The terms "gestation period" and "length of pregnancy" are commonly associated with the interval of time between date of onset of the last menstrual period (LMP) and date of delivery of the child or other product of pregnancy. General adoption of the modified term "gestational interval" has been urged as an improvement helpful to clearer thinking.[1] The suffix -al relates the measure to the gestation period without implying definition of the period.

GESTATIONAL INTERVAL FROM VITAL RECORDS

Laurel M. Hammes, B.S., and Alan E. Treloar, Ph.D., F.A.P.H.A.

Early Requirements in Registration

INFORMATION concerning the time of in-utero development of the newborn was first sought in this country through official registration procedures, approximately 30 years ago. In 1939, the National Office of Vital Statistics (NOVS), through the Standard Certificate for Live Birth, provided for inclusion of "number months of pregnancy" as an addition to the statements required at registration. At approximately this same time, the District of Columbia introduced a supplementary confidential section to its birth registration form, including "period of gestation—weeks" as one of the 47 items of medical information requested "for use of the Health Department." Neither NOVS nor the District of Columbia published any early report of the results of these drives.

The next revision of the Standard Certificate for Live Birth in 1949 introduced the supplementary confidential section on the national scene, with "length of pregnancy—weeks" as one of three items in this new section. Thus, weeks replaced months as the measure of time to be used. Much revision of birth certificates at state and city levels resulted from this recommendation of NOVS, with the result that information concerning "length of pregnancy" was required in 1950 by 40 states and each of the three city jurisdictions. However, five of the states did not require the interval to be recorded in weeks as had been recommended, and thus the time unit of months remained officially acceptable in some parts of the nation.

Tabulation and discussion of "period of gestation in weeks" in the national summaries of vital statistics began with the volumes for 1950.[2] The first two columns of Table 1 reproduce data from this first summary. Records submitted in months were assigned by NOVS to the appropriate broad classes of four weeks each as given in the table, except that nine-month records were assigned to a separate 40-week class. A brief discussion of these first data on gestation noted their "serious deficiency." Attention was invited (a) to a "distortion" at 36 weeks assumed to result from 9 months being considered equal to 36 weeks by many persons completing registration forms, and (b) to the "concentration" at 40 weeks (to

which NOVS had made its own contribution).

The original concentration of 84 per cent of all gestational intervals in the two classes of one week each (36 and 40) did not incite corrective actions. This statistical anomaly still persists for those registration areas which continue to ask for gestation period in their birth registration forms. In the 1966 national summary for those areas, the 36-week and 40-week classes of gestational interval contain almost 76 per cent of all white births, and 80 per cent of all nonwhite births. Nonuniform grouping of single weeks into the broader intervals subtly plays its role here, as elsewhere.

Uniform grouping in a statistical tabulation is most desirable if the reader is to judge the relative importance of successive classes from their frequencies. The final column of Table 1 converts the percentage frequencies of the penultimate column to a uniform "per week" basis. The peaking of emphasis on 36-week and 40-week gestational periods receives its appropriate representation in the final column of Table 1.

It is generally presumed that semantics are at play in development of this concentration or distortion phenomenon. The question "length of pregnancy in weeks" seems to incite an estimate of the normality in maturity of each infant. The favorite values for normal "length of gestation" are 40 weeks, or 9 lunar months. It is commonplace to consider a lunar month as being equal to 4 weeks.

Dated LMP in Birth Registration

Since the revisions of birth registration forms in 1950, state and city health departments have become increasingly concerned with the relationship between inutero development time and its relationship to prematurity, fetal mortality, and neonatal death. This has led to pioneering efforts by some registration offices to secure more acceptable data concerning the gestational period. Indeed, the District of Columbia had

Table 1—Variation in period of gestation for white births in the USA during 1950 (by place of residence)

Period of gestation	Births		
	No.*	%	% per week†
Under 20 wk (including 4 mo)	505	(a)	(c)
20–27 wk (including 5 and 6 mo)	14,896	0.5	0.1
28–31 wk (including 7 mo)	23,853	0.8	0.2
32–35 wk (including 8 mo)	55,321	2.0	0.5
36 wk	197,907	7.0	7.0
37–39 wk	248,387	8.8	2.9
40 wk (including 9 mo)	2,175,874	77.1	77.1
41–42 wk	91,750	3.3	1.6
Over 42 wk (including 10 mo)	12,298	0.4	(c)
Reported as premature	1,110	(b)	—
Not stated	241,726	(b)	—
Total	3,063,627	100.0	

* From Table 25, Vol. II, of Vital Statistics of the United States
† Distributed uniformly (a) less than 0.1 per cent; (b) excluded from total; (c) indeterminate.

already (1948) changed its question relative to the gestation period into the form, "first day of last menstrual period." In 1951, Taback[3] demonstrated the "bias" in length of pregnancy data derived from birth registration procedures by comparing official data for Baltimore with confidential data from three other intracity sources in which LMP dates were given. He did not claim that this bias would disappear from official records if a change to giving LMP date was required, but Baltimore did make this change in its birth registration form a few years later. Starting with the 1957 calendar year, the state of California and the cities of New York and Baltimore replaced the gestation period question by a request for LMP date. The desired interval from LMP to birth was now to be calculated by these vital statistics offices; precision was to replace loose estimation.

Data for California and New York City will serve to illustrate the effect of this change in registration requirements on our knowledge of the interval between LMP and birth. The city of New York assessed this effect very early; special tabulations of the interval between LMP and birth were prepared as soon as birth registrations for the first four months of 1957 were considered complete. The California Department of Public Health, in its Statistical Report for 1958,[4] presented state-wide data for the calculated interval from LMP to birth for that year, comparing the results graphically with the data on weeks of gestation received for the year 1955.

We reproduce in the upper panel of Figure 1 the frequency distributions for period of gestation in weeks for California in 1955 and for New York City in 1956. The corresponding values for gestational interval, as computed from LMP values by California for 1958, and by New York City for the first four months of 1957, are given in the lower panel of Figure 1. The traditional scale of "completed weeks" is used in these frequency distributions.

Just as the forms of frequency distribution are remarkably consistent within each panel of Figure 1, so also the contrast between the two panels is impressive. The statistical abnormalities so noticeable in the upper panel vanish in the lower panel. The contrast between the two types of results achieved by asking for "period of gestation" on the one hand, and by securing LMP date and computing the interval on the other, are striking.

LMP as a Currently Made Record

Since 1934 a statistical study of the basic biology of human reproductive functions has been maintained by one of us in the name of the University of Minnesota.[5,6] This research program is based on menstrual histories recorded currently; it consequently provides highly accurate records of all interruptions of menstruation because of pregnancy. We use 2,614 gestational intervals for live births within this study as a basis for evaluating the accuracy of LMP to birth intervals derived from other sources. Since the data being used as a reference standard are provided by a white population, only births for the white race may be used in comparison with it.

The frequency distribution of the 2,614 intervals from LMP to birth provided by the research program over the period from its inception to the end of 1967 is given numerically in column 3 of Table 2. This table also presents gestational interval data from two birth registration sources for 1966. A special tabulation by single days of gestational interval was provided by the state of California for 198,408 single births occurring in private and county hospitals within its jurisdiction; this is condensed to weeks in column 4 of Table 2. Births

within a special registration area (SRA) composed of California, Rhode Island, and the cities of New York, Baltimore, and Washington, D. C., are given for 1966 in the annual summary of vital statistics for the USA.[7] We have subtracted California from the SRA totals to secure 143,784 gestational intervals for a restricted special registration area (RSRA); these LMP-to-birth intervals appear in column 5 of Table 2.

The cumulative frequencies to upper-

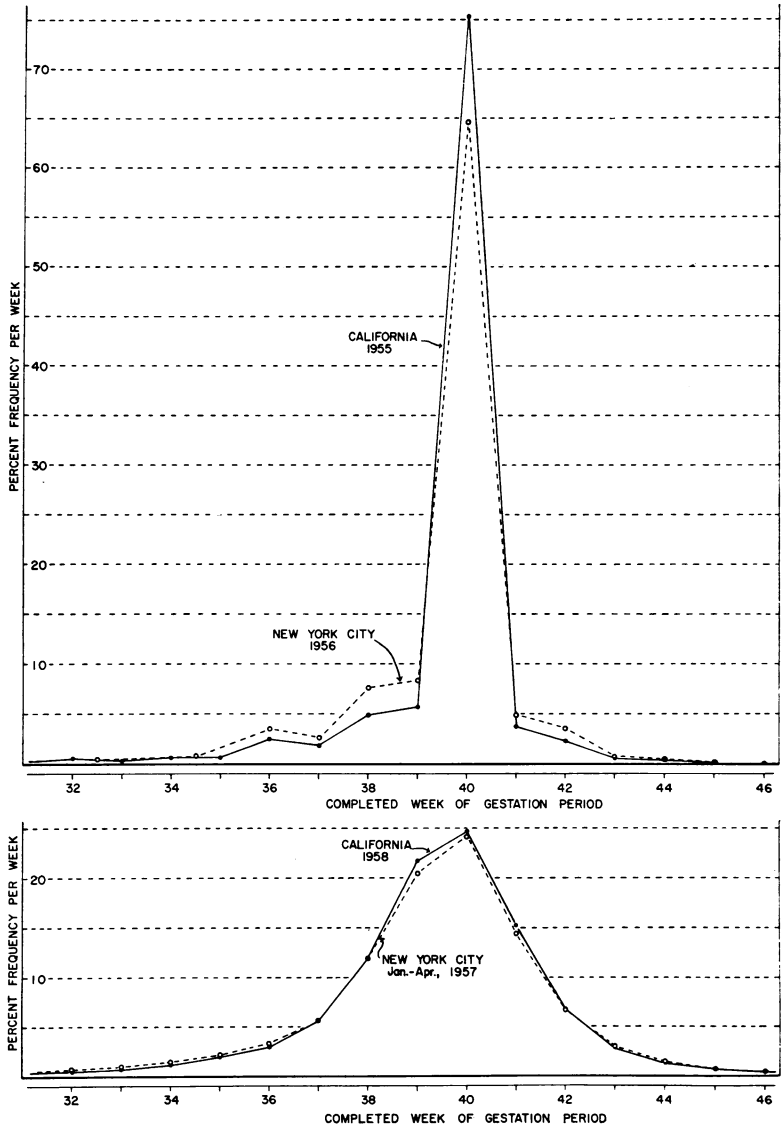

Figure 1—Officially recorded length of gestation in two jurisdictions before (upper panel) and after (lower panel) LMP date requirement in birth rgistration

Table 2—Variation in gestational interval for white births accumulated in a menstrual history research program (MH), 1934-1967, and in two registration areas (California and RSRA*) in 1966

Gestational intervals†		No. births			% cumulative frequency to upper-class boundary		
days	weeks	MH	Calif.	RSRA*	MH	Calif.	RSRA*
1	2	3	4	5	6	7	8
<141	<21	—	89	66	—	0.04	0.05
141–196	21–28	9	850	796	0.34	0.47	0.60
197–217	29–31	11	952	1,538	0.77	0.95	
218–224	32	2	602		0.84	1.26	1.67
225–231	33	12	834		1.30	1.67	
232–238	34	17	1,310	6,252	1.95	2.33	
239–245	35	22	2,276		2.79	3.48	
246–252	36	40	3,767		4.32	5.38	6.02
253–259	37	69	6,049	4,428	6.96	8.43	9.10
260–266	38	134	11,532		12.09	14.24	
267–273	39	324	25,246	58,196	24.48	26.96	
274–280	40	653	43,023		49.46	48.65	49.57
281–287	41	724	45,978	32,796	77.16	71.83	72.38
288–294	42	382	29,194	31,686	91.77	86.52	
295–301	43	125	13,968		96.56	93.58	94.42
302–308	44	47	6,217		98.35	96.69	
309–315	45	26	3,086		99.35	98.25	
316–322	46	10	1,571	8,026	99.73	99.04	
323–329	47	1	796		99.77	99.44	
>329	>47	6	1,068		100.00	100.00	100.00
Total stated		2,614	198,408	143,784			
Not stated		201	39,184	16,532	7.14‡	16.49‡	10.31‡
All births		2,815	237,592	160,316			

* New York City, Baltimore, District of Columbia, and Rhode Island state.
† Current time: subtract one to reach completed unit of time.
‡ Per cent of all births: MH values include 181 cases with LMP not available and 20 wherein LMP is known but pertains to prior birth or abortion.

class boundaries for each of these three series of data are given in percentage form in columns 6, 7, and 8 of Table 2. These percentages are plotted in Figure 2, with freehand curves superimposed on the MH and California points to provide helpful continuity. The RSRA points are too far apart for us to attempt any smoothing by a curve; they are plotted as points marked by + signs.

The absence of any mathematical equations defining the curves in Figure 2 is offset by freedom of these curves from any bias imposed by empirical selection of the form of the equation. The probabilities which may be read directly from the freehand curve undoubtedly correspond more closely to the observed frequencies than any derivable from a mathematical graduation process. Any "over-fitting" involved does not have appeal as a weakness in view of the very large frequencies involved in the present study.

In view of the diversity of sources (geographically, in time, and in the nature of the record) for these data on gestational interval, the agreement be-

tween the distributions in their probability values is surprising. Both centrally and at the extremes of range, the accord of three sets of official records with the results flowing from research is most impressive. Differences between the official data and those from the research program do appear consistently, but in small degree, in the "shoulders" of the curves, the moderate departures from most typical value of 280 days. The presence of relatively small errors of recollection in LMP dates on birth registration forms would be reflected in just such discrepancies in probability curve form. At deviations of approximately 15 days below and above the median, the probabilities flowing from vital records reach their maximum discrepancies from the standard used. These maximum discrepancies are roughly 3 percentage points (10 minus 7) at 265 days, and as much as 5 per cent (93 minus 88) at 295 days of gestation interval. On either side of 265 and 295 days, the deviation of official records from accurate intervals is progressively less. The accord of all series at 280 days testifies to lack of bias in the birth registration data.

A first approximation to measurement of errors of recollection in LMP dates, as recorded on birth registration forms, may be made (a) by using truncated distributions to avoid the open-ended classes, and (b) by assuming the errors to be independent of the LMP date. We find for a comparison of the California and MH data over the range of 32 to 47 weeks that the estimated standard deviation of errors of recollection is 1.07 weeks. If the error distribution is also considered to be a normal curve in form, then one can be 95 per

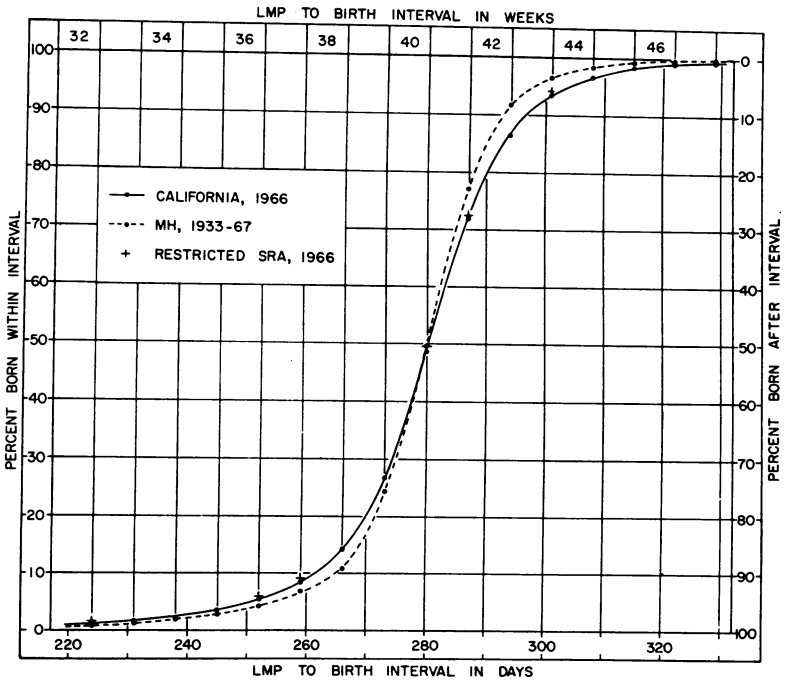

Figure 2—Proportions of births occurring in intervals after LMP date in official registration and menstrual history (MH) records

cent confident that the error of recollection in LMP date will not exceed plus or minus two weeks in any individual case. Our judgment is that this is a very reasonable figure and worthy of general acceptance.

On the Measurement of Time

Age in years satisfies demand for a measure of length of life in many scientific investigations. Although well aware of its negative bias, demographers rarely find it of importance to correct for that bias in their pursuit of precision. Life insurance companies have avoided the adjustment-for-bias problem by presenting their rates in terms of age at the nearest birthday rather than in terms of completed years of life.

Measurement of length of prenatal life has its parallel problem of completed weeks versus the nearest week. Our immediate concern centers on the problems generated when "completed weeks" must be reconciled with days of gestational interval as derived by computer operations, or by subtraction of dates at the office desk.

Time is continuous. Points of time are conceptual infinitesimals on a continuous scale. Each date is a span of time from one midnight to the next, or midday of the date plus and minus 12 hours. The error of measurement of an interval of time between two dates may vary consequently over the range defined by the given difference in dates plus and minus one day. If we knew precisely the time at which a pregnancy commenced, just as we know the time of delivery, the duration of pregnancy would be defined correctly as the difference in the given dates plus or minus as much as one day. If, however, one celebrates one's birthday at high noon on the eventful day, the precise error in timing must be generalized as plus or minus 12 hours, depending on the deviation of the time of birth from midday. In both cases, however, the precise error is trivial; it is also without bias of any consequence.

Age last birthday is a *convenient* measure of length of life. It is the convenience of not having to calculate the nearest birthday that leads to use of the last birthday. Duration of pregnancy measured in completed weeks has equivalence to age last birthday, but it does not have any equivalent advantage in convenience. When we ignore the fractional part of a week to express a gestational interval in completed weeks, we do not avoid errors of judgment; we simply introduce a bias which is too easily overlooked. In this rapidly developing era of computers, the designation of length of pregnancy in terms of weeks will result from grouping a scale of days. A "completed-weeks" scale will then merely add a negative bias factor which was not there before the fractional part was dropped.

When the World Health Organization recommended that premature birth be judged in part by the gestational interval of the birth, devices of slide-rule form were developed in this country to facilitate determination of completed weeks directly from dates. Among these, one issued by the Children's Bureau has served widely in the state offices of vital statistics. Instructions for use of the device leave no doubt that LMP date is the first day of the first week of current time, and that day 8 on this scale must be reached before one week is completed. Day 280 on that scale likewise closes the 39th week; day 281, which introduces a 40th current week, is the first day behind which lie 39 completed weeks.

Computers now widely replacing these devices will use programs written simply to subtract sequential day numbers on a suitable scale of time. The date of LMP corresponds to day zero on this gestational interval scale, and day 280 becomes the last day of the 40th week. Thus, a conflict in time scales origin exists between the devices and the computer process. But day 280 on the completed weeks scale is the same date as day 281 on the current week scale. The devices give the same interval between

two dates, for, whereas the devices count LMP date and ignore birth date, the subtraction procedure rejects LMP date as a counted day and accepts date of birth. The reconciliation of completed weeks with current time in weeks involves a fraction between zero and seven days, not six days as a polemic concerning day 280 may seem to indicate.

At present, presentations of gestational intervals in vital statistics use completed weeks. Precise definition of this term as it applies to gestational intervals has never been stated explicitly. Moreover, the modifier "completed" is all too commonly omitted, leaving the reader in a quandary concerning presence or absence of a bias. The lid should be closed on this Pandora's box. Looking about us as well as ahead, we urge that the gestational interval be defined basically in days as the difference between two dates yielded by standard subtraction processes. Weeks on this scale of differences would be formed as multiples of seven, starting with one through seven. This is an unbiased scale. The fortieth week in which birth may occur, following the LMP date, is thus defined as day 274 through day 280, inclusive. If it is desired to use the completed week scale at any time for an interval, it is one less than the current week scale, the week in which the event occurs.

Discussion

Inclusion of LMP date in the Standard Certificate of Live Birth has been officially recommended for use throughout the United States. Nearly all states replaced "length of pregnancy" by this item in 1968. This action undoubtedly reflects not only widespread confidence in greater validity of gestational intervals computed from LMP dates, but also judgment that the intervals so derived constitute a valuable tool for the study of factors influencing fetal development and mortality. The findings of the present study most certainly substantiate these views. Experience shows that LMP date is obtainable for the majority of deliveries, and that personnel responsible for record completion are usually willing to provide it. In 1966, 85 per cent of the birth certifications in the area requiring it contained the LMP entry.

We have not excluded from this study any live births judged premature by weight or gestational interval. Experience in neonatology does not justify the postulate that babies selected for low weight are, in general, not fully matured. Only a minor proportion of low-weight babies are judged premature on other criteria; nor does it seem reasonable to assume that the rate of intrauterine development of the fetus is nearly constant for all individuals, when the rate of postnatal development of babies is so commonly observed to be highly variable.

The magnitude of variation in gestational interval is a feature of fact and not a reflection of gross human error. When all menstrual periods are currently recorded, LMP is established without knowledge of any impending pregnancy. Nevertheless, approximately 1 per cent of all live births has been observed from such records to occur two months or more before the expected day of confinement, and another 1 per cent still remains to be born over a month later than the expected date.

Birth registration records of LMP date would not be expected to be as precise as those arising from a record of it made at the time. Errors of recollection in some cases, and of transcription in others, sometimes become superimposed on the actual dates. The evidence is that these errors, taken collectively, are relatively small. They have their most noticeable effect on gestational interval probabilities at approxi-

mately 15 days before and after the median values of 280 days. These errors lead to absolute discrepancies at the extremes of range which do not noticeably affect the range of gestational interval values.

Professionals giving prenatal care can accept LMP with more confidence than trite comments imply. It should not need to be emphasized that pregnancy is an important state to every woman. The first symptom of pregnancy is most likely to incite immediate recall of the LMP date as one to remember, if not to record. Recall of LMP date will usually occur at a time when errors of recollection concerning it would not exceed relatively few days in a majority of cases. It is in terms of this date that expectation for delivery is fixed, even if doubt lingers concerning when pregnancy started.

Summary

The time lapse between date of a birth and date of onset of the last preceding menstrual period (LMP) of the mother is the only commonly available measure related to the gestation period. Preferably designated at the gestational interval, this measure of length of prenatal life is widely useful, provided that errors of recollection of LMP do not intrude as a disturbing factor. Current recording of menstrual periods eliminates this error.

Since 1950, "length of pregnancy" entries on birth registration forms have been officially recognized as of doubtful validity. In 1957, the cities of New York and Baltimore, and the state of California, independently elected to replace this entry by requiring "date of the last (normal) menstrual period" on the birth registration form. It is not well known that the District of Columbia initiated this change nearly a decade before. But credit belongs to the two cities and one state for effective leadership in bringing about change. Their provision of new data for the gestational interval is shown to remove serious deficiencies from birth records requiring only a "length of pregnancy" entry.

The official vital statistics for the year 1966 (a) of the state of California, and (b) of the combined records of two major cities and the state of Rhode Island, all requiring LMP date instead of length of pregnancy at birth registration, are shown to yield data conforming very well indeed to desirable standards. This holds true when tested against highly accurate data on 2,614 gestational intervals provided in a research program by current recording of menstrual onsets. One can be 95 per cent confident that the bounds for recollection error in LMP dates is within plus and minus two weeks.

We urge that the gestational interval scale be based on simple subtraction of dates, and that this scale be classified into weeks in accord with the nearest unit principle to avoid problems of bias correction. Now that the Standard Certificate of Live Birth calls for the LMP date entry, this becomes an important step forward toward greater precision and consistent measurement practice. Although comparable to the scale of "age last birthday," the scale of completed weeks now appears to be less useful than originally was the case.

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Urgently Needed

The January, February, March, May, July, October, December, 1969, and January and February, 1970, issues of the American Journal of Public Health and the supplement, Medical Care: The Current Scene and Prospects for the Future, are urgently needed. Members who wish to donate their copies should send them to:

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