proposition to most people, who will successfully ignore this moral point and continue to insist on meat as long as it is available. It may not be available indefinitely, however; as the world's population increases, there must come a point where industry will cast an unromantic eye at cow pastures, sheep paddocks and other such inefficient institutions, and will insist on building something useful there.

My own research field is not a biological one, and the following may not be very practical but, I believe, ought to be given some thought: have tissue-culture specialists thought of applying their techniques to the culturing of edible animal tissues? A number of advantages over conventional animal culture spring to mind, the most important one perhaps the fact that, theoretically at least, one should be able to produce more "meat" in a given volume or area than by sending cows out to graze (even if the American cattle industry continues to rationalize its business). The technical problems and costs involved may well be tremendous, but this will become less and less relevant as the population increases. The anti-killing moralists would concede, I think, that a mass of cultured animal tissue is (except nutritionally) little different from cultured plant tissue (the hidden moral point—that, given an increasing human population density, we will eventually not be able to allow other animals much space—may be conveniently ignored here).

If the technical problems are soluble, there would be gastronomical advantages in this—there seems to be no reason why one should not culture a vast variety of "meats"; there will be no such thing as a rare and costly tissue—although it is doubtful that this "meat" would turn out like the fibrous stuff we eat now.

I envisage meat factories for the year 2000.

Yours faithfully,

D. Britz

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Multiple Authorship

Sir,—In this day of "publish or perish" one increasingly encounters papers authored by several persons. A high percentage of team work, and thus a high percentage of multiple authorship, can, in fact, be considered a reflexion of the state of advancement of a particular science[1]. The January 30, 1970, issue of *Science*[2] reporting on the scientific results of the Apollo 11 moon expedition is an excellent though exceptional case in point. In this issue there were 144 papers authored by a total of 619 persons, an average of 4.3 authors per paper. One paper was by 18 authors (is this a record?), two other papers by 14 authors each, one by 12, and two by 11 each; at the other extreme, ten papers were authored by only one person. Merely the names and addresses on the paper with 18 authors required five column inches of space.

The very number of publications listed in a bibliography of a scientist often gives an inflated estimation of the scientific contribution of that person. Obviously more entries are possible if a person participates in a great deal of team work. What is needed is some method to rate the equivalent value of a scientific paper authored by several persons. Each paper, no matter by how many authors, should count as unity (one equivalent paper). That is, the paper with 18 authors, if listed in bibliographies by each of the 18 authors, should count as one paper total, and not 18. The following table presents sample equivalent values for papers with up to six authors:

Paper authored by:	Values of equivalent papers per author — Author: A	B	C	D	E	F
A	1.00					
AB	0.67	0.33				
ABC	0.50	0.33	0.17			
ABCD	0.40	0.30	0.20	0.10		
ABCDE	0.33	0.27	0.20	0.13	0.07	
ABCDEF	0.29	0.24	0.19	0.14	0.09	0.05

For example, three papers individually authored by "X" (total of 3 equivalent papers) are "worth" slightly more than six papers authored by "Y" as follows: Y, YB, YB, AY, ABY, ABCY (total of 2.94 equivalent papers), even though "Y" has twice as many publications as "X".

There are two possibilities for situations with six or more authors per paper since the contribution of the sixth and additional authors ranges from 1/21 to $1/\infty$ (euphemism for essentially zero: for example, the contribution of author number 18 is 1/171 or 0.006 equivalent paper): (1) the contributors in excess of five might well (preferably!) be relegated to acknowledgment status in a footnote, or (2) they might be listed alphabetically (as is currently done with the more notable movie stars in epics).

A final plea: in personal bibliographies of scientists, entries for papers by several authors should include a list of the authors in the sequence they appear on the paper. Thus, in a bibliography for author "Y" a paper by "ABY" should be cited as "by ABY" and not, as is so commonly done, as "with AB", since the latter gives no indication of the ranking of the authors (and who did all the work).

I leave it to other workers to develop more exact and complex relationships taking into consideration other significant variables (length, type of paper (for example, taxonomic monograph, review paper), etc.).

Yours faithfully,

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[1] Manten, A. A., *Earth Sci. Rev.*, **6**, 181 (1970).
[2] *Science*, **167**, 417 (1970).

Cycles in Behaviour

Sir,—The whole approach of analogizing between the natural sciences and the behaviour of human society could well distinguish itself only by its naivety. Nevertheless, history is strewn with examples of the fertility of cross-disciplinary activities, and at least one Great Man has urged us to "only connect".

Young and Ziman (*Nature*, **229**, 91; 1971) concern themselves with establishing a nomenclature to facilitate discussion of cycles in social behaviour, by borrowing terms from physics. This they do very convincingly except that they do not make the important distinction between an oscillating function of time and a periodic function of time. An oscillating function is normally understood to be one which exhibits a sequence of turning points: thus one speaks of super-critically and sub-critically damped harmonic motion, where the former exhibits a monotonic trend toward some asymptote and is non-oscillatory, and the latter is oscillatory but not periodic. A periodic function would exhibit a waveform that is exactly repeated over intervals of the period.

The distinction between oscillations with regularly spaced turning points and periodic motion vanishes when the ordinate is non-numerable in the sense that an event can only be said to occur or not occur, for then only the intervals between events matter. However, there clearly exist cases where more quantification of a social variable is possible. For instance, as the authors point out, historical events sometimes display temporal influences that decay in a manner suggestive of a relaxation time. The "modulation" of a periodic function such as the yearly religious festivals by a decaying historical influence could clearly result in an oscillating social variable that is aperiodic.

Perhaps it is sometimes appropriate in discussing the behaviour of human society to use a logarithmic rather than a linear scale of time. The significance to us of a fixed interval of time seems to depend on average roughly how long ago that interval is placed. This follows if events have relaxation times. The "larger" the event and/or the longer its relaxation time the longer its significance: the memory we now have of some interval in history depends on the sum of its remnant influences, and the farther back the interval the less cause, on average, we now have to remember it. History, archaeology, geological eras, scientific papers, personal experience and future forecasting all seem to imply a roughly logarithmic concept of time ahead and time past.

The existence of relaxation times follows both from a subsequent accommodation by society of the effects of a historical event, and from failing memory. Clearly these two causes are not always distinct.

Yours faithfully,
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Obituary

C. V. Raman

MODERN science started taking root in India only in recent times. Sir Chandrasekhara Venkata Raman, who died in November at the age of eighty-two, was the outstanding figure during the last half century in this renaissance and, in more than one sense, he may be regarded as its originator and leader. Great as his personal contributions to science have been, greater have been his achievements in training and inspiring a large number of brilliant, self-reliant and distinguished Indians who have made significant contributions not only to pure physics but also to areas such as meteorology, seismology, geology, soil physics and mathematical physics. It is common knowledge that Raman himself had no training in foreign laboratories. He started his scientific career without any external stimulus and attained great eminence by his own individual effort. Many of his pupils and associates did likewise. The fact that they had built up flourishing and distinctive research schools without relying too much on foreign assistance reveals the profound influence exerted by the great leader on his colleagues.

He was born at Trichinopoly in south India in 1888 and was educated at the Hindu College, Visakhapatnam, where his father was professor of mathematics, and at the Presidency College, Madras. Even as an undergraduate, Raman did original work in acoustics and in optics, and his first scientific publications appeared as early as 1906 in *Nature* and in the *Philosophical Magazine* when he was in his eighteenth year. In the decade that followed, by a strange turn of events, he was an officer of the Indian Finance Department till 1917, but kept up scientific interests, studying the dynamics of vibrations and sound, and the theory of musical instruments. Those early studies culminated in his publishing in 1918 an article of some 158 pages dealing with the theory of the musical instruments of the violin family. He also contributed some years later an article on the theory of musical instruments to the *Handbuch der Physik*.

The year 1921 was important in his scientific career, as then began his work on the scattering of light. By 1924 he made significant contributions and was invited to open a symposium on the scattering of light at the Toronto meeting of the British Association. In fact, his researches in the seven years that followed dealt with different aspects of the scattering of light and led to the discovery early in 1928 of the phenomenon that now bears his name—the Raman effect. The effect can be seen when monochromatic light is diffused or scattered by matter. It occurs because, while most of the scattered light has the same frequency as the incident light, a definite fraction undergoes a change in frequency by exchanging energy with the matter.

While the discovery of this phenomenon was his outstanding contribution during the many years of his scientific work, he made significant contributions to allied areas such as ultrasonics, diffraction of light, photoelasticity, X-ray diffraction, magnetism and magne-crystalline action, electro and magneto-optics, crystal dynamics and so on. He also had a deep and aesthetic appreciation of nature and a scientific interest in the colours of birds, beetles and butterflies that evolved, in his later years, into a study of the colours of flowers and other natural objects. In addition, he made extensive contributions to the physics of vision and human hearing.

To realize the impact of the discovery of the Raman effect on the subject of physics as a whole, one should note that with the more recent discovery of the laser, the Raman effect has again become an area of great interest to physicists. The laser has introduced a new age of excitement in the field of light scattering, one in which it has become possible to study issues only accessible to strong sources of illumination such as those provided by lasers and in which a new effect has appeared, the Laser–Raman effect.

Honours were showered on Professor Raman during his lifetime. They are too numerous to be cited here. Honorary degrees from universities, fellowships from learned societies and medals and certificates from scientific institutions of many countries were received by him in large numbers, indicating the brilliance and originality of his researches, the truly international character of the recognition which his work received and the permanent place which his contributions have earned for him in the history of world science. He was awarded the Nobel Prize for Physics in 1930, two years after he discovered the Raman effect.

But for a brief period of about ten years during which he served as an officer of the Indian Government, he devoted all his life and all his energies to fulfilling his one ambition which was to secure a prominent place for India on the scientific map of the world. He has succeeded in a fair measure in achieving this objective. His singular and unswerving devotion to science, his uncompromising attitude towards any attempt made to draw him out of his chosen path, his refreshingly independent way of looking at things, his unique ability to expound intricate scientific discoveries to large audiences and, above all, his fine and delicate sense of humour are so well known, that his colleagues who knew him intimately admired him as much for these qualities as they admired him for his contributions to science. Many institutions and universities in India have benefited by his influence, advice and support. He was the Founder President of the Indian Academy of Sciences and continued to be its president till his death. In that capacity, he was looking after the Proceedings of the Academy, which were published with unfailing regularity during the past forty years. He was also the president of *Current Science*, a fortnightly journal published from Bangalore.

After retirement from the Indian Institute of Science, he worked at the Raman Research Institute in Bangalore, an institute founded by him and to which he gave all his property including the money he received with the Nobel award. The Raman Research Institute today houses, among other things, an unusual collection of precious stones, gems and other rare items of great scientific interest and value. The institute together with the traditions which he established remain as his great legacy.