even be taken into account when dealing at a subatomic level. The reason that gravity seems so strong to us is that it is a cumulative force. For example, each atom of the earth adds its bit of gravitational pull on the moon to make up what we see as the earth's gravitation. The bigger the object, the more gravity it has. Gravity, then, is the main force which keeps the planets, the galaxies and everything in the heavens together. The other forces do not operate cumulatively and their primary expression is therefore at a subatomic level. The weak force is much stronger than the gravitational force but weaker (hence its name) than the electromagnetic force which in turn is much weaker than the strong force.

According to Einstein, gravity just reflects curvatures in space. Space (actually space-time, since time and space can never be separated), according to Einstein, is actually curved. This curvature, or warping, is caused by the distribution of mass and energy within space-time. In the vicinity of a massive body, the curvature of space increases. The more massive the body, the greater the curvature.

Objects flying through space will naturally choose the shortest route to move in. When an object is going through a curved space, the shortest route may appear to us to be curved. For example, an airplane flying the shortest route between two points on the globe will appear to fly in a curved route. Stephen Hawking says this is like watching a plane flying over hilly ground. Although it follows a straight line in three-dimensional space, its shadow follows a curved path on two-dimensional ground. Since space-time is actually four dimensional, an object moving through space-time in the shortest route may nevertheless appear to be following a curved route. We interpret this as gravity. Gravity, then, simply reflects the change of the shortest route through curved space that an object might take.

Einstein's theory has been confirmed (and Newton shown to be wrong) in a number of ways. The exact orbit of Mercury, for example, follows the route predicted by Einstein but not by Newton. However, gravitational waves have never been measured directly. A massive effort is currently underway, involving expensive machines in several places around the world¹, to measure the faint gravitational ripples that ought to be produced by giant cataclysms in the cosmos such as black-hole collisions². These are so large that they are thought to cause the fabric of space itself to vibrate. By the time they reach the earth, however, these ripples are so faint that picking them up is comparable to noticing a single grain of sand added to all the beaches of Long Island, N.Y.³

ii-The Electromagnetic Force

Originally, it was thought that magnetism and electricity were two separate forces. In the first century, however, James Clark Maxwell showed that they were both different expressions of one force, which we call electromagnetism. This force holds the electrons in

¹Ligo in Livingston and Hanford, USA; Tama in Japan; Geo in the UK; and Virgo in Italy. Nasa and the European Space Agency are designing a group of laser-toting satellites that will help in the search. They are due to be launched in 2011.

²A gravitational wave ought to expand the space between the mirrors of these machines. The wave should hit each detector at a slightly different time, allowing astronomers to pinpoint the source and eliminate other causes of the vibration. The main problem is that these ultrasensitive devices pick up a lot of other noises, such as traffic and far away earth quakes.

³Scientific American, April 2002.

place around the nucleus and it holds the atoms in place together with their neighbors. What we know as solid mass is actually mainly empty space. It is the electromagnetic force that creates the impression of something being solid. What should happen when one bangs the table is that he should squash the few solid electrons and protons into a smaller space. The electromagnetic force is strong enough to prevent that from happening. It is this force which also determines the melting and boiling points of different substances. Although the electromagnetic force can theoretically operate at any distance, in practice, positive and negative charges usually balance each other out (an atom, for example, is always electrically neutral), so that this force only operates at short distances. Light is also a function of this force. There is a spectrum of electromagnetic energy. A small part of this spectrum (energy range) produces visible light; the rest produce ultraviolet and other forms of invisible light.

iii-The Strong Force

The nucleus of the atom is composed of neutrally charged neutrons and positively charged protons. Since like charges repel each other (which you can show by holding two magnets with their like poles together), the question arises why the protons don't cause the nucleus to blow apart. (The neutrons only marginally neutralize this force.) The answer is that a force, the strong force, much greater than the repelling electromagnetic force, is holding the nucleus together.

The Strong Force compared to the Electromagnetic Force

Electrons are held in their orbital around atoms by the electromagnetic force, which is relatively weak. The dominant force inside nuclei is about 100 times stronger (hence the name: the strong nuclear force). In addition, electrons are structure-less elementary particles, whereas protons and neutrons are themselves complex bundles of particles called quarks and gluons. The force between these nucleons is not directly a fundamental force like electromagnetism, whose equations we know exactly. Instead, the nuclear force acting between nucleons is a complicated by-product of the interactions of their constituent quarks and gluons. The nuclear force is strongly attractive for a few femtometers (10^{-15} meter) and then falls to zero. In contrast, electron orbitals lie some 10,000 times further away.

One hundred trillion (10^{14}) times denser than water, nuclei (a) are very tightly packed bundles of protons and neutrons. Because of the strength and complexity of the strong nuclear force that holds nuclei together, physicists have long resorted to approximate models to describe the quantum states of nuclei.

Over the decades, physicists have developed many theoretical models to try and describe it. The different models tend to work best for specific classes of nuclei.

iv-The Weak Force

This is the force which causes decay, for example, of a neutron into a proton, electron and neutrino. We experience the weak force when we see radiation and, most spectacularly, when there is a supernova explosion of some star in the galaxy. In a stable system, the weak force is too swamped by the strong and electromagnetic forces to express itself.

v-One force from four

(GUTs, TOE, Strings and supersymmetry)

As we said above, there are four fundamental forces in the world which account for all of physical reality:

- Gravity
- Electromagnetism
- The Strong Force, which holds atoms together
- The Weak Force, the main expression of which is radiation

For the last 40 or so years, scientists have been trying to combine these four forces into one. This is the force which they believe existed at the beginning of the Big Bang (and which could exist at very, very high temperatures today) and from which the four forces emerged as the universe cooled off. This is considered the biggest challenge in physics today.

In the early 1970's, the electromagnetic force was combined with the weak force to create what is known as the electroweak force. Then, in 1973, the electroweak force was combined with the strong force to create what was known as the Grand Unified Force or Grand Unified Theory (GUT). What remains now is to combine the fourth force, gravity, with the other three forces. This is more difficult because gravity operates at a macro level while the other three forces operate at a micro level. Combining gravity with these forces would create something called Quantum Gravity. By combining the four forces, the two major theories which describe all of reality, Quantum Physics (which describes the micro-world) and Relativity (which describes the macro-world), would also be combined.

There is much discussion whether, if successful, there will be anything of any significance left for physicists to do or whether science will then come to an end, so to speak.

One of the primary goals of physics is to understand the wonderful variety of nature in a unified way. The greatest advances of the past have been steps toward this goal: the unification of terrestrial and celestial mechanics by Isaac Newton in the 17th century; of optics with the theories of electricity and magnetism by James Clerk Maxwell in the 19th century; of space-time geometry and the theory of gravitation by Albert Einstein in the years 1905 to 1916; and of chemistry and atomic physics through the advent of quantum mechanics in the 1920s [see the illustrations titled Unification and Profoundest Advances].

Einstein devoted the last 30 years of his life to an unsuccessful search for a “unified field theory” which would unite general relativity, his own theory of space-time and gravitation, with Maxwell's theory of electromagnetism.

At the moment, there are two primary theories which describe all of physical reality. The first is the theory of relativity, which describes macro-reality. Gravity is the force that operates this reality. The second is quantum physics, which describes the sub-atomic world and is described by the other three forces. These two theories have not been reconciled. Although this does not really matter on a day-to-day basis because they describe different realities, occasionally, as in discussions of black holes, the two theories rub against each other.

The rubbing can be abrasive. Quantum theory radicalizes our assumptions about the relationship between observer and observed but pretty much buys into Newton's ideas of space and time. General relativity changes our notions of space and time but accepts Newton's view of observer and observed. This situation is deemed unacceptable by most physicists, and the race is on to find a unifying theory of quantum gravity, sometimes called a Theory of Everything. The idea is that ultimately everything, space and time, like matter and energy, come in quantized, indivisible units and that relationships, rather than things, are the fundamental elements of reality¹.

¹In his book, Three Roads to Quantum Gravity, Lee Smolin, professor of physics at Pennsylvania State University, describes the three most promising approaches to such a theory, all of which operate

Combining the four forces would automatically combine these two theories as well, although it may also require modifying one or both of them. Therefore, combining the four forces is also called the quantum theory of gravity.

The way to unity lay in the application of quantum mechanics to each one of the four forces in turn. In the late 1960's, this was achieved with respect to the electromagnetic field. This was called quantum electrodynamics (QED). In the early 1970's, the electromagnetic force was combined with the weak force to create what is known as the electroweak force. Then, in 1973, the electroweak force was combined with the strong force to create what was known as the Grand Unified Force or Grand Unified Theory (GUT) or more formally the Quantum Field Theory.

Although theoretically three of the four forces had now been combined making for a more unified reality, in some respects this world was becoming more complicated, requiring no less than 24 force fields.

An additional problem remains that the theory required the decay of protons. Although the average life-span of a proton is projected as being unbelievably long, a few of them should nevertheless be decaying at any one time. But this has never been observed.

What remains now is to combine gravity, the force which operates at a macro level, with the other three forces which operate at a micro level. Getting the particles which transmit gravity to obey quantum field theory, which combines the strong, weak and electromagnetic forces, has proven to be impossible. A new theory is clearly required. This theory has been called TOE or Theory Of Everything, combining all four forces into a single equation. In the 1980's, String Theory was the leading candidate to be the TOE. String theory states that the most elementary particle in the universe is an unimaginably tiny string (10 to the power of -33cm) which vibrates in many different modes, just as a violin string might do. The theory is basically pure mathematics of the most complicated sort and cannot, at present, be proven empirically. Recently, the theory has been revived by the addition of a concept called duality, which is a type of symmetry. (Symmetries in nature are essential elements in all attempts to combine the four forces. Therefore, such symmetries go under the name

on the so-called Planck scale of reality, 20 orders of magnitude smaller than the atomic nucleus.

One approach applies thermodynamics and information theory to black holes.

Another is string theory, which proposes that the ultimate elements of reality are vibrating linear mathematical entities existing (in one version of the theory) in nine spatial dimensions. String theory has the greatest support amongst the scientific community today. However, since it deals in objects as small as 10 minus 35 of a meter and particle accelerators can only measure things up to 10 minus 19, the theory is hard to prove. Recently, however, scientists have come up with some novel ideas of how to test the theory. (Scientific American, Oct. 2002)

Smolin pushes hard for a third approach, which involves something called quantum loops--quantized elements of spacetime that in their shimmerings evoke everything else, perhaps even strings.

Quantum loop theory proposes that spacetime is a kind of "spin foam," a pure geometry of Planck-scale loops and nodes that in its "knots, links and kinks" spins out a universe.

Scientific American, August 2001: *A Spin on Spin Foam* p. 81: All roads to quantum gravity, when they have battered their way to a common vision, will probably suggest that space and time, like matter and energy, come in quantized, indivisible units and that relationships, rather than things, are the fundamental elements of reality.

supersymmetry). One variation of the theory talks not of strings but of superstrings. This theory presumes that reality exists in ten dimensions, not only the four (three of space and one of time) which we are used to. This is not something which one can actually picture, but rather emerges from the mathematics involved. According to this way of looking at things, all particles were once superstrings which froze out at the time of the Big Bang into the types of particles we have now. At that time, the ten dimensions curled up into the four dimensions we have today.

One problem with string theories is that there are five competing string theories. Another theory, M-theory, actually manages to combine these four theories into one. According to the theory, besides the four dimensions of space and time, which we normally experience, there are another seven dimensions, which make a total of eleven. These other dimensions cannot be directly experienced because they are rolled up in tiny dimensions. The theory posits a force called super-gravity which replaces ordinary gravity.

At times, string theory has been more in vogue with physicists and at other times, M-theory. Today, however, scientists are showing that M-theory can be translated into string theory.¹

No one, however, knows how to write down the equations of this theory.

Stephen Weinberg² describes two great obstacles which stand in the way of formulating a general theory of all of the forces and all of the matter of the universe. "One is that we do not know what physical principles govern the fundamental theory. ... It seems probable that the fundamental theory is not to be formulated in space-time at all. ... How can we get the ideas we need to formulate a truly fundamental theory, when this theory is to describe a realm where all intuitions derived from life in space-time become inapplicable?

"The other obstacle is that even if we were able to formulate a fundamental theory, we might not know how to use it to make predictions that could confirm its validity.

"[One of the difficulties with such a theory is that we can never confirm it experimentally. The temperatures involved (10^{18} GeV) are simply too great. Nor can we look into the higher dimensions suggested by such a theory. Still it is believed that] we will not have any trouble in recognizing the truth of the fundamental unified theory. The test will be whether the theory successfully accounts for the measured values of the physical constants of the Standard Model, along with whatever other effects beyond the Standard Model may have been discovered by then.

"It is possible that when we finally understand how particles and forces behave at energies up to 10^{18} GeV, we will just find new mysteries, with a final unification as far away as ever. But I doubt it. There are no hints of any fundamental energy scale beyond 10^{18} GeV, and string theory even suggests that higher energies have no meaning.

"The discovery of a unified theory that describes nature at all energies will put us in a position to answer the deepest questions of cosmology: Did the expanding cloud of galaxies we call the big bang have a beginning at a definite time in the past? Is our big bang just one episode in a much larger universe in which big and little bangs have been going on eternally? If so, do what we call the constants of nature or even the laws of nature vary from one bang to another?

"This will not be the end of physics. It probably won't even help with some of the outstanding problems of today's physics, such as understanding turbulence and high-

¹*Scientific American*, Feb. 1998, pg. 54 - 59; N.Y. Science Times, Sep. 22, 1998. The M in M-Theory has been used to stand for a whole range of imaginative things like magic, mystery, mother, meta, matrix and membrane.

²*Scientific American*, Dec. 1999

temperature superconductivity. But it will mark the end of a certain kind of physics: the search for a unified theory that entails all other facts of physical science.”

As we explain below in Appendix D - Subatomic Particles, the four forces are transmitted by particles. So ultimately, forces and particles are really the same thing. Therefore, a theory which combines all the four forces is automatically a theory which combines all of matter as well.

Some go even further. Not only is matter just an expression of forces, but these forces are, in turn, just expressions of space-time. When the seven of the eleven dimensions of space-time get curled up very tightly so that we only experience the four remaining dimensions, the seven curled up dimensions express themselves as forces. According to this, the world is no more than just space and time.¹

¹GEORGE JOHNSON (NY Times December 7, 1999) explains this idea in greater detail:

Slightly smaller than what Americans quaintly insist on calling half an inch, a centimeter (one-hundredth of a meter) is easy enough to see. Divide this small length into 10 equal slices and you are looking, or probably squinting, at a millimeter (one-thousandth, or 10 to the minus 3 meters). By the time you divide one of these tiny units into a thousand minuscule micrometers, you have far exceeded the limits of the finest bifocals.

But in the mind's eye, let the cutting continue, chopping the micrometer into a thousand nanometers and the nanometers into a thousand picometers, and those in steps of a thousandfold into femtometers, attometers, zeptometers, and yoctometers. At this point, 10 to the minus 24 meters, about one-billionth the radius of a proton, the roster of convenient Greek names runs out. But go ahead and keep dividing, again and again until you reach a length only a hundred-billionth as large as that tiny amount: 10 to the minus 35 meters, or a decimal point followed by 34 zeroes and then a one. You have finally hit rock bottom: a span called the Planck length, the shortest anything can get. According to recent developments in the quest to devise a so-called "theory of everything," space is not an infinitely divisible continuum. It is not smooth but granular, and the Planck length gives the size of its smallest possible grains. The time it takes for a light beam to zip across this ridiculously tiny distance (about 10 to the minus 43 seconds) is called the Planck time, the shortest possible tick of an imaginary clock. Combine these two ideas and the implication is that space and time have a structure. What is commonly thought of as the featureless void is built from tiny units, or quanta.

"We've long suspected that space-time had to be quantized," said Dr. Steven B. Giddings, a theorist at the University of California at Santa Barbara. "Recent developments have led to some exciting new proposals about how to make these ideas more concrete." The hints of graininess come from attempts to unify general relativity, Einstein's theory of gravity, with quantum mechanics, which describes the workings of the three other forces: electromagnetism and the strong and weak nuclear interactions. The result would be a single framework -- sometimes called quantum gravity -- that explains all the universe's particles and forces.

The most prominent of these unification efforts, superstring theory, and a lesser-known approach called loop quantum gravity, both strongly suggest that space-time has a minute architecture. But just what the void might look like has physicists straining their imaginations. As Dr. John Baez, a theorist at the University of California at Riverside put it: "There's a lot we don't know about nothing."

Since the days of ancient Greece, some philosophers have insisted that reality must be perfectly smooth like the continuum of real numbers: pick any two points, no matter how close together, and there is an infinity of gradations in between. Others have argued that, on the smallest scale, everything is surely divided into irreducible units like the so-called natural or counting numbers, with nothing between, say, 3 and 4.

The development of modern atomic theory, in the 19th century, pushed science toward viewing the universe as lumpy instead of smooth. At the beginning of this century, sentiments swung further in that direction when Max Planck found that even light was emitted in packets. From that unexpected discovery emerged quantum field theory, in which all the forces are carried by tiny particles, or quanta -- all, that is, except gravity.

This force continues to be explained, in entirely different terms, by general relativity: as the warping of a perfectly smooth continuum called space-time. A planet bends the surrounding space-time fabric causing other objects to move toward it like marbles rolling down a hill.

Scientists have long assumed that unification would reveal that gravity, like the other forces, is also quantum in nature, carried by messenger particles called gravitons. But while the other forces can be

vi-A Fifth Force

Until recently, all expectations were that although the universe might still be expanding, the rate of expansion should, due to the force of gravity, at least be slowing down. However, in 1998, measurements of distant exploding stars showed that the expansion of the universe seemed to be speeding up rather than slowing down. Although these results are disputed, everyone agrees that cosmic expansion is slowing down less quickly than previously thought.

This implies one of two things: either there is a lot less matter in the universe than previously thought or some force must be speeding things up. One theory is that the vacuum

thought of as acting within an arena of space and time, gravity *is* space-time. Quantizing one is tantamount to quantizing the other.

It is hardly surprising that space-time graininess has gone unnoticed here in the macroscopic realm. Even the tiny quarks that make up protons, neutrons and other particles are too big to feel the bumps that may exist on the Planck scale. More recently, though, physicists have suggested that quarks and everything else are made of far tinier objects: superstrings vibrating in 10 dimensions. At the Planck level, the weave of space-time would be as apparent as when the finest Egyptian cotton is viewed under a magnifying glass, exposing the warp and woof.

It was Planck himself who first had an inkling of a smallest possible size. He noticed that he could start with three fundamental parameters of the universe -- the gravitational constant (which measures the strength of gravity), the speed of light, and his own Planck's constant (a gauge of quantum graininess) -- and combine them in such a way that the units canceled one another to yield a length. He was not sure about the meaning of this Planck length, as it came to be called, but he felt that it must be something very basic.

In the 1950's, the physicist John Wheeler suggested that the Planck length marked the boundary where the random roil of quantum mechanics scrambled space and time so violently that ordinary notions of measurement stopped making sense. He called the result "quantum foam." "So great would be the fluctuations that there would literally be no left and right, no before and no after," Dr. Wheeler recently wrote in his memoir, "Geons, Black Holes and Quantum Foam" (Norton, 1998). "Ordinary ideas of length would disappear. Ordinary ideas of time would evaporate."

Half a century later, physicists are still trying to work out the bizarre implications of a minimum length. In superstring theory, a mathematical relationship called T duality suggests that one can shrink a circle only so far. As the radius contracts, the circle gets smaller and smaller and then bottoms out, suddenly acting as though it is getting bigger and bigger. "This behavior implies that there is a minimum 'true size' to the circle," Dr. Giddings said. Many believe this will turn out to be roughly comparable to the Planck scale.

There are other indications of graininess. According to the Heisenberg uncertainty principle, certain pairs of quantities are "noncommutative": you cannot simultaneously measure a particle's position and momentum, for example, or its energy and life span. The more precisely you know one, the fuzzier your knowledge of the other becomes.

In string theory, the very geometry of space may turn out to be noncommutative, making it impossible to measure simultaneously the horizontal and vertical position of a particle to perfect precision. The graininess of space itself would get in the way.

Not everyone in the unification business is a string theorist. Coming from an entirely different direction, researchers in a discipline called loop quantum gravity have devised a theory in which space is constructed from abstract mathematical objects called spin nets. Imagine a tiny particle spinning like a top on its axis. Now send it on a roundtrip journey, a loop through space. Depending on the Einsteinian shape of the space the particle traverses, it will return home with its axis tilted in a different direction. This change then provides a clue about how the space is curved.

Using particles with various spins, theorists can probe space in more detail. The different trajectories can then be combined into a web, called a spin network, that captures everything you need to know about how the space is curved -- what physicists call its geometry. "Our space in which we live is just this enormously complicated spin network," said Dr. Carlo Rovelli of the University of Pittsburgh. He and Dr. Lee Smolin of the Center for Gravitational Physics and Geometry at Pennsylvania State University have figured out how to use spin nets to calculate area and volume -- all this information is encoded within the weblike structure.

of space itself creates energy which expresses itself as a repulsive or an anti-gravity force. This force is known as the cosmological constant and was first suggested by Einstein as a fudge factor to correct what he thought was a flaw in his relativity theory.

Einstein, however, was making his calculations according to what he thought was a static universe. When it was shown that the universe was expanding, Einstein abandoned his theory. At that stage it was thought that the density of the universe was much higher than it is thought to be now. Accordingly and given an expanding universe, the fudge factor was no longer necessary. However, it seems that unwittingly, Einstein may have been right. One confirmation of this is the fact that supernovae seem to be fainter than previously predicted. If

the universe has been moving much further apart because the vacuum energy pushes it this

way, the expected results work out perfectly¹.

APPENDIX 5: QUANTUM THEORY

In physics, the word quanta, which means an amount (as in the word quantity), refers to a specific package of energy. Electrons move around the nucleus of an atom at a certain distance depending on how much energy they have. The more energy, the closer to the nucleus. But to move from an outer to an inner orbit requires a very specific quanta of energy,

Suppose you are sitting at a table. To calculate its area you would add up the spins of all the links of the spin net that are passing through it, and multiply by the square of the Planck length. A table with an area of about one square meter would be impinged by some 10 to the 65th of these trajectories. The implication is that the very idea of a surface is an illusion generated by the spin network.

The picture gets even weirder. In quantum mechanics, an electron orbiting an atomic nucleus is thought of as a cloud of probability: a "superposition" in which all the electron's possible locations hover together. In the view of Dr. Rovelli, Dr. Smolin and their colleagues, the universe itself is a superposition of every conceivable spin net -- all the possible ways that it can be curved.

Where does time fit into the picture? A spin net provides a snapshot of the geometry of three-dimensional space at a particular instant. To describe space-time, Dr. Baez and other theorists have stretched spin nets into the fourth dimension, devising what they call spin foam. Slice it and each infinitely thin cross section is a spin net.

Most perplexing of all, spin nets and spin foam cannot be thought of as existing in space and time. They reside on a more fundamental level, as a deep structure that underlies and gives rise to space-time. "That is the core of the matter," Dr. Rovelli said. "They don't *live* somewhere. They *are* the quantum space-time." The universe, in this view, is conjured up from pure mathematics. And the old idea of space and time as the stage on which everything happens no longer seems to apply.

"If we believe what we really have discovered about the world with quantum mechanics and general relativity, then the *stage* fiction has to be abandoned," Dr. Rovelli said, "and we have to learn to do physics and to think about the world in a profoundly new way. Our notions of what are space and time are completely altered. In fact, in a sense, we have to learn to think without them."

¹Scientific American Jan. '99, pg. 33.

Recently, a new attempt to explain this fifth force has emerged by the name of quintessence. This theory tries to explain how a force which is repulsive, pushing the universe apart, rather than attractive, like gravity, might work. The problem, according to Andreas Albrecht of the University of California at Davis, is that in order to match all of the astronomical observations, the repulsion has to be weak for most of the history of the Universe and only become significant in the recent past, when the expansion began to take off. But that sudden "turn-on" behavior often requires theorists to choose specific parameter values just to match the data. This is tantamount to pulling numbers out of a hat. However, progress is being made on this front.

Quintessence models are based on the concepts developed in the 1980s for a now well-accepted theory of the early Universe called inflation, which also involves an accelerating expansion.

Joshua Frieman of the Fermi National Accelerator Laboratory in Illinois says that many researchers have been struggling with the "why now?" problem--the fact that the accelerated expansion began only a few billion years ago, when most of the post-big-bang action should have settled down. So he thinks the new work could be important, but he and Albrecht are both anxious to begin testing such models against the increasingly precise observational data that will be pouring in over the next several years. Without clear tests, theorists are just looking for models with the right properties, says Frieman.

The following extracts from an article by Jeremiah P. Ostriker and Paul J. Steinhardt in Scientific American January 2001, ***The Quintessential Universe. It explains some of the latest issues in greater detail:***

Where does the strange dark-energy, which repels rather than attracts, come from? The best-known possibility is that the energy is inherent in the fabric of space. Even if a volume of space were utterly empty--without a bit of matter and radiation--it would still contain this energy. Such energy is a venerable notion that dates back to Albert Einstein and his attempt in 1917 to construct a static model

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hence the name. In the 1920's, an entire theory of what happens at a sub-atomic level emerged, called quantum mechanics.¹

The following description of Quantum Theory was edited from an article in the *NY Times*, December 2000, by Dennis Overbye:

They tried to talk Max Planck out of becoming a physicist on the grounds that there was nothing left to discover.

Within a quarter of a century, the common sense laws of science had been overthrown. In their place was a bizarre set of rules known as quantum mechanics, in which causes were not guaranteed to be linked to effects; a subatomic particle like an electron could

of the universe. Like many leading scientists over the centuries, including Isaac Newton, Einstein believed that the universe is unchanging, neither contracting nor expanding. To coax stagnation from his general theory of relativity, he had to introduce vacuum energy or, in his terminology, a cosmological constant. He adjusted the value of the constant so that its gravitational repulsion would exactly counterbalance the gravitational attraction of matter.

Later, when astronomers established that the universe is expanding, Einstein regretted his delicately tuned artifice, calling it his greatest blunder. But perhaps his judgement was too hasty. If the cosmological constant had a slightly larger value than Einstein proposed, its repulsion would exceed the attraction of matter, and cosmic expansion would accelerate.

Many cosmologists, though, are now leaning toward a different idea, known as quintessence...A dynamical quantum field, not unlike an electrical or magnetic field, that gravitationally repels.

To explain the amount of dark energy today, the value of the cosmological constant would have to be fine-tuned at the creation of the universe to have the proper value—which makes it sound rather like a fudge factor. In contrast, quintessence interacts with matter and evolves with time, so it might naturally adjust itself to reach the observed value today.

...Gravitational repulsion resolves the “age crisis” that plagued cosmology in the 1990s. If one takes the current measurements of the expansion rate and assumes that the expansion has been decelerating, the age of the universe is less than 12 billion years.

Yet evidence suggests that some stars in our galaxy are 15 billion years old. By causing the expansion rate of the universe to accelerate, repulsion brings the inferred age of the cosmos into agreement with the observed age of celestial bodies.

In Newton's law of gravity, pressure plays no role; the strength of gravity depends only on mass. In Einstein's law of gravity, however, the strength of gravity depends not just on mass but also on other forms of energy and on pressure. In this way, pressure has two effects: direct (caused by the action of the pressure on surrounding material) and indirect (caused by the gravitation that pressure creates).

If the pressure is positive, as it is for radiation, ordinary matter and dark matter, then the combination is positive and gravitation is attractive. If the pressure is sufficiently negative, the combination is negative and gravitation is repulsive.

The repulsion stretches space, increasing its volume and, in turn, the amount of vacuum energy. The tendency to stretch is therefore self-reinforcing. The universe expands at an accelerating pace.

The total vacuum energy produced by all known fields predicts a huge amount...But if this estimate were true, an acceleration of epic proportions would rip apart atoms, stars and galaxies. Clearly, the estimate is wrong. One of the major goals of unified theories of gravity has been to figure out why.

One proposal is that some heretofore undiscovered symmetry in fundamental physics results in a cancellation of large effects, zeroing out the vacuum...A serious flaw, though, is that supersymmetry would be valid only at very high energies. Theorists are working on a way of preserving the perfect cancellation even at lower energies.

...Vacuum energy is not the only way to generate negative pressure. Another means...quintessence. Quintessence does not accelerate the universe as strongly as vacuum energy does. If anything, quintessence is more consistent with the available data, but for now the distinction is not statistically significant.

Where would such a strange field come from?

An exotic possibility is that quintessence springs from the physics of extra dimensions. Over the past few decades, theorists have been exploring string theory, which may combine general relativity and quantum mechanics in a unified theory of fundamental forces. An important feature of string models is that they predict 10 dimensions. Four of these are our familiar three spatial dimensions, plus time.

be in two places at once, everywhere or nowhere until someone measured it; and light could be a wave or a particle.

Niels Bohr, a Danish physicist and leader of this revolution, once said that a person who was not shocked by quantum theory did not understand it.

In 1913, Bohr set forth a model of the atom as a miniature solar system in which the electrons were limited to specific orbits around the nucleus. Einstein praised Bohr's theory as "musicality in the sphere of thought," but told him later, "If all this is true, then it means the end of physics."

While Bohr's theory worked for hydrogen, the simplest atom, it bogged down when theorists tried to calculate the spectrum of bigger atoms. "The whole system of concepts of

The remaining six must be hidden. In some formulations, they are curled up like a ball whose radius is too small to be detected (at least with present instruments). An alternative idea is found in a recent extension of string theory, known as M-theory, which adds an 11th dimension.

We are unable to see the extra dimensions, but if they exist, we should be able to perceive them indirectly. In fact...branes would act just like a field. ...It could exactly mimic the hypothetical quintessence field.

Why has cosmic acceleration begun at this particular moment in cosmic history? Created when the universe was 10^{-35} second old, dark energy must have remained in the shadows for nearly 10 billion years—a factor of nearly 10^{50} in age. Only then, the data suggest, did it overtake matter and cause the universe to begin accelerating. Is it not a coincidence that, just when thinking beings evolved, the universe suddenly shifted into overdrive? Somehow the fates of matter and of dark energy seem to be intertwined. But how?

If the dark energy is vacuum energy, the coincidence is almost impossible to account for. Some researchers, including Martin Rees of the University of Cambridge and Steven Weinberg of the University of Texas at Austin, have pursued an anthropic explanation. Perhaps our universe is just one among a multitude of universes, in each of which the vacuum energy takes on a different value... [Most] universes...expand too rapidly to form stars, planets or life. Our universe would have the optimal value. Only in this "best of all worlds" could there exist intelligent beings capable of contemplating the nature of the universe.

A more satisfying answer...could involve a form of quintessence known as a tracker field...Tracker fields have classical attractor behavior like that found in some chaotic systems. In such systems, motion converges to the same result for a wide range of initial conditions. A marble put into an empty bathtub, for example, ultimately falls into the drain whatever its starting place.

Similarly, the initial energy density of the tracker field does not have to be tuned to a certain value, because the field rapidly adjusts itself to that value. It locks into a track on which its energy density remains a nearly constant fraction of the density of radiation and matter. In this sense, quintessence imitates matter and radiation, even though its composition is wholly different. The mimicking occurs because the radiation and matter density determine the cosmic expansion rate, which, in turn, controls the rate at which the quintessence density changes. On closer inspection, one finds that the fraction is slowly growing. Only after many millions or billions of years does quintessence catch up.

So why did quintessence catch up when it did? Cosmic acceleration could just as easily have commenced in the distant past or in the far future, depending on the choices of constants in the tracker field theory. This brings us back to the coincidence. But perhaps some event in the relatively recent past unleashed the acceleration.

According to the big bang theory, the energy of the universe used to reside mainly in radiation. As the universe cooled, however, the radiation lost energy faster than ordinary matter did. By the time the universe was a few tens of thousands of years old—a relatively short time ago in logarithmic terms—the energy balance had shifted in favor of matter.

In a variation on the tracker models, this transformation triggered a series of events that led to cosmic acceleration today...But when the universe became matter-dominated, the change in the expansion rate jolted quintessence out of its copycat behavior. Instead of tracking the radiation or even the matter, the pressure of quintessence switched to a negative value. Its density held nearly fixed and ultimately overtook the decreasing matter density. In this picture, the fact that thinking beings and cosmic acceleration came into existence at nearly the same time is not a coincidence. Both the formation of stars and planets necessary to support life and the transformation of quintessence into a negative-pressure component were triggered by the onset of matter domination.

physics must be reconstructed from the ground up," Max Born, a physicist at Gottingen University, wrote in 1923. He termed the as yet unborn new physics "quantum mechanics."

The new physics was born in a paroxysm of debate and discovery from 1925 to 1928 that has been called the second scientific revolution. Wolfgang Pauli, one of its ringleaders, called it "boy's mechanics," because many of the physicists, including himself, then 25, Werner Heisenberg, 24, Paul Dirac, 23, Enrico Fermi, 23, and Pascual Jordan, 23, were so young when it began. Bohr, who turned 40 in 1925, was their father-confessor and philosopher king. His new institute for theoretical physics in Copenhagen became the center of European science.

In the short term, the focus of cosmologists will be to detect the existence of quintessence. It has observable consequences. Because its value differs from that of vacuum energy, it produces a different rate of cosmic acceleration.

In the beginning (or at least the earliest for which we have any clue), there was inflation, an extended period of accelerated expansion during the first few instants after the big bang. Space back then was nearly devoid of matter, and a quintessence-like quantum field with negative pressure held sway. During that period, the universe expanded by a greater factor than it has during the 15 billion years since inflation ended. At the end of inflation, the field decayed to a hot gas of quarks, gluons, electrons, light and dark energy.

For thousands of years, space was so thick with radiation that atoms, let alone larger structures, could never form. Then matter took control. The next stage—our epoch—has been one of steady cooling, condensation and the evolution of intricate structure of ever increasing size. But this period is coming to an end. Cosmic acceleration is back. The universe as we know it, with shining stars, galaxies and clusters, appears to have been a brief interlude. As acceleration takes hold over the next tens of billions of years, the matter and energy in the universe will become more and more diluted and space will stretch too rapidly to enable new structures to form. Living things will find the cosmos increasingly hostile. If the acceleration is caused by vacuum energy, then the cosmic story is complete: the planets, stars and galaxies we see today are the pinnacle of cosmic evolution.

But if the acceleration is caused by quintessence, the ending has yet to be written. The universe might accelerate forever, or the quintessence could decay into new forms of matter and radiation, repopulating the universe. Because the dark-energy density is so small, one might suppose that the material derived from its decay would have too little energy to do anything of interest. Under some circumstances, however, quintessence could decay through the nucleation of bubbles. The bubble interior would be a void, but the bubble wall would be the site of vigorous activity. As the wall moved outward, it would sweep up all the energy derived from the decay of quintessence. Occasionally, two bubbles would collide in a fantastic fireworks display. In the process, massive particles such as protons and neutrons might arise—perhaps stars and planets.

To future inhabitants the universe would look highly inhomogeneous, with life confined to distant islands surrounded by vast voids. Would they ever figure out that their origin was the homogeneous and isotropic universe we see about us today? Would they ever know that the universe had once been alive and then died, only to be given a second chance?

Experiments may soon give us some idea which future is ours. Will it be the dead end of vacuum energy or the untapped potential of quintessence? Ultimately the answer depends on whether quintessence has a place in the basic working of nature—the realm, perhaps, of string theory. Our place in cosmic history hinges on the interplay between the science of the very big and that of the very small.

¹Quantum theory ignited a scientific revolution 100 years ago, giving rise to paradoxical notions of lumpy light, wavelike particles and the disconnection of cause and effect. Leading physicists were among those who debated the theory at a 1927 congress in Brussels.

1900 Max Planck proposes that atoms emit energy in discrete amounts, called quanta, rather than in continuous waves.

1905 Albert Einstein explains the photoelectric effect (light strikes an atom and dislodges an electron) by suggesting that light is made of little energy bundles, which are later called photons.

Compact disc players work when the light (photons) from a laser strikes a sensor (photodiode) to generate electrical current (electron release).

The decisive moment came in the fall of 1927 with the Heisenberg uncertainty principle, which stated that it was impossible to know both the position and velocity of a particle at once. The act of measuring one necessarily disturbed the other.

Physicists uncomfortable with Heisenberg's abstract mathematics took up with a friendlier version of quantum mechanics based on the familiar mathematics of waves. In 1923, the Frenchman Louis de Broglie had asked in his doctoral thesis that if light could be a particle, why then couldn't particles be waves?

Inspired by de Broglie's ideas, the Austrian Erwin Schrodinger came up with an equation that would become the yin to Heisenberg's yang. In Schrodinger's equation the electron was not a point or a table but a mathematical entity called a wave function, which

1913 Niels Bohr proposes a planetary model of the atom in which electrons orbit the nucleus and jump between orbits as the atom absorbs or emits energy.

1924 Louis de Broglie develops the idea that matter, like light, can behave as waves. According to de Broglie's formula, the wavelength of an electron is only about one-10,000th the wavelength of a photon of light.

In electron microscopes, beams of matter, electron beams, explore spaces far smaller than those accessible to light. At right, the mouth of the common housefly.

1924 Einstein and Satyendra Nath Bose develop a set of statistics recognizing a class of particles, called bosons, which can collectively exist in the same state of energy.

Photons are bosons, so they can collectively occupy a single state, allowing them to coalesce as an intense laser beam.

1925 Wolfgang Pauli develops the exclusion principle, stating that no two electrons in an atom can occupy the same state of energy simultaneously. This explains the movement of electrons into successive orbits around the nucleus of an atom.

1926 Erwin Schrodinger proposes that an electron is best described by the mathematical function of all its possible energy states, a wave. Max Born later proposes that this wave is not the particle itself, but the probability of finding the particle in a particular place.

1926 Enrico Fermi and Paul Dirac describe the statistical properties of particles that obey the Pauli exclusion principle. Fermions, as they are known, include protons, neutrons and electrons and are distinct from particles that obey Bose-Einstein statistics.

Atoms in certain solids, semiconductors, will collectively fill out their energy orbits with electrons. When excited from a burst of energy, these electrons can move about. Semiconductors are at the heart of the circuits in microprocessors.

1927 Werner Heisenberg arrives at his uncertainty principle, theorizing that it is impossible to measure both the position and momentum of a particle at the same time

Quantum theory ignited a scientific revolution 100 years ago, giving rise to paradoxical notions of lumpy light, wavelike particles and the disconnection of cause and effect. Leading physicists were among those who debated the theory at a 1927 congress in Brussels. The discussion continues in Berlin this week.

Visible Quantum Effects:

Quantum physics, which permit an electron to be in more than one place at the same time, operate at a submicroscopic scale where we can't see or feel them. But quantum effects do occasionally obtrude into visible reality, as in the blobs of matter known as Bose-Einstein condensates which physicists have recently obtained by cooling stuff to near the absolute zero of temperature. Another quantum effect, also brought to light against a background of extreme cold, is that of the dots of relative heat and cold that cover the canvas of space like a pointillist painting.

The dots, which are about twice the size of the full moon, are minute temperature fluctuations that arise from the quantum effects that operated in the first few seconds of the universe's creation, some 15 billion years ago.

The existence of these fluctuations was first discovered in 1992, but in three recent experiments, one conducted at a telescope and two aboard balloons, astronomers have now measured their size, an important statistic that bears on the geometry of the universe. The size of the dots confirms that the universe is "flat", as predicted by an account of its creation known as the inflation theory..

But if quantum physics rules only at invisible scales, how come it can paint the sky with moon-sized dots? Although the answer to this is not clear, scientists believe that it has to do with the fact that the entire universe began as a submicroscopic domain of a size subject to quantum rules. (Reported by

extended throughout space. According to Born, this wave represented the probability of finding the electron at some particular place. When it was measured, the particle was usually in the most likely place, but not guaranteed to be, even though the wave function itself could be calculated exactly.

Born's interpretation was rapidly adopted by the quantum gang. It was a pivotal moment because it enshrined chance as an integral part of physics and of nature.

"The motion of particles follows probability laws, but the probability itself propagates according to the law of causality," he explained.

That was not good enough for Einstein. "The theory produces a good deal but hardly brings us closer to the secret of the Old One," Einstein wrote in late 1926. "I am at all events convinced that he does not play dice." Heisenberg called Schrodinger's theory "disgusting", but both versions of quantum mechanics were soon found to be mathematically equivalent.

Uncertainty, which added to the metaphysical unease surrounding quantum physics, was followed by Bohr's **complementarity** principle in 1927. **Ask not whether light was a particle or a wave, said Bohr, asserting that both concepts were necessary to describe nature, but that since they were contradictory, an experimenter could choose to measure one aspect or the other but not both.** This was not a paradox, he maintained, because physics was not about things but about the results of experiments.

A year later, Dirac married quantum mechanics to Einstein's special relativity, in the process predicting the existence of antimatter. (The positron, the antiparticle to the electron, was discovered four years later by Carl Anderson.) Dirac's version, known as quantum field theory, has been the basis of particle physics ever since and signifies, in physics histories, the end of the quantum revolution. But the fight over the meaning of the revolution had just barely begun, and it has continued to this day.

Quantum Wars

The first and greatest counterrevolutionary was Einstein, who hoped some deeper theory would rescue G-d from playing dice. In the fall of 1927 at a meeting in Brussels, Einstein challenged Bohr with a series of gedanken, or thought experiments, designed to show that quantum mechanics was inconsistent. Bohr, stumped in the morning, always had an answer by dinner.

Einstein never gave up. A 1935 paper written with Boris Podolsky and Nathan Rosen described the ultimate quantum gedanken, in which measuring a particle in one place could instantly affect measurements of the other particle even if it was millions of miles away. Was this any way to run a universe?

Einstein called it "spooky action at a distance."

Modern physicists who have managed to create this strange situation in the laboratory call it "entanglement." "Entangled objects behave as if they were connected with another no matter how far apart they are – distance does not attenuate entanglement in the slightest. If something is entangled with other objects, a measurement of it simultaneously provides information about its partners¹." Today, scientists are seriously working with this concept to see whether they can speed up the transfer of information.

Einstein's defection from the quantum revolution was a blow to his more conservative colleagues, but he was not alone. Planck also found himself at odds with the direction of the

Nicholas Wade, N.Y. Times, Nov 22 99)

¹Scientific American, November 02.

revolution, and Schrodinger, another of "the conservative old gentlemen," as Pauli once described them, advanced his cat experiment to illustrate how silly physics had become.

According to the Copenhagen view, it was the act of observation that "collapsed" the wave function of some particle, freezing it into one particular state, a location or velocity. Until then, all the possible states of the particle coexisted, like overlapping waves, in a condition known as quantum superposition.

Schrodinger imagined a cat in a sealed container in which the radioactive decay of an atom would trigger the release of cyanide, killing the cat. By the rules of quantum mechanics the atom was both decayed and not decayed until somebody looked inside, which meant that Schrodinger's poor cat was both alive and dead.

This seemed to be giving an awful lot of power to the "observer." It was definitely no way to run a universe.

Over the years, physicists have proposed alternatives to the Copenhagen view.

Starting in 1952 when he was at Princeton, the physicist David Bohm argued for a version of quantum mechanics in which there was a deeper level, a so-called quantum potential or "implicate order" guiding the apparent unruliness of quantum events.

Another variant is the many-worlds hypothesis developed by Hugh Everett III and John Wheeler at Princeton in 1957. In this version the wave function does not collapse when a physicist observes an electron or a cat; instead, it splits into parallel universes: one for every possible outcome of an experiment or a measurement.

Shut up and compute

Most physicists simply ignored the debate about the meaning of quantum theory in favor of using it to probe the world, an attitude known as "shut up and compute."

Pauli's discovery that no two electrons could share the same orbit in an atom led to a new understanding of atoms, the elements and modern chemistry.

Quantum mechanics split the atom and placed humanity on the verge of plausible catastrophe. Engineers learned how to "pump" electrons into the upper energy rungs in large numbers of atoms and then make them dump their energy all at once, giving rise to the laser. And as Dr. Lederman said in an interview, "The history of transistors is the history of solving Schrodinger's equation in various materials."

Quantum effects were not confined to the small. The uncertainty principle dictates that the energy in a field or in empty space is not constant but can fluctuate more and more wildly the smaller the period of time that one looks at it. Such quantum fluctuations during the Big Bang are now thought to be the origin of galaxies.

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In some theories, the universe itself is a quantum effect, the result of a fluctuation in some sort of pre-universal nothingness. "So we take a quantum leap from eternity into time," as the Harvard physicist Sidney Coleman once put it.

Where the Weirdness Goes

Bohr ignored Schrodinger's cat on the basis that a cat was too big to be a quantum object, but the cat cannot be ignored anymore. In the last three decades, the gedanken experiments envisioned by Einstein and his friends have become "ungedankenened," bringing the issues of their meaning back to the fore.

Two teams of physicists managed to make currents go in two directions at once around tiny superconducting loops of wire — a feat they compared to Schrodinger's cat. Such feats, said Wojciech Zurek, a theorist at Los Alamos National Laboratory, raise the question of why we live in a classical world at all rather than in a quantum blur. Bohr postulated a border between the quantum and classical worlds, but theorists prefer that there be only one world that can somehow supply its own solidity. That is the idea behind a new concept called decoherence, in which the interaction of wave functions with the environment upsets the delicate balance of quantum states and makes a cat alive or dead but not in between.

"We don't need an observer, just some 'thing' watching," Dr. Zurek explained. When we look at something, he said, we take advantage of photons, the carriers of light, which contain information that has been extracted from the object. It is this loss of information into the environment that is enough to crash the wave function, Dr. Zurek said.

Decoherence, as Dr. Zurek noted, takes the observer off a pedestal and relieves quantum theory of some of its mysticism, but there is plenty of weirdness left. Take the quantum computer, which Dr. Lederman refers to as "a kinder, gentler interpretation of quantum spookiness."

Ordinary computers store data and perform computations as a series of "bits," switches that are either on or off, but in a quantum computer, due to the principle of

superposition, so-called qubits can be on and off at the same time, enabling them to calculate and store myriads of numbers at a time.

In principle, according to David Deutsch, an Oxford University researcher who is one of quantum computing's more outspoken pioneers, a vast number of computations, "potentially more than there are atoms in the universe," could be superposed inside a quantum computer to solve problems that would take a classical computer longer than the age of the universe. In the minds of many experts, this kind of computing illuminates the nature of reality itself.

Dr. Deutsch claims that the very theory of a quantum computer forces physicists to take seriously the many-worlds interpretation of quantum theory. The amount of information being processed in these parallel computations, he explains, is more than the universe can hold. Therefore, they must be happening in other parallel universes out in the "multiverse," as it is sometimes called.

"There is no other theory of what is happening," he said. The world is much bigger than it looks, a realization that he thinks will have a psychological impact equivalent to the first photographs of atoms. Indeed, for Dr. Deutsch there seems to be a deep connection between physics and computation. The structure of the quantum computer, he says, consists of many things going on at once, lots of parallel computations. "Any physical process in quantum mechanics," he said, "consists of classical computations going on in parallel."

"The quantum theory of computation is quantum theory," he said.

Teleporting Atoms

In 2004, scientists first teleported individual charged atoms trapped in magnetic fields, taking characteristics of one atom and imprinting them on a second¹. The ability to create a replica of an object, or at least some aspect of it, at some distance from the original, destroys the original so it is impossible produce multiple copies. But it could prove an important component of so-called quantum computers. Although, currently, the atoms were just moved a fraction of a millimeter, in principle, the atoms could be teleported over much longer distances. Scientists hope that one day such computers will tap quantum mechanics to solve complex problems quickly by calculating many different possible answers at once; computers today must calculate each possibility separately. A conventional computer chip operates by either showing a one or a zero. The promise of quantum computers is that both a zero and a one can exist at once, just like the perplexing premise described by the Austrian physicist Erwin Schrödinger in which a cat in a box can be simultaneously alive and dead until someone looks inside. Teleporting can be seen as a way of transferring the information. A quantum computer could use teleportation to move the results of calculations from one part of the computer to another much quicker than current computers can manage, and faster even than moving individual atoms. Scientists have also succeeded in teleporting photons and the magnetic field produced by clouds of atoms. Teleporting a much larger object, like a person,

¹The scientists were able to transfer information from atom A to atom C without the two meeting by using a third atom, B, as an intermediary. First, atoms B and C were brought together, making them "entangled" and creating an invisible link between the two atoms no matter how far apart they were. Atom C was moved away. Next, A and B were similarly entangled. Then the scientists measured the energy states of A and B, essentially opening the boxes to see whether each contained a 1 or a zero. Because B had been entangled with C, opening A and B created an instant change in atom C, what Albert Einstein called "spooky action at a distance," and this, in essence, set a combination lock on atom C, with the data in A and B serving as the combination. For the final step, the combination was sent and a pulse of laser light was applied to atom C, almost magically turning it into a replica of the original A. Atom A was teleported to atom C.

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appears unlikely, if not entirely impossible, because too much information would have to be captured and transmitted¹.

The Roots of Weirdness

Quantum mechanics is the language in which physicists describe all the phenomena of nature save one, namely gravity, which is explained by Einstein's general theory of relativity. The two theories — one describing a discontinuous "quantized" reality and the other a smoothly curving space-time continuum, are mathematically incompatible, but physicists look to their eventual marriage, a so-called quantum gravity.

"There are different views as to whether quantum theory will encompass gravity or whether both quantum theory and general relativity will have to be modified," said Lee Smolin, a theorist at Penn State.

Some groundwork was laid as far back as the 1960's by Dr. Wheeler, who argued quantum theory with both Einstein and Bohr. Even space and time, Dr. Wheeler pointed out, must ultimately pay their dues to the uncertainty principle and become discontinuous, breaking down at very small distances or in the compressed throes of the Big Bang into a space-time "foam."

Most physicists today put their hope for such a theory in super-strings, an ongoing and mathematically dense effort to understand nature as consisting of tiny strings vibrating in 10-dimensional space.

In a sort of missive from the front, Edward Witten of the Institute for Advanced Study in Princeton N.J. said recently that so far quantum mechanics appeared to hold up in string land exactly as it was described in textbooks. But, he said in an e-mail message, "Quantum mechanics is somehow integrated with geometry in a way that we don't really understand yet."

The quantum is mysterious, he went on, because it goes against intuition. "I am one of those who believes that the quantum will remain mysterious in the sense that if the future brings any changes in the basic formulation of quantum mechanics, I suspect our ordinary intuition will be left even farther behind."

Intuition notwithstanding, some thinkers wonder whether or not quantum weirdness might, in fact, be the simplest way to make a universe. After all, without the uncertainty principle to fuzz the locations of its buzzing inhabitants, the atom would collapse in an electromagnetic heap. Without quantum fluctuations to roil the unholy smoothness of the Big Bang, there would be no galaxies, stars or friendly warm planets. Without the uncertainty principle to forbid nothingness, there might not even be a universe.

"We will first recognize how simple the universe is," Dr. Wheeler has often said, "when we recognize how strange it is." Einstein often said that the question that really consumed him was whether G-d had any choice in creating the world. It may be in the end that we find out that for G-d, the only game in town was a dice game.

When this theory is applied to the force of electromagnetism, it is called quantum electrodynamics, or QED. When it is applied to the strong force, it is called quantum chromodynamics or QCD. Although it was first proposed in the 1970's, scientists are still busy proving QCD. All the evidence thus far has confirmed it. Two recent experiments, the last finishing in November 1995, required a super-computer which could perform 11 billion

¹Adapted from Kenneth Chang, in the NY Times, June, 17, '04 (*Scientists Teleport not Kirk, but an Atom*)

arithmetic operations per second to run continuously for one and two years consecutively, but still only managed to come up with an approximation.

Recently, attempts have been made to apply quantum physics to space and time as well¹. This would mean that space and time also come in discrete quanta, or packages. In other words, they are not smooth but grainy². It is true that space and time look smooth to us, but this is just an illusion. If we look at the world on a small enough scale, we see a different picture³. We will see that space and time are made up of extremely fine-grained structures, which helps explain why they appear so smooth to us. Regarding time, “A blink of an eye has more fundamental moments than there are atoms in Mount Everest,” says physicist Smolin. Similarly with space: space is made of discrete atoms, each of which carries a very tiny unit of volume⁴.

Once space and time are shown displaying quantum effects, gravity too should be subject to these forces (for space and time also exist on a macro level, the level at which gravity operates). At large scales, the effects of gravity are easy enough to see: think falling apples or the movement of planets around the sun. At the atomic level, however, the force is extremely weak, making its quantum effects difficult to measure. But, in 2002, scientists were finally able to confirm what quantum rules predict: namely, that elementary particles under the influence of gravity move from one energy state to another by making quantum leaps.

APPENDIX 5: SUBATOMIC PARTICLES

i-The Standard Model, the Four Forces and their Particles

ii-Neutrinos

iii-Anti-Matter

iv-Missing Matter and Paired particles

v –Other Expected Particles

¹One theory which is used to describe this is called Loop quantum gravity.

²As Lee Smolin of Pennsylvania state University asserts in his new book, “Three Roads to Quantum Gravity”

³Smolin: Behind them is a world composed of discrete sets of events, which can be counted. At a level of between 10^{-33} centimeter to 10^{-43} seconds, i.e. the time it takes light to flash across such a narrow gap. This makes up a unit of measurement called the “plank scale” is the size at which space and time may be fragmented into distinct units.

⁴Smolin maintains that we must adopt a “relational” viewpoint, “in which space and time are nothing but networks of relationships.”

APPENDIX 5: SUBATOMIC PARTICLES

i-The Standard Model, the four forces and their particles

(See **Appendix B** for a description of each one of the four forces)

Atoms are comprised of a nucleus at the core and electrons surrounding it. The nucleus is in turn comprised of neutrons and protons which are really made up of quarks. So, the basic building blocks of the universe are really electrons and quarks plus a mysteriously neutral particle called the neutrino (which we will discuss below).

There are actually several hundred subatomic particles that have been discovered to date. Some of them exist for only fractions of a second, when electrons, protons or other particles collide. Every time a particle is created, so is an anti-particle. If a particle collides with its anti-particle they destroy each other. (Scientists have a hard time explaining why there are so many more particles than anti-particles in the universe.) Each of the four forces operates on some subatomic substance and also has a carrier substance to transmit or communicate the force from one place to another. The particles associated with the actual forces are called fermions, whereas the particles which carry the forces are called bosons¹.

Gravity operates on large objects. The particle which is supposed to transmit gravity is called the **graviton**. Gravitons have never been seen or even proven. This is because gravity is so weak that the effect of the graviton on matter is very hard to detect.

Both electromagnetism and the weak force operate on electrons (and heavier versions of the electron called muons and taus), though the weak force also operates on quarks (see the strong force below) and on the most common particle in the universe, the neutrino (See ii

¹Ultimately, all particles are divided between fermions and bosons. fermions are the particles which make up the material world. they are particles such as electrons, protons and neutrons, as well as the related particles the muon, the tau and the neutrinos. bosons generate the forces of nature. photons (responsible for electromagnetism) and gluons (which bind quarks together) are the best known bosons. w and z particles as well as the postulated graviton and higgs particle are also bosons. The underlying difference between bosons and fermions is this: in a collection of particles, if two identical fermions are swapped (for instance, switch two electrons), the total quantum state of the collection is inverted. (image crests and troughs of a wave being interchanged.) swapping two identical bosons, in contrast, leaves the total state unaltered. fermions are inherently the individualists and loners of the quantum particle world: no two fermions ever occupy the same quantum state. their aversion to close company is strong enough to hold up a neutron star against collapse when the crushing weight of gravity has overcome every other force of nature. bosons, in contrast, are convivial copycats and readily gather in identical states. every boson in a particular state encourages more of its species to emulate it. under the right conditions, bosons form regimented armies of clones, such as the photons in a laser beam or the atoms in superfluid helium 4. those characteristics lead to the pauli exclusion principle, which prevents two fermions from occupying the same quantum state. bosons, in contrast, prefer to collect in identical states, as demonstrated by helium 4 atoms in a superfluid. yet somehow in the mirror of supersymmetry, standoffish fermions look magically like sociable bosons, and vice versa. figuratively, you might say it is a symmetry that lets you compare apples and oranges. hold up an apple to the supersymmetry mirror, and its reflection looks and tastes like an orange. by mapping bosons onto fermions, and vice versa, supersymmetry opens up a new class of possible relations among particles. these relations results in far greater computational power for analyzing or predicting a system's behavior. for the known particles to obey supersymmetry, they must each have a "superpartner" – every boson must have a fermionic counterpart, and vice versa. the known particles do not have the right properties to be one another's partners, so new particles are predicted. the standard model is extended to the supersymmetric standard model. the postulated fermionic partners go by the names photino, gluino, wino, zino, gravitino and higgsino. the bosonic partners have an "s" added to their names: selectron, smuon, sneutrino, squark and so on. None of these particles have yet been detected.

- Neutrinos below). The transmitting particle for electromagnetism is the photon, which also transmits light. The transmitting particles for the weak force are the W and Z particles.

The Strong Force operates on **quarks**, of which there are at least 18 different kinds. However, only the lightest quarks, the up and the down quark, comprise ordinary protons and neutrons. The other quarks (the top and the bottom, the strange and the charm) do not occur in the natural world. They were thought to have existed, however, at the time of the Big Bang, and they have been reproduced in giant accelerators through the efforts of thousands of scientists. The most difficult of these quarks to reproduce, the top quark, was only finally confirmed by Fermilab (near Chicago) as late as 1995 by several teams comprising a total of 1,000 scientists. It turned out to be very heavy, more than an atom of gold, and has a lifetime of only about 10^{-24} of a second. However, at very high temperatures (such as soon after the Big Bang), the quark loses all mass (as do the W, Z, photons and leptons).

The strong force is so strong that even those quarks which do occur in the natural world can never be found on their own but rather only in protons and neutrons.

The transmitting particle for the strong force is the **gluon**. When the weak force acts on quarks, it causes them to decay and **it** to radiate energy (radiation).

The Standard Model

Scientific American, July 2000, *The Large Hadron Collider*:

In the past 30 years, particle physicists have established a relatively compact picture, the Standard Model, which successfully describes the structure of matter down to 10^{-18} meter. The Standard Model succinctly characterizes all the known constituents of matter and three of the four forces that control their behavior. The constituents of matter are six particles called leptons and six called quarks. One of the forces, known as the strong force, acts on quarks, binding them together to form hundreds of particles known as hadrons. The proton and the neutron are hadrons, and a residual effect of the strong force binds them together to form atomic nuclei. The other two forces are electromagnetism and the weak force, which operates only at very short range but is responsible for radioactive beta decay and is essential for the sun's fuel cycle. The Standard Model elegantly accounts for these two forces as a "unified" electroweak force, which relates their properties despite their appearing very different.

More than 20 physicists have won Nobel Prizes for work that contributed to the Standard Model, from the theory of quantum electro-dynamics (the 1965 prize) to the discovery of the neutrino and the tau particle (1995) and the theoretical work of Gerardus 'de Hooft and Martinus J G Veltman while at the University of Utrecht (1999). Nevertheless, although it is a great scientific achievement and is confirmed by a plethora of experiments (some to extraordinary precision), the Standard Model has a number of serious flaws.

First, it does not consistently include Albert Einstein's theory of the properties of space-time and its interaction with matter. This theory, general relativity, provides a beautiful, experimentally very well-verified description of the fourth force, gravity. The difficulty is that the Standard Model is a fully quantum-mechanical theory whereas general relativity is not quantum-mechanical and its predictions must therefore break down at very small scales (very far from the domain in which it has been tested). The absence of a quantum-mechanical description of gravity renders the Standard Model logically incomplete.

Second, although it successfully describes a huge range of data with simple underlying equations, the Standard Model contains many apparently arbitrary features. It is too baroque, too Byzantine, to be the full story. For example, it does not indicate why there are six quarks and six leptons instead of, say, two or four. Nor does it explain why there are

equal numbers of leptons and quarks – is this just a coincidence? On paper we can construct theories that give better answers and explanations in which there are deep connections between quarks and leptons, but we do not know which, if any, of these theories is correct.

Third, the Standard Model has an unfinished, untested element. This is not some minor detail but a central component, a mechanism to generate the observed masses of the particles. Particle masses are profoundly important, as altering the mass of the electron, for example, would change all of chemistry, and the masses of neutrinos affect the expansion of the universe. (Neutrinos' masses are at most a few millionths of an electron's mass, but recent experiments indicate that they are probably not zero.)

Physicists believe that particle masses are generated by interactions with a field that permeates the entire universe; the stronger a particle interacts with the field, the more massive it is. The nature of this field, however, remains unknown. It could be a new elementary field, known as the Higgs field, after British physicist Peter Higgs. Alternatively, it may be a composite object, made of new particles ("techniquarks") tightly bound together by a new force ("technicolor"). Even if it is an elementary field, there are many variations on the Higgs theme: how many Higgs fields are there, and what are their detailed properties?

To address this kind of physics requires re-creating conditions that existed just a trillionth of a second after the Big Bang, a task that will push modern technologies to their limits and beyond.

Charles W. Petit wrote the following article in the U.S. News & World Report, February 19, 2001, *By the light of the muon*:

Last week...researchers revealed the first sign of error in the Standard Model...

An international, 68-member team spent several years scrutinizing debris spawned by billions of protons crashing into nickel at nearly the speed of light in Brookhaven's cyclotron. They were looking for a number—specifically for a ratio in the magnetic behavior of spinning, short-lived particles called muons—particles like electrons, only heavier. They came up with 0.0011659203. The standard model, which has always been verified by such precise measurements, is more like 0.0011659159.

ii-Neutrinos

Neutrinos are tiny, electrically neutral particles, 600 million times more numerous than electrons and protons put together, which move at high speeds, nearly the speed of light, throughout the universe. Neutrinos penetrate anything and everything: there are millions of them going through us at any one time and they can even go through the earth from one side to the other.

Until 1998, it was thought that neutrinos have no mass, but then a huge detector placed 2000 feet down a mine shaft in Japan and filled with water discovered that they do, in fact, have a tiny mass.¹ If they have the mass of just one tenth of an electron volt, neutrinos would account for as much mass as the entire visible universe.

¹According to the Standard Model, neutrinos have no mass. But two years ago, a Japanese experiment called Super-Kamiokande found evidence that neutrinos have at least a small mass, without determining what that mass is. Experiments which involve shooting beams of neutrinos hundreds of miles underground to distant detectors are now underway to see if one type of neutrino changes into another en route. According to advanced theories, any such transmutation would be an indication of the mass. Knowing the value of the mass could help settle several mysteries, including how much swarms of neutrinos in space might contribute to the weight of the universe.

This is of great significance because it would account for much of the “missing matter” of the universe. It may also lead to significant modifications in the standard model of matter.¹

Neutrinos remain problematic, though, because the sun ought to be omitting many more than we measure coming from that source. Some theories speculate that there are at least four types of neutrinos (three are currently known to exist), and that one of these (the sterile neutrino) is undetectable.²

In July 2000, the tau neutrino was discovered at Fermilab (Fermi National Accelerator Laboratory) near Chicago³ (As reported in the NY Times by James Glanz). (The scientists had to fire an estimated 100 trillion tau neutrinos into an advanced emulsion similar to photographic film to find just four neutrinos which produced minute but clearly recognizable streaks in the emulsion. Although their existence had been suspected for 25 years, tau neutrinos had escaped detection because it takes a large amount of energy to create them and because neutrinos pass through most matter almost without a trace. Up until the mid 1990s, many scientists regarded detection of the Tau as virtually impossible.) This leaves just one particle yet to be discovered: the Higgs boson, which is predicted by the Standard Model, possibly the source of all mass in the universe.

Physicist Wolfgang Pauli first postulated the existence of neutrinos in the 1930's to account for energy and momentum that seemed to vanish during the radioactive decay of various elements. So weakly do the particles interact with matter that physicists had to wait nearly 30 years for the first detection of any neutrinos.

Neutrinos are produced in great numbers in the solar core. Most of the energy created in the center of the sun takes millions of years to reach the solar surface and leave as sunlight. Neutrinos, in contrast, emerge after two seconds. However, in thirty years of experiments the number of neutrinos arriving from the sun was always significantly less than the predicted total. The Standard Model of particle physics holds that there are three completely distinct, mass-less flavors of neutrinos: the electron-neutrino, muon-neutrino and tauneutrino. Experiments were designed to look exclusively for this one flavor - at solar neutrino energies, only electron neutrinos can convert chlorine atoms to argon. But scientists suspect that electron-neutrinos from the sun are transformed into one of the other flavors and thus escape detection⁴. The Neutrinos would then oscillate during their eight-minute journey through the vacuum of space from the sun to the earth.

Neutrinos can be observed deep underground because of the extreme weakness of their interaction with matter. To detect all types of Neutrinos, scientists built SNO. 1,000 tons of heavy deuterium water was brought to the bottom of a nickel mine in Sudbury, two

¹Scientific American, Aug. 1998

²NY Science Times, 1998

³Neutrinos, like electrons and muons, are all known as leptons within the Standard Model. Leptons are a class of particles that do not interact strongly with matter. So when Dr. Perl and colleagues discovered a new lepton, called the tau particle, in 1975, they assumed that the electron neutrino and muon neutrino would soon have company in the form of the tau neutrino. Dr. David O. Caldwell, a physicist at the University of California in Santa Barbara, said that it would have been "an incredible surprise" if the tau particle did not have its own neutrino, as the electron and the muon do. Some speculative theories beyond the Standard Model postulate yet another neutrino, a so-called sterile neutrino that would be associated with no other particle.

⁴The Standard Model would not allow for this. But, scientists are in agreement that the Standard Model is incomplete. This would allow for some neutrino flavors to mix with each other.

kilometers below the surface of the earth¹. Although the vast majority of neutrinos that enter SNO pass through it, on very rare occasions one will, by chance alone, collide with an electron or an atomic nucleus and deposit enough energy to be observed. Five million high-energy solar neutrinos pass through every square centimeter of the earth every second.

SNO results agree remarkably well with the predictions of solar models². We can now claim that we really do understand the way the sun generates its power.

If neutrinos change flavor through oscillation, they cannot be mass-less. After photons, neutrinos are the second most numerous known particles in the universe, so even a tiny mass could have a significant cosmological significance. Neutrinos were the last known particles that could have made up the missing dark matter. This amount is not quite enough to explain all the matter that seems to be present in the universe, and therefore, some particle or particles not currently known to physics must exist (with a density in excess of everything we do know).

Future neutrino experiments might probe one of the biggest mysteries in the cosmos: Why is the universe made of matter rather than antimatter? Russian physicist Andrei Sakharov first pointed out that to get from a Big Bang of pure energy to the current matter-dominated universe required the laws of physics to be different for particles and antiparticles. This is called CP (charge-parity) violation, and sensitive measurements of particle decays have verified that the laws of physics violate CP. The problem is that the CP violation seen so far is not enough to explain the amount of matter around us, so phenomena we have not yet observed must be hiding more CP violation. One possible hiding place is neutrino oscillations. To observe CP-violating neutrino oscillations will probably be more than a decade.

iii-Anti-Matter

In 1928, the English physicist P.A.M. Dirac predicted the existence of antimatter. Dirac claimed that for every particle of ordinary matter there was an antiparticle with the same mass but an opposite charge. These antiparticles could join to form anti-atoms, which in turn could form antimatter counterparts to every object in the universe – anti-stars, anti-galaxies, even anti-humans. What is more, if a particle of matter collided with a particle of antimatter, they would both be annihilated in an energetic burst of gamma rays. If a human and an anti-human shook hands, the resulting explosion would be the equivalent of 1,000 one-megaton nuclear blasts, each one capable of destroying a small city.

It was an extraordinary proposition. The theory was confirmed just four years later, when Carl D. Anderson, a physicist at the California Institute of Technology, detected the first antiparticle. While using a cloud chamber to study cosmic rays (high energy particles that bombard the earth from space), Anderson observed a vapor trail made by a particle with the

¹During the day, neutrinos easily travel down to SNO through two kilometers of rock, and at night they are almost equally unaffected by the thousands of kilometers that they travel up through the earth.

²must estimate how many of the apparent neutrinos are caused by something else, such as radioactive contamination. SNO must estimate how many of the apparent neutrinos are caused by something else, such as radioactive contamination.

Based on this, SNO results showed a total neutrino flux of 5.09 million per square centimeter per second. Nearly two thirds of the total 5.09 million neutrinos arriving from the sun are either muon- or tau neutrinos. The fusion reactions can produce only electron neutrinos, so some of them must be transformed on their way to the earth. The fundamental particles have properties contained in the Standard Model deduced 5.09 million neutrinos agrees remarkably well with the predictions of solar models

same mass as an electron but an opposite (that is, positive) charge. Dubbed the positron, it was the anti-matter counterpart of the electron. Antiprotons proved harder to find, but in 1955 physicists at Lawrence Berkeley Laboratory used a particle accelerator to create them. In 1995, scientists at CERN, the European laboratory for particle physics near Geneva, synthesized atoms of anti-hydrogen - for a brief instant - by merging positrons and antiprotons in a particle accelerator.

In recent years scientists have built sophisticated detectors to search for antimatter in cosmic rays. Because cosmic rays are destroyed by collision with the nuclei of air molecules, researchers have lofted their detectors in balloons into the least dense reaches of the atmosphere. There they have found many anti-particles of different sorts.

iv-Missing Matter and Paired Particles

Astronomers claim that as much as 90% of the universe may be undetectable or dark matter. There are three ways of measuring the total mass of the universe, each coming to a different result and each indicating that the universe is filled with some kind of extraordinary matter.

Another mystery which this missing matter would solve is why the four forces of nature differ so greatly in strength (for one thing, quantum forces ought to equalize the strength of these forces). One way of explaining this is by showing how each force actually pairs off with another, hidden partner in a kind of super-symmetry. The photons would pair off with a (theoretical) photino, the quark with a squark, and so on. For each particle, physicists believe there is a more massive "sparticle" that remains to be discovered.

The search for sparticles is a central goal of particle physics today. The easiest one to find should be the lightest one, the "neutralino." It is thought to be much bigger than a proton yet much weaker. Hence it is called a WIMP – a weakly interacting massive particle. Physicists think that WIMPs may make up the missing dark matter, or at least most of it¹. The amount of WIMPs which the Big Bang ought to have produced correlates nicely with the amount of missing or dark matter. In fact, in 1999 an Italian group of scientists actually claimed to have found WIMPs, though many scientists remain skeptical.²

¹There are at least two candidates for dark particle. One is called the axion, a wisp weighing less than a billionth as much as an electron. The other are WIMPs, heavier relics of the big bang that would weigh as much as a metal atom.

²Scientific American, March 1999.

A team of physicists based at the University of Rome has generated both intense excitement and profound skepticism among scientists around the world by presenting evidence that they may have detected a heavy particle that could solve a 70-year-old mystery in astronomy and lead to a conceptual breakthrough in physics.

The presumed particles would weigh at least 50 times as much as a proton and would almost always pass through other matter without a trace because of an extremely weak ability to interact with it. The new evidence, which so far has not been confirmed by other scientists, would suggest that space is swarming with enough of the particles to account for the long-sought "dark matter" variously called a neutralino and a weakly interacting, massive particle, or WIMP that astronomers believe makes up some 80 percent of all the mass in the universe.

Though astronomers have been measuring the gravitational pull of the dark matter since the 1930's, they have never succeeded in detecting it directly. A particle like the one that may have been found could also be part of an entire family of still-undiscovered particles predicted by an advanced theory of physics called supersymmetry. Many physicists regard supersymmetry as a possible first step toward an ultimate theory that would account for all the known forces and particle behaviors in nature -- marrying quantum theory and gravity, for example.

Analysis of data collected over three years in an underground experiment at the Gran Sasso National Laboratory east of Rome "favors the possible presence of a WIMP." The group came to its conclusion

Detecting a particle means getting it to interact with the ordinary matter in an instrument, quite a complex feat given that, ordinarily, interacting is just what dark matter particles don't do¹.

Dark matter may be made up, at least in part, of "supermassive" black holes². In October 2002, astrophysicists tracked a star, called S2, racing around a dark mass at the center of the Milky Way, which offered some support to this theory³.

Supermassive black holes (the term for black holes whose mass is more than 1 million times that of the sun) can be found at the center of many galaxies⁴. The pull of this dark mass is so great that even light can't escape it, rendering it invisible but still felt by its immense gravitational pull.

In the last two years, scientists have come to accept a second dark ingredient: some kind of dark energy that causes the universe to expand at an ever-increasing rate. Even if a WIMP blunders into one of these traps and scientists can finally move toward solving the dark matter mystery, the mystery of dark energy will remain⁵.

by noting seasonal variations in the counts registered on their detector, as expected if Earth is passing through a cloud of the particles in its orbit.

Because the sun is orbiting around the center of the Milky Way at a speed of about 140 miles per second, through the clouds of WIMPs, "a billion of them would be passing through your body every second. Rarely, however, a WIMP should interact with ordinary matter in a collision.

"The Copernican revolution told us we're not the center of the universe," Dr. Cline said. "This tells us we're not the matter of the universe." Intellectually, he said, the development "is just the tip of an incredible iceberg, if this is right." But a number of scientists, including Dr. Turner, said it was still unclear whether the finding was correct.

¹The answer is to design detectors discriminating enough to pick out the one dark matter particle in countless trillions that does signal its passage, without being swamped by noise from mundane sources such as radioactivity and cosmic rays. The attempt at snaring a WIMP involves putting in hockey-puck-size disks of germanium and silicon, cooled almost to absolute zero placed deep in a mine. Another team relies on 250 pounds of sodium iodide, a material that gives off faint flashes of light when particles collide with it. A third attempt will use a supercooled crystal detector. Yet another hopes to trap WIMPs in tanks of liquid xenon deep in Britain's Boulby mine.

²What is known is that at the center of the Milky Way, our galaxy, there is a dark mass of unknown composition. This is less mysterious than dark matter, which cannot be located at all. Nevertheless, research on the dark mass may throw light on dark matter as well.

³A star that happens to be close to a supermassive black hole will orbit very rapidly around a point of seemingly empty space. Another clue is the radiation emitted by gas that is heated up just before it is swallowed forever by the black hole.

Scientists tracked the orbit of the closest known star to the black-hole candidate Sagittarius A*, a dark mass 3 million times the sun's mass. Following the star for 10 years, they found that it does indeed orbit Sagittarius A*. Approaching the black hole's maw, the star reaches its highest velocity, whizzing past it at 5,000 kilometers per second.

⁴Supermassive black holes are thought to evolve when many smaller black holes merge like smaller bubbles into a big one at the center of a galaxy and start swallowing everything that comes their way. Such a black hole is what remains from an exploded sun much bigger than our own. The explosion is a rare celestial phenomenon called supernova, which happens when these developed stars use up all their nuclear fuel.

Without fuel to maintain the huge pressure that is required to counter gravity, the star first implodes, and then the outer layers rebound against its core and are violently ejected into space, in a process that is one of the most powerful explosions in nature. Simultaneously, the massive core continues to cave in and quickly collapses into itself to form a black hole.

⁵Tim Appenzeller in U.S. News & World Report, March 27, 2000, *Darkness Made Visible*.

ν –Other Expected Particles

There is another whole zoo of particles which are predicted to exist as a solution to what is known as the hierarchy problem. This is the problem of the gigantic differences in size between the basic particles. The electron is 350,000 times lighter than the heaviest quark, and neutrinos, if they have mass at all, are even lighter.¹ However, it is expected that the unified theory will produce much larger particles than the largest ones now known.² These particles only appear as expressions of each one of the four forces. However, when we try to combine all these forces, the energy scale jumps to an energy scale of 10 to about the 16^3 , a vast jump that makes the previous ratio of one to 350,000 seem tiny. There are several solutions proposed to this problem, all of them predicting many new particles. It is expected that Large Hadron Collider at CERN, near Geneva, will determine which theory is correct by about the year 2020.⁴

¹The heaviest known particle of the Standard Model is the top quark with a mass equivalent to an energy of 175 gigaelectron volts (GeV) One GeV is a little more than the energy contained in a proton mass.

²This energy level is in and of itself not the problem. This is because when these particles are (theoretically) measured at the same energy levels they all become equal to each other.

³The scale at which the first three forces combine is at 10 to the 16. The Planck Scale, which is when gravity is also combined with these three forces, is 10 to the 18.

⁴Based on Steven Weinberg's article in *Scientific American*, pg. 39.

APPENDIX 6: UNCERTAINTY & PROBABILITY

i- New Concepts of Matter

ii-Uncertainty

a - Practical Uncertainty

b - Uncertainty because Man a Part of the System

c - Quantum Uncertainty

APPENDIX 6: UNCERTAINTY & PROBABILITY

i- New concepts of Matter

In the twentieth century, the concept of matter as a solid physical reality has been disappearing. Solid tables and chairs are now known to be essentially empty space, the electrons and atomic nuclei within them occupying only the smallest of spaces. The reason our hand does not go through the table when we hit it is not because it is a solid mass but rather because of the forces which hold the atoms together. This is hard to understand because it is not what we see or experience. But scientists have proven that this is so.

The scientific concept of time and space also changed. Time and space, the correlates of matter, are no longer absolute concepts and cannot even be thought of as independent dimensions.

Even the little bit of matter that is left can be turned into pure energy, making the connection between the physical and the spiritual realms seem much more feasible.

In the *Tao of Physics*, Fritjof Capra paints a fascinating mural of just how far all this goes. We know that particles are also waves at the same time. But “they are not ‘real’ three-dimensional waves. They are ‘probability’ waves. ... These patterns ultimately do not represent probabilities of things, but rather the probabilities of interconnections. ... Subatomic particles [in fact] have no meaning as isolated entities ... Quantum theory thus reveals a basic oneness of the universe. ... We cannot decompose the world into independently existing smallest units. ... Nature does not show us any isolated ‘basic building blocks’, but rather appears as a complicated web of relations between the various parts of the whole.”¹

“Two ... developments in modern physics have shown that the notion of elementary particles as the primary units of matter has to be abandoned. ... On the experimental side ... we today know of over two hundred ‘elementary’ particles. ... It became clear that not all of them could be called ‘elementary,’ and today there is a widespread belief among physicists that none of them deserve this name. And at a theoretical level, it became clear that “a complete theory of nuclear phenomena must not only be a quantum theory but must also incorporate relativity theory. This is because the particles confined to dimensions the size of nuclei move so fast that their speed comes close to the speed of light.”²

Capra goes on to show that unless we regard particles as dynamic processes subject to relativistic laws, numerous paradoxes remain unresolved. The mass we perceive is only the specific manifestation of distribution of the available energy of the system³. This leads to the notion that forces and the objects on which they operate are really different expressions of the same thing⁴. Ultimately, empty space itself (in which force fields operate) and matter become indistinguishable. Virtual particles are a consequence of this, emerging spontaneously out of empty space itself!⁵

ii-Uncertainty

In the micro world of subatomic physics (the physics that deals with the particles inside an atom) there are three types of uncertainty:

¹page 78

²pg. 86

³pg. 89

⁴pg. 245

⁵pg. 246

a - Practical Uncertainty

This uncertainty derives from the practical difficulty of measuring things so small. Since even the greatest magnification in the strongest microscope isn't enough to actually see some of these particles first hand, the only way to observe some sub-atomic particles is to do things like bounce radiation off them or crash two such particles together and observe the tell-tale signs of the effect thereof. In this way, the observer is not just an objective bystander to what he is observing; he becomes a part of what he is observing, actually changing the subatomic world in the very act of trying to see it. This type of uncertainty is a practical uncertainty, a function of our not having found better ways of measuring.

b - Uncertainty because Man is a Part of the System

However, there is a second, more intrinsic type of uncertainty. In the early part of the century, Werner Heisenberg proposed what is popularly known as the Uncertainty Principle, namely that we can either know the position of an electron or its momentum but not both at the same time. This is because electrons and photons (the unit of light) act as both waves and particles. Logically, this seems impossible since a wave is a spread-out force (think of a sea wave) which has a wavelength, a peak and a trough, whereas a particle is a discrete entity, occupying a definite place in space and time. Nevertheless, there are actually many experiments to prove this (individually, the experiment proves that an electron is either a wave or a particle, but cumulatively they indicate both).

If we try to measure the momentum of an electron, we must measure its wavelength. To do this, we need to observe one wavelength over a certain distance, but then we cannot know its position since all we have is a smear of a wave. If, on the other hand, we want to know the position of that same electron, we have to allow many waves to interfere with each other at a certain point. The more precise the desired measurement, the more waves we need to interfere at that point. But each one of these waves has its own wave length, i.e. its own momentum. Therefore, we can never know the momentum of a specific particle.

As such, the reality of the subatomic, quantum world is that we must choose whether we want to know the momentum of the particle or its position, but we can never know both. Heisenberg showed that this choice is not just a practical difficulty, a type of experimental limitation, but that there was no way, even in principle, of ever overcoming this difficulty. In addition, our very choice of what to measure, and seemingly without any interference in the world, seems to determine the final reality of which hole an electron will go through or whether it will behave as a wave or a particle! This has led some physicists to call our world an observer-centered universe. The observant scientist Herman Branover claims that such a universe is necessary not only to allow freedom of choice but for human choices to actually change the universe.

c - Quantum Uncertainty

Emerging out of this, Neils Bohr showed that there was a third type of uncertainty known as quantum uncertainty. In order to know whether a particle has moved from point A to point B, one needs to measure the exact location of the particle at point A, the momentum of the particle and the exact location of the particle at point B. But, as we showed above, we

can never measure all these things together. So, all we can really talk about is the probability of a certain particle moving from A to B. The more electrons we have the higher the probability that some of them will reach a certain point, but we can never say for sure. What adds to this uncertainty is that electrons sometimes behave in unpredictable ways (for example, they tunnel through objects that they shouldn't be able to get through and appear mysteriously on the other side). So what we are left with is a type of a bell-curve graph which tells us the different chances that an electron has of re-appearing at a certain point.

Princeton physicist John Wheeler invented the term “quantum foam” to describe the fact that not only do particles pop in and out of existence without limit, but space-time itself constantly changes, “churning into a lather of distorted geometry”.

It was about such things that Einstein rebelled and stated, “I don't believe that G-d plays dice.” But, in the end, the physics community has shown that Einstein was wrong - there is uncertainty built into the universe.

There have been several attempts by leading scientists to make sense of quantum uncertainty. The best known, and historically the most influential, was the **Copenhagen Interpretation**. It says that there is an inherent duality in nature, called ‘complementarity’, according to which attributes that are classically contradictory (such as being a localized particle or a spread-out wave) can both be part of the makeup of the same physical object but can never be observed in the same experiment. Asking which attribute the object has objectively is deemed meaningless: the nature of the measurement determines which property is manifested. The *value* of the measured quantity (e.g. the specific position) is determined randomly at the moment of observation or interaction with the ‘classical level’. This random change is known as ‘collapsing the wave function’.

The **Many-Worlds interpretation** introduced by Hugh Everett in 1957 and currently advocated by David Deutsch and others says that there are a large number of parallel universes with greater or lesser similarity to our own. The ‘neighboring’ universes are ones which differ from our own only in the position of a few particles. Neighboring universes can't be detected directly but the particles in them can have an interference effect on the corresponding particles on our own universe, which explains the strange behavior of particles in interference experiments and, one day, quantum computers. Overall, reality (the ‘multiverse’) is non-random and independent of observers¹.

¹Based on an article in December 2000/January 2001 issue of Philosophy Now, The Many Worlds of David Deutsch.

APPENDIX 7: RELATIVITY

i-Space-Time

ii-Black Holes

APPENDIX 7: RELATIVITY

i-Space-Time

The effect of motion on time was formulated by Einstein in 1905 in his Special Theory of Relativity, and the effect of gravity on time was formulated in 1914 in his General Theory of Relativity.

The theory of relativity dramatically changed the way we perceive time and space. Firstly, time and space were joined, so that we can no longer talk about time or space but rather the four dimensions of space-time. Secondly, both space and time were shown not to be objective, absolute concepts. Rather, both can stretch or shrink.

The theory of relativity states that as objects go faster, time goes slower (it stretches or gets warped). Only the speed of light stays constant. If an object were to go faster than the speed of light, theoretically speaking it would be able to travel into the past. However, no object with any mass can ever go faster than the speed of light. This is because the faster an object is going the more time is being stretched (i.e. as it goes slower), and the space the object occupies is being shrunk - therefore increasing its mass. Close to the speed of light it becomes so heavy that it would take almost an infinite amount of energy to speed it up any further (There are objects, however, that have no mass. These can go as fast, or faster, than the speed of light).¹

This idea of time slowing down was dramatically illustrated by the twins example. One twin stays on earth and the second goes into outer space in a rocket. The second twin is going to experience a slowing down of time relative to the earth-bound twin. When we look at his watch, we see that each time his second hand moves, ours on earth has moved several times. (The space twin himself does not, however, experience this. He looks at his watch and it appears to function normally.) When the space twin finally arrives back on earth, he finds that his earth-bound sibling has aged ten years while he has only aged two years. Atomic clocks today are so accurate that they can measure the slowing down or the speeding up of time. These effects were observed in experiments conducted in the 1960's and the 1970's. In one such experiment in 1971, atomic clocks were carried in two high speed aircraft. One traveled eastward, that is, in the rotational direction of the earth, and the other westward. After the flight, the onboard clocks were found to have either lost or gained time (relative to a ground-based atomic clock), depending on their direction of travel, an effect of motion and on their altitude, an effect of gravity. The results confirmed the predictions made in Einstein's Theory of Relativity.

¹NYTimes, James Glanz: *Light Exceeds Its Own Speed Limit, or Does It?:* The speed at which light travels through a vacuum, about 186,000 miles per second, is enshrined in physics lore as a universal speed limit. Nothing can travel faster than that speed, Einstein's theory of relativity would crumble, theoretical physics would fall into disarray, if anything could.

Two new experiments have demonstrated how wrong that comfortable wisdom is. Einstein's theory survives, physicists say, but the results of the experiments are mind-bending and weird.

In the most striking of the new experiments a pulse of light that enters a transparent chamber filled with specially prepared cesium gas is pushed to speeds of 300 times the normal speed of light. That is so fast that, under these peculiar circumstances, the main part of the pulse exits the far side of the chamber even before it enters at the near side.

... Einstein's theory, and at least a shred of common sense, seem to survive because the effect could never be used to signal back in time to change the past... This is a special property of light itself, which is different from a familiar object like a brick, since light is a wave with no mass. A brick could not travel so fast without creating truly big problems for physics, not to mention humanity as a whole.

Time also flows more slowly when gravity is greater. Thus time goes a little slower on the ground than it does at the top of a skyscraper. This has actually been measured. So too, time on earth goes slower than time in outer space. In the case of black holes, gravity is so great that time seems to stop altogether (again, this is only from our earthly perspective.) When we look at a watch at the edge of a black hole, we cannot see its hands moving at all (See below **ii - Black Holes**).

Any one person slowing down, speeding up (no matter how much) or moving from low to high gravity will not notice any difference. It is only someone observing that person from a different frame who will see these differences.

Space can also expand or contract depending on the speed of the object. At the linear particle accelerator in Stanford, electrons are moving so close to the speed of light that the length of tube in their frame of reference is scarcely one foot in length.¹

In the 19th century, the Austrian physicist and philosopher Ernst Mach declared that all motion was relative and therefore speculated that the inertia of any given object in the universe was somehow determined by its relation to everything else in the universe.

Einstein was taken by what he called Mach's principle, and it was part of the inspiration for general relativity. That theory described space-time as a kind of sagging mattress where matter and energy, like a heavy sleeper, cause planets, falling apples and beams of light to follow curved paths instead of straight ones. Einstein's theory predicted the expansion of the universe and the existence of light-swallowing black holes.

But in a Machian twist that pleased Einstein, it seemed that rotating matter could not only make space sag but also cause it to spin. Just as stirring a thick milkshake with a spoon will cause the cup holding the drink to turn, a massive rotating object will slowly drag space-time around with it. That means that if you were orbiting, say, Earth, you would feel no force and think you were at rest, but you would find yourself spinning slowly with respect to the distant stars.

The effect, called frame dragging, is so tiny near Earth that physicists despaired of being able to test it for decades. In a year, the twist would be about one hundred-thousandth of a degree — about the thickness of a human hair as seen from a quarter of a mile away.

In 1959, three Stanford scientists agreed to team up on an ambitious effort to test Albert Einstein's theory of gravity, a prediction of Einstein's general theory of relativity. Gravity Probe A, which showed how gravity affects the **rate of clock**, flew in 1976. But, it took 45 years and \$700 million to put together Gravity Probe B, launched in 2004. Nearly 100 Ph.D.'s were awarded at Stanford and elsewhere for work on the project.

The probe contains four gyroscopes to measure whether and how the spinning Earth twists space-time around itself to produce gravity².

¹In Genesis and the Big Bang, Dr. Schroeder explains relativity at length.

Increasingly precise observations of satellites, the moon, planets and other bodies over the decades have already concluded that general relativity is correct¹. The latest measurement will add to this because it is free of astronomical uncertainties or theoretical frameworks². Despite this, most theorists believe that general relativity will ultimately fail³.

ii-Black Holes

One thing which relativity predicts is the existence of black holes. A black hole is a body whose mass is so dense and whose gravity is so great that anything which gets pulled towards it, including light, can never escape. It emits no electromagnetic radiation (at least not at levels astronomers could ever hope to detect); hence the name black hole.

Black holes are divided between their event horizon, which is the point of no return, and a singularity, the collapse of matter to nearly a mathematical point in the center of the black hole. According to relativity, gravity causes light to bend or curve. In the case of a black hole, the curvature is so great that after the light reaches the event horizon it spirals inwards, caught forever (According to Stephen Hawking, some radiation does, in fact, escape from the black hole).

One of the ways in which a black hole can be created is by the collapse of a star, though most stars do not become black holes when they burn out. However, conditions are sometimes right for the star to become denser and denser. They eventually pass the point where the density would be infinite and all the basic laws of physics break down.

Until recently, there was only circumstantial evidence for black holes. The two best proofs are as follows: Firstly, near galactic centers, stars are moving so rapidly that they would fly off unless the gravity of a huge mass – up to the equivalent of a billion suns – would hold them in. Whatever has this mass must be extremely dense, and theorists know of no alternative to a black hole. Secondly, many galactic centers and binary star systems (two stars rotating around each other) spew radiation and matter at gargantuan rates. They must contain an extraordinarily efficient mechanism for generating this energy. In theory, the most efficient engine possible is a black hole.

However, it is not certain from these proofs, especially the second one, that it must be a black hole causing these effects. There are two other candidates for this as well, neutron

¹Although frame dragging has not been detected directly, astronomers say it has been measured indirectly. Last year a group of Italian physicists claimed to have measured it within a margin of error of about 20 percent by analyzing data from the two Lageos satellites, spherical objects pocked with reflectors that were launched to serve as sort of geodetic markers in the sky. More satellites in coming years could reduce the margin of error to 1 percent, the precision that Gravity Probe B is aimed at. Meanwhile, last September, astronomers claimed that they had measured the parameter gamma by timing radio signals on their way to Earth from the Cassini spacecraft, which is approaching Saturn. The signals were delayed as they passed the Sun, dipping into its gravitational warp. The scientists found that gamma was equal to the Einsteinian value of 1.0 to a precision of about one part in 40,000.

²The squids have two missions. One is to measure the frame dragging, which would cause the gyros to turn in the direction of the Earth's rotation. The other is to measure a parameter called gamma, or how much matter causes the geometry of space to deviate from the "flat" Euclidean geometry familiar from high school. Because the Earth makes space-time sag, a circular orbit around the Earth should turn out to have a circumference ever so slightly less than pi times the orbit's diameter. This "missing inch," as Dr. Everitt calls it, should cause the gyros to turn in a direction perpendicular to the Earth's rotational axis. Some physicists regard gamma as a more interesting measurement than frame dragging, because many of their more exotic speculations, like hidden extra dimensions and undiscovered forces permeating space, could cause its value to deviate from the Einsteinian prediction of exactly 1.0.

³Based on Dennis Overbye in the NY Times, April, 13, 2004.

stars and white dwarfs. If one took the mass of the sun whose circumference is 1.4 million km, it would collapse into just 10,000 km in a white dwarf. In a neutron star the circumference would be 60 km and a black hole 6 km. In fact, some of these objects were indeed found to be neutron stars (so called because a large star has collapsed to the point where the atoms got crushed and their nuclei stacked together).

However, Scientific American¹ reported that astronomers may now have direct proof in the form of energy which they have observed vanishing from volumes of space without a trace. (See **Appendix I ii** for a discussion on the loss of information when it enters a black hole.)

¹May 1999

APPENDIX 8: RELIGION AND SCIENTISTS

i-Religious Beliefs of Scientists

- a - Isaac Newton**
- b - Herman Weyl**
- c - Max Born**
- d - Arthur Eddington**
- e - Max Planck**
- f - Robert Jastrow**
- g - Charles Townes**
- h - Carl Sagan**
- i – Steven Weinberg**
- j - Stephen Hawking**

ii-Orthodox Scientists - Historical

- a-Rambam**
- b-Vilna Gaon**

iii-Orthodox Scientists - Contemporary

- a-Avraham Steinberg**
- b-Elie Schusheim**
- c-Leo Levi**
- d-Abraham HaSofer**
- e-Cyril Domb**
- f-William Etkin**
- g-Alvin Radkowsky**
- h-Aaron Vecht**
- i-Rabbi Moshe Tendler**
- j-Herman Branover**
- k-Rabbi Dr. Naftali (Norman) Berg**
- l-Dr. Aryeh Gotfryd**
- m-Dr. Alexander Poltorak**
- n- Professor Velvel Greene**
- o- Professor Yakov Brawer**
- p- Professor Barry Simon**
- q-Arnold Penzias**
- r-Gerald Schroeder**

APPENDIX 8: RELIGION AND SCIENTISTS

i-Religious Beliefs of Scientists

In the body of the text, we have had several discussions about the beliefs of science and scientists. (See **Chapter F**. See also at the end of the critique of evolution, **The Secular Bias of Evolution**.) The following is a listing of the names of some individual scientists and their specific beliefs. It is important to note:

i- The majority of really world-famous scientists of the twentieth century believed in G-d. However, when leading scientists are asked whether they believe in a G-d with Whom one can have a relationship and to Whom one can pray, most leading scientists (60% in one study) answer in the negative. Whether the greatest contemporary scientists are drawn away from Divine Providence or whether the higher echelons of academia select for the trait of disbelief is an open question.¹ What is clear is that unlike believing scientists, who have usually been challenged to think quite deeply about why and what they believe, the reasons which scientists give for not believing are rarely clearly thought out. Ernst Mayr did a survey of his Harvard colleagues and found that there were two sources. One Mayr typified as, "Oh, I became an atheist early on. I just couldn't believe all that supernatural stuff." But others told him, "I just couldn't believe that there could be a G-d with all this evil in the world." Mayr adds that most atheists combine the two.²

ii- The nature of that belief was often very far away from the idea of a Divine Providence. (Some call this idea the "G-d of the scientist". However, there is no monolithic belief about G-d.)

a - Isaac Newton

The wonderful order of nature can be the effect of nothing other than the wisdom and skill of a powerful, ever living Agent. (Optics, in Baumer 53)

We must believe that He is the G-d of the Jews, who created the heavens and the earth and all things therein as expressed in the Ten Commandments. (Manuel Frank, Religion of Sir Isaac Newton, Oxford Press, 1974)

b - Herman Weyl

Professor of Math, Princeton: The ultimate answer lies beyond all knowledge, in G-d alone. (The Open World, Yale U Press, 1931, pg. 28)

c - Max Born

¹See Scientific American September 1999, pg. 81

²Ibid.

Gave final form to Quantum Theory: The scientist thirsts for something fixed...in the universal whirl: G-d, beauty, truth. (The Restless Universe, Dover, pg. 277)

d - Arthur Eddington

Leading astronomer: Religion not incompatible with science. Below the physical world lies a spiritual domain which lifts the veil in places. He believed there is a new approach to reality deep within the soul of man, beyond the material, revealing the presence of G-d. (Modern Physics, pg. 373)

e - Max Planck

Discovered Quantum Theory: The Law of Least Action provides clear evidence of a Supreme Intelligence reigning omnipotently over Nature. (The New Science, Meridian, 1959) (The Law of Least Action means that when light is faced with a number of substances of different densities and it has to travel through one of them to get to the other side, it will always find the density which will get it to the other side in the quickest possible time even though it would seem that it could just as well have chosen any number of other paths.)

There is evidence of an intelligent order of the universe to which both man and nature are subservient.

f - Robert Jastrow

World famous astronomer: He (the scientist) has scaled the mountains of ignorance; he is about to conquer the highest peak, as he pulls himself over the final rock, he is greeted by a band of theologians who have been sitting there for centuries. (G-d and the Astronomers, pg. 125 end of chapter entitled "The religion of science")

g - Charles Townes

(Co-winner of 1964 Nobel Prize in physics for discovering the principles of the laser.)

"Many have the feeling that somehow intelligence must have been involved in the laws of the universe."

Against this, a few leading scientists were quite secular:

h - Carl Sagan

Since the birth of the world could be explained by science alone, there was "nothing for the Creator to do," and every thinking person was therefore forced to admit "the absence of G-d."

i - Steven Weinberg

The more the universe has become comprehensible through cosmology, the more it seems pointless. (Most scientists came to just the opposite conclusion.)

Or agnostic:

j - Stephen Hawking

One of the greatest living physicists: The universe appears to contain a symmetry and precision necessary to create intelligent life which is difficult to explain except as an act of G-d. (*A Brief History of Time*, pg. 127)

k- Sir Fred Hoyle

Sir Fred Hoyle is honorary member of the U.S. Academy of Science, Plumian professor of Astronomy and Experimental Philosophy at Cambridge University, professor of Astronomy at Great Britain's Royal Institute, fellow of Great Britain's Royal Society, staff member at The Mount Wilson-Palomar Observatory, visiting professor of Astrophysics at California Institute of Technology, knighted for his accomplishments in science. Hoyle is renowned for debunking fuzzy thinking in evolution, showing how unlikely random events are likely to have been in contributing to each stage of life.

ii-Orthodox Scientists - Historical

a-Rambam

Famous Doctor

Wrote classical students' textbook summarizing Galen and others, books on poisons, psychosomatic diseases and others.

Extensive knowledge of mathematics and all the sciences

b-Vilna Gaon

הקדמה (פאת השלחן) quotes his Rebbe as saying:

“All the sciences are necessary for our holy תורה and are included in it.

“To the degree that a man is lacking in knowledge and the sciences, he will lack one hundredfold in the wisdom of the תורה.”

Also there:

"He knew them all, completely... algebra, trigonometry, geometry... he explained the nature of all sciences and said that he acquired them completely, except that in the medical sciences he knew only anatomy and the related disciplines. He wanted to learn pharmacology from contemporary physicians, but his father forbade him to study so that he should not have to put aside his תורה study by going to save lives."

He wrote works on mathematics and geography (צורת הארץ) and on the calculations of the seasons and the movement of the planets.

iii-Orthodox Scientists - Contemporary

a-Avraham Steinberg

Director, Center of Medical Ethics at Hebrew University Hadassah Medical School in Jerusalem (where he also teaches general pediatrics and neurology). Is listed in the International Who's Who of Intellectuals (1987), the Dictionary of International Biography (1989-90), and Who's Who in Israel (1991-92). Has written over 90 articles on neurology, general medical ethics, Jewish medical ethics, and medical history.

b-Elie Schusheim

The Knesset Doctor and medical consultant for the State Comptroller of Israel. Former Director and founder of Neve Simcha gerontological hospital 1967-71.

c-Leo Levi

A former Associate Professor of Physics at City University, today Director of Jerusalem College of Technology (1980 1990), author of many scientific books and articles in the area of applied optics.

d-Abraham HaSofer

Doctorate in mathematical statistics from University of Tasmania, Australia, heads the department of statistics at the University of New South Wales since 1969. Co-inventor of the Hasofer-Lind Reliability Index.

e-Cyril Domb

Former Professor of Theoretical Physics at King's College, having previously held Faculty appointments at Oxford and Cambridge Universities. He specialized in statistical mechanics.

f-William Etkin

Former Emeritus Professor of Albert Einstein College of Medicine. Specialized in the physiology of the endocrine system.

g-Alvin Radkowsky

Formerly the chief scientist of the US Atomic Energy Commission Naval Reactors during which he invented a method for prolonging the lifetime of nuclear reactors. Currently professor of nuclear engineering and physics at Tel Aviv and Ben Gurion Universities.

h-Aaron Vecht

Head of Materials Division, Thames Polytechnic, London, where he teaches optoelectronics and defect chemistry to postgraduate students. He has published and patented widely in the fields of semi-conductors and luminescence.

i-Rabbi Moshe Tendler

Chairman of Biology Department of Yeshivah University. Internationally recognized medical ethicist.

j-Herman Branover

Ph.D. from Moscow Institute of Aviation in magnetohydrodynamics. D.Sc. degree in physics and mathematics at the Leningrad Polytechnic Institute. Created the Center for Magnetohydrodynamics Studies at the Ben-Gurion University. Recipient of the S.D. Bergman Prize for the development of new technology in Israel. Foreign member of the Russian Academy of Natural Sciences in Moscow and the Latvian Academy of Science, a member of the Moscow International Energy Club, and has received honorary doctorates from the Russian Academy of Sciences and the Technical University of St. Petersburg.

k-Rabbi Dr. Naftali (Norman) Berg

Received BS and MS degrees in electrical engineering from the Illinois Institute of Technology and Ph.D. degree in electrophysics from the University of Maryland. Worked at the Pentagon research center. Concentrated on nuclear radiation effects on electronic materials and devices; acousto-optic signal processing; and the processing fusion of data from multiple sensors for battlefield applications. Received the Wilbur S. Hinman Outstanding Technical Achievement Award (1977); the Outstanding Paper Award of the Army Science Conference (1977) and the HDL Inventor of the Year Award (1979). He was also given an Army Research and Development Award (1981) and was named Engineer of the Year in 1982 by the Army Material Development and Readiness Command.

l-Dr. Aryeh Gotfryd

Hon B.Sc. in Zoology and a Ph.D. in Ecology from the University of Toronto. Awarded Ontario Graduate and Canadian Wildlife Scholarships.

m-Dr. Alexander Poltorak

Devoted his studies at the Kuban State University in Krasnodar to Einstein's theories of relativity and gravitation, published several papers in this field and wrote his doctoral thesis on a solution to a long-standing "energy problem" in General Relativity Theory.

n-Professor Velvel Greene

Professor of Public Health and Microbiology at the U. of Minnesota. Received BA in Agriculture, MA in dairy science and Ph.D. in Bacteriology and Biochemistry at the University of Minnesota. One of the original bioscience researchers participating in the US Space Program.

o-Professor Yakov Brawer

Completed Ph.D. at Harvard University. Was an Andelot Fellow in 1966. Worked as research fellow at Harvard for the National Institute of Neurological Diseases and Stroke. Appointed assistant professor of anatomy at Tufts University. In 1971 he won the William Wilkins Award from the American Association of Anatomists. Currently professor of anatomy and professor of obstetrics of gynecology at McGill University School of Medicine. Published over 60 papers in his research area of reproductive neuro-endocrinology and in related fields.

p-Professor Barry Simon

Dr. Simon received a Ph.D. in physics from Princeton in 1970 and has subsequently held several positions jointly in mathematics and physics. In 1981 he moved to Caltech where he became the IBM Professor of Mathematics and Theoretical Physics and Department Chair for Mathematics. He is a former vice president of the American Physical Society and a winner of the gold medal of the Association of Molecular Science for work related to quantum chemistry. He is the author of 12 scientific books (graduate level texts and advanced monographs) and approximately 300 research papers in his field of mathematical physics, especially in questions related to quantum mechanics.

q-Arnold Penzias

Co-discoverer of the background radiation which represents the afterglow of the Big Bang.

r-Gerald Schroeder

Dr. Gerald Schroeder earned his B.Sc., MSc, and Ph.D. at the Massachusetts Institute of Technology. He holds a Ph.D. in two fields: Earth and Planetary Sciences, and Nuclear Physics. He spent seven years on the staff of the M.I.T. Physics Department prior to moving to Israel and joining the staff of the Weizmann Institute of Science in Israel. He has authored approximately 60 publications in peer-reviewed scientific journals. The results of his research have been reported in Time and Newsweek, Scientific American, and newspapers from Boston to Adelaide. In his capacity as consultant to the U.S.-U.S.S.R. Nuclear Arms-Control Treaty, Dr. Schroeder witnessed the detonation of six atomic bombs. He has served as consultant to agencies in governments of USA, Peoples Republic of China, Philippines, Malaysia, Singapore, Thailand, and Canada. Dr. Schroeder is the author of Genesis and The Big Bang, published by Bantam Doubleday, now in six languages; and The Science of G-d, published by Free Press of Simon & Schuster.

APPENDIX 9: THE PHILOSOPHY OF NATURAL SCIENCE

i-Popper

ii-Kuhn

iii-Feyerabend

APPENDIX 9: THE PHILOSOPHY OF NATURAL SCIENCE

In **F - Underlying Beliefs in Science**, we described how issues of beauty, unity, etc. affect the legitimacy of the scientific idea. In **Appendix E** we described the three levels of uncertainty of science. Here we develop some other limitations and show, in **i – iii**, that there are distinct schools of thought on different issues. Popper, Kuhn and Feyerabend represent different levels of interpretation of just how scientific science is.

i-Popper

The Englishman Sir Karl Popper described how a proper scientific theory ought to work. According to Popper, a scientific theory can never be proven absolutely true; we can only, by repeated experiments, say that it is less and less likely to be proven false. Of course, just like theories of the past that were proven to be false, so current scientific theories may also be proven false. But as science continues to progress, we keep on getting closer to the truth.

For Popper (and others like Karl Mannheim in Ideology and Utopia), science is essentially a rational enterprise; hence, it is the one endeavor which is exempt from the dictum that knowledge is socially shaped.

ii-Kuhn

Thomas Kuhn of MIT wrote his famous The Structure of Scientific Revolution about 40 years ago. In it, he claimed that science moves very slowly for long periods of time until there is a sudden revolution during which the scientific community changes paradigms. A paradigm is a way of looking at the world, a way of filtering information. When operating in a certain paradigm, the scientific community only sees certain types of questions or unsolved scientific problems as legitimate areas of scientific concern and therefore they are only going to get certain types of answers. Eventually, someone comes and manages to break out of that paradigm, like Newton and Copernicus did in their day, and as did Einstein, breaking out of Newtonian ways of looking at the world. Usually this person is very young, not yet set too deeply in the existing paradigm. Very often, the older scientists never fully accept the new paradigm - they simply have to die out to allow for the new paradigm to take root. Therefore, if a theory is propounded before its time, it may not be accepted. An example of this is the wave theory of light, propounded by Young in the early 1800's in opposition to Newton's corpuscularian theories of light. (Some claim, however, that the theory simply had not been proven yet.)

The new paradigm may use the same words as the old, but it often means something completely different, making the old and new theories non-comparable. Since facts are always seen through paradigms, there is no such thing as a completely objective fact.

It is important to note that Kuhn subsequently modified his position considerably - the New Kuhn, in which he questions whether science actually progresses in some objective

sense when there is a paradigm changed. What we described above is the Old Kuhn which people usually refer to when mentioning his name.

iii-Feyerabend

Everyone agrees that from time to time, subjective bias creeps into science. One of the most famous cases was the purported discovery by a group of scientists of a heavy neutrino having a mass of 17 keV (17,000 electron volts). Such a particle would have a very sweeping impact on both particle physics and cosmology. A number of follow-up experiments confirmed the finding of an exact mass of 17 keV. Later on the whole thing was shown to be false. The scientists were not fabricating their evidence; they were simply seeing what they were hoping and expecting to see.¹

A more obvious case is that of cold fusion, the claim by Stanley Pons and Martin Fleischmann that nuclear fusion could take place at relatively low temperatures, although here the distinction between misleading expectations and downright dishonesty became blurred and other scientists were quick to expose the fraud.

Feyerabend on the West Coast turned these cases of subjective bias into a more generalized observation about science. He wrote a book called Against Method, in which he argued that there is no such thing as scientific method. Whatever rules science is supposed to go by are violated sooner or later. Of course, scientists think that they are following certain rules, but the real progress in science happens when scientists consciously or unconsciously violate those rules and even allow what may have been considered as irrational and counter-inductive processes to enter into their thinking. In Feyerabend's words: "Anarchism helps to achieve progress." This implies that despite the lack of real method, science actually does make progress. In other places, Feyerabend denies this.

Therefore, science is just one tradition among many. We ought to remove science from its pedestal and put it in its place along with other traditions like astrology, witchcraft

¹Alas, many "revolutionary" discoveries turn out to be wrong. Error is a normal part of science, and uncovering flaws in scientific observations or reasoning is the everyday work of scientists. Scientists try to guard against attributing significance to spurious results by repeating measurements and designing control experiments. But even eminent scientists have had their careers tarnished by misinterpreting unremarkable events in a way that is so compelling that they are thereafter unable to free themselves of the conviction that they have made a great discovery. Moreover, scientists, no less than others, are inclined to see what they expect to see, and an erroneous conclusion by a respected colleague often carries other scientists along on the road to ignominy. This is *pathological science*, in which scientists manage to fool themselves.

What may begin as honest error, however, has a way of evolving through almost imperceptible steps from self-delusion to fraud. The line between foolishness and fraud is thin.

January 13, 2002, *The Starry Environmentalist? The cases of Björn Lomborg and Galileo*: Stephen Schneider, a highly regarded climate scientist, explained the need to lie for justice to Discover magazine: "On the one hand, as scientists we are ethically bound to the scientific method, in effect promising to tell the truth, the whole truth, and nothing but — which means that we must include all the doubts, the caveats, the ifs, ands and buts. On the other hand, we are not just scientists but human beings as well. And like most people, we'd like to see the world a better place, which in this context translates into our working to reduce the risk of potentially disastrous climate change. To do that, we need to get some broad-based support, to capture the public's imagination. That, of course, entails getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have. ... Each of us has to decide what the right balance is between being effective and being honest."

and traditional medicine so that society can benefit equally from all of them. Feyerabend is not alone in his contentions. A group of academics at the University of Edinburgh "contends that scientific knowledge is only a communal belief system with a dubious grasp of reality." (Gottfried and Wilson, quoted in Scientific American Nov. '97, pg. 80) "Andrew Pickering, a sociologist at University of Illinois, writes in his book Constructing Quarks that "there is no obligation upon anyone framing a view of the world to take account of what 20th-century science has to say."(ibid)

Post-modernists question not just the objectivity of science but even the existence of objective reality. Many of these ideas have actually worked their way into the American educational system for teaching science, i.e. constructivism (ibid).

Interestingly, Popper, who thought science to be the most "scientific", was a philosopher, not a scientist. Kuhn is a scientist turned sociologist, whereas Feyerabend continues to be a scientist. In general, Feyerabend is regarded in academic circles as being too extreme, while Kuhn (and of course Popper) are taken quite seriously.

(Feyerabend is not consistent on this point, sometimes denying that science makes any progress at all... or rather that it makes progress only at the expense of other types of knowledge.)

APPENDIX 10: MISCELLANEOUS PRINCIPLES OF SCIENCE

- i - How Quantum Forces Translate into Classical Laws**
- ii - The Contradiction of Quantum Laws and General Relativity: Black Holes**
- iii - Symmetry - Exceptions**
- iv-Complexity/Chaos Theory**
- v - Genetics**

APPENDIX 10: MISCELLANEOUS PRINCIPLES OF SCIENCE

i - How Quantum Forces Translate into Classical Laws

Subatomic particles obey unpredictable quantum forces; larger structures obey predictable, classical laws. Yet, these larger structures are made out of subatomic particles. So, at some stage, quantum forces must translate into classical (Newtonian-like) laws. Scientists do not yet know when this takes place or how it does so, although there are currently many competing explanations.

ii - The Contradiction of Quantum Laws and General Relativity: Black Holes

(See **Appendix F ii - Black Holes** for general description of Black Holes)

Black holes are a creation of the law of gravity. They are singularities, i.e. places where gravity is so intense that the familiar laws of physics break down. According to the information paradox theory, once information has passed the horizon (i.e. the point of no return) it can never escape the huge pull of gravity of the black hole and is lost forever. Doing so would require it to flee faster than the speed of light. And Einstein's other great theory, special relativity, holds that to be impossible. (Although Black Holes do radiate, they do so in a standardized fashion. Since the information is thereby flattened, it would be impossible to reconstruct any lost information from such radiation.)

This, however, contradicts another principle, the quantum law that information can never disappear. For if information could disappear, it would mean that processes are not always reversible. Information could just leave the universe, never to be retrieved. If things are not reversible we cannot work backwards to figure out what the laws of nature are.

In addition, information is communicated through energy. If information can get lost, it means that so can energy, and that violates the principle of conservation of energy. In 2004, Stephen W. Hawking, the celebrated Cambridge University cosmologist, conceded to a long line of work by various theorists and declared that he had been wrong in 1997 when he said that information that had been swallowed by a black hole could never be retrieved from it. If Dr. Hawking had been right, it would have violated a basic tenet of modern physics: that it is always possible to reverse time, run the proverbial film backward and reconstruct what happened in, say, the collision of two cars or the collapse of a dead star into a black hole.

In 1974, Dr. Hawking stunned the world by showing that when the paradoxical quantum laws that describe subatomic behavior were taken into account, black holes should leak and eventually explode in a shower of particles and radiation. The work was, and remains, hailed as a breakthrough in understanding the connection between gravity and quantum mechanics, the large and the small in the universe.

But there was a hitch, as Dr. Hawking pointed out. The radiation coming out of the black hole would be random. As a result, all information about what had fallen in - whether it be elephants or donkeys - would be erased. In a riposte to Einstein's famous remark that G-d does not play dice, rejecting quantum uncertainty, Dr. Hawking said in 1976, "G-d not only plays dice with the universe, but sometimes throws them where they can't be seen."

That was a violation of quantum theory, which says that information is preserved, and quantum theory is a foundation of all modern physics. If Hawking was right, it would have led to the downfall of much of 20th-century physics.

Several theorists have developed a strange new view of the universe as a kind of hologram, in which the information about what happens inside some volume of space is somehow encoded on the surface of its boundary. In such a picture, "there is no room for information loss," Dr. Maldacena explained. But, he added, it does not explain what Dr. Hawking did wrong in 1974 or how information does get out of the black hole¹.

In his new calculation, Dr. Hawking said that because of quantum uncertainty, one could never be sure from a distance that a black hole had really formed. There is no way to discriminate between a real black hole and an apparent one.

In the latter case, an event horizon, the putative point of last return, could appear to form and then unravel; in that case the so-called Hawking radiation that came back out would not be completely random but would have subtle correlations and thus could carry information about what was inside.

According to quantum theory, both possibilities - a real black hole and an apparent one - coexist and contribute to the final answer. The contribution of the no-black-hole possibilities is great enough to suffice to allow information to escape, Dr. Hawking argued.

Another consequence of his new calculations, Dr. Hawking said, is that there is no baby universe branching off from our own inside the black hole, as some theorists, including himself, have speculated.

"I'm sorry to disappoint science fiction fans, but if information is preserved there is no possibility of using black holes to travel to other universes," he said. "If you jump into a black hole, your mass energy will be returned to our universe, but in a mangled form, which contains the information about what you were like, but in an unrecognizable state."

The new results are hardly likely to be the last word, either about the black hole information problem or about black-hole travel. Few physicists agree with the approach Dr. Hawking is using in his new calculation. Nobody knows how to weigh the different possibilities in such a quantum calculation, said Dr. Sean Carroll of the University of Chicago².

¹Seth Lloyd and Y. Jack NG, Black Hole Computers: Scientific American, November 2004: ...Although matter cannot leave the hole, its information content can...The escape hatch is entanglement, a quantum phenomenon in which the properties of two or more systems remain correlated across the reaches of time and space. Entanglement enables teleportation, in which information is transferred from one particle to another with such fidelity that the particle has effectively been beamed from one location to another at up to the speed of light.

The teleportation procedure, which has been demonstrated in the laboratory, first requires that two particles be entangled. Then a measurement is performed on one of the particles jointly with some matter that contains information to be teleported. The measurement erases the information from its original location, but because of entanglement, that information resides in an encoded form on the second particle, no matter how distant it may be. The information can be decoded using the results of the measurement as the key...

Other researchers have proposed escape mechanics that also rely on weird quantum phenomena. In 1996 Andrew Strominger and Cumrun Vafa of Harvard University suggested that black holes are composite bodies made up of multi-dimensional bodies called branes, which arise in string theory. Information falling into the black hole is stored in waves in the branes and can eventually leak out. Earlier this year Samir Mathur of Ohio State University and his collaborators modeled a black hole as a giant tangle of strings. This "fuzzyball" acts as a repository of the information carried by things that fall into the black hole. It emits radiation that reflects this information. Hawking, in his recent approach, has argued that quantum fluctuations prevent a well-defined event horizon from ever forming [see "Hawking a Theory," by Graham P. Collins; News Scan, October].

²Reported by Denni Overbee in the NY Times, July, 04

iii - Symmetry – Exceptions

One of the basic tenets of physics is rotational symmetry, i.e. whichever way you measure the universe the result will always be the same. However, exceptions to this were recently found¹. Some scientists claim that measurements of light coming from distant galaxies vary depending upon the galaxies' position in the sky. (More exactly, they found the rotation of polarized light to vary depending on the distance and location of the source.) This claim, however, is controversial and the issue remains to be resolved.

iv-Complexity/Chaos Theory

Complexity applies to things like the weather, how the brain works, economics or society. These things are difficult to reduce to simple theories for two reasons. Firstly, they involve huge amounts of information which is always changing. Secondly, they are non-linear. This means that the information in the system does not go step by step. Many things may cross over, all at the same time. Thus, when the brain recognizes the same face in profile, from the front or from any angle in between, it is firing hundreds of neurons which work to create a recognition that all the different pictures are in fact of the same person. A computer cannot, as of yet, do this, and may never be able to do so. One way of describing this ability is to say that the brain is adaptive; i.e. it is able to readjust its perception to differing inputs in order to maintain an equilibrium of recognition.

Another feature of these systems is that they are parallel rather than hierarchical. A hierarchical system has an identified control system, or an initial set of causes, from which one can begin to trace a process of events. But the human brain, for example, has no identified control system. We are not able to locate consciousness in any particular part of the brain. So too, the world economy has no known control system.

Because of these elements, these systems appear to be extremely complex, defying the sort of simple formula that describes the basic forces of matter, for example. However, scientists "believe" that, in time, these systems will also yield to simple and manageable formula.

A first step in this direction has already been taken - scientists have shown that these systems are not completely random or chaotic - they do show patterns. Hence "chaos theory" was born. This has become a much publicized and rapidly advancing area of science. (Heinz Pagels)

However, even when something does show a pattern of sorts, this pattern may be so complex that an exact solution to any given problem may always be beyond reach. Newton, for example, showed that when three or more objects - the Sun, the Moon and the Earth, for example - are interacting gravitationally, exact solutions of their motions generally remain beyond reach. Although very good approximations, good enough for space travel, can be made, exact resolutions cannot. Forecasting the potential future impact of an asteroid on earth, for example, cannot be made accurately, if only because the initial conditions of all the objects can never be known with precision.²

v-Genetics

After 10 Years' Effort, Genome Mapping Team Achieves Sequence of a Human Chromosome: Nicholas Wade, N.Y. Times December 2, 1999:

¹Scientific American, July '97

²N.Y. Science Times, Sep. 22, 1998

After a decade of preparation, scientists have for the first time decoded the information in a human chromosome, the unit in which the genetic information is packaged. The achievement, by a public consortium of university centers in Britain, the United States and Japan, is a milestone in the human genome project, an initiative started in 1990 with the goal of deciphering all of human DNA by 2005.

The success in decoding the first chromosome, even though it is the second-smallest of the 23 pairs in every human cell, validates the approach chosen by the public consortium and bolsters the chance that it can complete the full human genome as planned. In the last 18 months the consortium's strategy has been challenged by a private company, the Celera Corporation of Rockville, Md., which asserts it can sequence the genome faster by a different method. ...

Understanding the human genome is expected to yield vast medical benefits, because almost every disease has a genetic component. The central feature of each chromosome is an enormously long DNA molecule. The chromosome on which the latest work was done is called Chromosome 22, which, small as it is, contains 43 million units of DNA, of which researchers have now decoded 33.5 million. Though there is still much left to be done, the Chromosome 22 team believes that it has sequenced all regions of major interest to biomedical researchers -- that is, the regions that contain the protein-making genes.

The fruit of the team's labors is an eye-glazing march of A's, C's, G's, and T's, as the four chemical units are abbreviated, which would take up 949 pages of this newspaper if printed in ordinary type. Techniques for analyzing such vast molecules have only recently been developed. ...

Dr. Roe estimated the total cost of sequencing the chromosome at \$15 million to \$20 million. The human genome project as a whole is budgeted at \$3 billion.

So far, the Dunham team has identified 545 genes - each of which is composed of thousands of chemical units, and altogether there are probably 1,000 or so genes strung out along the chromosome. The total number of human genes is still unknown and estimates vary widely, from 60,000 to 120,000.

If there is a pattern in the types of genes nature has chosen to store on Chromosome 22, it has escaped the researchers. The genes appear to be a random assortment, including a large set of genes involved in the immune system and more than 20 genes that cause known human diseases when defective, such as DiGeorge and cat eye syndromes. In addition, one of the genes suspected of contributing to schizophrenia is believed to lie on Chromosome 22 but has not yet been identified.

Besides the interest in specific genes, biologists can also see for the first time the full architecture of a human chromosome. Their immediate reaction is in some cases pure awe at the daunting complexity of the structure and the distance yet to travel before its features are understood. "I don't often pick up a scientific paper and find myself getting chills, as I did when I saw this whole chromosomal landscape," said Dr. Francis Collins, director of the human genome project at the National Institutes of Health. "This is a phenomenal historical moment, to see a full chapter of the human instruction book."

Although the goal of the human genome project is to sequence every one of the three billion letters in human DNA, the sequence of Chromosome 22 is not yet complete. There are 11 gaps, all of known length and fairly short. These are mostly regions that could not be cloned in bacteria, the standard way of amplifying long segments of human DNA for further analysis.

In addition, the team has not sequenced the DNA in two important features of the chromosome. One is the centromere, a region that helps the chromosome get copied correctly to each daughter cell when the cell divides. The other is the chromosome's short arm -- a

length of DNA on the other side of the centromere -- which in Chromosome 22's case contains only multiple copies of genes involved in protein manufacture. ...

APPENDIX 12: NOTABLE QUOTES AND READINGS

i-Notable Quotes

ii-Readings

a - Primary

b - Secondary

APPENDIX 12: NOTABLE QUOTES AND READINGS

i-Notable quotes

The most incomprehensible thing about the world is that it is comprehensible (Einstein).

The Scientist is as interested in the leg of the flea as the creative throes of a genius... Science tells us how to heal and how to kill; it reduces the death rate in retail, and then kills us wholesale in war (Will Durant, The Story of Philosophy).

I want to know how G-d created the world. I am not interested in this or that phenomenon, in the spectrum of this or that element. I want to know His thoughts; the rest are details. (A. Einstein in A. Zee p. 8)

Einstein: Science without religion is lame; religion without science is blind.

ii-Readings

There are a huge number of good science books that have been written for the layman. We have given only a sampling of books here, leaving out well-known science writers such as Carl Sagan and Heinz Pagels (The Cosmic Code, Perfect Symmetry and Others), and omitting many well-read books like Stephen Weinberg's The First Three Minutes and James Gleick's Chaos. In addition, science is constantly changing and progressing and it is only really possible to keep up-to-date by reading regular science articles. The N.Y. Times Tuesday science supplement and the monthly *Scientific American* are the most readable. *Scientific American* is also available on the Web, although in a very truncated form.

a – Primary

Pollack, Lewis - Fingerprints of the Universe (Artscroll). Relevant chapters on the Big Bang, Evolution etc., very readable although a bit long winded

Munk, Elie - In the Beginning (Feldheim) - Jewish approach to evolution

Davies, Paul - Superforce (Simon and Shuster 1984) - for an introductory but still in depth catch-up of all aspects of the new physics.

Brody, David Elliot and Brody, Arnold R. - The Science Class You Wish You Had (Perigee 1997) - The easiest reading of the science books mentioned here. Includes all the basic laws of physics as well as of biology and places them in historic context.

Jastrow, Robert - G-d and the Astronomers

Genesis and the Big Bang, Gerald I. Schroeder, Ph.D. Bantam, Formerly an MIT professor, Dr. Schroeder compares contemporary theoretical physics and classical Jewish sources to reveal an almost identical description of the creation and age of the universe. Also available on cassette from <2001@aish.edu> for \$7.00 plus \$2.00 for shipping and handling.

Dr. Shroeder's more recent book is The Science of G-d, published by Free Press of Simon & Schuster.