Natural Sciences 4:
Twentieth-Century Science and Philosophy

This final Natural Sciences course continues with the fundamental question of natural Sciences 3—What is light?—and raises new questions: What is matter? What is life? and How do we know? Twentieth-century science has been a source of much knowledge, yet also shows some of the inherent limits to what we can know.

Natural Sciences 4 is the culmination of Shimer's Natural Sciences core sequence. In it we examine the consequences of applying Maxwell's equations to heat radiation and atomic spectra; and we look again at evolution and genetics, this time at the molecular level. The readings are very technical, but within our reach if we work together and are patient with ourselves and the readings. We will focus both on what the writers claim to know, and how they are sure it is correct.

In the analysis of the readings and our discussion, it will no longer be sufficient to adopt and cogently defend a position. Whatever your position, you will be expected to understand the opposite position as well, prior to arguing against it. Also, many of the readings are very difficult, and some classes will be spent in reading them line-by-line. We will not succeed without substantial contributions from all class members.

Table of Contents

The contents of this syllabus are as follows:

Texts

Required

The following texts are required:

Dyson, *Origins of Life*
Feynman, *QED: The Strange Theory of Light and Matter*
Heisenberg, *Physics and Philosophy*

One summary of the origins of quantum physics is required, preferably Gamow, *Thirty Years That Shook Physics.*

One twentieth-century work in the philosophy of science is required, preferably Polanyi, *Personal Knowledge.*

One work on molecular biology is required, preferably Margulis, *Origins of Sex*

The following work should be included, space permitting: Schrödinger, *What Is Life?*

Recommended

Any of the following works may also be used:

Einstein and Infeld, *Evolution of Physics*
Lwoff, *Biological Order*
McClintock, *A Feeling for the Organism*
Molecules for Life (SA book)
Murphy et al., *What Is Life? The Next Fifty Years*
Oppenheimer, *Quantum Physics*

Course Readings

A list of the books and articles used in this course follows in the order in which they are read. Additional assignments will be announced in class.

Shamos, *Great Experiments in Physics*
Feynman, *QED: The Strange Theory of Light and Matter*
Schrödinger, *What Is Life?*
Dyson, *Origins of Life*
Shimer Reprints:
Planck, *Origin of the Quantum Theory and Original Papers*
Einstein, *Photoelectric Effect*
Millikan, *A Direct Photoelectric Determination of Planck's* h and *The Electron*
Bohr, *On the Spectrum of Hydrogen*
De Broglie, *The Initial Idea of Wave Mechanics*
Schrödinger, *Four Lectures on Wave Mechanics, Remarks*
Davisson, *Are Electrons Waves?*
Driesch, *The Science and Philosophy of the Organism*
Spemann, *Embryonic Development and Induction*
Boveri, *On Multiple Mitosis as a Means of Analysis of the Cell Nucleus*
Avery et al., *Studies on the Chemical Nature* . . .
Crick, *The Structure of the Hereditary Material* and *On Protein Synthesis*
Jacob and Monod, *Genetic Regulatory Mechanisms in the Synthesis of Protein*
Heidegger, *The Question Concerning Technology*
Snow, *The Two Cultures*

Course Objectives

The heart of the Shimer educational method is the encouragement and practice of those skills that will make possible lifelong learning. To this end, certain commitments and competencies are expected in Shimer classes. These include:

- Commitment to one's own learning. This is measured by your attending classes *on time*, letting others know what you *do* and *don't* understand, and identifying for yourself issues of safety in the class discussion.
- Reading the source materials for the class carefully and completely
- Asking genuine questions within the discussion

- A growing ability to recapitulate someone else's point of view. This is measured by that other person agreeing that you have done justice to his or her position.
- The ability to express your emotional reactions to the readings and the learning process
- The ability to write effectively

In addition to the above, certain competencies are specific to Natural Sciences 4, and the student's achievement will be confirmed using the assigned papers and an exam. These competencies include the ability to:

- Explain the foundational ideas of quantum mechanics and their implications.
- Describe the basic processes controlling the development and functioning of organisms, particularly cellular biology, molecular biology, and embryology.
- Identify what modern scientific theories can and cannot explain about the physical world, especially the origins and character of living organisms.

These represent the key and basic objectives identified by the teacher. No list of objectives is rich enough to exhaust these readings, and I hope that you will identify your own objectives that go beyond these.

Course Requirements

Two papers, one exam, and class participation will constitute your graded assignments for Natural Sciences 4. Papers should be five to eight typed pages and should include both technical and philosophical considerations.

The first paper should be a "publishable" essay detailing the nature of light and/or elementary particles and the paradoxes associated with their behavior. This paper should describe enough technical and theoretical material to make clear just what these paradoxes are, and then examine some of the philosophical issues raised by these technical problems.

The second paper should be a "publishable" essay concerning scientific knowledge, with emphasis upon any differences you perceive between our knowledge of life and our knowledge of non-life. Feel free to take as global a perspective as you wish, bringing into play ideas from any of the natural science courses you have taken at Shimer (or any Shimer courses, for that matter).

A "publishable" paper is a formal one written for a specific audience, not just for the teacher. Generally, the audience would be scholarly (e.g., a paper written for a journal or magazine) but could also be professional (e.g., a paper written for teachers) or some other group. It also does not presuppose that the audience has read the materials used in class.

As an alternative to either paper, you may request to write an analysis of the differences between "classical" views of the physical world (i.e., Galileo to the end of the nineteenth century) and views presented by twentieth-century physics. This paper, like the others, should include both technical and philosophical considerations. If you want to consider this alternative, check with me first.

Except under unusual circumstances, late papers will *not* be accepted. Papers handed in on time may be rewritten, so it is better to hand one in and rework it than to get no grade on it. No papers—originals or rewrites—will be accepted after the last day of class.

Your course grade will be based upon the following components: class participation (quality, as well as quantity), 40 percent; papers, 40 percent; exam, 20 percent.

Philosophy of Grading

The grading policy for this class stresses the process of dialogue. Most students know that participating in the discussion and offering correct or insightful comments improves their participation grade. In Natural Sciences 4, the emphasis lies elsewhere. The best actions to perform in class are those that further the dialogue and draw out the participation of others. At the 4 level of Shimer courses, all students are as responsible as the teacher for the discussion.

In adopting and practicing this policy, everyone needs to be conscious of the difficulty or fear we often feel in making and expressing judgments. If you sense others hesitating to speak, inviting that person into the discussion and drawing them out both helps the discussion and will help raise your participation grade. If you yourself feel uncertain or confused about the reading or a point made during the discussion, sharing that confusion will aid both the dialogue and the grade. A good question is often more valuable than a good answer. With the material in this course, it is common for anyone—including the instructor—to feel confused. If you have any difficulty with the class or the readings or if you have any suggestions, please talk with me. Don't wait.

Syllabus

February

2/5	Planck	*Black Body Radiation* (background) *The Genesis and Development . . .*, pp. 4–22
2/6		*Introduction: On an Improvement . . .*, pp. 25–31
2/10		*On the Theory of Energy Distribution . . .*, pp. 32–39
2/12	Shamos	*Planck's Experiment*, pp. 305–314
2/13	Einstein	*Photoelectric Effect*, pp. 57–62
2/17	Millikan	*A Direct Photoelectric Determination . . .* *The Electron*, pp. 10–62
2/19	Bohr	*On the Spectrum of Hydrogen*, pp. 64–77
2/20	Shamos	*Bohr's Experiment*, pp. 333–343
2/24	De Broglie	*The Initial Idea of Wave Mechanics*, *The Undulatory Aspects . . .*, pp. 78–88
2/26	Schrödinger	*Remarks* (background), *Four Lectures on Wave Mechanics,* pp. 89–103
2/27		*Four Lectures . . .*

March

3/2	Davisson	*Are Electrons Waves?* pp. 105–117
3/3		FIRST PAPER DUE

3/9	Feynman	*QED: The Strange Theory of Light and Matter*, ch. 1
3/11		*QED*, ch. 2
3/12		*QED*, ch. 3
3/16	Driesch	*The Science and Philosophy of the Organism*, pp. 1–51
3/18		*The Science and Philosophy* . . ., pp. 52–109
3/19	Spemann	*Embryonic Development and Induction*
3/23	Boveri	*On Multipolar Mitosis as a Means of Analysis* . . ., pp. 29–41
3/25		*On Multipolar Analysis* . . ., pp. 41–49
3/26	Schrödinger	*What Is Life?* ch. 1–2
3/30		*What Is Life?* ch. 3–5

April

4/1		*What Is Life?* ch. 6–epilogue
4/2	Avery et al.	*Studies on the Chemical Nature* . . ., pp. 51–61
4/6		*Studies on the Chemical Nature* . . ., pp. 61–71
4/15	Crick	*The Structure of Hereditary Material*
4/16		*On Protein Synthesis*
4/20	Jacob/ Monod	*Genetic Regulatory Mechanisms* . . ., sec. 1 (pp. 128–130) and sec. 6 (pp. 173–176)
4/22		*Genetic Regulatory Mechanisms* . . ., sec. 2
4/23		*Genetic Regulatory Mechanisms* . . ., sec. 3a–3b
4/27		*Genetic Regulatory Mechanisms* . . ., sec. 3c–3e
4/29		*Genetic Regulatory Mechanisms* . . ., sec. 4
4/30		*Genetic Regulatory Mechanisms* . . ., sec. 5, 6
	Dyson	*Origins of Life,* ch. 1–4

May

5/4	Heidegger	*The Question Concerning Technology*, pp. 308–320

5/6		*The Question Concerning Technology*, pp. 320–341
5/7	Snow	*The Two Cultures* SECOND PAPER DUE