Weight-Watching at the University: The Consequences of Growth

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The great increase in university enrollment during the decade of the 1960's has been much remarked. Little attention, however, has been paid to the change in the *distribution* of the student population which took place during the same period (Table 1). In the fall of 1958, only ten institutions had total enrollments of more than 20,000, and these accommodated 8 percent of the national student population. Of these institutions, only one had an enrollment of more than 30,000, and it accounted for only 1 percent of the national total. Eleven years later, there were no fewer than 65 giant institutions in the over-20,000 category, and they accommodated 27 percent of the national total; of these, 26 were supergiants with more than 30,000 students, and they accounted for 15 percent of the national total. The growth of the student population during this period was thus accompanied by a trend toward the concentration of students in truly immense multiversities whose total population often exceeds that of the great cities of medieval times. The "community of scholars" has, therefore, undergone a radical transformation: in sheer size, the modern multiversity resembles medieval London rather than Oxford.

In principle, the increase in college enrollment could have been met by an increase in the number of institutions in each size category rather than by a policy of enlargement. In Great Britain, for example, the Robbins report of 1963 recommended the founding of six new universities and the expanding of regional colleges, in order to keep the enrollment of all institutions below 10,000 (*1*). In America, a different policy was implemented in virtually every state: the state universities, already large, were enlarged still further. This policy decision represented a choice for enlargement rather than multiplication, concentration rather than decentralization. The choice probably reflects two underlying assumptions. One is the conventional American notion that bigger is better. The second, a more sophisticated version of the first, is that continuous growth is at least manageable and, in any case, unavoidable (*2*). We wish to question both assumptions.

First, the most elementary experience with tools demonstrates that bigger is not necessarily better. One cannot do fine inlaying with a sledgehammer, or dentistry with a pickax. In short, size and function are intervolved. For every function, there appears to be an optimum size, or rather a useful range of sizes outside of which dysfunction results. Growth up to the optimum size range may be considered functional, growth beyond that range dysfunctional. We will consider both functional and dysfunctional consequences of university growth.

Second, everything we have learned from the study of biology argues against the proposition that continuous growth should be accepted as unavoidable or assumed to be manageable. Indeed, one of the most striking features of living organisms is the presence of homeostatic mechanisms, which act to limit growth. The existence of these mechanisms demonstrates that evolution has selected against continuous growth, which must, therefore, be dysfunctional. Conversely, when these mechanisms fail, as in the familiar case of neoplastic growth, the result is usually pathological. In short, biological examples suggest that continuous growth cannot be managed at all and that survival depends, instead, on preventing it.

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Scale Effects in Biology

Intrinsic factors limit the growth of biological systems in accordance with a general physical principle first stated by Galileo in 1638 (*3*). He demonstrated that scale itself has functional consequences, because certain physical properties of a system of interacting parts vary differently with variation in the system's size. As a result, the way a system functions depends on its size.

Bertalanffy restated the principle in a different form: "It is a truism in engineering that any machine requires changes in proportion to remain functional if it is built to a different size" (*4*). A branch of theoretical physics, the theory of models, concerns itself with questions of this kind (*5*).

Biological systems are, of course, not exempt from this constraint, as Galileo himself realized (*6*). General application of the principle to biological structure began with D'Arcy Thompson's *On Growth and Form* (*7*), first published in 1917, and has since been extended to other aspects of biology (*8*). We will illustrate this kind of analysis with two well-known biological examples.

Consider the manner in which the transport of metabolites and excretion products must limit cell growth. Almost all cells range in diameter from about 5 to about 100 micrometers. This range of sizes is remarkably restricted, as compared with the range of sizes of animals. An elephant, for example, is roughly 125,000 times larger than a mouse, but the cells of both animals are of the same order of magnitude (*7*). The restricted range of cell sizes is attributable to the fact that metabolic demands are proportional to cell volume —that is, to cell diameter cubed— whereas the area of the cells' surface, to and from which metabolites and reaction products must diffuse, is proportional to cell diameter squared. Accordingly, the demand for metabolites increases much faster with increasing cell size than does the supply of metabolites. The narrow range of size exhibited by typical animal cells is presumably a biological adaptation to this intrinsic physical limitation.

Another example is the manner in which the structural strength of limbs must limit the growth of trees and of terrestrial animals. From physical principles, it is known that the load which a column (for example, a leg or a tree) may sustain without bending

Table 1. Distribution by size of universities in the period from 1958 to 1969. Because of a change in the way educational statistics were collected over the period surveyed, the data for 1958 represent only degree-credit enrollment in accredited schools (*31*, *32*), whereas the data for 1969 represent both degree- and nondegree-credit enrollment at both accredited and nonaccredited schools (*33*). This discrepancy should, however, affect the overall distribution only marginally.

Size	Fall 1958 (*31, 32*)			Fall 1969 (*33*)		
	Enrollment	National enrollment (%)	Schools (No.)	Enrollment	National enrollment (%)	Schools (No.)
10,000–19,999	609,699	19	45	1,589,323	20	114
20,000–29,999	223,871	7	9	924,830	12	39
30,000 and over	32,990	1	1	1,180,983	15	26

is proportional to its cross-sectional area or diameter squared (*9*). On the other hand, the weight of an organism is proportional to its volume or mean diameter cubed. Thus, if an animal were scaled up, its weight would exceed the ability of its limbs to support it. The biological adaptation to this physical constraint requires a disproportionate increase in limb diameter with increase in size—for example, the huge legs of elephants. A terrestrial animal very much larger than an elephant would be quite immobilized by the bulk of its legs. Here again, as in the case of cells, the physics of the situation appears to dictate an upper limit on workable size.

Many other examples have been given (*10*), all of which have this form: if one constructed a perfect model of a bird to the scale of an elephant, the resulting animal couldn't get off the ground. In other words, the commonplace notion of "scaling up" is physically false.

It would be remarkable indeed if social institutions such as universities, whose interacting parts are human organisms, were not subject to so fundamental a principle. Social phenomena are complex, but this does not mean that they take place in a universe wholly different from that of physical and biological phenomena. Rather, we think it likely that there are social counterparts to at least the broader generalizations which characterize the relationship of parts in the natural world. With this in mind, we examine the consequences that flow from "scaling up" the university.

Dysfunctional Growth

Various dysfunctions have attended university growth. Some of them appear to be static consequences of scale, similar to the biological examples discussed above, while others are dynamic consequences of the growth process itself.

1) *Diffusion*. A sprawling campus poses logistic difficulties for pedestrians. At the same time, a large, urban university creates traffic congestion as people diffuse to and from by car. The multiversity seems bent on promoting both disabilities simultaneously. Moreover, continuous building expansion on or around the campus—it sometimes seems that the hard hat has replaced the mortarboard as the proper ornament for large state universities—aggravates both difficulties.

2) *Absence of community*. The myth of the multiversity as a community of scholars lingers on. The persistence of this phrase suggests a general recognition that a community provides a good environment for scholarship and education. In order for members of a group to comprise a community, it is necessary that, by and large, they know one another. But people have a limited capacity to associate names with faces, or to associate either with previous encounters; the limiting number is probably in the hundreds. If it is true that a community constitutes a good environment for scholarship, then university growth beyond a rather small size becomes progressively more dysfunctional as it eliminates, at one level after another, the possibility of community.

3) *Dead-end overspecialization*. There are probably numerical limits to community size, determined by the number of individuals with whom a single individual can make other than glancing contact. For a scholar, the microenvironment is the community of colleagues with whom he comes in contact, by virtue of physical proximity and shared concerns. He meets them in the hall, on the quad, at the table, or at faculty meetings. Out of these encounters come the friendships, banter, argument, and give-and-take that nourish personal and intellectual growth.

Giant universities hinder precisely this process of maturation among their faculties. In a small college, the individual scholar's microenvironment can include the entire faculty: men of letters, artists, scientists. In a somewhat larger college or university, the microenvironment is narrowed: humanists may still run into one another, but scientists are administratively and geographically isolated in another part of the campus. Finally, in the giant multiversities, the microenvironments become truly microscopic: a biochemist's immediate community is two dozen other biochemists, rather than zoologists, chemists, and mathematicians, let alone humanists; the immediate community for a student of English literature becomes five dozen other students of English literature—whose interests differ as to century or decade—rather than art historians or psychologists, let alone philosophers. No wonder that craft idiocy has become the norm.

4) *Administrative complexity*. Coherent function of an institution demands coordination among its elementary units. But as the number of units increases, the number of coordinations required increases disproportionately. Consider the simplest case: coordination of N objects, two at a time. The number of coordinations is given by $N(N-1)/2$, or approximately $N^2/2$. That is, the number of possible coordinations increases as the square of the number of units.

The institutional situation is more subtle, but the outcome is undoubtedly the same: administrative complexity must increase disproportionately with increasing numbers. At each stage of growth, newly adopted organizing principles enable the institution to cope with greater complexity, but always at some cost. The costs take many forms: bureaucratic impersonality; the familiar rigmarole of committees, reports, and deferred decisions; and decreased attention to the needs of the institution as a whole.

5) *Bureaucracy*. Bureaucracy may be regarded as a response to the organizational problems inherent in large size. The members of a large institution are too numerous to know one another or to make organizational sense of one another's activities. As a result, intermediaries are introduced to channel in-

formation and to coordinate. The need for intermediaries gives rise to a hierarchical structure simply for purposes of efficiency: the most efficient pathway for information transfer is bottom to top, the most efficient pathway for transmitting decisions is top to bottom. But bureaucratic organization brings with it certain well-known difficulties.

One of these is the garbling of information. Large bureaucracies transmit information through layers of intermediaries. However, each retransmission tends to lower the signal-to-noise ratio, a principle that arises in information theory (*11*).

A second difficulty is that hierarchical structures, although rapid and effective in the performance of simple, routine tasks, are slow and ineffective in areas that demand innovation, creativity, and adaptation to change. This principle has been pointed out in areas as diverse as business management (*12*) and the organization of scientific research (*13*). In fact, an experimental demonstration of the principle has been obtained in an ingenious study of the effects of organization on problem solving (*14*).

Finally, bureaucratic structures are impersonal. When very many of an institution's functions become bureaucratized—which seems unavoidable with great size—a pervasive atmosphere of impersonality develops. Students have repeatedly objected to this depersonalization ("do not fold, spindle, or mutilate me"); it is their most compelling and frequently voiced complaint against the multiversity.

6) *Alienation.* Anonymity, impersonality, absence of community, and bureaucratic complexity combine to diminish the possibility of fruitful human interaction. The community becomes a crowd. Activities become routine. Give-and-take between individuals gives way to the processing of IBM cards. This is *felt*. The subjective response, often called alienation (*15*), is not very precisely defined psychologically. Nonetheless, there are measurable indices of group morale that probably reflect alienation. Studies of morale in business organizations, employing such indices as motivation, productivity, frequency of absenteeism, and the perceived quality of personal relationships, have shown that morale tends to decline with increased group or institutional size (*16*).

In the case of academic institutions, data are less abundant, but certain indices of morale point in the same direction. A survey of attitudes among social

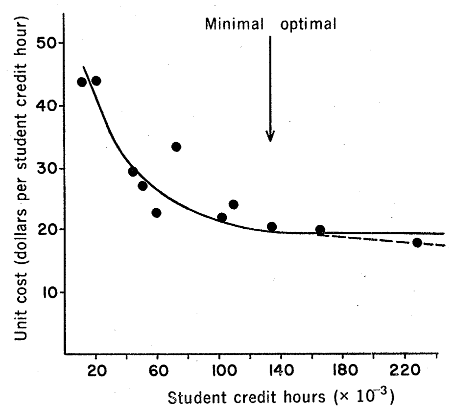

Fig. 1. Noncapital costs at California state colleges. Cost per student credit hour is plotted against the total number of student credit hours at each of the 11 state college campuses (*21*). The arrow indicates the minimal optimal scale for the solid line.

scientists at 165 colleges and universities found that the proportion reporting "unusually good relations between faculty members" and "unusually good relations between faculty and administration" declined regularly with increased institutional size (*17*). The Scranton Commission, surveying recent campus disruptions, concluded that "unrest is most prominent in the larger universities" (*18*, p. 78).

7) *The status game.* The aforementioned evidence of alienation in large organizations is statistical and, therefore, does not apply to everyone. For some individuals, it is precisely the large organization's size and bureaucratic structure that provide the arena

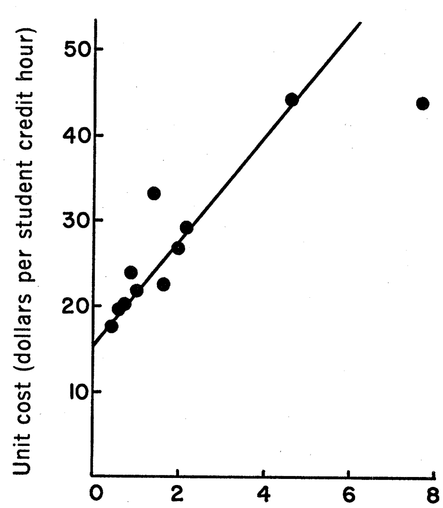

Fig. 2. Noncapital costs at California state colleges. Cost per student credit hour is plotted against the reciprocal of the total number of student credit hours (*21*). The ordinate intercept is the extrapolated unit cost at infinite population size.

for career motivation. The intrinsic satisfactions of meaningful work can be sought in organizations of any size or structure and, perhaps, most readily in free-lance autonomy. But large, hierarchical organizations are specially adapted to satisfy the hunger for status, which is gained by "moving up." Robert Presthus, in a study of the social psychology of large organizations, refers to such status-oriented individuals as "upward-mobiles" and describes their motivation as follows (*19*). "The upward-mobile's preoccupation with status is functional because he is anxious to rise, and because a disciplined self-promotion is required to impress those above him with his suitability for bigger things. As objective relationships between status and achievement become more difficult to establish, the collection of unearned status increments is encouraged. . . . *The acquisition of status and prestige becomes an end in itself rather than a derivative of some significant achievement.*"

The individual pursuit of status as an end in itself is, of course, dysfunctional for the organization as a whole because it distracts from the organization's true goals. Only the fraternal organizations exist simply for the purpose of providing tokens of status to their members. In a university, whose real goals are intellectual, the status game is not only distracting but corrupting.

The perpetual expansion of individual university units may be due more than a little to the pursuit of status. Size is often taken as a mark of status; and if a mediocre program cannot be good, it can at least be big. Upwardly mobile personalities, in consequence, mount a continuous campaign for expansion of their own units. In this way, the pursuit of status as an end in itself is transformed into the pursuit of size as an end in itself. Size and hierarchical structure may thus generate a cycle of dysfunctional growth.

Functional Growth

We have focused thus far on dysfunctional growth. To arrive at some notion, however rough, of an optimal size range for universities, we need to consider special advantages that come with growth and increased size. What are they?

1) *Economy.* The most obvious potential advantage of increased size is economy, meaning simply the money

saved through the sharing of facilities among numerous students. It is cheaper to educate 100 students in shared facilities than to build a university for each one. But we would expect the law of diminishing returns to apply to economies of this kind. For example, if the cost of education decreased linearly with increased population, there would be some population size at which education would cost nothing. Clearly, per capita economies of scale must approach some limiting value as population increases.

In economics, it is commonly observed that unit costs decline with the increasing size of a plant, or manufacturing concern. In most cases, a limiting unit cost is achieved at a finite, observable size, which is termed the "minimal optimal scale" (*20*). In order to carry out such an analysis on institutions of higher education, we examined data on the California state college system (*21*). This sample is reasonably large and homogeneous. [Units of the University of California, by contrast, are quite heterogeneous in terms of the proportions of undergraduate, graduate, and professional students, which produces gross differences in unit costs. For example in the 1953–54 academic year, the San Francisco campus, a medical school, showed five times the unit cost of the Santa Barbara campus, which had virtually the same number of student credit hours but was primarily an undergraduate institution (*21*).]

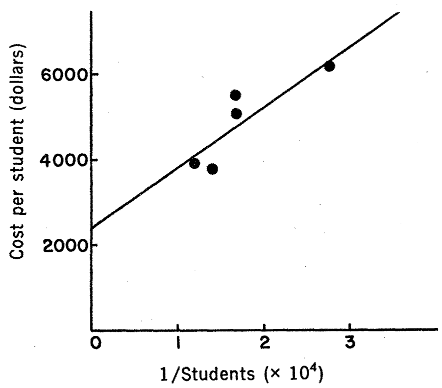

Fig. 3. Capital costs for the construction of five California state colleges. The cost per student is plotted against the reciprocal of the total number of students [see (*23*)].

Figure 1 shows noncapital cost per student credit hour plotted against number of student credit hours for the 11 California state colleges in the 1953–54 academic year. Unit costs decrease rapidly at first, then level off, closely approaching a limiting value. Since the last three points show very similar unit costs, one would identify the minimal optimal scale at roughly the point indicated by the arrow. This point corresponds to San Diego State College, with 134,239 student credit hours and a total enrollment of 3630.

It is quite possible that unit costs continue to decline very slowly above this size (dotted line). Economies of scale would appear to be marginal in this range, but let us attempt to evaluate them. We will assume that unit costs approach a limiting value asymptotically in accordance with the equilateral hyperbola, which characterizes the saturation curve, or adsorption isotherm (*22*). (In other words, economies of scale saturate in a manner mathematically identical to the saturation of a surface by a gas, or an enzyme by a substrate.)

$$Y = \frac{Y_{max}\,(X)}{K + X}$$

where, in the present case, Y is the number of students (or student credit hours) per unit cost; Y_{max} is the value toward which Y tends asymptotically; X is the size of the student population; and K is the saturation constant, corresponding to the population size at which Y attains one-half its limiting value. Y_{max} and K can be evaluated from a plot of $1/Y$ versus $1/X$. In such a plot, the Y intercept at $1/X = 0$ (that is, infinite population size) is Y_{max} and the slope is K/Y_{max}.

Figure 2 presents a plot of this kind for the data of Fig. 1. The data fit our formalism tolerably well, suggesting that it does reflect an underlying principle. The saturation constant—that is, the value of X at which cost-efficiency is half the maximum possible—is 43,000 student credit hours, corresponding to a state college of about 1200 students. This relationship means that a college of 20,000 students, for example, is only 6 percent less cost-efficient than an infinitely large college.

Data for *capital* costs of comparable institutions are less abundant. Figure 3 presents a plot of capital costs for the five California state colleges built during the 1950's (*23*), while Fig. 4 shows similar plots of projected capital costs, at three size levels, for the construction of universities, state colleges, and junior colleges (*23*, tables 25–26, p. 162). In each of these two figures, there are too few points to supply a rigorous test; nevertheless, the data are consistent with the formalism. The data of Fig. 3 indicate a saturation constant of about 5800, while the three curves of Fig. 4 all indicate saturation constants of less than 1000. The anticipated capital costs shown in Fig. 3, in particular, indicate that remarkably little economic advantage is achieved as enrollment

Table 2. Rank order correlation between departmental size and American Council on Education rating. We examined, in each field, departments listed under "leading institutions by rated quality of graduate faculty" in the 1970 ACE report (*24*). This tabulation lists the institutions that received ratings of 3.0 or higher by rank order, with the highest rated department first. The number of faculty members in these departments was obtained from current university catalogs; only assistant professors, associate professors, and professors were counted, and a value of 0.5 was assigned to faculty members on joint appointments. (The more significant data, namely the number of full-time equivalent teaching positions in each department, were not generally available to us. In a few cases, such as Harvard, the institution was removed from the sample because current data on departmental sizes were not available to us.) The sizes of the departments in each field were then ranked in order, the largest first. Table 2 shows Spearman's rank order correlation coefficient (r_s) between these two rankings and the significance level; n.s. means not significant at the 5 percent level. Since public universites are distinct in some respects, and since they tend to have larger departments than private universities, r_s was also computed for the public universities as a group.

Field	Entire sample			Public universities only		
	Departments (No.)	Size range	r_s	Departments (No.)	Size range	r_s
Biochemistry	24	10–32	−0.65 (1%)	12	10–32	0.18 (n.s.)
Economics	17	13–55	0.49 (5%)	7	26–55	−0.34 (n.s.)
Philosophy	14	10–27.5	−0.20 (n.s.)	6	15–23	−0.46 (n.s.)
Physics	25	18–106	0.015 (n.s.)	15	27–67	0.12 (n.s.)
Physiology	20	7.5–37	−0.11 (n.s.)	12	9.5–37	0.11 (n.s.)

grows beyond a few thousand. The clear implication is that there is little difference between the capital cost of expanding one institution and that of building a new one. The master plan study (*23*, p. 163), from which we have drawn these data, concludes: "With a constant percent housed, the estimated cost of expanding an existing campus is comparatively so little less than that of developing a new campus that such factors as land costs could tip the scales either way."

2) *Critical mass.* The second potential advantage of increased size is analogous to the principle of critical mass in nuclear physics. Both the elaboration of ideas and the formation of a stimulating educational environment require interaction among faculty members, just as the propagation of a chain reaction requires interaction among radioactive nuclei. What then is the minimum number of scholars in a given field—the critical mass—required to generate a high degree of academic excellence?

We have attempted to answer this question by examining the relationship between departmental size and one rough criterion of academic excellence: inclusion among the nation's top-rated graduate departments in the most recent study by the American Council on Education (ACE) (*24*). (Since these ratings reflect the considered opinions of hundreds of professionals in each discipline, we suppose that they bear a genuine relationship to at least some components of academic excellence.) Figure 5 presents data for five representative fields and expresses inclusion among the top-rated departments as a function of cumulative size; each point represents the percentage of top-rated departments with a faculty size equal to or less than the value plotted on the abscissa. It is clear that a critical mass does exist: no very small departments appear in the sample. Before estimating the critical mass for each field, however, we need to consider a related question.

Is any improvement in academic excellence to be gained by exceeding the critical size? Departmental chairmen seeking to justify additional appointments often assert that it is (perhaps based on a faulty analogy to the concept of critical mass in physics). The ACE ratings supply one way to test the assertion. If it is true that academic excellence tends to increase with departmental size, then there ought to be a correlation between departmental size and ACE rating.

Table 3. Critical mass for departmental size in five fields. Table gives, in each field, the number of faculty members (counted as in Table 2) in the smallest department that was included in the "leading" category in the 1970 American Council on Education report (*24*).

Field	Faculty (No.)
Biochemistry	10
Economics	13
Philosophy	10
Physics	18
Physiology	7.5

Plots of ACE rank versus faculty size generate scatter diagrams, one of which is illustrated in Fig. 6, in which correlation is something less than obvious. A statistical test of rank order correlation (Table 2) reveals little if any significant correlation. For the whole sample [public and private universities (*24*)], there is no significant correlation in three of the selected fields; in biochemistry, a significant negative value of Spearman's rank order correlation coefficient (r_s) suggests a tendency for departmental distinction to decline with departmental size, while in economics, a significant positive value of r_s suggests a tendency for departmental distinction to rise with departmental size. Considering the public universities alone, there is no significant correlation in any of the five fields.

Thus, over the range of size exhibited by the ACE study's "leading" graduate departments, size and relative distinction behave as independent variables. This absence of correlation can, perhaps, be brought home by some striking individual examples: the smallest and the largest physics departments in our sample, with 18 and 106 faculty members, respectively, tied for fifth place in ACE rank order; the smallest department in biochemistry, with 10 faculty members, and the largest, with 32, tied for twenty-third place.

Thus, the analogy to critical mass seems a reasonable first approximation: inclusion in the category of "leading" departments shows a discrete minimum, above which there appears to be little relationship between size and relative rating. Presumably, therefore, the critical mass for academic excellence (at least by the criteria employed in the ACE study) is equal to or less than the size of the smallest "leading" department in each field.

The faculty numbers in the smallest "leading" departments (Table 3) suggest another sort of minimal optimal scale for the university—a scale consistent with departmental sizes as large as the critical mass. The total number of faculty members at such a university would equal the sum of the numbers presented in Table 3 multiplied by the ratio of total faculty to the complement in the five fields surveyed. Taking this ratio from the University of California at Berkeley, the minimal optimal faculty would be 670; the ratio at the University of Kansas implies 680 faculty members, while the ratio at the University of Washington (where these five fields appear to be underrepresented) implies 977 faculty members. These numbers can be converted into student enrollments on the basis of the student-faculty ratios at each of the three universities. For the Berkeley model, the minimal optimal student enrollment would be about 12,000; for

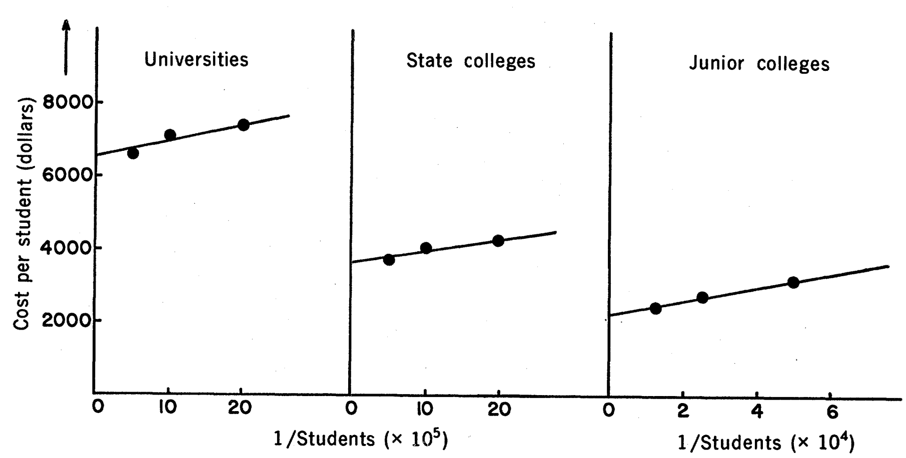

Fig. 4. Projected capital costs for university, college, and junior college construction. Cost per student is plotted against the reciprocal of the total number of students. Projections were made by the Master Plan Commission (*23*, p. 162).

the University of Kansas, it would be about 13,000; for the University of Washington, it would be about 18,000 (*25*). However, the student-faculty ratios at each of these universities are substantially greater than those recommended as desirable in a recent National Science Foundation study (*26*). Applying the recommended ratios to the University of Washington model, we arrive at a minimal optimal student enrollment of slightly over 9000.

3) *Flexibility*. The most compelling argument for university growth is independent of size per se; it depends, rather, on a dynamic aspect of growth. The president of the University of Washington, Charles Odegaard, put the argument tersely several years ago (*27*).

> The fact of growth itself gives an institution increased flexibility and freedom of entry into new fields and subfields of knowledge. . . . To put it bluntly, unless there is pressure from enrollment increases to make available additional faculty positions, the institution may very well find increasingly that it must wait for professors to move, die, or retire before it is able to react flexibly to the shifting frontier of knowledge by appointing scholars and scientists representative of new intellectual interests. And to be even more blunt about a matter of interest to faculty members, the imposition of a ceiling is likely to restrict opportunities for retention of younger scholars within the university faculty and to slow down advancement through the junior ranks toward full professorships.

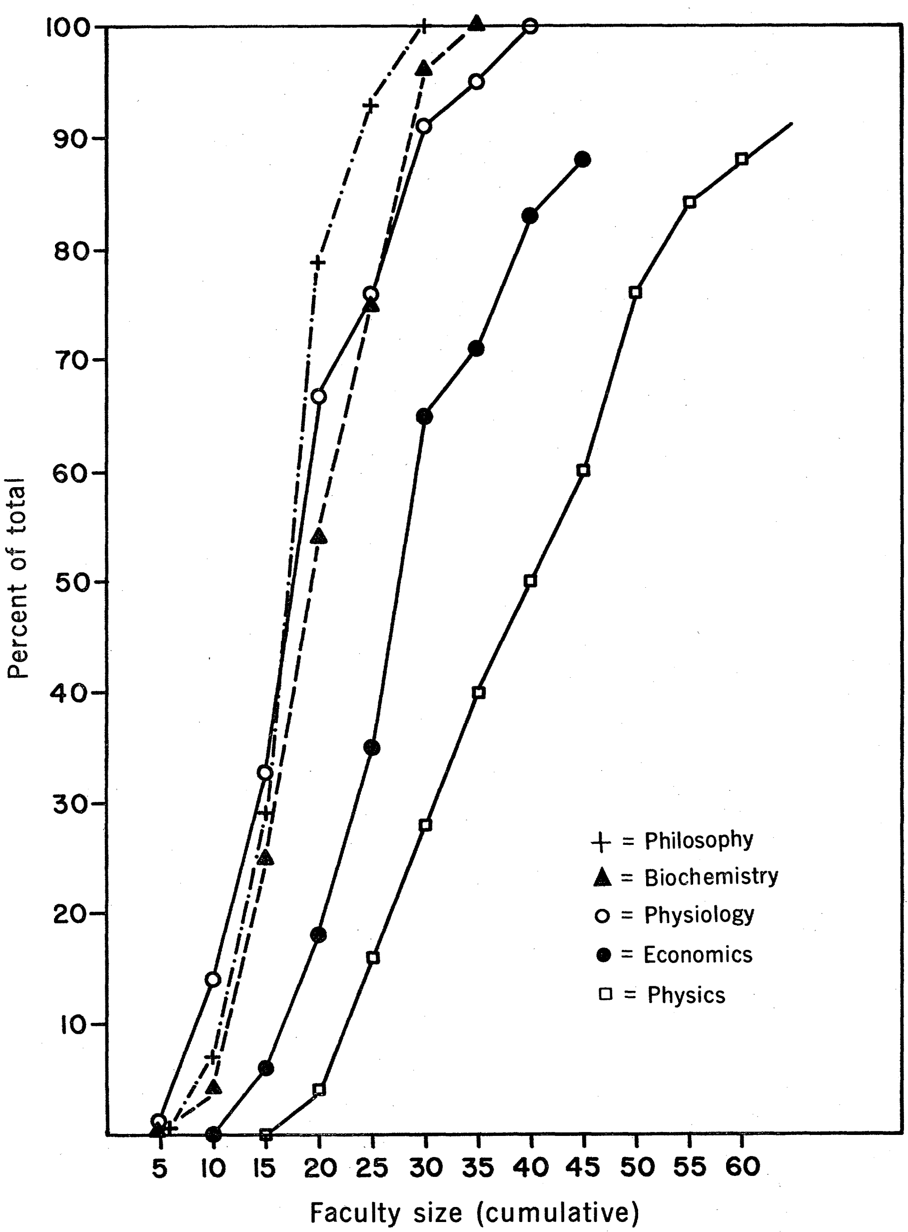

Fig. 5. Cumulative distribution in five fields of departments in "leading" institutions as a function of departmental size. The fields examined were philosophy, biochemistry, economics, physiology, and physics, as listed in the 1970 ACE report (*24*) under "leading institutions by rated quality of graduate faculty." The number of faculty members in these departments was obtained from current university catalogs; only assistant, associate, and full professors were counted, and a value of 0.5 was assigned to faculty members on joint appointments. Plotted on the ordinate is the proportion of "leading" departments found at population sizes at or below the values plotted on the abscissa.

This argument appears to be incontrovertible, but it overlooks one crucial factor. If there is such a thing as dysfunctional growth, then sooner or later the cumulative effect of dysfunctions must begin to outweigh the benefits of the growth process. In short, the advantages of growth described above can only be enjoyed temporarily.

As is the case for biological systems, we must expect university growth to be a self-limiting process. That is, at some point dysfunctions of growth will become so palpable as to preclude any further expansion. If universities fail to plan for an optimum size, then they will indeed rejoice in the short-term advantages of growth—right up to that Malthusian limit. But this would hardly constitute intelligent planning.

Moreover, the pressure from enrollment increases cannot be expected to last for very much longer. A recent demographic analysis suggests that university enrollment will stop increasing by about 1980 and may actually decline during the 1980's (*28*). Institutions that have not learned how to get along without perpetual growth may be brought up very short indeed.

Finally, we might note that there are certain special functions that small colleges cannot afford or put to efficient use. Examples are large research libraries, medical schools, resident string quartets, massive student demonstrations, and so on. Here again, the law of diminishing returns ought to apply. Most of these special functions become possible in the size range between the small college and the medium-sized university. It is difficult to see what further advantages, other than the possibility of United Nations membership, can accrue to a university population above 10,000 souls.

Conclusions

We began by pointing out that tools (for example) have size optima that are dictated by function. If we assume that the university has a function, it would seem reasonable to think about the size which will serve that function best.

The principle of size optimization is fundamental, but its application to the university at once encounters a difficulty: What *is* the function of a university? It might take forever to secure general agreement on the answer to this question. The problem is that universities have a number of different functions, to which different individuals will attach different weights, and each function may well have a unique size optimum. Just as it is, in general, mathematically impossible to maximize simultaneously for two different functions of the same variable (*29*), so it is unsound to conceive of a single optimum for the multiversity. Nonetheless, a range of workable sizes may be defined by analyzing the effect of variation in size on all essential functions.

The examples from biological systems illustrate this approach. Cells exist in a variety of sizes, each size presumably representing an optimization to one or another set of constraints, yet there are upper bounds. There are no cells the size of basketballs because essential metabolic functions are limited by the surface-to-volume ratio. We must emphasize that one does not need a grand theory of life in order to identify this limiting condition. If cells could talk, they would no doubt differ on the general philosophy of being a cell, yet all conceptions would be subject to certain physically inevitable limitations on size.

In the case of the university, no grand theory of education is needed in order to identify dysfunctions of growth that affect essential activities (for example, the diffusion of individuals through, in, and out of the university) or that affect all activities (for example, overall morale). Balanced against these dysfunctions are such advantages of growth as economy, the achievement of a critical mass, and flexibility in staffing.

Our analysis of data from the California system indicates that unit costs of education decline very little above a size of 10,000 or 15,000 students. Moreover, the critical mass for departmental excellence, at least in terms of the ACE ratings of graduate departments, is achieved by a university of about this size. Growth beyond this size range continues to provide flexibility in staffing and spares administrators the trouble of having to make

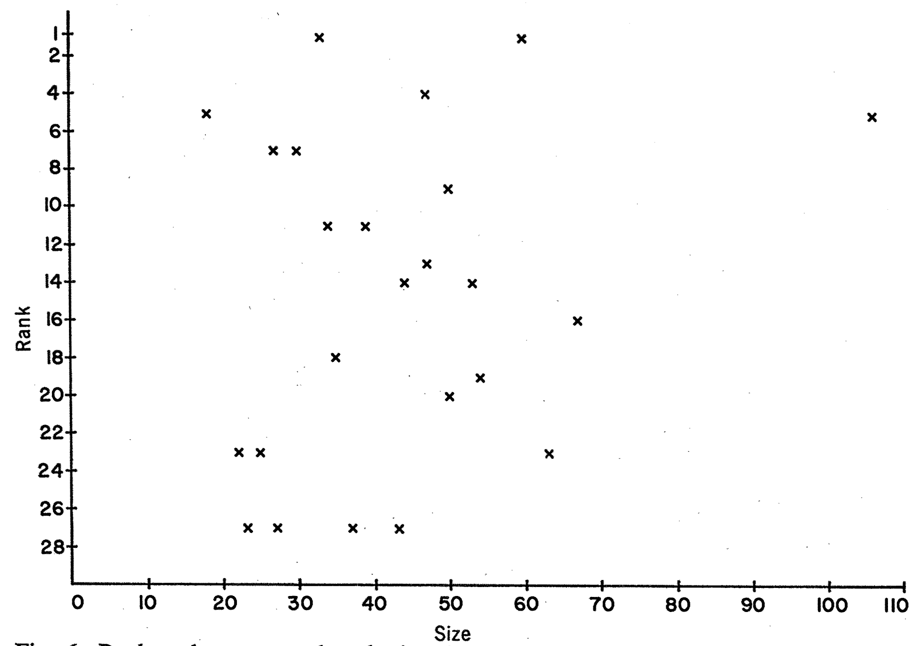

Fig. 6. Rank order among the physics departments at "leading" institutions plotted against departmental size. (Plots for the other four fields were scattered similarly.) A statistical summary of the results for all five fields is given in Table 2.

difficult decisions. At the same time, the dysfunctions attendant on growth become steadily more severe.

Our impression is that the dysfunctions have not been seriously considered, while the advantages have been greatly oversold. The idea of dysfunctional growth, although fundamental in biology, contradicts one of America's most cherished illusions. Particular dysfunctions of growth are rarely formulated, set down, and explicitly weighed against the potential advantages. Rather, the American prejudice has been to assume that growth is always good, or at least inevitable, and to treat the dysfunctions (which *are* inevitable) as managerial problems to be ironed out later or glossed over.

There has also been a remarkable failure to think in terms of optima and to distinguish in this way between what we have termed functional and dysfunctional growth. Rather, the tendency has been to extrapolate functional growth into the dysfunctional range: If a university population of 10,000 confers certain advantages as compared with a population of 1,000, then it is assumed that a population of 100,000 must confer even more advantages.

We suggest that it is time, in fact past time, to subject university growth to a more searching scrutiny. Functional and dysfunctional consequences need to be spelled out. Scale effects ought to be considered in connection with every plan for expansion. Ideally, one might expect a farsighted and tough-minded administration to carry out this function. This has rarely been the case. Too often administrators regard their function as simply that of broker among competing expansionist tendencies. Such a conception replaces philosophy by politics and often encourages mindless growth. Perhaps it is time for faculties to involve themselves in long-range planning and to pay the price of a more satisfactory environment by giving up some individual dreams of empire. The first step for every large university ought to be a careful analysis of scale effects (*30*).

If analysis indicates that continued growth of a university will be, on balance, dysfunctional, we suggest that plans be formulated to establish an absolute limit on further enrollment increase, and an absolute limit on further building expansion.

If further analysis indicates that a university is already well into the dysfunctional size range, then the obvious solution is to cut back. If this turns out to be the case, then we suggest that a program for the gradual reduction of the campus population be undertaken. There are two distinct ways to accomplish this: (i) the establishment of a new university and (ii) the decentralization of the existing university into two or more campuses. Decentralization strikes us as an attractive idea, worthy of careful study. One of the recommendations of the Scranton Commission was, "Large universities should take steps to decentralize or reorganize to make possible a more human scale" (*18*, p. 14). Returning to the natural world, we note again that cells do not grow indefinitely. Instead, they divide.

References and Notes

1. *Higher Education,* Report of the committee appointed by the Prime Minister under the chairmanship of Lord Robbins, 1961–1963 (Her Majesty's Stationery Office, London, 1963), p. 152.
2. The connection between these assumptions and the decision to expand already large state universities was probably not made explicitly in most cases. Nonetheless, the assumptions are embedded in a general outlook that still prevails in American culture, and we suggest that they *conditioned* the choice for enlargement and centralization. For example, many faculty members, administrators, and legislators may well confuse a great university with a great big university. Moreover, both legislators and administrators perceived enlargement as the path of least resistance precisely because they assumed indefinite growth to be manageable and because they were not used to thinking about the disadvantages of growth. The effect of cultural preconceptions is especially striking if one compares the prevailing tone of American administrative bulletins during the 1960's, which invariably celebrated expansion per se as "progress," with the cautionary note sounded by the Robbins report (*1*).
3. Galileo Galilei, *Dialogues Concerning Two New Sciences*, H. Crew and A. De Salvio, Transls. (Macmillan, New York, 1914).
4. L. von Bertalanffy, *Helgolaender Wiss. Meeresunters.* **9**, 5 (1964).
5. H. L. Langhaar, *Dimensional Analysis and Theory of Models* (Wiley, New York, 1954).
6. "From what has already been demonstrated, you can plainly see the impossibility of increasing the size of structures to vast dimensions either in art or in nature; likewise the impossibility of building ships, palaces, or temples in such a way that their oars, yards, beams, iron bolts, and, in short, all their other parts will hold together; nor can nature produce trees of extraordinary size because the branches would break down under their own weight; so also it would be impossible to build up the bony structures of men, horses, or other animals so as to hold together and perform their normal functions if these animals were to be increased enormously in height; for this increase in height can be accomplished only by employing a material which is harder and stronger than usual, or by enlarging the size of the bones, thus changing their shape until the form and appearance suggest a monstrosity" (*3*, p. 130).
7. D. Thompson, *On Growth and Form*, J. T. Bonner, Ed. (Cambridge Univ. Press, New York, 1966), p. 40.
8. S. Brody, *Bioenergetics and Growth* (Reinhold, New York, 1945); W. R. Stahl, *Advan. Biol. Med. Phys.* **9**, 355 (1963).
9. A. G. Greenhill, *Proc. Cambridge Philos. Soc.* **4**, 65 (1881); F. H. Newman and V. H. L. Searle, *The General Properties of Matter* (Arnold, London, 1965), p. 123.
10. J. M. Smith, *Mathematical Ideas in Biology* (Cambridge Univ. Press, New York, 1968), chap. 1, p. 6.
11. The increase in noise with each retransmission does not make error-free transmission impossible; however, the price of error-free transmission is a decreased rate of transmission or the use of increased redundancy. See N. Abramson [*Information Theory and Coding* (McGraw-Hill, New York, 1963), p. 158].
12. P. R. Lawrence and J. W. Lorsch, *Organization and Environment* (Harvard Business School, Division of Research, Boston, Mass., 1968).
13. L. Kowarski, *Bull. At. Sci.* **5**, 186 (1949); A. M. Brues, *ibid.* **11**, 344 (1955).
14. H. J. Leavitt, *Harvard Bus. Rev.* **40**, 90 (July-August 1962).
15. As originally used by Marx, the term "alienation" meant the estrangement (*entfremdung*) from work produced by the marketing of labor as a commodity and aggravated by the conditions of work in the industrializing 19th century. In more recent times, other writers, for example Erich Fromm, David Riesman, and Paul Goodman, have extended the term's usage to the various factors in large organizations and mass society that estrange or alienate the individual from intrinsic motivation and to the human consequences of institutional action. An illuminating discussion can be found in R. Presthus (*19*). We are using the term in this larger sense.
16. H. Campbell, *Occup. Psychol.* **26**, 15 (1952); D. Hewitt and J. Parfit, *ibid.* **27**, 38 (1953); R. Marriott, *ibid.* **23**, 47 (1949); *ibid.* **25**, 15 (1951); J. C. Worthy, *Amer. Sociol. Rev.* **15**, 173 (1950).
17. P. F. Lazarsfeld and W. Thielens, *The Academic Mind* (Free Press of Glencoe, Ill., 1958), p. 24.
18. *The Report of the President's Commission on Campus Unrest* (Government Printing Office, Washington, D.C., 1970).
19. R. Presthus, *The Organizational Society* (Knopf, New York, 1962), p. 186.
20. J. S. Bain, *Industrial Organization* (Wiley, New York, 1959), p. 151.
21. *A Restudy of the Needs of California in Higher Education* (California State Department of Education, Sacramento, 1955), table 53, pp. 426–427.
22. V. Henri, *Lois Generales de l'Action des Diastases* (Hermann, Paris, 1903); L. Michaelis and M. L. Menten, *Biochem. Z.* **49**, 333 (1913); I. Langmuir, *J. Amer. Chem. Soc.* **38**, 2221 (1916).
23. *A Master Plan for Higher Education in California, 1960–1975* (California State Department of Education, Sacramento, 1960), table 24, p. 161.
24. K. D. Roose and C. J. Anderson, *A Rating of Graduate Programs* (American Council on Education, Washington, D.C., 1970).
25. The disparity between the University of Washington model and the other two reflects a different allocation of resources at the upper- and lower-level divisions.
26. *Graduate Education Parameters for Public Policy* (National Science Board, National Science Foundation, Washington, D.C., 1969), p. 155. This study recommends different student-faculty ratios for "low-cost" and "high-cost" subjects at lower-level divisions, upper-level divisions, and graduate levels. We have computed a mean student-faculty ratio based on these recommendations and weighted according to the distribution of students in these categories at the University of Washington. The resulting mean student-faculty ratio is 9.3.
27. C. Odegaard, "Report from the president to the faculty" (University of Washington, Seattle, 1965).
28. A. M. Cartter, *Science* **172**, 132 (1971).
29. D. J. Wilde and C. S. Beightler, *Foundations of Optimization* (Prentice-Hall, New York, 1967).
30. The University of Washington faculty senate recently voted, almost unanimously, in favor of creating a faculty council on planning and priorities. This council is charged with responsibility for considering all policy matters relating to student enrollment, budgeted faculty positions, creation or discontinuance of schools, departments, or other academic units, as well as with physical plant and land acquisition.
31. *American Universities and Colleges* (American Council on Education, Washington, D.C., 1960), ed. 8.
32. National Center for Educational Statistics, *Projections of Educational Statistics to 1978–1979* (Government Printing Office, Washington, D.C., 1969).
33. National Center for Educational Statistics, *Digest of Educational Statistics* (Government Printing Office, Washington, D.C., 1970).

34. We are grateful to Ruth Pickering for assistance with some of the library work involved in this study, and to the Division of Planning and Budgeting, University of Washington, Seattle, for providing data.