

SOLI-LUNAR CYCLES

IN

GREEK RESEARCH

AND

JEWISH REVELATION

by

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SOLI-LUNAR CYCLES
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Those who are acquainted with the work of the Foundation for the Study of Cycles⁽¹⁾ or who have otherwise investigated the subject know that rhythmic fluctuations or cycles pervade not only inanimate nature but also many departments of human activity and thought.

The present treatise is concerned with discoveries which indicate that such cyclic relationships extend into the realms of the moral and the theological.

Physical and moral phenomena are, of course, in some ways quite distinct. Modern investigation has demonstrated that in many spheres the moral bears little or no causal relation to the physical. Injustice does not occasion an eclipse, nor envy an earthquake. Physical elevation not moral depravation attracts lightning. Physical phenomena occur in accordance with established and uniform physical principles. So, likewise, the physical is no criterion of the moral. Degrees of holiness and sin cannot be measured by a ruler. Size is no criterion of moral worth. It is only figuratively that a man's character can be weighed in the balances. Moral phenomena are governed by moral laws.

Nevertheless, the moral and the physical are not entirely

(1) A purely secular scientific organization "created to pursue and foster research into rhythmic fluctuations in all branches of natural and social phenomena" and numbering amongst its members some of the greatest scientists of Britain and America.

separate realms. They do exist together and, however we explain it, must bear some inter-relationship. Either the moral has arisen from the physical, as materialists say, or the underlying substance of things has both physical and moral potentialities, or both the physical and moral realms owe their existence to a Divine Author. That there is some inter-relationship no one will deny.

Further, it is evident that in time we have an element common to both realms.

There is a physical time order. "The sun knoweth his going down." The moon and the planets have their appointed seasons. Eclipses occur at fixed times. Ancient Greek research long ago brought to light the fundamental elements of these physical cycles.

But time is related also to the moral realm. The righteous are not always oppressed. "The time of the promise draws nigh." "The fulness of time comes." In this moral realm the sacred literature of the Jews is supreme. Here we find professed revelations of great moral cycles, times appointed for the duration of empires and kings and for the deliverance of the righteous.

Centuries of independent research in regard to these appointed times or cycles of the physical and moral realms have culminated in the discovery of certain curious relationships between them. These relationships constitute the burden of this thesis and, we humbly hope, may seem of sufficient significance to some to strengthen their faith in a theological interpretation of nature and history.

Physical Cycles

The real and apparent motions of sun, moon, and planets form the basis of nature's time order. The day, the lunar month, the year, and the planetary periods are the principal units. The matter is complicated, however, by the fact that each of these heavenly luminaries possesses more than one type of periodic motion. The moon, for example, has four main periodic elements all producing easily observable effects, and all known centuries before the time of Christ. Each planet has two principal periods.

The four lunar periods or months are the sidereal, the synodic, the anomalistic, and the nodical.

The sidereal month is simply one complete revolution of the moon about the earth or, in other words, the mean time taken for the moon to return to the same place in regard to the fixed stars.

The synodic month is the mean time taken for the moon to return to the same position in relation to the earth and the sun. And as the earth itself is in motion about the sun, this does not correspond to the sidereal month. The synodic month is the time from full moon to full moon or from new moon to new moon.

The anomalistic month is the time taken for the moon to return to the corresponding point on its elliptical orbit. And as the ellipse itself is in motion the anomalistic month is not the same in length as the sidereal. The anomalistic fluctuation is the principal cause of the considerable difference in length observable between individual synodic months. It also affects the nature of eclipses. When a full solar eclipse occurs with the moon at apogee the eclipse is total, but when a

full solar eclipse occurs with the moon at perigee the eclipse is annular.

The nodical month is fundamental to eclipses. The moon in its revolution about the earth does not revolve in the same plane that the earth does in its revolution about the sun, but in a plane at an angle to it. The nodical month is the time taken for the moon to return to the corresponding point in its plane. And as the plane is in motion neither does this period correspond to the sidereal month. It is obvious, further, that eclipses can occur only when the sun, earth, and moon are in a straight line. Two conditions are therefore necessary:

- (1) The moon must be full (for a lunar eclipse) or new (for a solar eclipse);
- (2) The moon must be at a node, i.e., it must be cutting the ecliptic, the plane in which the earth revolves about the sun.

Hence it is evident that eclipses will recur only at intervals which are synodic nodical cycles.

The two principal planetary periods are the sidereal and the synodic. The sidereal period is the mean time taken by the planet to complete one revolution about the sun. The synodic period is the mean time taken for the planet to return to the same position in relation to the earth and the sun.

Of these various units in nature's time order the most important are those which are suited to calendareographical uses, viz., the day, the synodic month, and the tropical year. It is well known, further, that these units are not commensurate. One tropical year, for example, does not contain an exact number of synodic months. It is possible, however, to find periods which do contain very nearly exact

numbers of both tropical years and synodic months. Such periods are called soli-lunar cycles⁽¹⁾ and are of first importance in the formation of calendars based on the motions both of sun and moon.

The first cycle of this sort to be used in Greece⁽²⁾ was the eight years' cycle or octaeteris. Commenting upon the origin and nature of this cycle Geminus tells us⁽³⁾ that the period was considered to contain 99 months (of which 3 were intercalary) and 2922 days. These numbers were arrived at, he says, on the assumption that the lunar year contains 354 days⁽⁴⁾ and the solar year $365 \frac{1}{4}$ days. Thus the epact would be $11 \frac{1}{4}$ days, which in eight years would amount to a whole number of days and a whole number of months; viz., 90 days or 3 months. In other words, 8 solar years exceed 8 lunar years by 3 lunar months. If, then, the lunar years are not to lag farther and farther behind the solar, it will be necessary in the course of every eight years to make three of the lunar years leap years of 13 instead of 12 lunar months.

Geminus then proceeds to note certain modifications of the 8 years' cycle suggested by a more accurate estimate of the length of the lunar month. The true length of the lunar month is, he says, $29 \frac{1}{2}$ plus $\frac{1}{33}$ days.⁽⁵⁾ Hence 99 months contain not 2922 days but $2923 \frac{1}{2}$ days. Thus, he says, every 16 years 3 days will have to be added in

(1) Censorinus calls them great years (anni magni) cf. De Die Natali, 18/5.

(2) It was also the first cycle employed by the Babylonians in their calendar and the first cycle employed by the early Christians for fixing the date of Easter.

(3) Gemini Elementa Astronomiae 8/27 f. Manitius' edition p.110, l. 21, f. Geminus flourished in Rhodes c. B.C. 77.

(4) The lunar year consisted of 12 months alternately "full" and "hollow", i.e. of alternately 30 and 29 days.

(5) $29 \frac{1}{2} + \frac{1}{33} = 29.5303$ days, which is not far from 29.5306 days, the actual length of the synodic month.

order to harmonize the days with the lunar months. But since 8 solar years do contain 2922 days,⁽¹⁾ in 16 years the months will be in excess of the years by the 3 added days. This excess will increase to a full lunar month in 10 of the 16 year periods or in 160 years, when a full month will have to be dropped out to correct the cycle.⁽²⁾

Finally, Geminus notices the 19 years' or Metonic cycle⁽³⁾ and its modifications. This cycle equates 19 years, 235 months (7 of which are intercalary), and 6940 days. In order to obtain the correct proportion of "full" and "hollow" months the Greeks dropped every 64th day from an hypothetical calendar containing 235 months of 30 days each. Thus the omitted day in the "hollow" months did not always come at the end of the month. The 64th day was arrived at by dividing 7050 (the number of days in 235 months of 30 days each) by 110 (the difference between 7050 and 6940 and hence the number of days that had to be dropped out).⁽⁴⁾

Callippus suggested that the error of Meton's cycle could be corrected by dropping one day after four cyclic periods or 76 years.

(1) Actually 2921.94 days.

(2) This system of correcting the octaeteris on the basis of a 160 years' cycle seems to have been first suggested by the great Greek geometrician and astronomer, Eudoxus, and a system based upon it to have been actually introduced in Athens possibly in 381 or 373 B.C., cf. Heath, Aristarchus p.293. Judged by accurate modern values the 160 years' cycle has an error of slightly more than two days:

$$160 \text{ years} = 58,438.75 \text{ days}$$

$$1979 \text{ months} = 58,441.03 \text{ days}$$

(3) Named after Meton who discovered it c. 432 B.C. It has an error of less than a day (19 years = 6939.60 days, 235 months = 6939.69 days) and came to be the most widely used of all calendareographical cycles of the tropical year and the synodic month. It is still used in the Jewish calendar and also, for fixing the date of Easter, in our own calendar.

(4) Heath, Aristarchus, p.293. Geminus 8/50-56.

The Callipic cycle thus equates 76 years, 940 months, and 27,759 days (instead of 27,760.)⁽¹⁾

About 125 B.C. Hipparchus devised a still further correction, dropping another day after four Callipic cycles, thus equating 304 years, 3760 months and 111,035 days (instead of 111,036).⁽²⁾

Thus the practical necessity of devising an accurate calendar led the Greeks and other ancient peoples to investigate the relationship between the synodic month and the tropical year. Scientific interest led them on to investigate other more profound mysteries of nature's time measurements: the remaining elements of the moon's motion, (elements which affect the time and character of eclipses), and the periodicity of the planets. The brilliant results of this research are set forth in Claudius Ptolemy's⁽³⁾ great *Syntaxis Mathematica* or "Almagest" the greatest extant astronomical work of antiquity, a work "which for fourteen centuries was the authoritative 'scripture of astronomy.'"⁽⁴⁾

In discussing the motions of the moon Ptolemy tells us⁽⁵⁾ that the ancient mathematicians sought for a period which would harmonize the Moon's various incommensurate motions, and that, through observations of

(1) Actually 76 years = 27,758.41 days
and 940 months = 27,758.75 days

(2) Cf. Heath, Aristarchus, p.296,7.
Actually 304 years = 111,033.63 days
3760 months = 111,035.01 days

(3) Ptolemy flourished at Alexandria about A.D. 140.

(4) Astronomy, Russel, Dugan, Stewart,, p.243.

(5) Ptolemy, Syn. Math. 4/2.

The extent of the errors of the cycle may be seen from the following figures:

223 synodic months = 6585.32 days
239 anomalistic months = 6585.54 days
242 nodical months = 6585.36 days
241 sidereal months = 6584.52 days

lunar eclipses, discovered that 6585 $1/3$ days (18 years 11 days) was such a period, for it contained 223 synodic months, 239 anomalistic months, 242 nodical months, and 241 sidereal months. In later times this remarkable period came to be known as the "saros". Amongst the shorter periods it is the fundamental eclipse cycle. Each saros contains a series of eclipses very similar to that in the previous saros.

After telling us that some tripled this period of 6585 $1/3$ days in order to eliminate the fraction, Ptolemy proceeds to recount that Hipparchus,⁽¹⁾ by making use of Chaldean observations as well as his own discovered another distinct and very remarkable eclipse cycle, a cycle which equates 345 years, 4267 synodic months, 4573 anomalistic months, 4630.5 nodical months,⁽²⁾ and 4612 sidereal months.⁽³⁾

Two other lunar cycles are mentioned by Ptolemy, the one a synodic anomalistic cycle equating 251 synodic and 269 anomalistic months,⁽⁴⁾ the other a synodic nodical cycle equating 5458 synodic and 5923 nodical months.⁽⁵⁾

In modern times the search for eclipse cycles has been taken

(1) Hipparchus flourished c. B.C. 130.

(2) Ptolemy does not note the number of nodical months in the period though in the very nature of the case, as an eclipse interval, it must contain either an integral or (as in this case) a semi-integral number of nodical months.

(3) The errors of the cycle may be seen from the following:

$$345 \text{ years} = 126,008.56 \text{ days}$$

$$4267 \text{ synodic mo.} = 126,007.02$$

$$4573 \text{ anomalistic mo.} = 126,006.96 \text{ days}$$

$$4630.5 \text{ nodical mo.} = 126,006.18 \text{ days}$$

$$4612 \text{ sidereal mo.} = 126,007.50 \text{ days}$$

(4) A very accurate cycle

$$251 \text{ synodic months} = 7412.178 \text{ days}$$

$$269 \text{ anomalistic months} = 7412.174 \text{ days}$$

(5) Another very accurate cycle

$$5458 \text{ synodic months} = 161,177.95 \text{ days}$$

$$5923 \text{ nodical months} = 161,177.98 \text{ days}$$

taken up by the well-known astronomer Simon Newcomb.⁽¹⁾ He discovered that 358 synodic months and 388.5 nodical months form a cycle.⁽²⁾ He further noticed that the third multiple of this cycle has the additional feature of being an anomalistic cycle: 1074 synodic months, 1165.5 nodical months, and 1151 anomalistic months are all of very nearly the same length.⁽³⁾ Finally Mr. Newcomb noticed that in its eighteenth multiple the cycle possesses the yet additional feature of embracing an integral number of Julian years. Thus 521 Julian years, 6444 synodic months, and 6993 nodical months are equated. Newcomb illustrated the cycle historically by measuring 521 year intervals from the Nineveh eclipse of June 15th, 763 B.C. Thus eclipses recur on June 15th by the Old Style or Julian Calendar of the years 763, 242 B.C., A.D. 280, 801, 1322, and 1843. However, June 15th, 1843, Old Style is the same as June 27th, 1843 by the Gregorian or present day calendar. It must be remembered, therefore, that this cycle is remarkable simply in regard to the artificial Julian year but not in regard to the true tropical year. It should be noticed, too, that in this form (521 years) the anomalistic error of the cycle has increased to such an extent that it can no longer be regarded as an anomalistic cycle.⁽⁴⁾

(1) Cf. Newcomb's article, Eclipse, in the eleventh edition of the Encyclopaedia Britannica.

- (2) 358 synodic months - 10,571.951 days
 388.5 nodical months - 10,571.947 days
- (3) 1,074 synodic months - 31,715.85 days
 1,165.5 nodical months - 31,715.84 days
 1,151 anomalistic months - 31,715.29 days
- (4) 521 Julian years - 190,295.25 days
 6444 synodic months - 190,295.11 days
 6993 nodical months - 190,295.05 days
 521 tropical years - 190,291.19 days
 6906 anomalistic months - 190,291.72 days

TABLES OF CYCLES

The calendareographical and eclipse cycles that we have been discussing above are units in nature's time order, some of them remarkable and important units, but they are not the only units, nor the only remarkable units. In order, therefore, to obtain a more comprehensive grasp of nature's time order and in order to provide a basis of comparison by which we may judge of the relative accuracy and unusualness of various cyclical periods, we shall set forth in tabular form some of the main types of cycles.

TABLE 1

Cycles of the Solar Year and the Lunar Year

The epact between one solar year and one lunar year is 10.8751 days. This epact increases to a full lunar year in $\frac{354.3671}{10.8751} = 32.5852$ solar years. That is, in 32.5852 solar years there are 32.5852 lunar years plus one lunar year. Hence all multiples of 32.5852 will contain integral epacts, and those multiples which are themselves integral will be true cycles of the solar year and the lunar year, that is, will contain integral numbers of each.

By this method we have located the solar year lunar year cycles found in the following table. The table contains all cycles shorter than 4,000 years with errors less than a day. The bracketed number of the primary cycle appears after cycles which are not themselves primary. In calculating the errors of the cycles the values employed are: for the tropical year, 365.24219879 days; for the lunar year, 354.3670582 days, which are the values for the epoch A.D. 1900. The effect of secular acceleration on the error is such that in past centuries cycles with a lunar-greater-than-solar error had somewhat smaller errors, but those with a solar-greater-than-lunar error had somewhat larger. The effect is so slight, however, that for our present purposes we shall only occasionally need to draw attention to it.

TABLE 1.

Cycles of the Solar Year and the Lunar Year

Solar Years	Lunar Years	Days in the Solar Period	Lunar Difference (days)
163	168	59,534.48	- .81
391	403	142,809.70	+ .22
554	571	202,344.18	- .59
782 (391)	806	285,619.40	+ .45
945	974	345,153.88	- .36
1,173 (391)	1,209	428,429.10	+ .67
1,336	1,377	487,963.58	- .14
1,499	1,545	547,498.06	- .95
1,564 (391)	1,612	571,238.80	+ .90
1,727	1,780	630,773.28	+ .09
1,890 (945)	1,948	690,307.76	- .73
2,118	2,183	773,582.98	+ .31
2,281	2,351	833,117.46	- .50
2,509	2,586	916,392.68	+ .54
2,672 (1,336)	2,754	975,927.16	- .28
2,900	2,989	1,059,202.38	+ .76
3,063	3,157	1,118,736.85	- .05
3,226	3,325	1,178,271.33	- .86
3,291	3,392	1,202,012.08	+ .99
3,454 (1,727)	3,560	1,261,546.55	+ .17
3,617	3,728	1,321,081.03	- .64
3,845	3,963	1,404,356.25	+ .40

TABLE 2.

Cycles of the Solar Year and the Lunar Month

The epact between one solar year and one lunar year increases to a full lunar month in $\frac{29.53059}{10.8751} = 2.715$ solar years. Hence all multiples of 2.715 will contain integral numbers of lunar months and those multiples which are themselves integral will be true cycles of the solar year and the lunar month, that is, they will contain integral numbers of each.

By this method we have located the solar year lunar month cycles found in the following table. The table contains all cycles shorter than 3000 years which have errors less than a day. Below 100 years all cycles whose errors are less than two days are included. The value of the synodic month employed in calculating the errors is that for the epoch 1900, viz., 29.53058818 days. The bracketed number of the primary cycle appears after cycles which are not themselves primary.

Cycles of the Solar Year and the Lunar Month

Solar Years	Lunar Months	Days in the Solar Period	Lunar Difference (days)
8	99	2,921.94	+ 1.59
11	136	4,017.66	- 1.50
19	235	6,939.60	+ .09
27	334	9,861.54	+ 1.68
30	371	10,957.27	- 1.42
38 (19)	470	13,879.20	+ .17
46	569	16,801.14	+ 1.76
49	606	17,896.87	- 1.33
57 (19)	705	20,818.81	+ .26
65	804	23,740.74	+ 1.85
68	829	24,836.47	- 1.24
76 (19)	940	27,758.41	+ .35
84	1,039	30,680.34	+ 1.94
87	1,076	31,776.07	- 1.16
95 (19)	1,175	34,698.01	+ .43
114 (19)	1,410	41,637.61	+ .52
125	1,546	45,655.27	- .99
133 (19)	1,645	48,577.21	+ .61
144	1,781	52,594.88	- .90
152 (19)	1,880	55,516.81	+ .69
163	2,016	59,534.48	- .81
171 (19)	2,115	62,456.42	+ .78
182	2,251	66,474.08	- .73

TABLE 2.

Cycles of the Solar Year and the Lunar Month

Solar Years	Lunar Months	Days in the Solar Period	Lunar Difference (days)
190 (19)	2,350	69,396.02	+ .86
201	2,486	73,413.68	- .64
209 (19)	2,585	76,335.62	+ .95
220	2,721	80,353.28	- .55
239	2,956	87,292.89	- .47
258	3,191	94,232.49	- .38
277	3,426	101,172.09	- .29
296	3,661	108,111.69	- .21
315	3,896	115,051.29	- .12
334	4,131	121,990.89	- .03
353	4,366	128,930.50	+ .05
372	4,601	135,870.10	+ .14
391	4,836	142,809.70	+ .22
410	5,071	149,749.30	+ .31
429	5,306	156,688.90	+ .40
448	5,541	163,628.51	+ .48
467	5,776	170,568.11	+ .57
478 (239)	5,912	174,585.77	- .93
486	6,011	177,507.71	+ .66
497	6,147	181,525.37	- .85
505	6,246	184,447.31	+ .74
516 (258)	6,382	188,464.97	- .76

TABLE 2.

Cycles of the Solar Year and the Lunar Month

Solar Years	Lunar Months	Days in the Solar Period	Lunar Difference (days)
524	6,481	191,386.91	+ .83
535	6,617	195,404.58	- .67
543	6,716	198,326.51	+ .92
554 (277)	6,852	202,344.18	- .59
573	7,087	209,283.78	- .50
592 (296)	7,322	216,223.38	- .42
611	7,557	223,162.98	- .33
630 (315)	7,792	230,102.59	- .24
649	8,027	237,042.19	- .16
668 (334)	8,262	243,981.79	- .07
687	8,497	250,921.39	+ .02
706 (353)	8,732	257,860.99	+ .10
725	8,967	264,800.59	+ .19
744 (372)	9,202	271,740.20	+ .28
763	9,437	278,679.80	+ .36
782 (391)	9,672	285,619.40	+ .45
801	9,907	292,559.00	+ .54
812	10,043	296,576.67	- .97
820 (410)	10,142	299,498.60	+ .62
831 (277)	10,278	303,516.27	- .88
839	10,377	306,438.20	+ .71
850	10,513	310,455.87	- .80

TABLE 2.

Cycles of the Solar Year and the Lunar Month

Solar Years	Lunar Months	Days in the Solar Period	Lunar Difference (days)
858 (429)	10,612	313,377.81	+ .80
869	10,748	317,395.47	- .71
877	10,847	320,317.41	+ .88
888 (296)	10,983	324,335.07	- .62
896 (448)	11,082	327,257.01	+ .97
907	11,218	331,274.67	- .54
926	11,453	338,214.28	- .45
945 (315)	11,688	345,153.88	- .36
964	11,923	352,093.48	- .28
983	12,158	359,033.08	- .19
1,002 (334)	12,393	365,972.68	- .10
1,021	12,628	372,912.28	- .02
1,040	12,863	379,851.89	+ .07
1,059 (353)	13,098	386,791.49	+ .16
1,078	13,333	393,731.09	+ .24
1,097	13,568	400,670.69	+ .33
1,116 (372)	13,803	407,610.29	+ .41
1,135	14,038	414,549.90	+ .50
1,154	14,273	421,489.50	+ .59
1,165	14,409	425,507.16	- .92
1,173 (391)	14,508	428,429.10	+ .67
1,184 (296)	14,644	432,446.76	- .83

TABLE 2.

Cycles of the Solar Year and the Lunar Month

Solar Years	Lunar Months	Days in the Solar Period	Lunar Difference (days)
1,192	14,743	435,368.70	+ .76
1,203	14,879	439,386.37	- .74
1,211	14,978	442,308.30	+ .85
1,222 (611)	15,114	446,325.97	- .66
1,230 (410)	15,213	449,247.90	+ .93
1,241	15,349	453,265.57	- .57
1,260 (315)	15,584	460,205.17	- .48
1,279	15,819	467,144.77	- .40
1,298 (649)	16,054	474,084.37	- .31
1,317	16,289	481,023.98	- .22
1,336 (334)	16,524	487,963.58	- .14
1,355	16,759	494,903.18	- .05
1,374 (687)	16,994	501,842.78	+ .03
1,393	17,229	508,782.38	+ .12
1,412 (353)	17,464	515,721.98	+ .21
1,431	17,699	522,661.59	+ .29
1,450 (725)	17,934	529,601.19	+ .38
1,469	18,169	536,540.79	+ .47
1,488 (372)	18,404	543,480.39	+ .55
1,499	18,540	547,498.06	- .95
1,507	18,639	550,419.99	+ .64
1,518	18,775	554,437.66	- .86