

may even be, considering the spider's differential sensitivity, that higher frequency vibrations, despite their smaller amplitudes, are a more intense stimulus than lower frequency vibrations.

W. MITCHELL MASTERS
HUBERT MARKL

Fachbereich Biologie,
Universität Konstanz,
D-7750 Konstanz,
Federal Republic of Germany

References and Notes

1. C. V. Boys, *Nature (London)* **23**, 149 (1880).
2. H. Frings and M. Frings, *Ecology* **47**, 578 (1966); A. A. Grünbaum, *Psychol. Forsch.* **9**, 275 (1972); G. W. Peckham and E. G. Peckham, *J. Morphol.* **1**, 383 (1887).
3. W. M. Barrows, *Biol. Bull. (Woods Hole)* **29**, 316 (1915); H. Peters, *Z. Vergl. Physiol.* **15**, 45 (1931); M. H. Robinson and J. Olazarri, *Smithson. Contrib. Zool.* **65**, 1 (1971); P. N. Witt, *Biosci. Commun.* **1**, 7 (1975).
4. F. J. Liesenfeld, *Z. Vergl. Physiol.* **38**, 563 (1956).
5. A. Finck, G. M. Stewart, C. F. Reed, *J. Acoust. Soc. Am.* **57**, 753 (1975); B. Krafft, *Symp. Zool. Soc. Lond.* **42**, 59 (1978); D. A. Parry, *J. Exp. Biol.* **43**, 185 (1965); E. Tretzel, *Z. Morphol. Ökol. Tiere* **50**, 375 (1961); F. Vollrath, *Science* **205**, 1149 (1979).
6. K. Graesser, thesis, University of Frankfurt (1973).
7. R. B. Suter, *Behav. Ecol. Sociobiol.* **3**, 283 (1978).
8. J. W. Burgess, *Anim. Behav.* **27**, 157 (1979); C. Walcott, *J. Exp. Biol.* **40**, 595 (1963).
9. A fourth vibration type, torsional motion of the radius, is also possible, but we have as yet no way of measuring it and must neglect it here.
10. For a more complete discussion of laser vibrometry, see P. Buchhave, *DISA Inform.* **18**, 15 (1975); A. Michelsen and O. N. Larsen, *J. Comp. Physiol.* **123**, 193 (1978).
11. It is not always possible to position the laser beam precisely along the correct path for optimal detection in a chosen direction, especially when measuring longitudinal vibration where the optimal path is then directly along the axis of the strand, but so long as the angle between the correct path and the actual path is $< 30^\circ$ (in practice, $< 15^\circ$ was always attainable), the underestimate of the true vibration amplitude will be < 1 dB.
12. Adult female spiders collected near Konstanz, Federal Republic of Germany, were kept (22° to 27°C , 13 hours of light and 11 hours of darkness) in wooden frames (45 by 45 by 6 cm) covered with removable plastic foil, in which they readily built webs. They were given water almost daily and fed flies of ~ 40 mg every 2 to 3 days. Measurements were made on freshly spun (< 24 hours) empty webs at 22° to 27°C , and at relative humidity of 40 to 60 percent.
13. The tip of the vibrator, a ceramic bimorph from a phonograph cartridge, was attached to the radius with beeswax without changing the equilibrium position of the strand. Orientation of the vibrator determined the type of vibration excited. The amplitude of the vibrator tip [0.1 to 30 μm (root-mean-square) depending on frequency], measured with the vibrometer (DISA Elektronik A/S, DK-2740, Skovlunde, Denmark) served as reference (0 dB) for the web transmission curves. Stability of the reference vibration was better than ± 1 dB throughout the session, which could last up to 10 hours.
14. A spectrum analyzer (Nicolet Scientific Corp., Northvale, N.J., model 446A) operating in the peak storage mode measured the output of the vibrometer; it served as a narrow-band filter to improve the signal-to-noise ratio of measurements and provided digital readout of frequency and amplitude. Between 40 and 100 measurements of signal amplitude over the range 1 to 10,000 Hz were made at a given point in the web, compared to the input (J_3) vibration at the corresponding frequency, and plotted against frequency (Fig. 2). To ensure that the vibrometer worked on spider webs, we measured the motion of the vibrator and the web adjacent to it. Readings agreed within ± 2 dB. Measurements of one or more vibration types were made on 18 webs spun by 11 spiders. Transversal vibration was measured eight times, lateral nine times, and longitudinal six times, at two to four points for each type.
15. R. M. Langer [*Am. Zool.* **9**, 81 (1969)] discusses the physics of spider webs.
16. F. G. Barth, in *The Insect Integument*, H. R. Hepburn, Ed. (Elsevier, Amsterdam, 1976), p. 445.
17. We do not know whether the spider can distinguish longitudinal from transverse and lateral vibration, nor can we infer from our results that the spider should be able to do so in order to locate prey. If the spider were equally sensitive to all three types and the prey produced equal-amplitude vibration in all three directions, the better transmissibility of longitudinal vibration would ensure its domination in the total (combined) signal, thus providing directional information.
18. Higher frequency vibrations have been reported in sheet webs and cobwebs (8).
19. F. J. Liesenfeld, *Biol. Zentralbl.* **80**, 465 (1961); C. Walcott and W. G. van der Kloot, *J. Exp. Zool.* **141**, 191 (1959).
20. B. Dumortier, in *Acoustic Behavior of Animals*, R.-G. Busnel, Ed. (Elsevier, Amsterdam, 1963), p. 346; H. Esch and D. Wilson, *Z. Vergl. Physiol.* **54**, 256 (1967); W. M. Masters, *J. Comp. Physiol.* **135**, 259 (1980).
21. Our preliminary measurements show that at least some trapped insects produce vibrations in the kilohertz range.
22. We thank A. Moffat for her many contributions to this work, A. Michelsen for discussions on laser vibrometry, K. Thaler for identifying the spiders, and T. Eisner and J. Tautz for comments on the manuscript. Supported by a NATO Postdoctoral Fellowship (to W.M.M.) and by Deutsche Forschungsgemeinschaft grants Ma 374/13 and Ma 374/15-2 (to H.M.).

23 September 1980; revised 28 January 1981

Age at Menarche: A Misunderstanding

Abstract. *Through a misinterpretation of historical data, the age of menarche in the 19th century is erroneously taken to have been 17 years. This error has resulted in unwarranted beliefs about change in female sexual maturation in the United States.*

Until recently, historical data about the age of menarche were probably of interest only to a few specialists. Much of the current publicity about the historical age of menarche has to do with the belief that in American girls menarcheal age has dropped from 17 years in the 19th century to 12.5 years today. This supposed trend has been regarded as the most significant factor in increasing teenage sexuality and the "growing problem of teenage pregnancy" (1). Stories about it have appeared in almost every kind of popular journal from *Newsweek* to *The Nation*, and in scholarly literature of anthropology, psychology, child development, nursing, and other fields. It apparently has even entered into predictions of demographic trends. Notions about the magnitude of the change in menarcheal age are based upon misinformation. There has been some change, but very much less than has been assumed.

In the United States in the present day the mean age at normal menarche is estimated to be 12.3 years (some would say 12.5 or 12.6) and the range from 9 to 17 years. Individual differences are attributed to differences in general health and nutrition, heredity, psychosocial development, and a number of other factors. Pediatricians would normally do a diagnostic work-up for girls who have not begun menstruating by 16 (2). It is important to emphasize the broad range of menarcheal age, because in the past each clinician contributing to the subject did so, with a few exceptions, on the basis of a very small sample, and historical data can be skewed because of this.

The informed guesses and best estimates of the past can be tested against age at first pregnancy, age at marriage, and other factors traditionally dependent upon menarche. Roman law, for example, assumed that females were mature at the age of 12, and classical writers described menarche as taking place sometime between the ages of 12 and 14 (3). Medieval authorities tended to agree. Much of our information comes from the later Middle Ages. One of the best indicators of medieval assumptions is in the gynecological text *De passionibus mulierum*, attributed to Dame Trotula, extant copies of which date from the 13th century. There are numerous copies of the English provenance, 18 at Oxford alone. In 12 of the English manuscripts there are tables on menarche, and the ages appear to vary according to the scribe's personal knowledge. Most of the Oxford copies put menarche at age 14; the most common other age given is 13 (4). Other medieval writers set it within the same range, 13 or 14 (5). In Islamic countries it was a criminal act to have sexual relations with a woman before she had menstruated. Before a marriage could be consummated women were to examine the girl to see that she was physically prepared, and Arabic law set a range of ages for this examination between 12 and 13 (6).

Some of the 19th- and early 20th-century data put menarche slightly later than classical or medieval authorities do. J. Whitehead, writing in the 1840's, put the average for Manchester working-women at 15 years 7 months and for "educated ladies" at 14 years 6 months (7). E. W. Murphy reported that obstet-

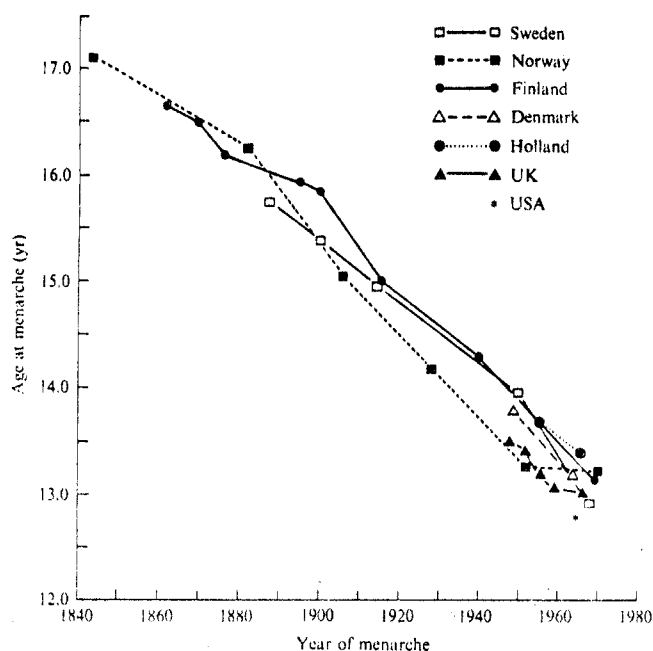


Fig. 1. Diagram in P. B. Eveleth and J. M. Tanner, *Worldwide Variation in Human Growth* (Cambridge University Press, Cambridge, England, 1976), figure 168(a), page 218. Reproduced by permission of the publisher. Many slight variations of this diagram have been published.

Trend toward earlier median age of menarche in Europe from 1840 to 1970.

ric patients in University College Hospital, London, in 1930 had begun menstruating at 14 years 4 months (8); Rigden's estimate for similar patients in 1855 was 15 years 5 months (9). Menarche for London middle-class women was set at 15 years in 1880 by another observer (10). For Scottish women in 1870 it ranged between 15.5 and 16.5, upper-class women having earlier menarche than lower-class women (11). In Germany in 1869 the average was estimated as 15 years 7 months (12). American women seemed consistently to begin menstruation earlier than European. Edward B. Foote, author of the best-selling American home medical manual in the last part of the 19th century, set the age of menarche as between 12 and 14 (13), and most American authorities followed suit. Statistical data gathered in 1905 led one authority to set it at 14 years (14). Others have continued to set a later date of 15 years 7 months (15). Girls who menstruated before 12.5 were considered precocious (16).

Where, then, does the age of 17 become established as the age of menarche in the 19th century? The source of this statement turns out to be an authority on physical development, J. M. Tanner. In 1962 Tanner wrote that "age at menarche has been getting earlier by some 4 months per decade in Western Europe over the period 1830-1960" (17).

Tanner used a graph to illustrate this statement, but a close reading indicates that his data do not verify it. Figure 1 is a similar graph from a more recent publication of Tanner's, in which a similar

statement appears (18, p. 218). For the 19th century the graph shows data only from Norway, Finland, and Sweden, and some of that from a very small sampling. It does not show any 19th-century data from American and English or other sources that Tanner cites. The American, Danish, Dutch, and British data in the graph begin with the 1940's. If the Dutch, British, German, or other available data were graphed from 1840 onward, the decline would be seen to be from between 14 and 15 years to between 12 and 13. Only one of Tanner's sources reports menarche at 17, and that is for Norway in 1844 (19). Since there is much individual variation, and menarche is dependent on diet, skeletal maturation, heredity, and perhaps other factors, a small, isolated Norwegian sample might not represent all of Norway. In fact, elsewhere Tanner states that menarche occurred at 15 in Norway in the 19th century (20). Some of Tanner's data put the age of menarche in the 19th century at 16, but all other 19th-century data show ranges of 14 to 15 years.

Present-day surveys conducted by a number of authorities indicate a variation between 12.5 and 14.5 in most of the world. The Bantu, some of the Maya, and some residents of New Guinea exceed 15 years. One isolated New Guinea group averages over 17, according to one observer (21). The fact that there is such a standard range today in spite of the differences in the state of nutrition would seem to verify that traditionally menarche occurred when classical and medieval medical authorities said it did, be-

tween 12 and 14 years of age, with individual and other variations. For the 19th century the data offered by Tanner suggest that the age 17 is derived from an isolated report on a small sample, and that it is well within the range of a standard deviation and should not be taken as an average.

Undoubtedly there has been some drop in menarcheal age in the United States since the 19th century, to under 13 in the 1980's. Women in most European countries still have menarche sometime after their 13th birthday. This difference is an additional reason for caution in using 19th-century European data to generalize about the changing age of menarche here.

VERN L. BULLOUGH

Faculty of Natural and Social Sciences, State University College at Buffalo, Buffalo, New York 14222

References and Notes

1. *Newsweek* 96, 51 (1 September 1980).
2. Various pediatric texts give slightly different ages. This statement is taken from *Nelson Textbook of Pediatrics*, V. C. Vaughan and R. J. McKay, Eds. (Saunders, Philadelphia, ed. 10, 1969), p. 1373. See also S. Kaplan, *Growth Disorders in Children and Adolescents* (Thomas, Springfield, Ill., 1964), pp. 12-13; J. G. Hughes, *Synopsis of Pediatrics* (Mosby, St. Louis, 1967), p. 32; D. W. Smith, *Growth and Its Disorders* (Saunders, Philadelphia, 1977), pp. 718-773.
3. M. K. Hopkins, *Popul. Stud. (London)* 18, 309 (1964-65), especially pp. 310-313.
4. A survey of the manuscripts can be found in J. B. Post, *ibid.* 25, 83 (1971). For an English translation see Trotula, in *The Diseases of Women*, E. Mason-Hohl, Ed. and Transl. (Ward Ritchey, Los Angeles, 1940).
5. V. L. Bullough and C. Campbell, *Speculum* 55, 324 (1980).
6. *Koran II, The Cow*, 234; Ali ibn abu-Bakr, *The Hedaya or Guide: A Commentary on Mussulman Laws*, C. Hamilton, Ed. and Transl. (Premier Books, Lahore, West Pakistan; reprint, 1957), book 7, chap. 2, p. 186; R. Levy, *The Social Structure of Islam* (Cambridge Univ. Press, Cambridge, England, 1957), p. 17.
7. J. Whitehead, *On the Causes and Treatment of Abortion and Sterility* (Church, London, 1847).
8. E. W. Murphy, *Dublin J. Med. Sci.* 26, 177 (1844).
9. W. Rigden, *Trans. Obstet. Soc. London* 11, 243 (1869).
10. A. E. Giles, *Med. Chron.* 34, 161, 254 (1901).
11. J. M. Duncan, *Fecundity, Fertility, Sterility, and Allied Topics* (Black, Edinburgh, ed. 2, 1871). This includes data on 16,301 women.
12. H. H. Ploss, M. Bartels, P. Bartels, *Woman: An Historical Gynecological and Anthropological Compendium*, E. J. Dingwall, Ed. (Mosby, St. Louis, 1936), p. 564.
13. E. B. Foote, *Plain Home Talk . . . Embracing Medical Common Sense* (Wells, New York, 1871), p. 454.
14. C. A. Mills, *Hum. Biol.* 9, 43 (1937); *ibid.* 22, 71 (1950).
15. C. V. Fluhmann, *The Management of Menstrual Disorders* (Saunders, Philadelphia, 1956).
16. R. P. Harris, *Am. J. Obstet. Dis. Women Child.* 3, 611 (1871).
17. J. M. Tanner, *Growth at Adolescence* (Blackwell, Oxford, ed. 2, 1962), p. 152.
18. P. B. Eveleth and J. M. Tanner, *Worldwide Variation in Human Growth* (Cambridge Univ. Press, Cambridge, England, 1976).
19. G. Backman, *Acta Anat.* 4, 421 (1948).
20. J. M. Tanner, *Sci. Am.* 229, 43 (September 1973).
21. These more current figures are also dependent on Tanner's efforts. They are reported in (18), pp. 212-217.

10 October 1980; revised 1 May 1981