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Chapter 54 Historical Interactions Between Judaism and Science and Their Influence on Science Teaching and Learning

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54.1 Introduction

To the eye of the layman, Jews and science seem to have a definite association. To support such claims, some point to the large number of Jews who have won Nobel prizes in the sciences and Fields Medals in mathematics (Efron 2007) and to the numerous scientists of Jewish origin teaching at US-based universities (Lipsett and Raab 1995). However, as Efron (2007, p. 2) rightly points out, statistics such as these are "crude" given that most practicing scientists of Jewish origin are not usually guided by the tenets of Judaism, so it is a misconception to argue that Judaism, in of itself, is the reason for these scientists' interest or even association with their respective fields. The question, therefore, is what does Judaism have to say about science?

In this chapter, we will examine the historical and philosophical meeting between Judaism and science and how it in turn has influenced the teaching and learning of science. In so doing, we will be asking the following questions: How has the relationship between science and Judaism developed over history? What are the philosophical approaches that have developed in Judaism for dealing with the challenges that science sometimes poses? What are the subjects of science that most specifically create such challenges for Judaism? And most important for this book chapter: How has this meeting between Judaism and science affected the teaching and learning of science?

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In order to answer these questions, we will first provide a brief review of the historical interactions between Judaism and science, the goal being to examine the major trends that have developed through time. Based on these historical trends, we will define the major philosophical approaches (or models) that have developed within Judaism for dealing with the possible challenges posed by the domain of science. By understanding how Jewish thinkers have coped with these perceived challenges, it will be possible to analyze how this relationship has affected the modern science education system (specifically in Israel or in educational systems, outside of Israel, where Jews are the majority). The answers we provide to these questions may serve as a guide towards improving the quality of science education in Jewish school systems around the world.

54.2 Judaism and Science: A Historical Overview

To give a comprehensive analysis of the interactions of Judaism with science over the ages is beyond the scope of such a short chapter. Instead, as this chapter is found within a book on the role of history and philosophy of science in science teaching, we specifically define those interactions between Judaism and science that have relevance for science teaching. In this way, we will be better positioned to understand how Jewish teachers and students of science understand and even cope with potential conflicts between the two perspectives.

In order to understand the Jewish position on science, we will begin by defining what we mean by science for this chapter. In early Western-Greek culture, the philosopher was de facto the scientist: the physicist, the astronomer, and the medical doctor. Therefore, in order to gain a broad understanding of Judaism and science throughout the ages, we have to relate to three categories which characterize the scientific enterprise over the ages and their interface with Judaism: (1) technology, (2) exact sciences (most notably, astronomy and biology¹), and (3) natural philosophy in antiquity. In the modern era, with the separation of science and philosophy, we have to relate as well to the fields of (4) cosmology and cosmogony (most notably, evolution). The first two categories represent the products

¹ In this historical discussion, we address, among other things, the simple question of the rejection or the acceptance of biology, in general, as a science in antiquity. In the twentieth century, the issue of biomedical ethics has developed tremendously and so have the discussions concerning medical ethics and Jewish law. Much has been written about, including organ transplants and the definition of death, fertility issues, machines for prolonging life and disconnecting terminal patients from them, and cloning. Steinberg (2003) wrote an *Encyclopedia of Jewish Medical Ethics*; moreover, *Shaare Zedek Hospital* in Israel has a journal dealing with such issues titled, *Asiya*, and much discussion can be found in legal journals as well. However, there are two reasons why this issue is not part of this short chapter: First, the research is all done on the graduate level and by experts and does not find its way to the classroom at the high school or even undergraduate level. Secondly, this

of human reason and the third and fourth, human speculation and inquiry about life and the (formation of the) universe.

To understand any Biblical Jewish position, we must use the oral tradition, or as it is also known, the rabbinic tradition, to interpret the Masoretic text of the Bible; this rabbinic tradition commences with the Talmudic and Midrashic period (100 BCE–600 CE) and represents the classical period of Jewish literature.²

54.2.1 Technology

In the Book of Genesis, Noah, was so named by his father Lamech to mean: "This one shall comfort us for our work and the toil of our hands because of the ground which the Lord has cursed" (Genesis 5, 29). The curse of the ground is mentioned twice before in Genesis: the first time as part of Adam's punishment for partaking of the Tree of Knowledge (Genesis 3, 19) and the second time when Cain kills Abel (Genesis 4, 11–12). The rabbinic understanding of the curse was that the land would not produce food so easily, so man would have to sweat and toil to produce something which is not just thorns and thistles. However, this curse is not insurmountable; it takes human initiative and cooperation to overcome it. The Midrash (Tanhuma Genesis, 11) writes that until Noah was born, one planted wheat and barley but harvested mostly thorns. After Noah was born, "They harvested that which they had planted; not only that, but until Noah they did the work by hand. [However, after] Noah was born he invented ploughs, scythes, and shovels and all their work tools" (Poupko, 1990).

¹ By necessity, we focus on primary sources of the Jewish literary tradition, such as the Bible (the Masoretic text), the Talmud (Preisler & Havlin, 1998) and the Midrash, and their interpretations. We do so because it is these source texts and their interpretations that have been used authoritatively by Jewish thinkers, and in addition it is these texts which have been used for coping with different scientific positions. In turn, this has affected the modern science education curricula in many Jewish school systems. The Talmud is the authoritative body of Jewish law and lore accumulated over a period of six centuries (c. 100 BCE–c. 500 CE) in both Israel and Babylonia. The Talmud has two components: the Mishnah (Kehati, 1991), the first written compendium of Judaism's Oral Law, as redacted by Rabbi Judah the Prince in 200 CE, and the Gemara, an in-depth discussion of the theoretical base of the laws of the Mishnah. In addition, the Gemara includes nongal discussions and interpretations of Biblical texts called Aggadot as well as stories with moral implications to human behavior. The Gemara written in Babylonia is the more popular corpus and it is also referred to as the Babylonian Talmud. There was a parallel Gemara written in Palestine, and it is referred to as the Palestinian or the Jerusalem Talmud (Rozenboim 2010). If "Jerusalem Talmud" is not mentioned by name in the references in this chapter, then one can assume that the Babylonian Talmud is the version being referenced. Midrashim (pl.) are rabbinic interpretations of the Hebrew Bible consisting of homily and exegesis, on both its legal ramifications and its lore. Much of the Midrashic writings are attributed to the Tannaim (rabbinical scholars of the period of the Mishnah who lived between 100 BCE and 200 CE). Individual Midrashic commentaries continued to be composed by rabbis after 200 CE until the Middle Ages. The Talmudic and Midrashic texts are seen as the classical period of Judaism in which the oral traditions and interpretations were put to text. This literature is referred to as classical rabbinic (or *Hazal* in Hebrew) literature. All denominations of Judaism are in a dialogue with this classical literature whether they see it as authoritative (as does

For the rabbinic mind, human ingenuity and the technology it produced is not only a positive thing, but it is how humankind is expected to overcome "the curse of the ground." Instead of taking a passive position of accepting a Divine punishment, the rabbinic literature saw this "curse of the ground" as something that humankind brought about through misguided human behavior and therefore had become an issue that had to be resolved. This is comparable with the Biblical story of Moses breaking the tablets of the law after which God told him to make new ones. The idea of fixing what you break is how the rabbis of the Talmudic period interpreted this story. The resultant technology was and is the human attempt to rectify the flaws of nature caused by their own wrong actions.

A second way of viewing technology (and science) is from a practical point of view: providing one with the practical means to have an occupation. The Talmud (Makkot, 8b) says that it is incumbent upon a father to teach his son an occupation. Thus, the rabbis learned from the verse "And you shall live by them" (Deuteronomy 30, 19) that one may take time away from Torah study to study an occupation (Jerusalem Talmud, Peah 1, 1).

This second approach is also reflected in the famous debate between Rabbi Ishmael and Rabbi Simeon Bar Yohai, in which Rabbi Ishmael said that one must take off time from Torah study for a livelihood, whereas Simeon Bar Yochai thought that one should strive to devote all one's time to Torah (Talmud Brakhot, 36). The Talmud, however, preferred the view of Rabbi Ishmael finding it more practical and applicable. From the Biblical period until modern times, Jewish religious authority has largely remained positive towards the role of technology in society.³

54.2.2 Exact Sciences

The Talmud did not limit science's role to the practical task of insuring one's livelihood. Exact sciences, such as astronomy, were seen as bringing one to recognize the wonders of God's world, as seen by the Talmudic statement:

Rabbi Joshua Ben Pazi in the name of Bar Kapara said: anyone who can calculate the seasons and the astral [movements of the heavens] and does not, about him the verse says: "and the acts of God he does not behold and the works of His hands they did not see" (Isaiah 5, 12). Rabbi Samuel Ben Nahmani said: How do I know that it is a mitzvah [a Divine commandment] for one to calculate seasons and astral [movements]? For it says: "For you shall keep and do [these commandments] for this is your wisdom and knowledge in the eyes of the nations" (Deuteronomy 4, 6). Which wisdom is considered by the nations? This is the calculations of seasons and astral [movements] (Talmud Shabbat, 75a).

³In recent times, members of the ultra-Orthodox camp have raised concerns over the access that some computer technology gives to the media that is not in accord with their (Jewish) philosophy. As an example, some 40,000 ultra-Orthodox, US-based Jews attended a meeting at Citi Field (in New York, NY) to hear lectures about the dangers of the Internet (Grynbaum 2012). Similarly, in Israel, public calls are sometimes made to ban home computers in ultra-Orthodox communities.

Rabbi Samuel Edeles (known as Maharsha), the sixteenth-century Biblical commentator, argued that this rabbinic statement is not speaking about calculating the Jewish calendar, since this is a calculation by the moon, but rather we are speaking here of the mathematical calculation of the movements of the heavenly bodies. Thus, Rabbi Josef Karo (2009) in his *Code of Jewish Law* (published 1565) allows one to look into an astrolabe on the Sabbath since Rabbi Karo understood that there is a rabbinic ordinance to study the heavens.

Both of these rabbis based their opinions on the rabbis of the Talmud who held scholars of astronomy in great esteem and had no problem admitting a mistake if proven wrong by non-Jewish scientists in this issue (Talmud Pesachim, 94b). In general the feeling was that there was wisdom to be gained from the scholars of the nations in this field, as the rabbinic dictum states: "If they tell you there is wisdom among the nations, believe them" (Midrash Rabbah Eikhah, 2, 17) (Freedman & Simon, 1939).

Aside from the high regard, the rabbis had for astronomy, the relation to the exact sciences was seen in quite a practical sense, similar to the attitudes towards technology. In the area of biology, we have a few sources for the study of zoology or botany in order to better understand the commandments. The Talmud states that Rav, the third-century head of the Talmudic academy in Sura, Babylonia, spent 18 years with shepherds in order to be able to differentiate between temporary and permanent wounds in animals. This he did to identify which animal qualified as a first born (sacrifice) for the Temple (Talmud Sanhedrin, 5b).

The students of Rabbi Ishmael dissected the dead body of a criminal to understand issues of purity and non-purity (Talmud Bekhorot, 45a). Again, the Talmud accepts the opinion of non-Jewish botanists when deciding an issue concerning the agricultural laws; its regard for the science of biology can be seen from the very fact that it allows one to go to a physician claiming that medicine is a legitimate science and furthermore claims that a doctor who does not charge for his skills is probably not worth seeing (Talmud Bava Kama, 85a).

54.2.3 Philosophy

In order to correctly understand the rabbinic attitude towards general knowledge, one (also) needs to understand the rabbinic attitude towards philosophy, especially Greek philosophy, which was the forerunner of scientific knowledge in the West; and in order to understand their attitude towards philosophy, it is important to introduce the subject with a brief discussion of the Talmud's attitude to Greek culture, as Greece was the birthplace of philosophy.

In this discussion we differentiate between two issues: Greek language on the one hand and Greek philosophy on the other. The Mishnah (Megilla 1, 9) states that Rabbi Gamliel permitted the translation of the Torah from Hebrew into Greek. In the Talmud, Ben Kapara added that speaking Greek was appropriate for a Jew since the beauty of Jewish (father of Yavan in Genesis 10,2 which is the Hebrew name for Greece) should

Rabbi Simeon Ben Gamliel claimed that only Greek could capture the meaning of the Torah in translation (Jerusalem Talmud Megilla, 1, 9).

Despite the Talmud's positive attitude towards the Greek language (and the exact sciences) it saw the Greek use of verbal intimation negative light but was generally silent about Greek philosophy (See *Hokhma Yevanit* in Zevin (1963)). In the post-Talmudic period Greek philosophy was an issue debated for centuries among Jewish thinkers that set the tone for some of the modern Jewish attitudes towards philosophy and science.

Rabbi Hai Gaon of eighth-century Babylonia saw Greek philosophy as something which could sway one from the path of truth. Saadiah Gaon (882–942 CE), however, embraced the Islamic Philosophy of the Kalam,⁴ which was strongly based on the Greek philosophical model, and was well versed in the sciences of his day. Isaac Israeli (855–955 CE) in Kairouan (modern Tunisia) also drew heavily on the philosophy and science of his day.

In Spain, the attitude of most rabbinic figures began with the acceptance of the value of Greek philosophy. Solomon Ibn Gabirol (1020–1057 CE) took a neo-platonic stance in his *Fons Vitae* (the Latin edition of what has been shown to be the original *Mekor Hayim – Source of life*) as well in his classic poem *Keter Malkhut (The Crown of the King)*. Abraham Ibn Daud (1110–1180 CE) wrote an astronomical work and was the first to create a Jewish philosophical work based on the writings of Aristotle, titled *Emunah Rameh (The Sublime Faith)*. Bahya Ibn Paquda, in the late eleventh century saw the study of Greek philosophy as an important tool for understanding nature and metaphysics incorporating these ideas in his *Duties of the Heart* (Ibn Paquda 1970). Abraham Bar-Hiyya (1070–1136 CE) embraced Aristotelian thinking openly in his *Higeyon Henefesh (Meditation of the Soul)* and wrote works on astronomy, mathematics, and geometry (Bar-Hiyya 1968). Similarly, Abraham Ibn Ezra (1089–1164 CE) incorporated Aristotelian ideas and astronomy into his Torah commentary. He wrote a work entitled *Lukhot (Tables)* entailing astronomical tables and wrote a work on the astrolabe entitled *Keif Nehoshet (The Copper Instrument)* as well as *Yesod Mispal (Basic Numbers)* on arithmetic.

Maimonides (1135–1204 CE) was an avid believer in the importance of studying Greek philosophy and science and formulated in his *Commentary on the Mishnah*, the famous statement: “Accept truth from whoever offers it” (Maimon 1961). This echoes the (previously discussed) Talmudic respect for all knowledge, even that which originates outside the Jewish world. In addition to discussing issues of Greek philosophy and cosmology in his philosophic work, *Guide for the Perplexed* (Maimon 1956), Maimonides even incorporates ideas on cosmology into the first volume of his Halakic⁵ work, the *Mishneh Torah (Repetition of the Torah)* (Maimon 1987). Maimonides saw human reason and faith as inseparable. After all, if God created

humankind with the faculty for reason, then it cannot be that this God-given gift is at odds with revelation. The faculty of human reason is the “image of God” through which He created us (*Guide for the Perplexed*, I, I). Therefore, we need to use this faculty to understand revelation correctly. The need for harmony between reason and revelation, he states clearly: “We always attempt to integrate Torah and reason, and therefore will always explain issues (of faith) from a natural point of view. Only that which is clearly described as a miracle (by the Bible) without any other possible explanation, will we grant it the name of miracle” (as cited by Shilat 1995). Therefore, in issues of science and philosophy, Maimonides goes to great lengths to demonstrate how the scientific thinking of his day is in total harmony with Jewish faith.

Even with the difficult issue of Aristotle's theory of the eternity of the universe, which appears totally opposed to the Biblical notion of creation, Maimonides defends the (Biblical) act of creation by using Aristotelian logic and arguments from nature (*Guide for the Perplexed* 2, 13–32). The place of logic is so important in Maimonides thinking that he argued that logical deductions from revelation are part of the original intention of the revelation (*Guide for the Perplexed* 3, introduction); therefore, revelation and reason can never contradict each other. Maimonides believed in the inseparability of revelation and reason (and its derivative, science). This is best demonstrated by his statement that “if he would have been convinced that science had proven that the earth was created differently than our understanding of the Biblical text, he would have had no problem reinterpreting Genesis 1, 1” (based on *Guide for the Perplexed* 2, 25 as cited by Sacks (2011, pp. 219–220)).

The philosopher Gersonides (1288–1344 CE) accepted the Aristotelian ideas as filtered through Islamic philosophy and was an avid student of the sciences himself writing on arithmetic, geometry, trigonometry, and astronomy (Touati and Goldstein 2017). He is said to have invented a marine navigational tool called Jacob's ladder (Stanford Encyclopedia of Philosophy, <http://plato.stanford.edu/entries/gersonides/>).

Even Judah Halevi (1075–1141 CE) who claimed in his *Kuzari* that philosophy was limited in its ability to prove religious belief was still well-versed in philosophy and the sciences (Halevi 1998). In addition, the Raavad of Posquieres, in the twelfth century, who was a contemporary of, a commentator on, and fierce opponent of Maimonides, is still quite silent concerning Maimonides' embrace of philosophy. In addition, Nahmanides (1194–1270 CE) despite his leaning towards Kabbalah, defended the study of the sciences and Maimonides' *Guide to the Perplexed* in face of French rabbinic opposition (Shavel 1963).

In general, the entire Spanish era (900–1391 CE), prior to the inquisition was an age of acculturation in which rabbis openly embraced Western thought and culture while remaining faithful to their religious beliefs. It was also the most creative period of religious philosophy in which the three monotheistic religions, Judaism, Christianity, and Islam, stood side by side on the Iberian Peninsula. Despite any ongoing political struggle, the thinkers of all three religions openly borrowed ideas from each other in the common battle against problems arising from Aristotelian thinking.

Maimonides borrowed ideas from Al-Farabi and Avicenna. Gersonides borrowed openly from Averroes and Al-Farabi and Thomas Aquinas borrowed openly from

⁴Kalam is an Islamic school of philosophy that seeks theological principles through dialectic; it flourished in what is today modern Iraq, from the eighth to tenth century CE (Wolfson 1976).

⁵Halakha is the collective body of Jewish religious law, including Biblical law and later Talmudic law. It is the basis of Jewish religious and communal life. Judaism classically draws no distinction in its

Hayim (Source of Life), translated into Latin, was mistakenly thought to be the product of an Arab-Christian scholastic philosopher by the name of Avicbron until the Hebrew original was discovered in 1846 by Solomon Munk.

In general, as Shuchat (2008) noted, Jewish philosophy evolved when two events occurred: (1) a meeting between Judaism and Western culture took place and (2) a period in which the Jewish community enjoyed at least minimal civil rights as a minority. This occurred during three time periods: (A) the Hellenistic period from about the second century BCE in Israel and Egypt until the end of the revolt against the Roman empire in 115 CE in Alexandria; (B) the Muslim period, from the eighth century until the expulsion of Jews from Spain in 1492; and (C) the modern period, from the emancipation of the late eighteenth century until today.

In these three periods Jews experienced both Western culture and felt accepted enough to ask themselves how their neighbors saw them and took interest in the surrounding culture and thought. In the interim periods, where the Jews of the Western world did not enjoy these rights, they usually limited their study to Jewish legal writings and Kabbalah.⁶

54.2.3.1 The Opposition to Philosophy

The controversy over Maimonides writings saw the growth of an anti-philosophical movement in Provence and Spain. The Maimonidean controversy began during Maimonides' lifetime but turned into an anti-rationalist debate only in its second stage (1230–1235 CE). Solomon B. Abraham of Montpellier, David B. Saul, and Rabbi Jonah Gerondi led the anti-philosophy movement in 1232 CE. Their argument seems to have been more that the Jewish philosophers were compromising on the observance of the law and allegorizing scripture and Biblical miracles, than an attack on philosophy per se. With the burning of Maimonides books by the church in 1232 CE, the shock brought Rabbi Jonah Gerondi to retract and the controversy ended (Ben Sasson et al. 2007).

The third stage of the controversy (1288–1290 CE) was short lived, but the fourth and final controversy (1300–1306 CE) seems to have erupted again due to renewed allegations that the rationalists gave allegorical interpretations of the Bible, were lax in observance of the law, and denied Biblical miracles.

Rabbi Moses Aba Mari Astruc of Lunel persuaded Rabbi Solomon Ben Adret (also known as Rashba) to join forces. The Rashba was willing only to ban the study of philosophy or the natural sciences before the age of 25 (Ben Adret 2000).

⁶ Kabbalah (literally "receiving") is a discipline and school of thought discussing the mystical aspects of Judaism. It is a set of esoteric teachings meant to define the inner meaning of both the Bible and the traditional rabbinic literature (including Midrash and Talmud) as well as to explain the significance of Jewish religious observances in light of the inner soul and upper spiritual worlds. The term Kabbalah, meaning Jewish mysticism, is a term from the twelfth century CE and afterwards. However, Jewish mystical texts date back to at least the second temple period if not earlier. The Hebrew word for Kabbalah is the book of Zohar or more correctly Zoharic literature.

However, even Rashba, who opposed philosophy, neither had no problem with the study of Greek medicine (Reponsa part 1, letter 415) nor was he actually against studying the exact sciences.

It is possible that the political changes in Spain helped create the anti-rationalist movement. With the re-conquest of Spain by the Christians, Jews were suffering from the crusades and from the impact of martyrdom in their wake. The Maimonidean synthesis with Greek culture seemed less appealing and a move to mysticism was being felt. After the massive conversion of Jews to Christianity during the months of Spanish rioting against the Jewish communities in 1391, many Jewish scholars regarded the adherence to philosophic doctrine as a threat to the Jewish community; this included Hasdai Crescas (1340–1412 CE) who criticized Aristotelian physics in what was to be one of the first serious attacks on the system (Wolfson 1929).

After the Spanish expulsion, the interest in philosophy dwindled in the Jewish world. With the exception of scholars such as Joseph Solomon Delmedigo (1591–1655) in his book *Seder Elin*; R. Moses Isserles (1520–1572) of Cracow and R. Abraham de Herrera (1570–1635), who combined philosophy and Kabbalah; R. Menasseh Ben Israel (1604–1657); R. Moses Zacuto (1625–1697), a kabbalist who was in contact with Spinoza; and R. Loew of Prague (1520–1609, known as the Maharal), Kabbalah took over from philosophy as the main intellectual interest.

David Nieto (1654–1728 CE), in his *Second Kuzari*, claimed that the rabbis of the Talmud were never against philosophy (Nieto 1993). In the eighteenth century, scholars like Rabbis Elijah Ben Solomon Zalman (1720–1797, better known as the Vilna Gaon), Jacob Emden, and Jonathan Eibeshitz still held the sciences in great respect. The Vilna Gaon was quoted as saying that for every amount that one lacks knowledge of the general sciences, he lacks one-hundred fold in the study of Torah (Baruch ben Jacob (1780) of Shklov, *Introduction to his translation of Euclid* in Hebrew). The Vilna Gaon even wrote his own treatise on algebra titled, *Avil Meshulash (The Three Rums)*, but concurrently he was rather cold towards philosophy (Shuchat 1996).

With the onset of the Jewish emancipation (from the later eighteenth to twentieth century) in Europe and Russia came the rise of the Jewish *haskalah* (or *enlightenment*) movement, which saw its goal to reintroduce secular education to the traditional Jewish masses. In Western Europe, the father of the Jewish *haskalah* movement was Moses Mendelssohn (1729–1786), a traditional and observant Jew well versed and acculturated in German intellectual society. Mendelssohn set out to portray Judaism as a religion of reason in his work *Jerusalem*, using religion and philosophical reasoning hand in hand as Maimonides did before him. The first period of the *haskalah* (in the late eighteenth century and the beginning of the nineteenth century) saw many religious Jews, especially in Eastern Europe, even rabbis, embracing the message of secular studies alongside Torah studies; however, with the secularization of the Russian and Eastern European *haskalah* movement, rabbinic leaders disassociated themselves with it and even became

In Bialystok, Hayyim Selig Slonimski (1810–1904 CE) was a talmudist, a mathematician, and a popularizer of science for traditional Jews. Coming from the same mind-set of the Vilna Gaon and *Sefer Hachrit* that secular knowledge is needed for the proper comprehension of Torah, he published his first volume on mathematics titled, *Mosdei Hokhma (Foundations of Wisdom)* in 1834 with rabbinic approbations (Robinson 1983). In 1838, he published a book on astronomy entitled *Toldot Ha-shamayim (The Heavenly Hosts)*. He was one of the first to explain that the six days of creation are really six eons and therefore came closer to the ideas of the geology of the time than those relying on Biblically based calculations for the Earth's origins (Robinson 1983). In sum, Slonimski looked for synthesis between science and rabbinic literature.

In Western Europe, however, Jewish thinkers seem to have been quicker to accept this new worldview. Raphael Halevi of Hanover (1685–1779 CE) a mathematician and philosopher, who had studied with Leibnitz, published two books in astronomy in 1756 CE. In his *Tekhninat Ha-Shamayim (Astronomy of the Heavens)*, he openly embraces the Copernican system. It is of interest that Rabbi Landau read this work and quoted from it, without adopting this position (Brown 2008). Similarly, Joseph Ginsburg in his *Itim La-Bina (Wisdom of our Days)* explained that one could accept the Copernican model and remain a faithful Jew. Dov Ber Rukenstein in his two-part series on astronomy entitled *Mesilat Ha-Meorot (Pathways of the Heavenly Bodies)* (as cited in Robinson 1983) talked of Copernicus' model as being accepted by all scientists of his day. Therefore, writing in the late nineteenth century, Rabbi Samson Raphael Hirsch could say:

What Judaism does consider vitally important is the acceptance of the premise that all the hosts of heaven move only in accordance with the laws of the one, sole God. But whether we view these laws from the Ptolemaic or Copernican vantage point is a matter of total indifference to the purely moral objectives of Judaism. Judaism never made a credo of these or similar notions (Hirsch 1992, p. 263).

54.2.4.2 Cosmogony (Including Evolution)

In classical Jewish philosophy, Aristotelian physics and cosmology were seen as a challenge, rather than as an overt threat; thus, although being diametrically opposed to the book of Genesis, great effort was invested in order to reach a synthesis between the Aristotelian theory of the eternity of the universe and the Biblical creation narrative. In the twelfth century, Maimonides in his *Guide for the Perplexed* took great pains to explain how one can explain creation with the same Aristotelian hypothesis but with some alterations.

In the nineteenth century, rabbinic thinkers dealing with the new theories of cosmogony and particularly evolution acted in a similar same way. Orthodox Rabbi Israel Lipschutz of Danzig was a learned legalist who had a great interest in the science. Writing in the 1800s, before Darwin's *On The Origin of Species* was published, Lipschutz was familiar with the "evolutionary" theories of Lamarck. Rather than seeing the new theories as a threat to Biblical belief, he sees the idea of

an ice age and the regeneration of life as a proof for the Jewish belief in the eventual resurrection of the dead. No criticism of the theory can be found in his writings, just a great enthusiasm that science is now proving the age old Kabbalistic theory that there were earlier worlds than ours (Shuchat 2005).

In the post-Darwinian world of the nineteenth century, there was still no major change. Jewish thinkers like Rabbi Elijah Benamozegh of Italy and Samson Raphael Hirsch of Germany, writing at the same time that the Church and the scientists of Europe were battling each other verbally, did not see evolution as a major threat to Jewish belief. For example, Rabbi Hirsch writes:

Judaism is not frightened even by the hundred of thousands and millions of years which the geological theory of the earth's development bandies about so freely. Judaism would have nothing to fear from that theory even if it were based on something more than mere hypothesis, on the still unproven presumption that the forces we see at work in our world today are the same as those that were in existence, with the same degree of potency, when the world was first created. Our rabbis, the Sages of Judaism, discuss [Bereshit into existence and subsequently destroyed by the Creator before He made our own earth in its present form and order. However, the rabbis never made the acceptance of this and similar possibilities an article of faith binding on all Jews. They were willing to live with any theory that did not reject the basic truth that every beginning is from God (Hirsch 1992, p. 265).

Rabbi Elijah Benamozegh (1862) saw the new scientific discoveries as proving the Midrashic and Kabbalistic notion of earlier worlds which God created before our own:

In conclusion, this belief in earlier worlds is an ancient one in our nation and it stands as a proof for the divine nature of the Torah, which natural science now confirms. . . . And I finish [this discussion] with the dear words of the scholar in the Kuzari [1, 40] who said: 'If a believer in Torah had to admit to the existence of primordial matter of earlier worlds that predated us, this would not blemish our faith' (Benamozegh 1862).

In addition, Benamozegh saw the new theories of evolution as a proof of human potential and ultimately of the resurrection:

I believe, as science teaches, that animal forms appeared on the earth and evolved into more perfect beings, either as Cuvier said, by revolutions and cataclysms, or by slow evolutionary processes, like the opinion of the modernist Lyell, or Darwin and others. More and more perfect species have developed, one after the other, over the course of millions of years on the face of the earth. The most perfect form is Man. But will nature stop here? This would indeed be strange. Present humankind, as Renan [French expert of Middle East ancient languages and civilizations] says, will evolve into another, more perfect human being. But Renan and the others stop here. They do not say that the order that reigns in the physical world has to reign in the moral one as well, and that there is no reason to believe that the 'I' that force which created the actual human, does not have to create the future human as well. They do not say that the 14 monads, the atoms, which are minuscule forces, are indestructible (as science teaches) for it is inevitable to believe that they will compose the future Man on a regenerated earth. All this is stated by Judaism, and is called the Resurrection (Benamozegh 1877, pp. 276–277).

Similarly, Rabbi A. I. Kook's writing in the early twentieth century also displayed an optimistic view of evolution claiming that it is closer to the Kabbalistic

notion of creation than the philosophical idea of creation *ex nihilo*.¹² Despite this enthusiasm in his more philosophical writings, in his public letters, Rabbi Kook writes more cautiously. After explaining to a correspondent why the new theories of evolution do not contradict the Torah, he writes:

We do not have to accept theories as certainties, no matter how widely accepted, for they are like blossoms that fade. Very soon science will be developed further and all of today's new theories will be derided and scorned and the well-respected wisdom of our day will seem small-minded (Feldman (1986, p. 6).

Continuing this trend, Rabbi Isaac Halevi Herzog (the first chief rabbi of Israel), writing in the mid-twentieth century, displayed the discomfort that many later rabbinic figures were to have with the theory of evolution. This discomfort was caused not just by the challenge which this theory posed to Biblical exegesis but by the fact that it was considered to be one of the paradigms of modern secular scientific thought, which many of these rabbinic figures felt was in opposition to all organized religion (Robinson 2006).

Some rabbis of the second half of the twentieth century began, like their Christian contemporaries, to see the theory of evolution as a threat. As Orthodox Jews entered the arena of the sciences, many of them entered the battle against evolution, arguing from a scientific standpoint, rather than a Biblical or Talmudic point of view, and looked to those who opposed evolution as their comrades in arms (Cherry 2006). Rabbi Herzog's attempt to look for ways to harmonize the simple meaning of Genesis 1 with evolution without the multitude of rabbinic commentaries reflects this new attitude:

How can the Torah chronology be scientifically defended, in view of the aeons which science postulates for the existence of man upon this earth? There is, of course, the well known Midrash, 'boneh olamot-naharvan' [he built his worlds from annihilation] [Midrash Genesis Rabbah 3, 7; Ecclesiastes Rabbah 3:11], but this can only help if we assume that "naharvan" does not mean annihilation, so that we can assume that fossils of man asserted by science to be so many hundreds of thousands of years old are relics of a previous earth. Yet anthropology seems to assert upon internal evidence that the present man is already hundreds of thousands of years old! [...] Of course, strictly literal interpretation of the Pentateuchal text is out of the question. But super literary interpretation should be resorted to only when reason absolutely rules the literary sense being utterly impossible... (as cited in Shuchat 2008–2009, p. 155).

Rabbinic scholars are not detached from the world around them. During periods of social turmoil, when the thinkers of the age begin to doubt the validity of the scientific order of the day, Jewish thinkers do so as well. The events of the Second World War proved both the supreme power of scientific technology as well as the threatening implications of the misuse of that power. The subconscious social impact of the atom bomb attacks on Japan and a war that used modern technology to claim millions of lives cannot be underestimated. Although faith in science

remained unsathed for the first decade and a half after the war, and the scientific community emerged from the war with enhanced prestige, these events planted the seed for the disillusionment with science, in general, and more specifically evolution that put it on the defensive in the 1960s and 1970s (Ben-David 1991).

The technological boom of the nineteenth and early twentieth centuries led to a belief in the omnipotence of science, and religious fundamentalist voices against the theory of evolution were stifled, out of respect for science; by the 1970s, however, attacks on science gained legitimacy, and the popular reaction to science was now a mixture of enthusiastic support and profound mistrust (Ben-David 1991).

In the Jewish world, a second element contributed to increased disdain for science. After the destruction of European Jewry, including all major institutions of Jewish learning and culture, some of the Orthodox rabbinic leadership did everything possible to hold on to what remained and held suspect any new way of thinking that might pose some type of threat to religious survival. These feelings of suspicion towards all new ways of thinking became more manifest in the seventies, as society as a whole became critical of science. As a result, the late twentieth century saw the Jewish attitude to science take on different voices. The theory of evolution, in particular, which was seen as one of the paradigms of modern, secular (scientific) thinking, became representative of how various elements in Judaism see religion and science. The syntheses of classical Jewish philosophy were therefore at times forgotten.

Approaches of Reform and Conservative Thinkers Towards Evolution in the Twentieth Century

The historical picture for Judaism in the nineteenth and twentieth centuries becomes even more complex with the rise of non-Orthodox movements in Europe, which eventually made their way to North America in the late nineteenth century. The non-Orthodox rabbis of the early twentieth century were very committed to finding a way to synthesize between science and Judaism, specifically the modern theory of evolution. The theological debates, which arose in light of the Scopes trial in 1925 over the legality of teaching evolution in public schools in Tennessee (Numbers 1998), generated a discussion among leading Reform rabbis in the United States of how to treat this sensitive issue.

The view of Reform rabbis of the 1920s was identical to their predecessors. Rabbi Kaufmann Kohler and Emil Hirsch of the late nineteenth century, in their belief that fundamentalists had erred in understanding the first verses of Genesis, literally, and in assuming that evolution denied a creator (Swelitz 2006). They agreed that Genesis is not a textbook for science and literal interpretations of it were not acceptable. Reform rabbis went as far as claiming that progressive change and design were an inherent part of evolution and therefore provided a case for God as a creator (Swelitz 2006). In the 1930s, Rabbi Cohen, Brickner, and Felix Levy saw the new physics as supporting the view of intelligent design making the evolution of life possible (Swelitz 2006).

¹² The kabbalists had a different take on creationism seeing it more as an act of emanation rather than creation *ex nihilo*. They also differed on the question of the time that it took to create the universe (Shuchat 2009).

Conservative rabbis in the 1920s and 1930s like Levinthal and Finkelstein took the same position as the Reform on this issue (Sweilitz 2006). Rabbi Mordecai Kaplan was somewhat of an anomaly at this point adopting a naturalist approach to God that disregarded the theological arguments leading from evolution to God.

In the postwar era of the 1950s and 1960s, Reform Rabbi Emil Fackenheim, Rabbi Abraham Joshua Heschel of the Jewish Theological Seminary, and theological scholar Will Herberg believed that an excessive reliance on science and reason had distorted the proper understanding of Judaism (Sweilitz 2006). No evolutionary argument can explain a personal God. It is necessary to demarcate the boundaries between science and religion, they argued.

By the end of the 1960s, evolution was generally ignored by most among the Conservative and Reform, except in the writings of Reform Rabbi W. Gunther Plaut. This position, separating science from religion, was challenged by Reform Rabbis Levi Olan and Roland Gittelsohn and Conservative Rabbi Robert Gordis, who defended the centrality of reason and science in Jewish theology. Gittelsohn was personally interested in evolutionary biology and advocated what he called "religious naturalism" invoking the new science to aid one in proving the existence of God (Sweilitz 2006). Gordis shared Milton Steinberg's belief that religion has to provide a philosophy of life which includes the conclusions of science.

In the 1980s there was a renewed interest in evolution, with the attempt by creationists in the United States to gain equal time in public schools for teaching Biblical creation. However this time, Reform rabbis, like William Leffler and Jack Luxemburg, maintained the need to emphasize the limitations of science in proving or disproving God (Sweilitz 2006). This apparent divorce of science from religion in the 1980s was followed by evolution reentering Jewish theology with the renewed interest in Kabbalah. The idea of cosmic evolution was adopted by Reform Rabbi Lawrence Kushner as well as Rabbi Zalman Schachter-Shalomi of the Jewish Revival Movement and Prof. Arthur Green.

Approaches of Ultra and Modern-Orthodox Thinkers Towards Evolution in the Twentieth Century

Turning to the postwar Orthodox world of North America, we see that the situation was different. It was mentioned previously that Rabbi Herzog was hesitant in utilizing the rabbinic notion of earlier worlds and preferred to see if there were scientists who held other views. The second half of the twentieth century saw Orthodox responses to evolution, which were much different than those of the late nineteenth and early twentieth centuries. The ultra-Orthodox saw evolution as representing a secular alternative to the religious weltanschauung and therefore saw it as stepping over its legitimate boundaries. Rabbi Moses Feinstein claimed that

Textbooks of secular studies that contain matters of heresy with respect to the creation of the world... are forbidden to be taught... If it is not possible to obtain other books, it is necessary to tear out those pages from the textbook (Feinstein 1982).

More modern-Orthodox thinkers looked for inroads to recreate the syntheses of earlier days. Like his predecessor Rabbi Herzog, Rabbi Aaron Lichtenstein wrote in the late twentieth century:

(Confronted by evident contradiction [between Torah and science] one would... initially strive to ascertain whether it is apparent or real... whether indeed the methodology of madda [science] does inevitably lead to a given conclusion, and ... whether... Torah can be interpreted... so as to avert a collision (Robinson 2006, p. 78).

An interesting phenomenon that developed in the second half of the twentieth century, with the entry of Orthodox Jews into Western universities, was the place of the Orthodox Jewish scientist. In 1948, some of these scientists founded a group they called the *Association of Orthodox Jewish Scientists* (AOJS). One of its aims was to resolve "apparent challenges of scientific theory to Orthodox Judaism" (Robinson 2006, p. 79), and evolution, specifically, was an important issue that they needed to deal with.

In the late twentieth century, three Orthodox Jewish physicists can be seen as representing three different approaches to evolution: Prof. Hermann Brannover, Prof. Nathan Aviezer, and Prof. Gerald Schroeder. The American-trained Prof. Aviezer (1990) of Bar-Ilan University in Israel, in his work *In the Beginning*, took a nonliteral attitude to the 6 days of creation, seeing them as epochs rather than days of 24 h, but then continues to read into the literal text a novel interpretation in which he claims that the main elements of the Biblical story harmonize with all the main elements of modern scientific cosmogony (Cherry 2006). Aviezer also takes a non-chronological reading of the creation story in which he sees the 6 days of creation as representing two stages: days 1–4 which represent the formation of the structure of the universe and days 5–6 which represent the inhabitants of the universe which begin while the universe is being formed.

The second approach is from another American-trained physicist from Israel, Gerald Schroeder. Schroeder (1998) accepts, as does Aviezer (2002), the evolutionary timetable; however, in a novel literary hermeneutic, he claims that the 6 days of creation were 6 days of 24 h, but claims that according to Einstein's theory of relativity and time dilation, from the perspective of the forward rushing cosmos ("God's perspective"), 6 days is equivalent to 15 billion years looking backwards.

A third perspective is that of Russian-educated Prof. Hermann Brannover of Israel. Associating himself with the ultra-Orthodox Haredic community of Lubavich, he holds a literalist view of the creation story. He uses alternative scientific views to argue against scientific evolution.

Ultra-orthodox groups such as the Israeli outreach organization "Arachim" feel more comfortable with these more aggressive fundamentalist anti-evolution positions. The open attacks of these fundamentalists against scientific thinking have gone so far as to find among them those who now are even questioning again Copernican heliocentricity in the twenty-first century. Moderate elements in the ultra-Orthodox world, such as the Aish Hatorah outreach organization, see Schroeder's position as saving both creationism and science, whereas modern-Orthodox Jews feel comfortable with Aviezer's ideas or just accept a nonliteral interpretation of the creation story (Sacks 2011).

Evolution aside, mainstream Orthodox Jewish rabbinic thinkers tend to adopt a generally positive attitude to science. This view of the legitimacy of science to overcome the Biblical curse of the ground mentioned earlier or to heal the sick is the age-old Jewish view which sees the idea of scientific progress as a way of mending the world when used for the good.

54.3 Historical Summary

This brief historical overview shows a somewhat complicated relationship between Judaism and science, but certain tendencies can be deduced from it. As we have seen, from earliest times, technology was seen positively as something that can help mankind overcome the difficulties of life. The Talmud praises the study of astronomy and sees biology and medicine as legitimate fields of study. The Jewish rationalists of the middle ages, especially in Spain, were particularly open to general studies and well versed in the sciences, medicine, and philosophy of their day.

The debate over philosophy in the post-Maimonidean era seems to have been more of an attack against lax observance, as well as the non-Orthodox ideas of the rationalists, than a ban on science per se. Philosophy was often seen as the culprit which brought in foreign ideas to Judaism. This same style of controversy can be seen in the middle to late nineteenth century Eastern Europe between the secular exponents of the Haskalah (or enlightenment) and their rabbinic counterparts.

The late nineteenth century saw the rise of Darwinian evolution and its entrance into Jewish thinking. Early thinkers until the First World War had an open and even accepting attitude, but in the post Second World War period, suspicion arose and the fear of foreign elements challenging Jewish faith renewed the debate over the relationship of science and Judaism. Most modern orthodox, as well as almost all Conservative and Reform thinkers, showed an attitude of acceptance; in contrast, the postwar ultra-Orthodox camp, suspicious of most modern concepts, showed antagonism to these ideas, even if they did not oppose the study of the sciences for the need of a livelihood or to practice medicine. Jewish educators abroad and in the educational system of the State of Israel struggle to this day to accommodate these different philosophical approaches, as we will see in the next sections of this chapter.

54.4 Philosophical Approaches Towards the Interaction Between Science and Judaism

Our brief historical survey confirms what Efron (2007) previously noted about the attitudes of Jewish thinkers towards science, in that historically it was "never subject to consensus." Certainly, we have seen that there were specific periods and regions where (rabbinical) authorities were worried about how secular science might affect Jewish piety and so strongly opposed contact with secular learning,

including science, or specific scientific disciplines. At the same time, Judaism has often looked positively upon science, and its precursor, the study of nature and astronomy in antiquity, not just in its applied form where it benefits man's ability to derive a living or protect one's health but also in order to gain a better understanding of the natural world.

Moreover, Efron (2007) suggests that Judaism has avoided many of the science-religion clashes that have occurred among the Christians. In part, this was due to the fact that Jews never developed institutions with the coercive power to declare an idea or a book to be an anathema.¹³ More importantly, in his view, the long exegetical tradition within Judaism of reading and interpreting texts meant that Jews by their nature did not sanctify the ideal of consensus. In fact, Jewish exegetes actively sought to multiply interpretations to arrive at deeper understandings of a text. Indeed, we can see this tradition of multiple interpretations operating in our brief historical review in the previous section of this chapter.

Thus, even if there might have been a mainstream trend during any period of Jewish history concerning how Judaism saw science, or any of its disciplines, from a practical viewpoint, rather than looking for consensus, it is better to discuss a spectrum of philosophical approaches that were developed to classify the (multiple) positions of Judaism towards science. In this section, we will discuss these approaches in order to create a set of definitions that can be applied to our discussion about Judaism and its interaction with science education.

Much of the work dealing with the philosophical interaction between religion and science has focused on Christian perspectives. The four most comprehensive works on this interaction include the books of Barbour (1997), Brooke (1998), Haught (1995), and McGrath (1999).

Among sources dealing with Judaism's interaction with science, there are two comprehensive works: Lamm's (2010) *Torah Umadda* and Rosenberg's (1988) *Science and Religion in the New Jewish Philosophy* (published in Hebrew). Both works are important but emphasize different approaches. Lamm's (2010) work is somewhat broader in that it deals with how Jewish thought has dealt with worldly knowledge, in general, rather than just science, which is Rosenberg's focus. From a practical perspective, Rosenberg's (1988) work has been used in a number of science education studies to classify the positions held by religiously Jewish teachers (Hodick et al. 2010) and students (Allouch 2010) in Israeli schools, and so we will examine his approaches here, as a precursor to our discussion of science education; nonetheless, whenever possible, we will integrate Lamm's (2010) discussion.

In structure, Rosenberg's (1988) approaches are somewhat similar to those mentioned in Barbour (1997) albeit the number of categories he developed was larger. Moreover, both Rosenberg (1988) and Lamm (2010) develop a set of approaches or models based on Jewish thinkers and their interpretation of classical

¹³ One of the most famous historical examples of the use of coercive power in the Christian world was the Church's imprisonment of Galileo as a heretic in 1613 for his support of the heliocentric theory. Bronowski (1973, p. 218) argues that "the effect of the trial and the imprisonment was to put a total stop to the scientific tradition in the Mediterranean."

Jewish texts (such as the Talmud and Midrash) which contrast, with Barbour's approach in which he delineates a set of historical-based Christian attitudes towards science. Thus, Lamm (2010) and Rosenberg (1988) provide us with greater insight than Barbour (1997) when we examined science education and its interaction with Judaism. In his book, Rosenberg (1988) talks about four main approaches.

54.4.1 Limiting Approach

This approach opposes any attempt at integrating secular knowledge with Jewish thought. From this point of view, such a mixture creates the chance that heresy may infect the student of Torah, therefore, from a practical perspective, there was no room in the curriculum of a Torah student for such lesser knowledge (Lamm 2010). When faced with a scientific approach to problematic issues such as creation, those adopting this approach reject the scientific approach, as it challenges the primacy of the Bible's literal meaning. An example of this approach can be found in the writings of the late Rabbi Menachem Schneerson the former leader of the Lubavitch Hassidic movement in his commentary concerning geologic time and evolution:

In view of the unknown conditions which existed in prehistoric times (atmospheric pressures, radioactivity) conditions which could have caused reactions of an entirely different nature and tempo from those known under present-day processes of nature, one cannot exclude the possibility that dinosaurs existed 5,722 years ago, and became fossilized under terrific natural cataclysms in the course of a few years rather than millions of years (Schneerson 1972).

In philosophical terms, Rabbi Schneerson (1972) was rejecting the principle of uniformity which states that the laws of nature remain unvarying throughout time. This approach to secular learning, in general, and science specifically is most common among the ultra-Orthodox. Such explanations also *seem* to match most closely with a Christian fundamentalist view of religion and its relationship to science, most notably those issues connected to creation and evolution.¹⁴

54.4.2 Explanatory Approach

In this approach, Biblical texts are not understood literally, but rather are explained so that religion and science can be brought closer together. Contradictions are

¹⁴ Regarding evolution, Robinson (2006) argues that care should be taken in blindly comparing ultra-Orthodox attitudes to fundamentalist Christians too closely. The ultra-Orthodox are united in their opposition to Christian creationism as it is based on the King James Bible and not on traditional Jewish texts, which incorporate the cumulative perspectives obtained from (a large number of) traditional Torah commentaries and interpretations. In fact, Robinson (2006) could only find one source written from an ultra-Orthodox perspective whose author identifies as a creationist. Thus, at least in philosophy, if not deed, the ultra-Orthodox do differ from fundamentalist Christians.

viewed as a misunderstanding of the Bible and simply require proper interpretation. For example, with regard to the Earth's age, some Jewish Biblical commentators explain that the days of creation went far beyond a 24-h period of time, or as Rabbi Abba states in the Midrash that "God created [many] worlds and destroyed them until he created this one" (Rabba Bereshit, 3, Sect. 7). Thus, according to this interpretation, there were cycles of destruction and creation culminating in this world, such that the age of this world far exceeds the 6-day period of creation.

Among the most important exponents of the explanatory approach was Maimonides. More than that, his attitude to secular studies, in general, was not just that it was permissible but that there was an "obligation to pursue them as an act of mitzvah" (i.e., religious command) (Lamm 2010, p. 67).

54.4.3 Parallel Approach

This approach sees contradictions between science and religion as being derived from not clearly separating between the domains, as the former deals with rational explanations of nature, while the latter focuses on religious belief which illuminates human purpose, meanings, and values. Each domain has value for human experience, but they should not be integrated. Scientist and philosopher Yeshayahu Leibowitz is a noted exponent of this approach:

There is no mutual dependency between scientific knowledge and decisions about [religious] values. What can the immense achievement of science contribute to these decisions on values? Science cannot contribute anything because concerning the problem addressed by these decisions, such as to be a believer, not only does science have nothing to contribute, but these questions cannot even be posed because these concepts do not appear in the lexicon of science (Leibowitz 1985, p. 35).

Historically, one of the more important exponents of the parallel approach in the Jewish world of education is Rabbi Samson Raphael Hirsch's Torah Im Derech Eretz ("Torah with secular knowledge") (Lamm 2010) whom we discussed previously. This approach also represents, as we have seen, the position of Reform Rabbi Emil Fackenheim, Rabbi Abraham Joshua Heschel of the Jewish Theological Seminary, and the theological scholar Will Herberg. Philosophically, the parallel approach is also equivalent to scientist Stephen J. Gould's (1997, 1998, 1999) principle of "respectful noninterference" between the worlds of science and religion or *NOMA* (Nonoverlapping Magisteria).

54.4.4 Complementary Approach

This approach suggests that science complements religion, creating a synthesis of the sacred and secular. Supporters of this approach see a strong (though not necessarily literal) fit between scientific discoveries and what is described in the Bible (Lamm 2010). This approach is personified by Rabbi A. I. Kook who viewed the

theory of evolution as a model for spiritual growth; thus, he did not see it posing a threat to religion:

The theory of evolution that is presently gaining acceptance in the world has a greater affinity with the secret teachings of the Kabbalah better than all other philosophies. Evolution which proceeds on a course of improvement offers us the basis for optimism in the world. How can we despair when we realize that everything evolves and immediately improves? In probing the inner meaning of evolution toward an improved state, we find here an explanation of the divine concepts with absolute clarity. Evolution sheds a light on all the ways of God (Kook 1938, p. 555).

54.4.5 Conflict Approach

This approach was not found in Rosenberg (1988), but it emerged as a consequence of interviews that were held by Dodick et al. (2010) with religiously observant Jewish teachers (in the Israeli high school system) and scientists (in the Israeli university system); it was therefore added to the taxonomy used by Dodick et al. (2010) to classify the philosophical approaches of religiously oriented, Jewish teachers and scientists. Conflict emphasizes the understanding that there sometimes exists a contradiction between science and religion because of the overlap between the two domains such as occurs with evolution. Such conflict largely arises because of the open, unanswerable questions that occur due to this overlap. Nonetheless, although some are affected by this conflict, they are willing to live with the situation and do not reject science as is the case with the limiting approach.

54.5 Judaism and Its Interaction with Science Education

In discussing Judaism and its interaction with science education, it should be understood that prior to the emancipation period in Europe, Jewish contact with general secular learning and science learning, specifically, was largely limited to those rabbis who approved of and conducted such learning (Efron 2007). Thus, it is impossible to talk of the interaction between Judaism and science education on a large scale before that time period. Even post-emancipation, there is no published research dealing with science education until we enter the twentieth century. Therefore, we will confine our discussion to recent times because all of the education research that has been conducted on this topic has been done in the last 20 years or so.

Unfortunately, there are only a small number of studies dealing with the interaction between Judaism and science education, especially when compared to the larger number of studies from a Christian perspective. This is due to a number of interrelated factors. Most science education studies dealing with the interaction between science and religion emanate from Western countries, where the dominant religious background (measured by population) is Christian. Therefore, by default, such studies are strongly flavored by a Christian perspective because the majority of school-age students come from a Christian background.

Hence, if we are to understand how Jewish attitudes towards science influence science education, we need to discuss the situation where Jews represent the majority and thus influence the school system. If we are talking geographically, we must focus on Israel, the only country with a Jewish majority. If we are talking systemically, we can also include the extensive private Jewish school systems that have developed in Western countries, most notably in the United States, which contains the world's second-largest Jewish population after Israel (DellaPergola 2010).¹⁵

Historically, for those groups of Jews who were not opposed to the integration of secular knowledge into the Jewish domain, the scientific issues that are most challenging to Judaism emanate from subjects touching upon Biblical creation including cosmology, geologic time, and most notably evolution. Not coincidentally, these issues have also had the greatest impact on the interaction between Judaism and science education, and it will be a discussion of these conflicts that will dominate this chapter.

However, before analyzing this conflict, we must discuss Jewish school systems, both within and without Israel, because their structure affects how controversy is dealt with. Indeed, school systems that serve the Jewish public are guided by a specific religious philosophy and in turn this philosophy guides the school system's interaction with secular subjects such as science, so it is important that we discuss their basic structures.

In Israel, the school system is divided between Hebrew and Arabic speakers. The two largest divisions among the Hebrew-speaking system are the Secular State and National Religious systems, respectively (Dodick et al. 2010). The Secular State system teaches a population of primarily secular and traditional students with many of its teachers coming from secular backgrounds. Its matriculation system is designed so that students have the possibility for continuing to higher academic studies. The only component of "religion" in this system is that the Bible is one of the core subjects (and is taught as part of the cultural background of Israel, and not from a religious perspective).

In contrast, the National Religious school system's philosophy is to integrate secular and (Orthodox-based) religious studies, making it possible for its students to pursue both secular studies at a university and religious studies at a Jewish seminary.¹⁶ Many of the teachers are religious in orientation and have a professional background from a university, college, or seminary, depending on the subjects they teach.

A third system of schools in Israel, termed independent, focuses exclusively on the ultra-Orthodox population. For male students, the focus is on religious studies with little to no secular studies, including science learning; the ultimate goal is to prepare them for higher religious studies in a *Kollel*.¹⁷ There is more flexibility in

¹⁵ Of the approximately 13.5 million Jews in the world in 2010, Israel's Jewish population accounted for 42.5%, and the United States' Jewish population accounted for 40% of the total (DellaPergola 2010).

¹⁶ Philosophically, Israeli-based National Religious schools are most similar to modern-Orthodox day schools outside of Israel.

¹⁷ A *Kollel* is a Yeshiva learning program for married men.

the education of the female population who study secular subjects, including some subjects in science, out of a practical need to secure their families' financial futures. However, studies in the female ultra-Orthodox system do not usually lead to higher academic learning.

Outside Israel, concerns about inculcating youth in the practices and religious literature of Judaism spurred on the development of private "day" schools as well as afternoon schools, among the various denominations of Judaism in many Western countries. Day schools offer a "dual" curriculum, offering a secular program including science and math, as well as course offerings in traditional Jewish subjects such as the Bible, Hebrew, and Jewish history. With the exception of ultra-Orthodox schools, secular subjects share equal time with religious subjects including science (as part of a longer school day). This means that the majority of graduates from (K-12) Jewish-based schools are well displaced to tackle higher education, if they so desire. Afternoon schools offer various Jewish subjects and are attended by students who attend secular schools during the day.

In the case of the ultra-Orthodox within Israel (as well as sometimes outside of it) secular learning is (largely) omitted for its male population because religious subjects take priority; all the more so, scientific issues of creation are not taught because they challenge the belief in God's creation. In simple terms, they have strongly adopted a limiting philosophical approach. In the exact opposite way, scientific issues of creation pose much less difficulty to the liberal branches of Judaism, including the Conservative and Reform movements¹⁸; thus, they are taught as a usual part of the science curriculum.

However, the situation is different within modern-Orthodox schools. Although most are committed to a *Torah Umadda* (*Torah and Science*) philosophy, which believes in the integration of religion and secular learning, creation issues can test that resolve, creating conflict, so this group will be a prominent feature of our discussion.¹⁹

We begin this discussion by examining both the philosophical approaches of the schools and the teachers that work within these schools. We start here, because the roots of students' approaches to the conflict between science and religion are

¹⁸ As we have seen, Sweltz (2006) extensively explored the historical responses of Conservative and Reform rabbis towards evolution. Using Rosenberg's (1988) system, their responses can be classified as falling within the parallel, explanatory, and complementary approaches. They do not adopt a limiting approach, in contrast to some among the Orthodox. Looking at the Conservative movement today, although they appear to have no official position, many of their Rabbis have adopted the idea of theistic evolution. Rabbi David Fine, who has authorized official responsa for the Conservative movement's committee on *Jewish Law and Standards*, expressed this idea as the following: "Did God create the world, or not? Is it God's handwork? Many of the people who accept evolution, even many scientists, believe in what is called 'theistic evolution,' that is, that behind the billions of years of cosmic and biological evolution, there is room for belief in a creator, God, who set everything into motion, and who stands outside the universe as the cause and reason for life" (<http://www.jewishvirtuallibrary.org/source/Judaism/jewsevolution.html>).

¹⁹ It will also be seen that almost all of the empirical studies that examine the relationship between Judaism and science education focus on the modern Orthodox, so this is another reason for this focus.

strongly shaped by how they understand science, its nature, and its relationship to religion and it is the schools and their teachers that most strongly shape this understanding. It might also be added that school choice both reflects and is influenced by informal sources – parents and religious authority.

Outside of Israel, Selya (2006) has completed the only major study concerning modern-Orthodox day high schools and their perspectives towards evolution, surveying 12 such schools in the United States and Canada, she discovered four approaches for teaching evolution (that largely match the philosophical approaches of Rosenberg 1988). These approaches include curricula where evolution is taught in class without a religious discussion, whatsoever (parallel approach). In other schools, teachers teach evolution with the aid of a religious teacher or rabbi who interprets the creation story either in a nonliteral way (explanatory) or from an intellectual design perspective (limiting/complementary). A third perspective is assigning students' readings on evolution without discussing them in the class (sometimes because it was part of the mandated final year examinations) (parallel approach). Finally, evolution was not taught at all (limiting approach).

There were no instances of substituting a creation-science curriculum to replace the standard biology texts or of school administrators removing the chapter from the science textbooks as reported by Wolowesky (1997) and Landau (1991); the latter, as we have seen, was recommended by Rabbi Feinstein (1982), one of the most important ultra-Orthodox rabbinic decisors of Jewish Law in the twentieth century.

Selya (2006) showed that ten of the schools surveyed taught evolution in the classroom and that eight of them suggested that this scientific theory was religiously compatible. Not surprisingly, schools that separated the sexes, a sign that a school is more religiously oriented, either did not teach evolutionary theory or criticized it as being incompatible with religion.

As part of this research, Selya (2006) also interviewed teachers and administrators at five of the schools, all of which were coeducational, with strong college preparatory programs, and which both teach evolution and stress its compatibility with religion. All of these schools share certain philosophical and/or historical roots, including a commitment to the *Torah Umadda* philosophy. Three of the schools were founded by prominent rabbinic figures, one of whom was Rabbi Joseph Soloveitchik who is considered to be the unofficial leader of modern (Orthodox) during much of the twentieth century.

In sum, Selya's (2006) survey seems to show that evolution is being taught in some form in the majority of modern-Orthodox day schools. However, caution should be applied to her small-scale survey, as in the United States (alone), there are 86 schools, accounting for more than 27,000 students, classified as being modern (Orthodox) (Schick 2009).

Although further studies, like Selya (2006), are needed, Schick's (2009) demographic studies of Jewish day schools in the United States indirectly may point to a trend of increased resistance to science subjects that are considered to be controversial, such as evolution, among Orthodox Jews. Although the numbers of students increased in modern-Orthodox schools from 1998 to 2009, the number of students that were learning in ultra-Orthodox schools increased at a much faster rate. This is

due to the much higher birth rate of the ultra-Orthodox which is more than twice that of the modern Orthodox.²⁰ And if the school is based on an ultra-Orthodox philosophy, it is more than probable that evolution was not part of their science curriculum.

Moreover, among the modern Orthodox, there are factors that indicate some of its adherents are moving towards ultra-Orthodoxy, a process Waxman (1998) labeled "Haredization" (based on the Hebrew term for ultra-Orthodox). This phenomenon has been documented over a 20-year period by a collection of historians and social scientists.²¹ A small (educational) indicator of this shift is the fact that *Torah Umesorah*, the National Society of Hebrew Day Schools, an umbrella organization that provides educational materials to Orthodox schools is increasingly distancing itself from coeducational institutions, which is one indication of increased religious practice.

There are many reasons for this shift, but the most important factor for science education is the increasing number of ultra-Orthodox Jewish teachers who are now teaching in modern-Orthodox schools (Heilman 2005; Helmreich and Shinnar 1998). As most in the modern-Orthodox world have avoided teaching, due to its lower remuneration and lack of prestige in comparison to many other professions, the modern-Orthodox school system has turned to ultra-Orthodox teachers (especially for its Jewish studies departments), which in turn affects the philosophy of the schools and their students (Heilman 2005; Helmreich and Shinnar 1998).²²

Inside Israel, research has focused on teachers within the National Religious system, rather than the school as the unit of analysis. Such research has importance because teachers, like the schools they teach in, are one of the most critical factors influencing the balance between Judaism and science education. We say this because, as Rutledge and Mitchell (2002) have noted, teachers' attitudes and views about a subject directly influence their instructional decisions on how to teach a subject. Their research shows that teachers' background in the philosophy of science and knowledge of evolution influences their acceptance of and willingness to teach evolution. One would assume that a similar relationship exists for scientific subjects that are considered to be challenging to Judaism.

In a similar vein, Dodick et al. (2010) surveyed teachers in the National Religious school system to understand their philosophical approaches towards the interaction between Judaism and science. In total, 56 teachers were extensively surveyed using a Likert-type questionnaire developed for this research, which surveyed the

teachers' approaches to the nature of science in general, geologic time, cosmology, and evolution. Eleven of the teachers were also randomly selected for interviews.

Additionally, 15 (Orthodox) scientists from the major branches of science were surveyed with the same instruments to both contrast their views with the teachers, as well as to better understand their coping strategies when confronted by scientific topics that challenge their beliefs. In the cases of both teachers and scientists, their philosophical approaches were classified according to Rosenberg's (1988) typology.

Results indicated that no single philosophical approach earned an overwhelming support from the teachers or scientists. Instead, the teachers and scientists related separately to each source of possible conflict, such as evolution, in accordance with the philosophical approach that appears to be the most fruitful for resolving a specific conflict.

The teachers did differ from the scientists in their stronger preference towards philosophical approaches which help them better integrate the domains of science and religion. Thus, the teachers favored the explanatory and complementary approaches, whereas the scientists most preferred the explanatory and parallel approaches. Possibly, the teachers favor an integrative approach because they prefer answers that avoid delivering an open, contradictory message to their students and through them to their parents and school administrators.

With regard to the scientists, tenured in academia as they are, they have the security to research issues that are both open and controversial. This also explains why some scientists adopted a conflict approach (their third most favored approach), as they acknowledge that some problems are open and (currently) unsolvable, while concurrently accepting the inherent contradictions in this situation. Unlike the teachers, however, none of the scientists adopted a limiting approach, as they saw no reason to constrain the science they practiced. This last result is important because it counters critiques (such as Nussbaum 2002) that highlight Orthodox Jewish scientists who are charged as being antisience towards issues such as evolution. In other words, it supports the idea that there truly is a spectrum among scientists who are also Orthodox in practice.

On specific issues of conflict, geologic time was much less controversial for teachers than either cosmology or evolution. With this issue, the teachers referred directly to religious sources which implied that were either multiple creations of older worlds or that each day of creation was much longer than 24 h. The teachers' flexibility was based on the openness of classic Biblical commentators on this issue. Such commentators provide sanction for interpreting the Bible, but particularly with the age of the Earth, this sanction has greater impact because there is no direct reference within the Bible to the traditional Jewish calculation of the age of the Earth.²³

²⁰ As Schick (2009, p. 12) notes, "In the 1998 census, I reported that there were 3.26 children in the families of Modern Orthodox eighth graders as compared to 6.57 and 7.92 children respectively in yeshiva-world and Hassidic families."

²¹ Friedman (1991), Heilman (2005), Helmreich and Shinnar (1998), Lieberman (1998), Solovitchik (1994), and Waxman (1998).

²² Heilman (2005, p. 265), based on a personal communication with Schick, who has completed a series of demographic studies on Jewish day schools in the United States, claims that "nearly two-thirds of today's Judaica teachers in day schools come from the *haredi* [ultra-Orthodox] world."

²³ Some Jews believe that the Earth is currently 5,722 years in age (in 2012 CE). In fact, this figure, which has also influenced Christian fundamentalists' understanding of the Earth's chronology, has been calculated based on the interpolation of ages of Biblical personalities mentioned in Genesis starting from Adam's creation on the sixth day of creation (this calculation can be found in the book *Seder Olam Rabbah*, ascribed to the second century CE Rabbi Yossi ben Halafta). In turn, this calculation leaves the possibility of interpreting the first 6 days of creation before man's appearance as being much longer than six 24-h days (Dodick et al. 2010).

"Thus, it becomes easier for teachers, who are familiar with such commentaries, to accept geologic time.

In contrast to the age of the Earth issue, approximately half of the teachers saw some conflict between the theory of evolution and Biblical creation because its random nature contradicts the belief in creation directed by the "hand of God"; moreover, some cited the fact that it also conflicted with their belief in man as the "crown of creation." It should be noted that some scientists also felt such conflicts but they were willing to live with them.

At the university level, inside Israel there is one comprehensive university that integrates "Jewish heritage" and secular studies – Bar Ilan. Its Faculty of Life Sciences provides courses in evolution, as well as integrates this subject within its various course offerings. In the United States there is a strong dichotomy between the approach of Yeshiva University, whose very motto incorporates Torah Umadda and other Orthodox institutions of higher learning. Indeed, university President Richard Joel (2003, p. 3) in *YU Review* claimed that a "moral underpinning" for science at his university was "to marry the wisdom of faith with the need to explore our universe's mysteries."

In the same issue of this magazine, biology Professor Carl Feit noted that he saw no contradiction between Judaism and biology while arguing that the evolutionary ideas could actually be used to strengthen one's faith (Eisenberg 2003). In a conversation with Selya (2006), Feit notes that he includes evolution as part of his course syllabus while adding readings from the philosophy of science, philosophers, and Jewish Biblical commentaries.

In contrast, Touro College, which was founded in 1971 to "enrich the Jewish heritage" and serves a largely ultra-Orthodox student population, takes an unsympathetic view towards evolutionary biology. As a psychology instructor at Touro, Nussbaum (2002) elicited great opposition from his students for his support of teaching evolution. Moreover, the science professors at this institution routinely criticized evolution while teaching creationism.

Schools and teachers set the curricular standards which ultimately affect students; thus, to complete our understanding of the interaction of Judaism and science education, we will be looking at studies dealing with students. Of these studies, those concerned with K-12 students have emanated from Israel.

Rauch and colleagues (1996) performed a comparative survey study with 185 students evenly distributed among National Religious and secular state students in middle (grade 9) and high schools (grades 11 and 12). The middle grade high school cohort had not yet learned evolution in contrast with the high school cohort. After learning evolution the high school students from both school systems substantially increased their knowledge of evolution. However, their attitudes towards this subject were in opposition. The students of the National Religious stream increased their acceptance of creationism, whereas the Secular State students increased their acceptance of evolution.

More recently, Allouch (2010) also examined the attitudes of middle (grade 9) and high school (grade 10) students from the National Religious school system. This sample consisted of 369 students, 79 of them who were studying evolution.

The design of this study relied upon a Likert-type questionnaire (37 statements) that focused on evolution but also included a small number of statements dealing with the nature of science, cosmology, and geologic time.

Similar to the teachers sampled by Dodick et al. (2010), prior to studying the unit, the students were more accepting of a nonliteral reading of the Biblical creation time line, as well as the "Big-Bang" explanation of cosmology, than they were of evolution. Post-program, a similar result occurred. Positive attitudes connected to time and cosmology improved significantly (despite the fact that this was not the focus of their learning), whereas for the most part, their attitudes towards evolution remained at a no agreement level, even after learning the unit.

Again, similar to the teacher sample of Dodick et al. (2010), the students displayed a variety of philosophical approaches towards different issues, although based on Allouch's (2010) results, the students seem to be more conservative (religiously) in their attitudes towards these creation issues than their teachers. Nonetheless, like the student sample of Rauch and colleagues (1996), the students significantly improved their understanding of some of the issues connected to evolution (most notably Natural Selection). In sum, the results from both Rauch and colleagues (1996) and Allouch (2010) parallel the findings of Lawson and Worsnop (1992) with US students who found that a change in knowledge (about evolution) was not necessarily associated with a change in (religious) attitudes.

It must be remembered that in the case of the students in the religious stream they are exposed to far more religious learning than learning about evolution and this would likely affect their attitudes. In fact, Allouch's (2010) study showed that one of the external factors which influenced the students developing a greater acceptance of evolution was the number of curricular hours devoted to this subject. Moreover, for this group of students, part of their school success is measured by how they understand and apply their religious training; in their community, such application is seen as having great value.

It would be expected that difficulties with issues connected to evolution would also affect Orthodox students who attend university. This was addressed by Nussbaum's (2006) survey study among a sample of 176 Orthodox Jewish students at a single public college in New York City. This study provides for some rather disheartening conclusions about the state of science education among Orthodox Jews. The responses received to questionnaire probes dealing with evolution, such as "Evolution correctly explains the origin of life," and geologic time, such as "What is the age of the universe?" indicate that the subjects tended towards creationist or intelligent design perspectives. Moreover, Nussbaum's (2006) data also seems to show that the students that were science majors were even less accepting of mainstream science than those who were not science majors.

However, we should be careful in viewing this study as a summary of the attitudes of all Orthodox university students in the United States because of its methodological problems. The sample consisted of 176 subjects, surveyed at one university, with little demographic data collected concerning the subjects (such as school background). Moreover, the wording of some of the probes is to be questioned. For example, "Evolution correctly explains the origin of life" with a binary answer

format would necessarily exclude theistic evolutionist approaches.²⁴ Finally, interviews were not held with any of the subjects, which would have more deeply probed their philosophical approaches. Still, given the fact that Jewish Orthodox society is moving towards more ultra-Orthodox views, the results of this study do seem to reflect such societal change.

54.6 Conclusion

In looking at the relationship between Jews and science education in our modern world, we see mostly positive trends. This might be a surprising conclusion in light of what was written in the previous section; however, these trends are supported by historical, sociological, and demographic factors.

Those denominations in Judaism who have difficulties with science learning, most notably the ultra-Orthodox, and some of the modern Orthodox represent a demographic minority; in total, the Orthodox in the United States represent no more than 13 % of the Jewish population (Ament 2005).²⁵ Thus, over all, it is possible to say that among Jews connected to their Judaism, methods have developed, historically, in order to deal with the conflicts posed by modern science.

Indeed, it is possible to say that Reform and Conservative Jews have few or no problems with modern science education; this is why their role is downplayed in the previous section which discussed science education. There is simply no evidence that what is considered to be a challenge by some in the Orthodox world is considered to be the same in schools belonging to the Conservative and Reform movements. Thus, it would seem that science is taught in their day schools in the same ways as it is taught in the public school systems.

Moreover, it must be remembered that even among those Orthodox Jews that are challenged by scientific findings, it is *not all of science* that is considered to be a challenge, but specific sciences that touch upon issues of Biblical creation. This is the reason why our review of the science education research has not focused on science in general, but specific issues, such as evolution which are considered to be threatening to the religious sensibilities of its followers.²⁶ In fact, most modern-Orthodox day schools in the United States are known for the high quality of their secular studies including science education.

²⁴ Theistic evolution claims that God's method of creation was to design a universe in which various systems would naturally evolve.

²⁵ Among those of Jewish origin, who see their faith as an integral part of their lives, the Orthodox represent a higher percentage than stated; still the Orthodox do represent a minority when compared to the number of Jews belonging to movements such as the Conservative and Reform.

²⁶ Simply put, there are no science education studies that have examined Jewish attitudes/approaches towards science as a whole. All of the known studies focus on one or a few specific subjects such as geologic time, cosmology, and especially evolution, which (supposedly) are threats to the Jewish worldview.

It should also be remembered that although there is large demographic growth within the worldwide Orthodox sector and, especially among the ultra-Orthodox, their philosophical approach to challenging issues of science does not carry over to other school systems, largely because of their isolationist approach. Such physical and social isolation was historically adopted by the ultra-Orthodox to limit contact with and infiltration of foreign ideas (which included ideas promulgated by other Jewish denominations) that do not fit into their religious worldview (Liebman 1983; Hellman 2005). In terms of educational policy, this has meant that in Israel the ultra-Orthodox and their independent school system do not affect curricular policy within the Secular and National Religious school systems.

Outside of Israel, a similar isolationist approach has been adopted by both ultra-Orthodox and their school system towards other Jewish denominations. This is very different from the situation in the Christian world, most notably in the United States, where fundamentalists have sometimes successfully gained elected control of school boards leading to critiquing evolutionary theory (<http://www.discovery.org/a/9851>) and even removing the teaching of (macro)-evolution, as occurred in Kansas in 1999 (<http://www.agiweb.org/gap/legis106/evolution.html>). Nonetheless, it was noted previously that there is a more subtle influence from the "Hardization" of the modern-Orthodox education system due to the increased number of ultra-Orthodox religious teachers entering that system (Hellman 2005; Helmreich and Shinnar 1998). Such sociological factors could have a stronger influence than the actual content of the science education enterprise in the Jewish world. Many Orthodox elements see the challenges posed by the secular philosophy of science as being more of an educational threat than science per se; however, the larger issue of how various groups see secular learning in general, especially secular higher learning, is an indication of how they see science as well.

Certainly Reform and Conservative Jews attend university with no limits to what they study. So too, the modern Orthodox also attend college, although as Soloveitchik already noted in 1994 (p. 64) with "somewhat less enthusiasm" than in previous years. The ultra-Orthodox, who are known historically for their opposition to higher education, are divided in their approaches (Soloveitchik 1994). In the United States, there is recognition of the (economic) utility or even necessity of a degree, and various arrangements have been made to enable ultra-Orthodox to receive such degrees, albeit with (societal) restrictions on what is studied. In Israel, the opposition to higher education is much stronger, although due to the very weak economic condition of most ultra-Orthodox, colleges specifically designated for training this populace have been rapidly developing (Lamm 2010).

Certainly, economic incentive is a path towards increased involvement in secular learning, in general and science, specifically. And in fact it may be the only path that the ultra-Orthodox will accept in the near future. But some in the modern-Orthodox world desire a synthesis represented by a Torah Umadna philosophy because they see the inherent value in secular knowledge and learning. How is this possible?

One possible synthesis is provided by Rabbi Norman Lamm (2010) who has articulated a series of models, based on the philosophies of important rabbinic thinkers of the past. Obviously, to understand and then adopt any of these models requires a deep investment in studying the religious sources and their philosophy, as well as science and its nature.

Indeed, such an investment in learning fits well with one of the recommendations made by the Orthodox scientists interviewed by Dodick et al. (2010) when they were asked how Orthodox Jewish teachers might cope with what they felt were controversial scientific topics, such as geologic time or evolution.

It must be remembered that the Orthodox (high school) science teachers in Israel are adequately educated in science, and many received training in a religious seminary. However, such education rarely deals, systematically, with the possible philosophical conflicts between science and religion. Therefore, the scientists argued that it was important to improve the teachers' understanding of both scientific and Jewish sources that will permit them to settle their internal conflict while providing them with the tools to teach such conflicting subjects with confidence.

Indeed, Lamm (2010) shows how both in the past and today confusion has been created by the lack of understanding about the Jewish philosophical approaches to all secular learning. Moreover, he even shows how traditions that normally would never be considered to be in a Torah Umadda world (specifically, his "Hasidic" model) can be designed to create a synthesis between Judaism and science.

Although knowledge is a primary tool, the Jewish education world is a hierarchical system, especially among the Orthodox, in which teachers must answer to a series of authorities including rabbis, administrators, and parents. Thus, teachers feel more comfortable if they have experts upon whom they can rely (scientists, rabbis, and texts) which allow them to teach scientific issues that are considered to be challenging. Unlike academic scientists, teachers have less freedom to express controversial notions in science or religion, nor are they as well trained in science. Thus, their desire to have a support network of rabbis and scientists who can deal with this conflict is understandable.

This approach also has support from a previous science education study in which Colburn and Henriques (2006) interviewed a group of eight Christian clergymen for whom evolution and religion were compatible and who also believed that Scripture was not meant to be understood, literally. Based on their findings, Colburn and Henriques (2006) suggested that the science education community might find in the educated clergy an articulate ally in helping citizens better understand contentious issues surrounding science and religion.

Because they are not constrained by authority, the scientists interviewed by Dodick et al. (2010, p. 1541) instead recommended that teachers focus on two interrelated issues connected to *application* and *education* to deal with possible conflicts. *Application* is connected to how scientists see religion and science possibly integrating; by *education*, the scientists were referring to how they would like to see the conflict being taught.

Concerning application, the scientists showed a divergence in their choice of philosophies, with the two dominant approaches being the parallel and explanatory approaches. These philosophical differences fit well with application in that some of the scientists favor an approach which emphasizes the points integrating science and religion (comparable to the explanatory approach); in contrast, some of the scientists would rather avoid using science in building religious understanding (comparable to the parallel approach), as the use of science in this way resonates with a fundamentalism with which they don't identify.

Regarding "education," some of the scientists which Dodick et al. (2010) surveyed emphasized critical understanding of learning materials dealing with this conflict. Moreover, some of the scientists desired to see issues of conflict being taught pluralistically by showing students the different philosophical approaches in science and religion that deal with this conflict. This suggestion connects nicely with scientists holding either an explanatory or complementary philosophy as they connect between the domains of science and religion. As these approaches are sympathetic to the perceived desires of the teachers to also bridge the gap between science and religion, this pluralistic approach might be easier for teachers to implement.

Such integration also has support from the literature (Jackson et al. 1995; Shipman et al. 2002; Smith and Siegel 1993). For example, Jackson and colleagues (1995, p. 605) noted that the current treatment of controversial scientific topics in schools, such as the evolution of humans, is independent of any other way (including via religion) that a student or teacher might seek answers to such topics. They argue that "Scientists and science teachers cannot continue to see themselves as participating in an epic struggle to eradicate mystical superstition and hasten the irresistible ascendancy of materialistic naturalism."

What is missing from this discussion is empirical research. As was seen, much of the education research concerning Judaism and science have focused on the attitudes of students, teachers, and scientists, mostly within the Orthodox world, towards issues of controversy, such as evolution. Future work needs to be more expansive in widening its perspective to other denominations within Judaism²⁷ and other branches of the sciences. Moreover, for those issues that challenge religious sensitivities much more research must be invested in testing different models of instruction, based on the philosophical approaches that have developed in Judaism. Selya's (2006) work shows that in the modern-Orthodox world, schools have already adopted a number of instructional philosophies for dealing with such controversy; however, research has not yet been conducted to determine their effectiveness. If the goal of Jewish educators is to attain some sort of balance between the world of science and Judaism, then these next steps are crucial.

²⁷We could reference only one paper concerning the interaction between science education and Judaism from a non-Orthodox perspective. Authored by Rabbi Laurie Green (2012), who comes from the Reform movement, this policy paper argued for greater integration (similar to the explanatory approach) between religion and science studies for students belonging to the Reform movement.

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