EUCLID:
THE MEASURE OF A MAN-Otto and Hannah Soderlund

I. INTRODUCTION

Definition: to "measure" is to find out or estimate the extent or dimensions. (1)

Definition: to "take someone's measure" is to make an estimate or judgment of someone's ability or character. (1)

Definition: element (1) in its various uses means:

1. The basic, irreducible part or principles of anything concrete or abstract.
2. In math, an infinitesimal part of any magnitude or differential.
3. In ecclesiastical usage, the bread and wine of Communion are the elements.
4. In computer terminology, an element is one item of data.
5. Element or in Greek, *stoichea* was coined by Plato. Aristotle's definition: "Element is a pure substance that cannot be decomposed into any simpler substance."

This paper is an attempt to take a measure of the man, Euclid, the Father of Geometry, also known as "the elementator." (2) Geometry in Greek, *geometrein*, means "the measure of the earth". Out of the earth, man was made (Gen. $2:7^2$). Hence, in a sense, when you measure the earth, you are measuring man.

Euclid attempted to compile and systematize all the mathematical formulas and theories in his 13-volume book, *Stoichea* or *Elements*. Written approximately 300 B.C., *Elements* had reigned for almost 2,000 years as the undisputed standard on Geometry. Proclus said, "*Elements* is to Mathematics what the letters of the alphabet are to language." (3)

Mathematics is the science that deals with quantities, magnitudes, and forms and their relationships or attributes expressed by numbers and symbols. (1) Mathematical is from the Greek "mathematikos" and means inclined to learn, or generally meaning to be alert or to pay attention. To put it another way, the mathematical mind is to observe the natural order of the physical world and express its relationship by numbers and symbols. As stated by Kline, "Mathematics is the foundation of all exact knowledge of natural phenomena." (4)

Scope of Study:

Paul Cox wanted "a biography put together of the Greek mathematician, Euclid." A biography is an account of a person's life described by another. An account is to furnish a reckoning. A reckoning is a measuring of possibilities for the future. (1) Hence, this biography of Euclid considers the scant information about his life and the impact of his work. This is not a mathematical treatise or analysis of *Elements*.

II. AN ACCOUNT OF EUCLID

"*The laws of nature are but the mathematical thoughts of God.*" - *Euclid*

Euclid's name in Greek, "Eukleides" means "renowned" from "eu"=good + "kleos"=fame, glory. (5)

Euclid's major contribution *Elements* survived, but Euclid's life story did not. Archeologists have combed through historical documents and ancient artifacts searching for a missing biography on Euclid. Added to the confusion was that Euclid of Alexandria (the author of *Elements*) was for a time mistaken for the philosopher Euclid of Megara.

There are those who doubt Euclid's existence.[3] However, we think we can establish that Euclid was a real person because we have several of his works and because other Greek mathematicians mention Euclid in their writings[4] or wrote commentaries on the *Elements*. We learn about Euclid through inference and deduction.

Briefly, we surmise six things about Euclid (the Detailed Explanation will follow the Sources):

1. Euclid's time in history was approximately 300 B.C.
2. Euclid received his mathematical training in Athens from the pupils of Plato.
3. Euclid taught in Alexandria, Egypt.
4. Two anecdotes are told about Euclid: about his student and about Ptolemy I.
5. Some personality traits: Euclid was kind, friendly and appreciative of other mathematicians, not inclined to quibble, accurate and humble.
6. Euclid wrote at least 10 books, the most famous of which was the *Elements* or *Stoichea*.

A. Sources of our suppositions: Proclus, Pappus and Stobaeus

From Proclus (410-485 A.D.), a Greek mathematician, comes the following excerpt:

> "Not much younger to these [other mathematicians] is Euclid, the compiler of the *Elements*, who arranged in order many of Eudoxus' discoveries and completed many of Theaetetus' enquiries, raising to the level of unimpeachable demonstration what had been rather weakly proved by earlier workers. This distinguished man lived in the reign of Ptolemy I, for Archimedes in his first book has a reference to Euclid, and indeed they say that Ptolemy once asked Euclid if there were not a shorter road in Geometry than by a system of elements, and the latter replied that into Geometry there was no royal road. Thus Euclid is junior to Plato and his disciples, but senior to Eratosthenes and Archimedes, who (as Erastosthenes somewhere says) are contemporaries. " (2) (6) (7)

From Pappus of Alexandria, a Greek mathematician from the 4th century A.D. comes the following extracts (8) (9):

- "…the department of mathematics which treats of analysis, is, in short, a certain peculiar matter prepared for those who, having gone through the elements [the basics], wish to acquire the power of solving problems proposed to them in the construction of lines; and it is useful for this purpose only. It has been treated of by three men—Euclid, the author of the *Elements*, Apollonius of Perga, and Aristaeus the elder—and proceeds by the method of analysis and synthesis."
- "…as to this, Euclid, approving of Aristaeus as a worthy mathematician on account of the *Conics* which he handed down, and not being in haste, nor wishing to lay down anew the same treatment of these subjects--for he was most kind and friendly to all those who were able to advance mathematics to any extent, as is right, and by no means disposed to cavil[5], but accurate, and no boaster like this man Apollonius—wrote as much as could be proved by his Conics…"

- "But he, Apollonius,…having been furnished with the ideas by the books already written by Euclid on the same *Locus*, and having been for a long time a fellow-pupil of the disciples of Euclid in Alexandria, from which source he derived his habit of thought, which is not unscientific."

From Johannes Stobaeus,[6] the Greek anthologist from the 5th century A.D., comes this excerpt:

> "someone who had begun to read geometry with Euclid, when he had learnt (sic) the first theorem, asked Euclid, 'But what shall I get by learning these things?' Euclid called his slave and said, 'Give him threepence, since he must make gain out of what he learns.'" (6)

B. Detailed explanation for our suppositions:

1. Euclid's time in history was approximately 300 B.C.

   From Proclus, we derived Euclid's time in history:

   a. Euclid lived in the time of the first Ptolemy (who reigned over Egypt from 305 to 283 B.C.)[7]

   b. Euclid was younger than the pupils of Plato (who died 347 B.C.)

   c. Euclid is older than Eratosthenes (276-194 B.C.) and Archimedes (287-212 B.C.)

2. Euclid received his mathematical training in Athens from the pupils of Plato.

Proclus said that Euclid's *Elements* contained many of Eudoxus' and Theaetetus' theorems. Both Eudoxus of Cnidus and Theaetetus of Athens attended the Academy of Plato. Plato founded the Academy in 387 B.C. This Athens school was the center of learning before Ptolemy I commissioned the Alexandria Museum (or the University) and Great Library in 295 B.C. (10) (11)

3. Euclid taught in Alexandria, Egypt.

Pappus said that Appolonius of Perga (262 – 190 B.C.) studied with the pupils of Euclid at Alexandria. We do not know if Euclid joined the Museum or if he founded his own school. We can only conjecture that Euclid taught at Alexandria.

4. Two anecdotes are told about Euclid.

   a. Euclid pays his student to learn.

   Stobaeus wrote: "someone who had begun to read geometry with Euclid, when he had learnt (sic) the first theorem, asked Euclid, 'But what shall I get by learning these things?' Euclid called his slave and said, 'Give him threepence, since he must make gain out of what he learns.'" (6)

   b. Euclid and Ptolemy I: "No royal road to learning geometry."

   We are uncertain if the above anecdote is true because it was attributed to both Euclid and Menaechmus, another Greek mathematician.

   Proclus stated, "they say that Ptolemy once asked him [Euclid] if there was in geometry any shorter way than that of the *Elements*, and he answered that there was no royal road to geometry." On the other hand, Stobaeus related the same anecdote this way: "Alexander [the Great] asked Menaechmus to teach him geometry concisely, but the reply was: 'O king, through the country there are royal roads and roads for common citizens, but in geometry there is one road for all.'" (6)

5. Some personality traits: Euclid was kind, friendly and appreciative of other mathematicians, not inclined to quibble, accurate and humble.

   We derive this from Pappus' description of Euclid: "

   a. "as to this, Euclid, approving of Aristaeus as a worthy mathematician on account of the Conics which he handed down…"

   b. "…most kind and friendly to all those who were able to advance mathematics to any extent, as is right, and by no means disposed to cavil [quibble], but accurate, and no boaster…"

6. Euclid wrote at least ten books.

   Based on what other Greek mathematicians reported and what copies exist, we know that Euclid wrote the following works (6):

   a. *The Pseudaria* (lost work);
   b. *The Porisms* (lost work) [8]
   c. *The Surface-loci* (lost work)
   d. *The Conics* (lost work)
   e. *Elements of Music* (lost work; Note: This work is cited by Heath, but other authors say that there is no conclusive evidence that Euclid wrote this.)
   f. *On Divisions of Figures* (lost in Greek; available in Arabic);
   g. *The Data* (available);
   h. *The Phaenomena* (available)
   i. *The Optics* (available)
   j. *The Elements* (complete copies available in Greek, Latin and Arabic)

III. MEASURED BY HIS FRUIT: ELEMENTS

Since Euclid's biographical information is quite scanty, Euclid is mostly known through his enduring famous work, the *Elements*.

Though no original copies exist, the text that everyone uses is as dependable as is possible by the comparison of ancient manuscripts.[9] The two oldest complete Greek manuscripts are dated from 9th century A.D.: "codex Vaticanus Graecus 190 vol. 1 fols. 38 verso - 39 recto math01 NS.01" (shown on the left) is owned by the Vatican Library and "D'Orville 301"(shown on the right) is owned by the Bodleian Library of Oxford University (12) (13).

What was mathematics like before Euclid's *Elements*? From about 3000 B.C., the Babylonians and Egyptians pursued mathematics for practical purposes, i.e., it was problem-centered. If one wanted to solve a particular problem, one would sift through the available clay tablets or papyri to see if someone with superior mathematical abilities had written a formula. (4) For example, the Rhind Mathematical Papyrus from Egypt, about 1500 B.C., contained 84 mathematical problems and solutions; it included such things as how one would go about building a pyramid, but it did not explain how it got the formulas or why it was solved that way. (14)

Euclid's achievement was to organize and systematize this hodge-podge of available knowledge. The Greeks who came earlier, like Thales of Miletus (approximately 500 B.C.), had already started using deductive reasoning

to construct theorems which required proofs. (15) Euclid used this deductive reasoning to provide a standardized methodology for studying geometry, algebra and other sciences.

Euclid began *Elements* with Defintions. He defined 23 basic mathematical terms, such as "a point is that which has no part". Then using these definitions, he put forth 5 postulates and 5 common notions[10]. Then in 13 volumes (or so-called "Books") Euclid presented approximately 467 propositions with corresponding proofs, using previous propositions to establish later ones and adding more definitions as needed.

Criticisms Leveled against Euclid:

Through the centuries, many mathematicians have attempted to prove or disprove everything in *Elements*: the definitions, postulates, common notions, the propositions and proofs. On the definitions, some said it was not simple enough; others said that it was too simple. Critics pointed out flaws in Euclid's proofs. Many mathematicians focused particularly on Postulate 5, also known as the Parallel Postulate.

To show why Postulate 5 drew their special attention, we enumerate Euclid's five postulates as translated by Heath (6):

1. To draw a straight line from any point to any point.
2. To produce a finite straight line continuously in a straight line.
3. To describe a circle with any center and radius
4. That all right angles equal to one another.
5. That, if a straight line falling on two straight lines makes the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which are the angles less than the two right angles.

While Postulates 1 through 4 are simple phrases, Postulate 5 is almost a paragraph. Mathematicians thought that Postulate 5 should be a proposition because it is long and complex. It has remained a postulate because nobody could find a proof. However, mathematicians in the 19th century developed a deeper understanding of Postulate 5.

Because mathematicians (most notably, János Bolyai, Nikolai Lobachevsky, Bernhard Riemann and Carl Friedrich Gauss) obsessed over Postulate 5, they deduced non-Euclidean geometry. (15) To put it simply, the Euclidean geometry described in *Elements* is what we now call "plane geometry" for three-dimensional space, while non-Euclidean geometry describes 4-dimensional (or multi-dimensional) space. Furthermore, Albert Einstein, in turn, used this non-Euclidean geometry to prove his theory of relativity, which describes space and time, the fourth dimension. (15) (16) As Aaboe said, "Euclid was thus vindicated by non-Euclidean geometry." (17)

Another frequent criticism leveled at Euclid was that he did not discover original mathematical theories, but merely collected the theories at that time. Whether Euclid was an original thinker or not, Reid's rebuttal was: "Euclid selected, substituted, added, rearranged the definitions, axioms, theorems and proofs; and what came out in his *Elements* was a distillation of all those that had come before—a model of systematic thought." (18)

Euclid provided a framework for understanding the principles. He not only broke down principles to its basic "elements," but he also arranged them so that by understanding earlier principles, you would understand succeeding ones. Euclid's demonstrated use of deductive reasoning became the model for presenting scientific works. An analogy for Euclid's achievement would be Dmitri Mendeleev's publishing the Periodic Table of Elements. Other scientists discovered different elements but Mendeleev noted a pattern in the unique atomic number and common properties of each element. Mendeleev's table provided an orderly way to study chemistry. (19) In the same way, Euclid provided an orderly way to study mathematics and other sciences.

IV. A RECKONING OF EUCLID

Even by today's standards, *Elements* is a publishing success. The first printed edition was in 1482 A.D. and the first English edition in 1570 A.D.[11] (20) Heath wrote: "This wonderful book [*Elements*] with all its imperfections, which indeed are slight enough when account is taken of the date at which it appeared, is and will doubtless remain the greatest mathematical textbook of all times. Scarcely any other book except the Bible can have been circulated more widely the world over, or been more edited and studied." (6)

Moreover, mathematicians wrote and continue to write commentaries along with their translations, adding longer explanations and footnotes, and providing more proofs. These include ancient mathematicians such as Heron, Porphyry, Pappus, Proclus and Simplicius, as well as modern mathematicians. Frankland stated: "The editors of the *Elements* of Euclid have in these days given us more often what Euclid should have written than what Euclid did actually write twenty-two centuries ago." (2) Euclid himself included no preface, no commentaries, no footnotes, and no appendices in *Elements*.

To further illustrate Euclid's influence, here is a sampling of his impact on other famous people:

- Geminus of Rhodes, the mathematician (approximately 1st c. A.D.), said: "…it is the excellence of his *Elements* that they provide a complete introduction to the theory of the primary figures. On the other hand, the passage from things simpler to things more complex is effected in clear and orderly wise by deduction of the theory from accepted ideas." (2)
- Abraham Lincoln (1809-1865):
  a. "At last I said, 'Lincoln, you never can make a lawyer if you do not understand what demonstrate means'…[So] I left my situation in Springfield, went home to my father's house, and stayed there till I could give any proposition in the six books of Euclid at sight. I then found out what 'demonstrate' means, and went back to my law studies." (21)
  b. "At age forty, Abraham Lincoln studied Euclid for training in reasoning, and as a traveling lawyer on horseback, kept a copy of Euclid's *Elements* in his saddlebag. In his biography of Lincoln, his law partner Billy Herndon tells how late at night Lincoln would lie on the floor studying Euclid's geometry by lamplight." (20)
  c. Lincoln's logical speeches and some of his phrases such as "dedicated to the proposition" in the Gettysburg address are attributed to his reading of Euclid." (20)
- Albert Einstein (1879-1955) said: "If Euclid failed to kindle your youthful enthusiasm, then you were not born to be a scientific thinker." (20) Einstein called *Elements* "the holy little geometry book." (22)
- Fyodor Dostoyevsky (1821-1881), the Russian novelist, in *Brothers Karamazov*, let his character, Ivan say: "I tell you that I accept God simply. But you must note this: If God exists and if He really did create the world, then, as we all know, He created it according to the geometry of Euclid." (20)
- Immanuel Kant (1724-1804), the German philosopher, wrote in 1783: "There is no book at all in metaphysics such as we have in mathematics. If you want to know what mathematics is, just look at Euclid's *Elements*". (10)
- Jesuit Father Matteo Ricci (1552-1610), together with Xu Guangqi, translated *Elements* into Chinese: On his death in 1610, Fr. Ricci received the great honor of being buried in the imperial cemetery; Ye Xianggao, the Grand Secretary explained: "even not considering his [Ricci's] virtue and his other writings, this book [*Elements*] alone should have been enough to grant him a burial ground." (23). Pope Benedict noted that Fr. Ricci and Marco Polo are the only two foreigners honored as part of Chinese History in Peking's Millenium Museum. (24)

- Lewis Carrol (1839-1898), the author of *Alice's Adventures in Wonderland* wrote a play in defense of Euclid: "Euclid and His Modern Rivals". (25)

Afterword:

As we considered the man Euclid, we saw the impact of his book. It was reasonable, setting the standard for reasoning and developing a disciplined mind. It was universal, finding acceptance in cultures throughout the world. It was prophetic, willing to accept the unknown as seen in the 5th Postulate which opened the door to Non-Euclidean mathematics. It was basic, providing a foundation from which to build sound mathematics. Finally, at its heart, it is humble, reflecting a humble man who let his work stand on its own without preamble, self-aggrandizement or excuses.

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END NOTES

[1] This Greek papyrus fragment, dated from 75-125 A.D. is called Oxyrhynchus I.29 and is owned by the Museum of Archeology and Anthropology of the University of Pennsylvania.

[2] Gen 2:7 And the LORD God formed man of the dust of the ground, and breathed into his nostrils the breath of life; and man became a living soul [LITV].

[3] For example, Raju contended that Euclid the person does not exist and that the Europeans merely copied the Indian mathematicians who developed trigonometry and calculus. He said that Indian culture prized inductive reasoning because deductive reasoning lead to errors. (42)

[4] An example of Euclid's being mentioned is from Simplicius who said: "I shall now put down literally what Eudemus relates, adding only a short explanation by referring to Euclid's Elements, on account of the summary manner of Eudemus, who according to archaic customs, gives only concise proofs." (8)

[5] Cavil = to object when there is little reason to do so; to resort to trivial fault-finding; to quibble. (1)

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[6]Johannes Stobaeus (approximately 5th c. A.D.) compiled excerpts from about 200 classical Greek manuscripts to educate his son, Septimius. (33)

[7] Ptolemy I *Soter* (or Ptolemy the Savior) was one of Alexander the Great's Macedonian generals. Alexander chose Alexandria, Egypt to replace Athens as the center of the Greek world. After Alexander died, Ptolemy crowned himself king of Egypt and started his own royal dynasty.

[8] Heath: "A porism occupies a place between a theorem and a problem." (6)

[9] In the 4th c. A.D., Theon of Alexandria, copied and edited the *Elements*. Theon's copy was the accepted version until 1808 when the Vatican manuscript was found. A revised text was published between 1883 to 1888 by Danish mathematician J.L. Heiberg; for his translation, Heiberg reconstructed the original text by using the Vatican manuscript as his main text and by removing Theon's additions based on comparisons to other ancient manuscript fragments. (37)

[10]Both Postulates and Common Notions refer to assumptions or self-explanatory statements that need no proof; they differ in subject matter; Euclid used the word "Postulates" to state assumptions in mathematics and then used "Common Notions" to state general assumptions; e.g., Common Notion 1 is "Things which are equal to the same thing are also equal to one another." Propositions are formulas or theorems. (17) (6)

[11] Dr. Menso Folkerts of the University of Munich, Germany has compiled a list of Latin and Arabic manuscripts, translations and/or commentaries from the Middle Ages; not counting the Arabic manuscripts, Latin translations number at least 1,500. For a time after the fall of Rome, the rise of the Catholic Church and the rise of European City-States, *Elements* was better known in the Arabian world. Hence, there was a surfeit of Arabic translations and commentaries. A legend even arose that Euclid was Arabic and his name meant, "key to Geometry". (32) (3)