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SCIENCE. There is no generic word for "science" in the language of ancient Egypt. *Rḫ* ("to know") comes closest and had a wide range of meanings. For simplicity's sake, this article focuses on our modern concept of "science," with its many disciplines. The ancient Egyptians would not have used the same categories, and probably no such categories existed. Science was the domain of the god Thoth.

Artifacts, tomb paintings, inscriptions, and papyri inform on the Egyptians' knowledge of science. Our study of their hand-crafted objects, tools, and buildings offers insight about their techniques and, indirectly, suggests the knowledge required to develop such techniques. There is, however, no proof about the degree of knowledge reflected in those artifacts. Images of craftsmen at work, for example, have illustrated manufacturing processes and some applied techniques; these illustrations are often accompanied by short explanatory texts and sometimes contain specific terminology. The greatest significance is given, however, to those Egyptian texts that are regarded as "scientific" literature in the broadest sense. Since the preserved material is only a small percentage of the original, our holdings are incomplete and our knowledge of Egyptian science somewhat sketchy.

Scientific Disciplines. The following sciences are documented for ancient Egypt:

- Anatomy (for art)
- Astronomy and astrology (the two disciplines being inseparably linked in ancient Egypt)
- Biology and veterinary medicine
- Chemistry
- Geography
- Geology

- History
- Law
- Linguistics
- Mathematics, including geometry
- Medicine
- Mineralogy
- Pedagogy (education)
- Philosophy
- Physics (above all mechanics)
- Sociology (the rules for social life)
- Theology

Historical Development. From prehistoric times, the inhabitants of the Nile Valley had to make sense of the world around them. Gathering and storing foods, selecting materials for shelters, making tools, struggling against disease and disorder—such concerns and others would have led them to acquire and pass on a wide range of knowledge. As their social structure became more complex, some tasks grew more specialized, so only certain groups knew or used certain kinds of specialized information. Toward the end of the fourth millennium BCE, Egypt was unified under one king into an empire that stretched from Aswan in the South to the Mediterranean coast. This sociopolitical development advanced Egyptian science, since the state provided an administration to manage labor and goods. Without writing, this would have been extremely difficult to achieve, but with the beginning of writing, about 3000 BCE, a new profession became important—that of the scribe. With both specialization and writing, Egypt had the basis for scientific expansion. Later the Egyptians themselves recognized this period as a golden era in science, the arts, and technology.

From the Old Kingdom, examples of historical records are known, including lists of annals. Theology and magic are represented by extensive collections (e.g., the Pyramid Texts). In copies made during later periods, some Wisdom Literature is also contained. Just how specialized individual disciplines could be in ancient Egypt is best understood when considering medicine. From tomb monuments specialized physicians are known (e.g., eye doctors). The remains of the Middle Kingdom, an era whose attitudes were influenced by the dissolution of the Old Kingdom, give evidence for other sciences. Onomastica (lists) show the efforts undertaken to create an encyclopedic record of the world. In mathematics, there were, for example, a good approximation for, and a method of calculating the surfaces and volumes of, the various geometric shapes. Astronomy, until then scarcely evident, was represented in separate texts, albeit strongly integrated into religion. This was also the beginning of the Bronze Age in ancient Egypt, after the adoption and widespread use of bronze.

In the course of the Second Intermediate Period, the Hyksos kings, Near Eastern rulers over the Delta region, seem to have been very interested in Egyptian science; the Rhind Papyrus on mathematics, for example, has been dated to the time of the Hyksos king Apophis. The Hyksos, as later the Persians, tried to ingratiate themselves as popular rulers by taking an interest in Egyptian culture.

During the New Kingdom, when Egypt expanded into the Near East and south into Nubia, the knowledge of foreign lands seems to have enriched Egyptian science—seen most clearly in the foreign plant and animal illustrations within the temple of Karnak, the "Botanical Garden" of Thutmose III. The Onomastica and the teaching texts of this period list many foreign location names, but foreign contacts were by no means restricted to military or diplomatic efforts. Near Easterners began to reside in Egypt, and some advanced to high administrative office. Then, too, Egyptian physicians resided at various royal and princely courts in the Near East. How much foreign expertise was learned is difficult to say, but the scientific texts in Babylonian cuneiform script found in Amarna point to relevant contacts. Even the technique used in applying plant dyes to fabric came to Egypt from Palestine during the New Kingdom.

In the Late period, Egypt was ruled by foreign kings but always maintained and developed its own culture. The Late period was characterized both by a deliberate focus on the Egyptian culture of the distant past, as well as by the adoption of new ideas. The Persian king Darius I (r. 521–486 BCE), who had absorbed Egypt into his empire, was recognized in Egyptian sources as an expert on Egyptian magic, a patron of Egyptian science, and for having commissioned a compilation of Egyptian law; evidence also exists to show that knowledge was transferred from Mesopotamia to Egypt during the Persian era. The expertise acquired by the Egyptians was mostly in areas that were then more advanced in Mesopotamia or then completely unknown in Egypt. Egyptian astronomy, astrology, and mathematics gained the most from contacts with the Mesopotamian tradition. Omina (which foretold the future by observation of the sun and the moon and on which the Babylonian calendar is based) were used in Egypt from the sixth century BCE onward. The zodiac, also originating in Mesopotamia, was introduced to Egypt as late as the third century BCE, and from that time forward it played an important role in Egyptian astronomy and astrology. Not yet known exactly are when the Pythagorean theorem (known in Mesopotamia since the second millennium BCE), the approximation formula for the root of irrationals (attributed to Hero of Alexandria), and the number 3 as an approximation of π (pi) were brought to Egypt from Babylon.

The Ptolemaic era, during which Egypt was ruled by a

Hellenistic dynasty of Macedonian origin, was a turning-point in Egyptian science in several ways. The new administration operated increasingly in Greek, with the Egyptian language gradually receding into the background of public life. Few career opportunities where Egyptian was used remained available, outside the priesthood. Since the majority of Egyptian scribes were soon among the priesthood—and not, as had been the case, in administration—it meant that representatives of Egyptian science gathered in an ever smaller priestly elite. Perhaps the local priests rejected Greek science as it began to flourish in Egypt because they took great pride in their own ancient traditions. Few documents indicate that Egyptian priests adopted any aspect of Greek or Hellenistic science, whereas ample evidence indicates that the Greeks learned from the Egyptians. The mathematical and geometric theorems mentioned above are a case in point. Greek authors wrote on Egypt and its culture, and they even translated Egyptian literature, law, and scientific texts. Through Hellenistic science and the Museion in Alexandria—a research facility that attained international acclaim at the beginning of the third century BCE—Egyptian knowledge was introduced to Europe. During the Ptolemaic era, scientific texts were written in Egypt in Demotic, a cursive style of script. Notable examples are the Onomasticon Papyrus Cairo CG 31168+31169 and some papyri on mathematics.

In 30 BCE, Egypt fell under Roman rule and the Egyptian language was almost removed from its public life. The Egyptian scripts became known and practiced only by Egyptian priests; numerous scientific texts, however, show the intensity with which they were studied and copied. Some works, such as the "Book of the Temple," have survived in Hieratic and Demotic versions, and even in Greek translation. New copies were made of older works, and some were glossed (above all works on religion and spells) or commentated (the astronomic-cosmological treatises of the Carlsberg Papyri 1 and 1a). Egyptian science reached as far south as the empire of Meroë in Nubia. There, upper-class families knew how to write in Demotic and in hieroglyphs; they also studied Egyptian religion and astronomy, as shown by graffiti on the island of Philae in the Nile.

The impact of Egypt on the Greeks and Romans continued to be of importance. For example, the Egyptian calendar, modified with the introduction of leap years, was introduced in the Roman Empire by Julius Caesar in 46 BCE. Known as the Julian calendar, it remains the basis for the modern Western calendar (the Gregorian calendar), with adjustments made for accuracy in 1582 CE. The enormous effort made by the Egyptians to counteract the downfall of their culture, with a flood of writings—"writing against the tide" so to speak—became futile as Christianity spread across Egypt in the first centuries CE and pagan cults were banned. Thus ended "Egyptian" science, which was by then restricted to the priesthood. The Copts (Christian Egyptians) rejected Egyptian science as pagan and preferred Greek and, later, Arab traditions. (Still, the Hermetic scripts—a collection of Greek works on theology and philosophy, created between the second century BCE and the third century CE—seems to be a continuation of pagan Egyptian works, such as the *Book of Thoth* [Jasnow/Zauzich, in *Proceedings of the Seventh International Congress of Egyptologists Cambridge, 1995.* Leiden, 1998, pp. 607–618]

Principles and Methods. It is difficult to ascertain which mnemonic aids were known to the Egyptians other than (and prior to) writing. Images show that counting from 1 to 10 with the help of the fingers was common, while painted dots were used to calculate greater sums. A finger-counting "rhyme" indicates that verses were used as an aid in memorization. One visual manner of recording information is documented in laundry lists that date from the New Kingdom, where each piece of clothing is illustrated and accompanied by the relevant number of dots (not the number symbols of script). Writing had the greatest role in recording, above all in the area of science. There were fully composed texts as well as lists; both types of text were sometimes visually structured by the use of red ink for headings or subheadings, called "rubrics."

Various techniques were developed for recording scientific texts, although in Egypt they never became canons with a fixed wording. The most conservative approach was to record word by word. The word-by-word transcription into another script of the Egyptian language (e.g., transcribing a Hieratic text into Demotic) was another technique that made it possible to hand down material without changes in content. During Greek and Roman rule, some Egyptian works were also translated into Greek. The reduction of a text to the essential—at times even in the form of keywords or lists—was a more radical treatment, but it had more effect on the form than the content, provided the scribe was still working with the complete text. Conversely, lists could be expanded into full text.

Glosses, created to explain difficult terminology or to clarify a specific context, led to a new kind of text, especially when the glosses were not treated as explanatory notes but as components of the text. This occurred naturally when a glosses was written in the same language and script as the basic text. Since glosses were intended to make the text easy to understand, they were often written in everyday vocabulary and, during Greek and Roman times, frequently in Demotic as the most widespread Egyptian script. Many glosses were written in Greek in

the Roman era, especially those recording the exact pronunciation of Egyptian words in scholastic or magic texts—since Greek, in contrast to the Egyptian scripts, contained vowels.

Commentaries were a more detailed form of written explanations, such as the commentaries on medical writings and the Carlsberg Papyri 1 and 1a, which record commentaries on a thousand-year-old astronomy and cosmology text. There were also some collected writings, in which material on related subjects had been gathered from various sources, as found in several of the medical papyri (e.g., Ebers Papyrus, Hearst Papyrus). Texts were created for teaching, in which were posed specific tasks for the student of the material that was being taught; these usually also demonstrated the solution (of all the texts on mathematics, this type is most common).

The following concepts and devices were used—singly or in combination—depending on the branch of science.

- *Analogy:* thinking in complementary sets of two, characteristic for Egypt, was practiced in an approach whereby the two arguments either corresponded with one another or were in opposition. (Thus, for example, from the idea, based in etymology, that humans had been created from the tears of a creator god, an analogy was formed to state that gods were created in his laughter.)
- *Approximation:* deliberate use of approximation in mathematics—for example, during the Middle Kingdom (8/9 of diameter)^2; in Demotic texts, 3 as an approximation of π (pi); the roots of irrationals; and approximation formulae to calculate the area of segments and irregular rectangles.
- *Comparison:* often used in description.
- *Definition:* for medical expressions and special terminology.
- *Description:* for plants, animals, diseases, wounds, gods, and so on—a very important component of Egyptian science texts.
- *Etymology:* plays on words were often used in theology, to help deduce the essential similarities and the relatedness of different things. Using similar words or allusions might explain the origin of names, of sacred sites, and so on. (Thus, the tears of the creator god, *rmṯ*, ["to weep"] were understood as the origin of human beings [*rmi*]).
- *Rules:* comparatively little evidence exists for universally applicable rules formulated by the Egyptians, who tended to operate with practical values underlying rules.
- *Schematization:* the reduction of complicated facts into simplified schemata, as used in texts on astronomy, among others.
- *Sequences:* found in the so-called 2:*n*-table (of mathematics), where the division of 2 by multiples of certain numbers resulted in unit fractions based on an identical scheme; at times, such calculation patterns were explicitly put forth as rules.
- *Sorting:* by content and, in later periods, alphabetically.
- *Technical language:* each science had its own terminology, to varying degrees, which had an impact not only on the vocabulary as a whole but also on grammar. For example, some verb forms are typical for scientific texts; and these often followed specific patterns of construction, so that a point-form style could be used. Frequently used words were also often abbreviated.
- *Tests:* used explicitly in mathematics to check solutions or to determine the degree of accuracy in approximations.
- *Trial:* to provoke reactions in a patient, which was relevant for diagnosis.
- *Visualization:* sketches for geometric tasks or even maps (of areas in the sky and in the afterlife), sometimes strongly schematized.

The knowledge recorded in texts had been gained in many different ways. Adaptation from other cultures has been mentioned in the historical overview. The ancient Egyptians would sometimes indicate that a god had written a certain book, which was subsequently discovered; other texts were ascribed to earlier kings. In fact, most of the texts (with the exception of the Wisdom texts) were anonymously authored and were obviously understood to be a collective cultural achievement. This cannot have occurred, however, without discoveries made by individuals. Amenemhet, for example, boasted that he had manufactured and developed a new water clock during the reign of Amenhotpe I, stating that in summer the night lasts for twelve hours, whereas in winter it has fourteen hours. Most such realizations were based on observation—the basis of all science. In the case of astronomy, long-term observation was the approach. In general, though, Egyptian science had little empirical thrust; there was no ambition to systematically research the entire world. Thus, although invasive practices were used in mummification, no evidence has been found that corpses were dissected to gain knowledge in anatomy. Expeditions to foreign lands were usually undertaken for military or economic reasons, and not in search of knowledge. The circumnavigation of Africa, an event whose veracity remains contested, is said to have been initiated by Necho II (r. 610–595 BCE) and had likely more to do with the king's naval policy than with a quest for knowledge. The New Kingdom expeditions of Queen Hatshepsut to the land of Punt

were undertaken primarily to acquire exotic goods; the detailed paintings in her tomb in Deir el-Bahri do show, however, that foreigners were carefully observed. The depictions of animals and plants in the "Botanical Garden" of Thutmose III in Karnak confirm this impression, yet again they were acquired because of this ruler's war campaigns in the Near East. Next to observation, from which deductions were drawn, speculation played a large role. Those phenomena that could not be observed were especially speculated upon, such as the netherworld, gods, demons, and the creation of the world. Speculation commonly involved drawing analogies to the known world on earth.

Organization. Specialization is one of the most striking features of Egyptian science. As early as the Old Kingdom, there were already specialized physicians. Then the training of scribes, on which scientific recording was based, specialized at an early stage, to prepare the student for his future work. A "basic schooling" of about four years was sufficient for most. The training of scribes focused on Egypt's classic literature. In more advanced studies, students learned how to compose their own letters and how to study the natural sciences. As students were apprenticed to masters early in their training, they gained practical experience in their field and, at the same time, all the specialized training they would need. There is no evidence that a final examination was held at the end of the training years (yet craftsmen were required to pass a special test, as indicated by examination dialogues embedded into religious contexts).

Scribes who did not enter into a specialized profession after their training were devoted to creating purely scientific inscriptions in the House of Life. In the House of Life—each major temple had its own—religious inscriptions were authored, copied, and stored. It was not only a library, scriptorium, and "university" but also a central cult site, where the well-being and flourishing of Egypt and its population was safeguarded, with the help of cult and magic. Inscribing religious and scientific texts was subordinate to that all-important task and helps explain the strong link between science, religion, and magic. Separating the three is the modern approach. Specific houses of life seem to have been held in especially high regard. The priests of Heliopolis, for example, were renowned for their wisdom, as was reverently recorded in Egyptian as well as in classical texts. Centers of scholarship were engaged in a lively exchange of information, since the same texts were known in various locations.

The Egyptian priesthood must have been very organized in creating written records during Roman times, when it alone was responsible for carrying on the Egyptian tradition in science. There seems to be no other explanation for the enormous amount of text produced during that time. The temples, however, seem to have been increasingly short of funds, as is evident in the many manuscripts written on poor quality or recycled papyrus or onto the back pages of Greek administration records. When pagan cults were banned in 392 CE and the temples were closed, Egyptian science lost its organizational basis.

In summary, it is important to emphasize the task-orientation of Egyptian science and its integration into religion. Systematic research and experimentation in a multitude of fields—the pursuit of "pure" knowledge—did not exist in ancient Egypt. Knowledge to the Egyptians was not gained from nature, but found in books. This reflects the importance of script in Egyptian science and the role of essential cultural traditions in the intellectual life of ancient Egypt. Tradition, in turn, was deeply rooted in religion. Hence, Egyptian science served theology or was a component of theology, in an attempt to explain—by means of speculation—that which could not be understood by any other means. To Egyptians, magic was the culmination of knowledge, for with its help one could even coerce the gods.

The conditions and possibilities for scientific pursuits were very different in ancient Egypt than they are today. Yet there was without question a sincere search for knowledge. While the goals and methods were different from today's, this does not mean that they were illogical. Their sophistication in the development of terminology and of principles would make it erroneous to dismiss ancient Egypt as "unscientific." The modern concept of "science" is the product of a developmental sequence which, among other traditions, began in pharaonic Egypt.

Update of Research Interests. Researching Egyptian science is difficult because of the sketchiness of the available material—a difficulty common to all research on ancient Egypt but especially true for the earliest periods. Publication policies pose another problem. The publication of Egyptian texts from the Greco-Roman era [in Egypt] had been neglected, although more resources exist from that period than from more ancient times. Such texts were thought of as works that had been marred by a nascent degeneration in the culture or, conversely, as works that were too strongly influenced by the Greek tradition, having been created during a culturally coopted, barren, or otherwise unproductive period. It was assumed that such factors made texts from that period unworthy of close study. New publications have begun to redress that preconception. The lack of interest in the later period has also had an adverse effect on work needed to revise and include individual texts in collections, which often follows the first edition. Thus, the only complete collection for the Greco-Roman era, with full source references, is a work on astronomical texts. The collected publica-

tions on other branches of science either omit the later period—as has been done for the Onomastica—or, instead, focus exclusively on the later period without taking the preceding eras into account (e.g., for mathematics: only the Demotic papyri have been compiled). The study of the way the different branches of science evolved across the millennia in ancient Egypt is, therefore, a task still largely incomplete. There are no era-specific studies, which present the spectrum and the status of science for a specific cultural phase against the intellectual history of Egypt. For that context, it is also vital to research the relevant intercultural contacts; however, that would be possible only for some of the eras, since the material available is still fairly limited. It is also evident that as yet there is no treatise on the all-embracing topic of science in ancient Egypt.

[*See also* Astrology; Astronomy; Mathematics; Medicine; *and* Technology and Engineering.]

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