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10.

Biological Models and Empirical Histories of the Growth of Organizations

Introduction—The Biological Model

THE BIOLOGICAL MODEL FOR SOCIAL ORGANIZATIONS—AND HERE, particularly for industrial organizations—means taking as a model the living organism and the processes and principles that regulate and describe its growth and development. It means looking for lawful processes in organizational growth grounded in factors inside the firm, and for the forces shaping it as it grows. It means restating, in specific terms, the interdependence of size, shape, and function in organizations. Looking for these things demands something which, surprisingly enough, is rare in all the work on organization theory—empirical data on how organizations have, in fact, grown. From the point of view of the firm in its context of the economy, it means reviewing the problem of ecological equilibrium and its applicability to social organisms. In many ways this facet of the approach is only a little way removed from the "natural selection" interpretation of the growth of firms. Each of these things—lawful processes in the forces shaping industrial organizations; their grounding in constituent elements; the interdependence of size, shape, and function; the balance between firm and environment; and the actual histories of some firms' organizations—will be treated in a little detail in this chapter. Let us take them up briefly, one at a time, first.

Organization theories have covered a wide variety of approaches. The classical theorist—Urwick or Fayol, for instance—emphasized control, and a neat interlocking of functional specialties toward the institution's objectives (Urwick, 1944; Fayol, 1949). The decision theorists focus on another aspect. For them the structure of organization comes from the provision of information and decision at appropriate levels. Still another view is seen in the emphasis on the conflict between individual goals and organizational objectives (Argyris, 1958). None of them has focused on the fact that an outstanding characteristic of a social organization is simply that it is a special kind of aggregation of individuals. Many of the problems of organization seems to arise from two facets of this fact—first, that it is made up of individuals, and, second, that it is an aggregation of them. From the first comes the problem of conflict between individual and organization, and the organizational necessity of resisting the centrifugal force associated with individuals—each with his own goal and each tending to fly off from the path of the whole. From the second comes the pressure, as the size of the aggregation increases, to provide communication among the parts, integration of the parts into the whole, and the possibility of specialization of function.

It is in these last areas particularly—those growing out of the size of the aggregation—that the biological model seems most appropriate. Here, too, we have the problem of integrating the parts into a single functioning unit, of maintaining communication among them, and of developing and coordinating specialized functions. If we look at the living organism for a moment, while we think of the problems of an organization, the relevance of the model may become clear.

The first step—the interdependence of size, shape, and function—can be seen particularly well in an example of D'Arcy Thompson's (Thompson, 1952). Taking the story of Jack the Giant Killer, Thompson points out that Jack had nothing to fear from the Giant. If he were, as he is pictured, ten times as large as a man and proportioned like one, Jack was perfectly safe. The Giant's mass would be 10^3 or a thousand times a man's, because he was ten times as big in every dimension. However, the cross section of his leg bones would have increased only in two dimensions, and they would be 10^2 or a hundred times as big as a man's. A human bone simply will not support ten times its normal load, and the Giant, in walking, would break his legs and be helpless. He was trapped by a simple principle called the square-cube law which points out that in normal spatial geometry, as volume increases by a cubic function, the surface enclosing it increases only by a square.

We will have to come back to this square-cube law later, but it is worthwhile to spend a moment on it here, because it is of central importance. We see here the force of gravity acting to put a limit on increase in size without a corresponding change in shape. The organism exists under the pressures of the environment, and a simple relationship drawn from the geometry of its shape expresses the factor through which the environmental pressure is exerted. A man cannot grow as big as a giant and still have the shape of a man. A deer cannot grow as big as an elephant and still look like a deer; it has to look (something) like an elephant to support the elephant's mass. The size cannot vary completely independently of the shape.

A similar application of the principle shows the interdependence of functions with size and shape. Small, unicellular organisms can take in oxygen directly through the skin, and one side is sufficiently near the other so that oxygen permeates the entire organism. As an organism gets bigger, however, the same square-cube law, operating with atmospheric pressure, demands a change in structure and shape. In a larger mass, oxygen no longer permeates throughout, and it is necessary to provide specialized veins and arteries to carry the blood through the whole system. At the same time, the skin surface has become inadequate—growing only by a square—to assimilate adequate oxygen. New folds of spongy tissue—maximizing surface in relation to mass—develop (as lungs), providing a specialized function and shape to accommodate a change in size.

In dealing with the growth of industrial organizations, it has been customary to see the specialized function of the chief executive as the limiting factor leading to diminishing returns with increase in size. Since the supply of this specialty is inelastic within a firm but infinitely elastic within an industry, a limit is seen to profitable expansion. It seems likely, however, and empirical evidence seems to suggest, that the limitation also comes from other implications of the size-shape-function relationship. As the organization grows, its internal shape must change. Additional functions of coordination, control, and communication must be provided and supported by the same kind of force that previously supported an organization without these things. If the relationship were linear, there would be no problem. If each increment in size produced one increment (or one plus) in productive capacity and needed one increment of additional supportive function, there would be no limit. However, in the organism, the proportion of skeleton needed to support the mass grows faster than the mass itself and puts a limit on size as a function of the environmental forces playing on it. Similarly, it is suggested that, as the size of a firm increases, the skeletal structure (needed to support it against the forces tending to destroy it) grows faster than the size itself, and hence comes to consume a disproportionate amount of the productive capacity of the organization. If this is so, it becomes important to identify the skeletal support of the firm, the forces it resists, and the rates at which the support must grow. Some empirical findings will be presented along these lines.

In the organismic examples used above, it was the force of gravity, and the closely related atmospheric pressure, which impressed modifications on a living form as its size changed. In organisms of other scales of size, other forces seem primarily determinative. In small insects, for example, where the ratio of wet weight to dry weight is high, it seems to be surface tension which determines modifications in form (de Beer, 1924). In still smaller microscopic organisms, it may be the shocks and jars associated with Brownian movement. What kind of force field can be the relevant one for social organisms? It is hard to hypothesize. However, knowing something of the forces operating on living organisms, we could study the modifications with growth, and see the operation, for example, of gravity. In industrial organizations, we can study the history of growth and infer the operation of the forces from the direction of changes in shape and function as size changes. With adequate empirical histories it should be possible to infer some of the characteristics of the force, even before it is possible to identify it.

One of the kinds of forces that has been suggested in this connection is that connected with the competition among firms within an industry. Probably no one who has attempted the introductory explanation of such competition has been able to avoid some reference to the analogy of the trees in the forest, the relation between the size of individuals and the number in the group, and the growth of one at the expense of the others. Certainly this kind of environmental equilibrium in the competitive field must work on firms, just as it does on living organisms. And yet it still seems possible that there is an entirely different kind of force, associated with factors largely internal to the organization. In the same way, internal physical forces act on organisms in addition to the pressures on them arising from their ecological equilibrium. Kenneth Boulding (1952) has pointed to this kind of homeostatic balance, going beyond the simple competitive pressure, but without specifying the forces in great detail. It seems likely that there are forces within the organization, arising from the fact that it is made up of individuals, which determine the course of its growth. They would be the forces associated with the cohesion of groups; with the demand for integration and communication; and with the development of specialization of function. Again, one may hope that a collection of empirical histories of how organizations have grown will give us a suggestion of the forces determining their growth patterns.

Some kinds of clues seem to exist to help in this job. For one thing, in physical organisms, the form itself shows where the force tending to destroy the organism is strongest. A shelf bracket is thickest and strongest where the tendency for the loaded shelf to break from the wall is greatest. The bowstring arch of a bridge is shaped as it is, not for aesthetic reasons, but to provide maximum support where the weight associated with the size of the bridge tends to destroy it. In general, as physical objects get bigger but retain the same proportions, they get weaker, and a larger and larger proportion must go toward supporting their own mass. Consequently, with increase in size their forms are modified to resist the force associated with size. The appropriate modification is a clue to the force. The appropriate support for a physical structure is a perfect diagram of the forces tending to destroy it. Similarly, in the industrial organization, special attention to the modification of form as size increases may give us at least a clue to the strength of the force tending to destroy it, and to its point of application.

One of the things that made it possible to see the pressure of forces on the physical organism was the simple geometry of the situation. The powerful square-cube law flows from the relation of surface and volume in conventional space. Again, successive representations of a physical form at different stages of growth makes it possible to see points of relative growth, much as time-lag photography makes it possible to see the order and direction of growth in a plant or flower. In industrial organizations, the conventional "family-tree" kind of representation seems poorly adapted to this kind of geometry, and shows us little of the pattern of growth. The preliminary empirical data to be discussed here will also be focused on this problem of the appropriate geometry for representing growth in social organizations. Some first theoretical and empirical steps have been made in the representation of group geometry, and we will point to their application to industrial organizations.

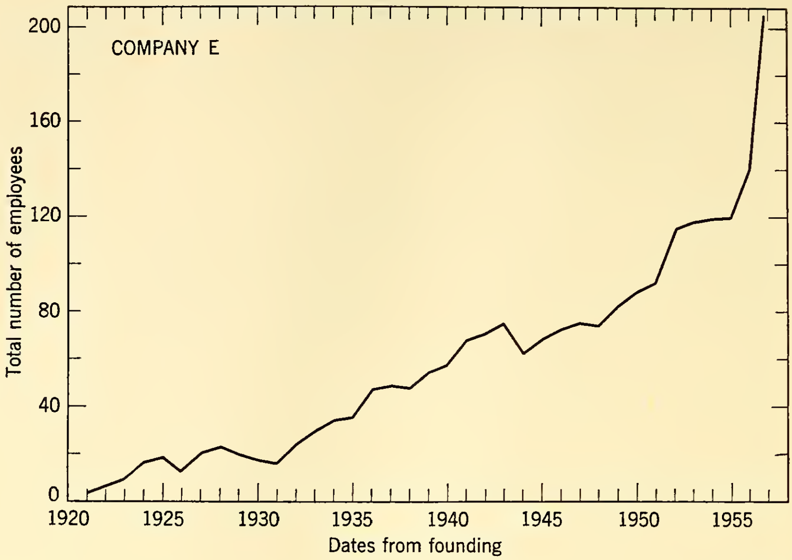
Empirical Histories of Firms

In order to see some of the phenomena of growth in industrial organizations, let us look at the histories of some actual firms.[1] Four companies will be reported on here. These reports are the first results of a research project designed to study growth, and the sample is not necessarily representative of all of industry along any dimension. Several factors dictated the choice of companies. One of them was the simple availability of the firm and the cooperation of the management. To make accurate studies, it was necessary to take payroll records, telephone books, organizational charts, and similar data back to the beginning of the company; finally, sometimes we had to interview the oldest living inhabitants about the origins. These procedures were expensive both for the companies and for the research workers, but accurate data on size and assignment were seldom readily available. Another selective factor, associated with the first, was size. To encompass data of this kind in the early stages of investigation, it was necessary to use relatively small groups. The four firms reported here recently totaled about 2,000, 200, 275, and 300 employees; larger organizations will come later. Still another criterion was youth; in the first studies it seemed useful to try to get companies in which it was still possible to trace histories from the start. Finally, an attempt was made to choose firms where the growth was rapid and where technological advantage in the company materially reduced the pressure of competition on the firm's growth.

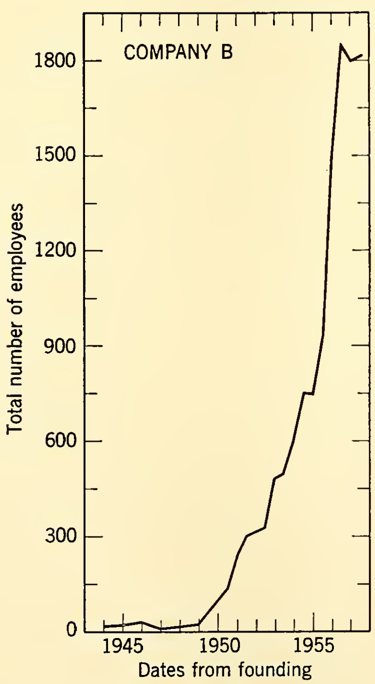
General growth

The over-all growth of these firms in terms of total employees is shown in Figures 1–4. They show various slopes of exponential functions. Figures 5–8 show the same data fitted with theoretical curves. The curves are the logistic equation often applied to population growth. The assumptions are simple. In the first case (illustrated in Figures 1 and 5), it is assumed that each member of the population at a given time produces 1.5 offspring in the next generation. The rate of increase can be determined from the first few

[1] The empirical work reported here was supported by a grant from the Foundation for Research on Human Behavior and was done at the Institute of Industrial Relations at the University of California, Berkeley.



▲ Figure 2



◀ Figure 1

Patterns of growth in four manufacturing companies.

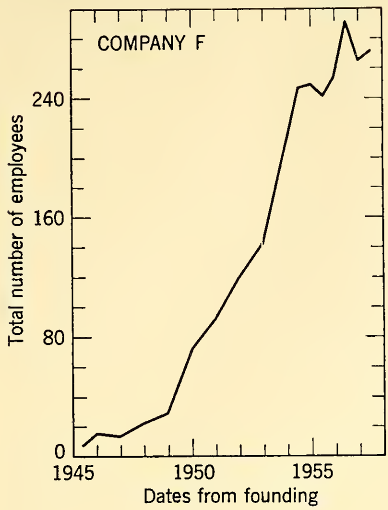


Figure 3

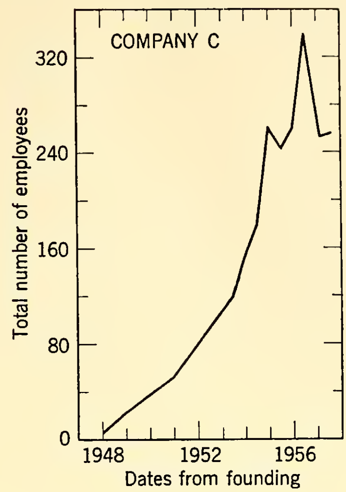


Figure 4

generations. From then on, the growth is described by a simple equation

$$\frac{dN}{dt} = N \log_e R$$

where R is the rate of growth, here established by the increase in the first three years. Once this rate is observed, the number of people employed is obtained (in the theoretical curve) by the expression $N = N_0 R^t$. It will be noticed that the observed growth over a period of fourteen years fits this simple formula remarkably well.

Here the rate of growth was taken at 1.5—the average in the first three years. That is, each employee makes it possible for there to be 1.5 employees in the next "generation." This description is for a population of unlimited expansion, where no environmental pressures reduce growth. In general, in living organisms, as populations grow they encounter limitations imposed by the environment. They use up the environmental support—space, nourishment, air, etc.—and the description of their growth must be limited by a factor associated

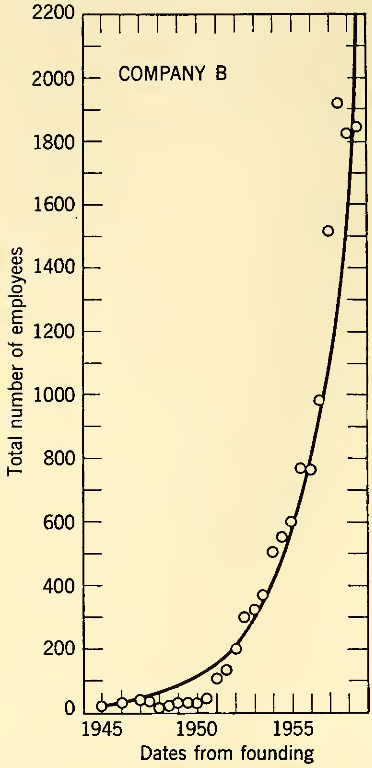


Figure 5

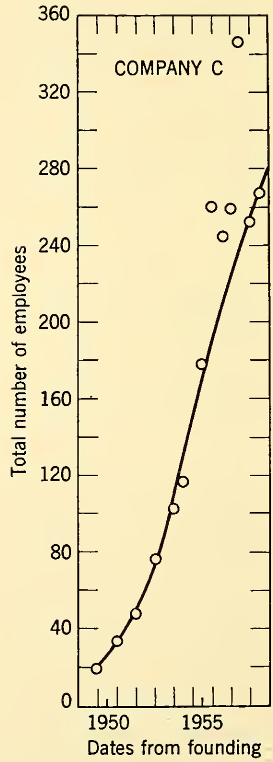


Figure 6

with this. To take account of this, the logistic curve describing the rates of growth is often modified to the form

$$\frac{dN}{dt} = \left(\frac{K - N}{K}\right) N \log_e R$$

where K is the limit on the size of the population imposed by the existence of limited environmental support. Figures 6, 7, and 8 illustrate applications of this expression and describe growth. Again, the rates of growth are taken from the first years, and the values of K are somewhat arbitrarily assigned to express limits for these firms. It will be noticed that the observed growth fits growth as predicted by the simple theoretical function, even though only two or three years are used to predict growth achieved in a period of ten to thirty-five years.

The roles of the R and K values in these equations are worth a little special attention. These two values determine the slope and the shape of the curve of growth. In living organisms, for example, different strains within a species show characteristically different slopes, paralleling one another at their own rates. Again, in living organisms, it is possible to vary the K values experimentally by manipulating the nourishment available in the medium of growth, and produce members of a family of curves fitting the same equation with different values. Here the R and K values seem likely to be associated with characteristics of the industry. The rate of growth seems related to the technological character of the process and the attendant ratio of investment per worker. The K value may be associated with the related state of competition in the industry and the demand for the product.

Apart from the problem of organizations, it would be delightful if it were possible to observe two years of growth and predict the next fifteen, as in the company pictured in Figures 1 and 5. Investment, for example, would be tremendously simplified. It should be pointed out, however, that while the values of R used in these equations are empirically determined by observing the first years' growth, the K's are quite arbitrarily chosen. However, it does not seem impossible to develop rough approximations of the limiting values characteristic of the demand and competition in an industry to provide general guide lines.

The use of a simple curve without limitation to describe the growth of a company as in Figure 5 is obviously unrealistic. With the rate of growth of exponential functions, it would mean that quite soon the company would employ everyone. It seems likely that this is not simply the lack of a good value of K, but that eventually another value of R will have to be applied. At what stage this inflection comes, and what causes it, is part of the problem of the internal price paid for increase in size.

The possibility of fitting a group of diverse companies' histories with a set of curves generated from a single, simple principle is a heartening suggestion in the search for lawful processes of growth. The assumptions behind these particular functions may not be ideal, but some equations may be found to fit more broadly. In the firms reported here, the deviations from fit are interesting. In Figures 5 and 6 it will be noticed that the values for 1956 are well off the theoretical curve, but that the succeeding points return to very good

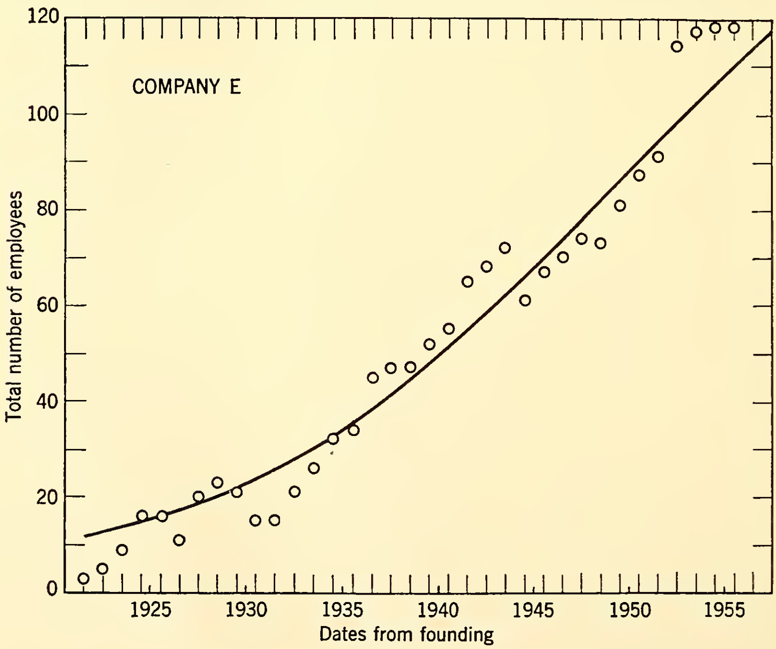


Figure 7

approximations of the value. As for the company in Figure 6, it was possible to interview the president about the growth. Referring to the 1956 spurt, he said, "We just got too big too soon and began to lose money. We had to trim back to a reasonable size." In both instances, the return to the pattern predicted by earlier growth suggests the operation of inexorable forces operating on the social organism. Again, in the company represented in Figure 7, it is clear that a single curve fits the growth for a considerable period of time, but that in recent years a quite different pattern appears. It was at this point that the company, which had been privately held, became the wholly owned subsidiary of a larger firm, with the attendant capital opportunities and expansion of marketing and distribution facilities. Again, this change in the basic curve suggests a place to look for the values associated with the description of orderly growth processes within industries.

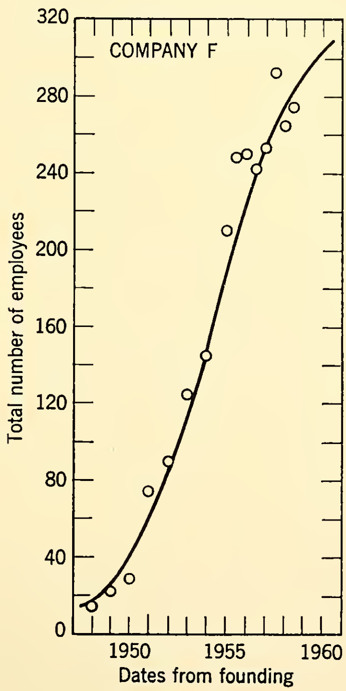


Figure 8

The geometry of growth

In discussing living organisms, particular attention was called to the square-cube law as an illustration of the application of environmental forces and also as characteristic of the geometry of the space in which physical objects grow. It would be immensely useful for the study of social organisms if a similar geometry could be developed for the space in which they live. In order to take a first step in this direction, an attempt was made to apply the square-cube law to the firms studied here, and reported above.

The square-cube law describes an invariable relationship between surface and mass of physical bodies. To apply it to companies, a naive definition was made of "inside" and "outside." "Outside" was taken to mean all the people having to do primarily with things outside the firm. Purchasing and shipping employees; receptionists, and the like are outside. The labor negotiations are external while the personnel function is internal. Often, individuals had to be split up and assigned partly to one and partly to the other. A set of definitions of this sort was established and then applied to the four firms. It was further assumed that the area of the surface of the firm was best measured by the number of people who inhabit it, and similarly for the volume. Both these assumptions—the definition of internal and external, and the measurement of surface and mass—are first approximations and subject to modification, but they seemed the best available at the time.

The square-cube law says that mass grows by a cube function while surface grows by a square. If one were to take the cube root of volume and the square root of area and plot them for different stages of growth, the result would be a straight line from the origin with a slope of 1. As the cube of the mass doubles, the square of the surface doubles. The line would be described by the single regression formula

$$y = a + bx$$

in which the intercept is 0 and b is unity.

The four firms studied are plotted in this fashion, and the results appear in Figures 9–12. It will be seen, first, that the square of the outside and the cube of the inside in each case provides a very good fit to a straight line. Nothing in the nature of the definitions—apart from the geometry of the space in which they exist—demands this. There is no immediately obvious organizational artifact that imposes this orderly progression on each of the growth patterns. It looks as if a geometry very similar to conventional spatial description can be used in picturing social bodies.

The fits to a straight line are very good in each case. The correlation coefficients of the four plots are .99, .96, .95, and .97, indicating remarkably little variance from linear progression. As was true in the general growth curves, the first few years establish slopes which describe succeeding relationships in growth very well. It should be pointed out that these regularities and the great similarity from firm to firm occur in spite of wide differences in conventional operating descriptions. One of them (Figure 12), for example, does little direct marketing itself, but disposes of manufactured products entirely to a handful of large firms in the field who retail it. Another (Figure 9) works directly with a dealer organization for part of its product, while a third (Figure 10) deals mostly with a very limited group of customers under government contract.

Two other things stand out from these plots. In the first place, each of them has an intercept greater than zero on the axis representing the cube root of the mass. In other words, here it is possible to have zero surface and some mass—an impossibility in physical geometry. This may be an artifact of the definitions, and they could no doubt be adjusted to remedy it, but it seemed better to leave them as they were set up *a priori* without the influence of observed data. On the other hand, positive intercepts may be characteristic of industrial organizations so plotted, and it is worth noticing that all four have remarkably similar values of about 1 or 2 on the y axis.

The second deviation in these data is in their slopes. In physical objects, as was pointed out, the square-root–cube-root plot yields a slope of 1. In these cases, the slopes are .72, .51, .50, and .97. Again, these variations from unity may be artifacts of the definitions or may be characteristic of the geometry applying to such social organizations. Certainly there is a remarkable similarity in the slopes.

The regularity with which these data fit simple expressions derived from a geometrical model strengthens the possibility of an eventual representation of social groups in a useful geometry. If that were possible, as has been suggested, it would enable us, with successive representations, to see changes in shape with growth, and from this to infer the size and direction of the forces associated with organizational expansion. A real possibility in this kind of representation seems to exist in the somewhat geometrical model Bavelas (1948) has proposed for describing communication nets in organizations. He provides definitions of radii, and centrality of parts and neighborhood which make possible a spatial definition of organizations. Danzig

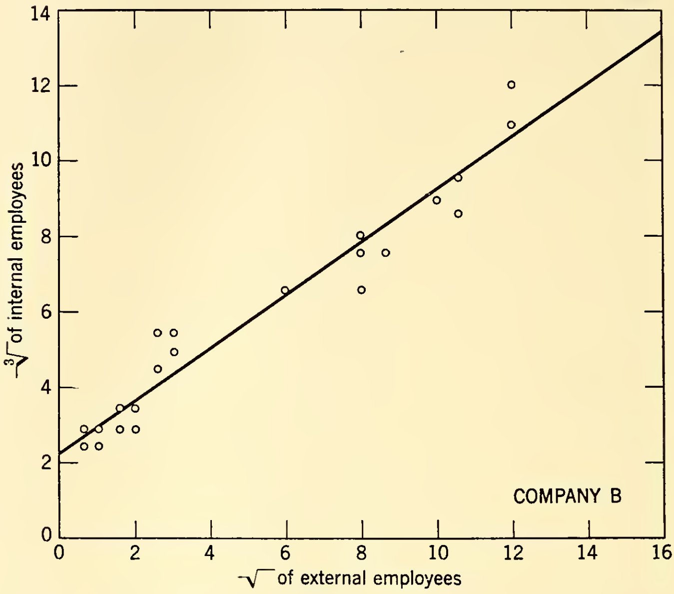


Figure 9

and Galanter (1955) have used very similar definitions in studying the operation of work groups of about two hundred people, and their results show that it is operationally possible, and that the results are meaningful. If, for example, one were to determine all the radii within an organization, their proper ordering would uniquely define a shape. Successive representations of this sort would show us where the shape had to be modified over a time to accommodate growth, and hence would be an index of the pressures associated with size and shape in social groups. Three things seem to combine to make this a very fruitful possibility for the study of industrial organizations: the existence of theoretical models of the type of Bavelas'; the operational success of the Danzig and Galanter application; and the regularity

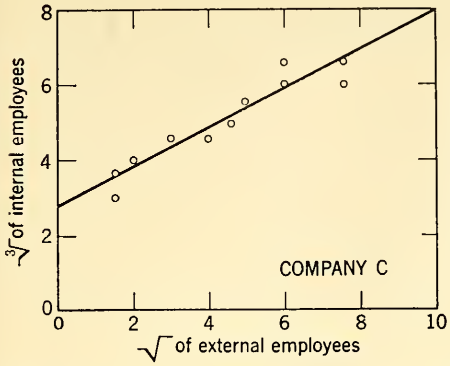


Figure 10

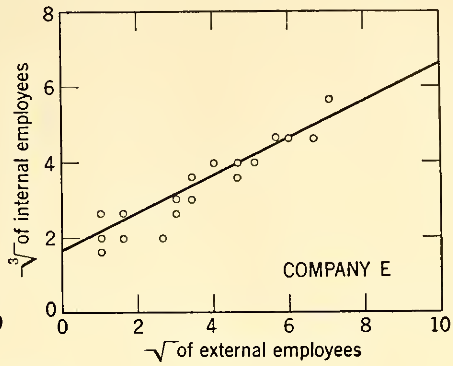


Figure 11

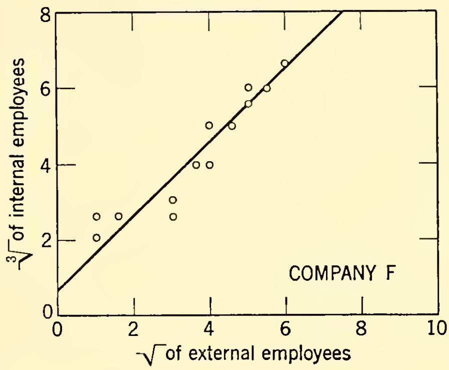


Figure 12

Internal-external analysis with regression lines superimposed. Abscissa = $\sqrt{\text{external employees}}$. Ordinate = $\sqrt[3]{\text{internal employees}}$.

with which geometrical concepts described here seem to portray the orderly process of growth.

Internal changes associated with growth

Physical models of organizations lead us to notice the relative proportions of parts as the size of the whole changes, and to measure the proportion progressively assigned to such functions as communications and integration. A look at the internal changes in the organizations studied will give us some suggestions about these problems and will provide also some data on growth of functions which have been conspicuously lacking in discussion of organizations.

The relative proportions assigned to line and staff are shown in

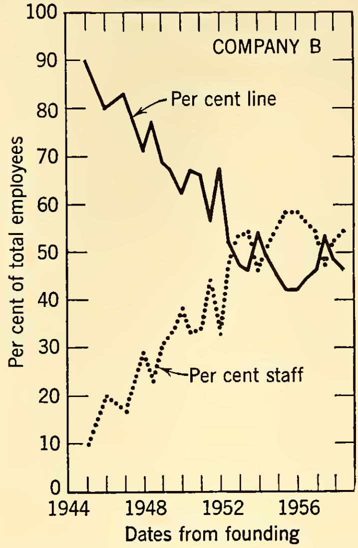


Figure 13. Per cent of line and staff personnel.

Figures 13–16. It was necessary to provide some definitions of line and staff to make these measures comparable from one firm to another. In industrial practice there seems to be no uniformity in the use of the terms. Here the distinction is made as follows: the "line" includes those who directly make and sell a product; the "staff" includes those who provide specialized support, advice, and help. In borderline cases the proximity to the product and direct control over it were taken as determinative. For example, product planning, when intimately connected with the actual production organization, is here considered as line; product research is not. Similarly, a quality-control function may operate as part of the line, if it is immediately in the operation and stops production, modifies practice directly, and rejects output. In some instances, it serves a staff function when, for example, it is a more removed reportorial service comparable to the financial control afforded by bookkeeping practices.

Two patterns seem to appear. Two of the firms stabilize at about fifty percent devoted to staff, and two at about twenty-five percent. All four companies seem to show a relatively stable proportion in recent years. In all of them the initial proportion, of course, was virtually one hundred percent line. The average size of these companies in the first year of their operation was about eight people, a figure which neither requires nor leaves much room for functional specialization. Beyond this point, however, all four show a rapid shift toward a higher proportion of staff, and the first six to ten years in each firm showed a steep increase in the percent of staff until the figures stabilized.

There seems to be less relation between absolute size and the steady state of the line-staff proportion than with age. The sizes varied considerably, but the age of six to ten years at the time of steadying gave a narrower range. The fact that three of the four companies are young, with their staff growth in the recent post-war years suggests that it is perhaps more a function of the times than of growth in general. The fourth company, however, shows much the same pattern, though its main staff growth reached just into the depression thirties, suggesting that the particular times are not determinative.

The rapid rise of the proportion of the whole allocated to staff function with early growth takes us back to the argument about the shelf bracket. The brace is strongest where the force tending to destroy it is greatest. If this is true in industrial organizations, the force tending to destroy is greatest at the point where it is shored up by increased staff. What can that force be? The two main functions of the staff are to provide information for control and coordination, and to provide expert assistance beyond the skill or training of line executives. The pressures which threaten to crack the organization as size increases must be in these areas.

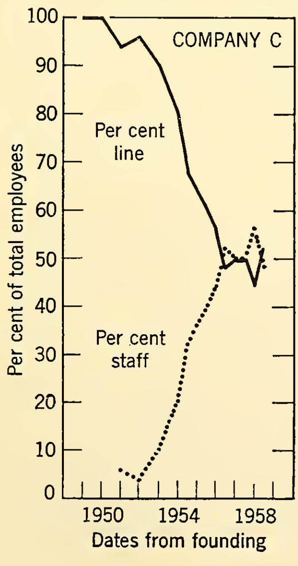


Figure 14. Per cent of staff and line employees.

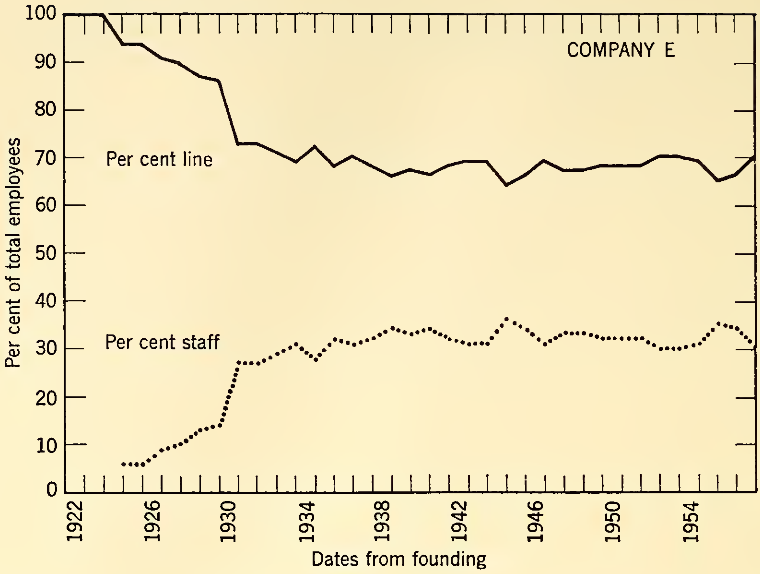


Figure 15. Per cent assigned to staff and to line.

It seems fruitful to think of an organization as built on a module determined by the amount and kind of work one man can do. The best definition of a superior in the hierarchy is that he is responsible for more work than one man can do. As the job grows to be more than he can do, he is given subordinates to help him get it done. In this manner a new level is created in the organization. When the job of supervising these subordinates grows too big, he is given sub-subordinates. In general, the vertical extent of the organization grows out of this simple module of the amount of line work one man can do or supervise. To be sure, this same pressure sometimes expands the organization horizontally—divisions are created for line specialties, or, more often, to accommodate geographical distributions of the basic activities—but the real branch organization comes from another pressure. Levels are formed, in general, when a man has more than he can do of essentially the same kind of responsibility he has had. However, where a special expertise is required, usually somewhat different from the basic function, the horizontal extent is increased by the addition of branches. It is still the same module—what one man can do—but in a slightly different realm of competence. The specialized functions are of two rough types: control and coordination, as in the case of personnel function, financial control, quality control, and the like; and technical specialties such as research and development, advertising, legal counsel, and, perhaps, industrial relations.

These two pressures flowing from the amount of work one man can do seem to be at the base of the direction of growth of companies. Roughly, when it is more work of the same kind, we have vertical extension; when it is special competences, horizontal. Can these be said to be the pressures tending to destroy the organization? I think so. Whyte (1948) gives a delightfully succinct history of the growth and decline of a restaurant—the industry in which more organizations fail early than in any other. Here the one-man diner flourishes. The owner has been cook, counterman, and cashier, as well as greeter and purchasing agent. He expands and now must keep the cook cooking well, the waitresses efficient and happy, and the cashier honest. He has functions of public relations to supervise (but not to perform) as well as those of labor relations, purchasing, and the like. Very often, in the Shakespearian mold, the very qualities that lent him his worth in his individual operation lead him to fail, as he cannot effectively assume his new responsibilities. They are of two kinds: as supervisor he must get the subordinates to help him get the work done and keep information flowing back and forth for control

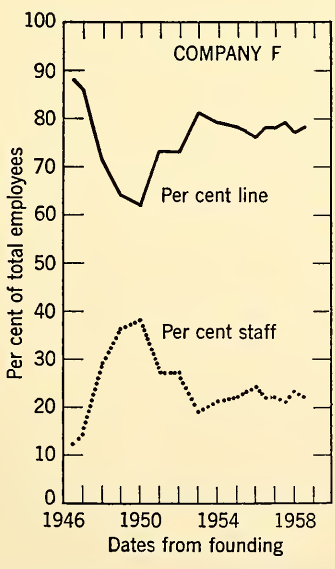


Figure 16. Per cent of line and staff personnel.

and coordination; as manager he must have the specialized skills of the staff branches, often before he can afford to represent them in individuals.

In the cases reported here, it is the support for these supervisory and managerial tasks which grow most rapidly in the first six to ten years. Apparently the basic line function grows without much threat to the life of the social organism. The structure is strengthened most to provide support for control and coordination on the one hand, to expert assistance for policy-making and planning on the other. It seems reasonable to argue that the relative growth of staff to line provide a parallel to the shelf bracket or the bridge arch—the organization grows fastest where the force tending to destroy it is strongest; the shape of the support is a diagram of the forces acting against the structure.

Before we leave the staff-line relationship, one or two other points are worth noticing. It has been argued that as the line grows by a linear function, the staff will grow geometrically (Davis, 1951). This old wives' tale—which, like many pronouncements having to do with organization theory, is completely unsupported by empirical evidence —seems to be widely accepted. Only one study of the facts in the case has come to light. Baker and Davis (1954) have shown that, in surveying about two hundred companies, the line and staff both grow linearly. Unfortunately, Baker and Davis' data are also misleading on this point. They questioned companies at a point in time, to get a cross-sectional rather than a longitudinal result. Then, when they plot size of staff against size of total, they get a spurious growth curve. It is not a curve of growth representing the dynamics within an organization, but a set of static measurements arranged by size.

The four companies studied here, while differing considerably in their patterns of growth, all show both the points mentioned above. In the early years, while the line grows linearly, the staff grows by some exponential function (though no single one seems to describe the curve well). Later, in another period of growth, they grow at quite similar rates. In terms of rough averages, during the period when the line first doubled, the staff grew about six times as large. When the line next doubled, the staff grew about five times; the next doubling of the line was accompanied by a tripling of the staff, and from then on they (approximately) each doubled. Early, the staff grows geometrically as the line grows linearly, but this relation tapers off to parallel growth.

Two other points might be noticed with regard to the staff before we leave it. One is the remarkable resistance of the staff to negative growth. The companies studied did not all grow uniformly larger. At times they cut the total personnel. In the total histories observed, there were nineteen such cases of layoffs, totaling 311 people from all firms. What proportion of these were line and what were staff? During the time in which 311 were laid off, there were actually 325 line workers furloughed; fourteen new staff people were hired during the very layoff period. Many reasons might be advanced for this. Staff people are specialists and harder to come by than line; it is simple economy to save them. Cutting down line and saving staff builds for the future. When business picks up again the line workers can be rehired to take places in the organization the staff has held intact. A more cynical interpretation might be that the staff plans and designs the layoffs, though line management makes the policy. No one ever plans to let himself go. Indeed, the process of laying off apparently required more staff to do it. Whatever the reason, it is clear that the staff is the place to take a job. It seems to have built-in tenure.

A second point which might be mentioned is the considerable regularity shown in the point of introduction of one staff function—personnel. The four companies had separate personnel people when their sizes were 177, 152, 138, and 248. Except for the last one, the figures are remarkably close together.

The growth of supervision and the span of control

Earlier we referred to the idea that the limiting condition leading to diminishing returns is based on the fact that the pyramidal shape of an organization always has a single individual at the apex, and that this chief executive's function is inexpandable within the firm. This view of the function of the executive seems to be based on two notions: one, that there is a unit of decision-making potential of finite size, which can be stretched to cover only a certain amount of operation; and two, that there is a "span of control" which limits, more or less absolutely, the rate at which the pyramid can spread out beneath the top executive. The first notion—of an indivisible, inexpandable unit of decision-making—seems to leave out the possibility of decentralization, and the extreme of virtually autonomous organization within a single skin in the style, for example, of General Motors. While there may be an eventual upper limit on size associated with the operation of a factor of this kind, it does not seem to be limiting in the range of sizes which characterizes most of the industry. The second assumption, about the span of control, is even more tenuous. For one thing, even granting the reality of this span, it is not very sharply limiting. A figure of eight subordinates controlled by each superior occurs quite frequently in writings about span of control. In practice, a company with six levels of command below the vice-presidents is not out of the question. This would give us six levels of superiors with each man supervising eight subordinates. Such an organization would have a total payroll of 8^6 or about a quarter of a million; if we increase the span of control to ten, the same-shaped organization would give us a million employees. Surely this factor does not limit the size of industrial firms in the ranges with which we are familiar. Again, in practice, this kind of span of control does not seem to fit observed facts; Sears Roebuck is the classic example in which the number of subordinates reporting directly to policy-making levels has been increased well beyond the number usually discussed. Sears often has fifty subordinates reporting to a single man. To man a full organization of six levels, with fifty men reporting to each superior, would take one hundred times the population of the United States.

The idea of the span of control in itself is an interesting one. It is often discussed as if there were some absolute answer to the question—"How many subordinates can a superior manage?"—as if the span were a kind of inflexible constant in social organizations, rather than a factor which itself is variable as a result of a number of things such as: the training of the subordinates; the objectives of the group; the situation in which they find themselves; the communication facilities available to them; and the like. The idea of span is often traced back to the military organization, where the principles of squad-platoon-company organization has perhaps become too fixed in many of our minds (Hamilton, 1921). The squad organization is relatively recent in American military history, and it seemed to emerge for two main reasons which are important to students of organization. Through the Civil War, the main tactical exercise was the movement of large masses of men under the immediate control of high-ranking officers. The squad as a unit does not appear in American army organization until the *Infantry Drill Manual* (1891). General officers attempted to control directly the activities of whole armies and corps. It was partly this which accounted for the appalling loss of high-ranking officers on both sides in the Civil War; Stonewall Jackson, in the second level of command immediately below Lee, was killed in just such a foray to exercise immediate command over front-line troops. This striking example of the considerable cost of the failure to decentralize command might be taken as a suggestion to top executives to stay off the production floor.

After the Civil War the units of the American armies were forced to the smaller span of control by improved weapons technology—the development of the Minie ball whose effectiveness made massed formations lethal—and it was made possible by the beginning of telegraphic communications for strategic, if not for tactical, control of the battlefield. These two factors seem to be the important ones in connection with the military history of the span of control, and they should be borne in mind in studying any organization: the change in what might be called "productive" technology determines the appropriate size of the unit; and the decentralization of authority demands vastly better communications—faster, more complex, and with more connections. Function, size, and shape are interdependent.

In dealing with principles of management, one often sees references to Graicunas' formulation of the limitations of authority (Gulick and Urwick, 1937). Graicunas stresses the number of relationships with and between subordinates as their number increases. Using almost all possible relationships, he comes to a formula of

$$r = N\left(\frac{2^N}{2} + N - 1\right)$$

where r is the number of relationships and N is the number of subordinates. With three subordinates, for example, we get a total of eighteen relationships, with four, forty-four. These surprising totals, however, are achieved only by taking a most elaborate view of human interactions. We must consider A's relationship with B in C's presence separately from his relationship with B alone and separately from his relationship with C in B's presence, and include B's relationship with C as well as C's with B. While all these relationships are logically contained in the system, it is not clear how they limit the span of control. Koontz and O'Donnell (1955), for example, say:

> An executive with four subordinates may well hesitate before adding a fifth member to the group when by doing so he increases the total possible relationships *for which he is responsible* [italics mine] by 127 percent (from 44 to 100) in return for a 20 percent increase in subordinate working capacity.

Surely this is just plain silly. Students must have been misled by the mathematical nicety Graicunas introduced in a previously foggy field. Making the superior responsible in any direct sense for all the relationships between and among his subordinates seems to extend unduly the functions of the executive. It would seem to me that these figures point again to the complexity of communication required to maintain contact within a growing organization, rather than to a limit on the realm of authority of the manager. This communication problem is one to which we will have to return later.

When we look at the average number of line production workers supervised by first-line foremen, the simple ratio of one to eight does not stand up. In 1958, the four companies had an average of thirteen production workers reporting to each line foreman. The companies varied between themselves. Over their total life, the average number of men reporting to a supervisor were 19, 18, 7, and 13 for the four companies—a ratio of about 1 to 14 for all four

Table 1

Average Number of Employees per Supervisor

Size of Company	Average Number Supervised
20–50	11.5
50–100	14
100–200	12
Over 200	21

Table 2

Top and Middle Management as a Percent of Total

Size of Firm	Percent in Top and Middle Management
20–50	13.6
50–100	10.5
100–200	5.9
Over 200	4.1

companies for their total life span. The ratio of supervisors to supervised does not go up as the company grows. On the contrary, as the line increased, each supervisor was responsible for more men. To return to the argument from the shelf bracket, more supervision is not one of the supports against the destructive forces associated with size.

The ratio of top and middle management shows an even greater decline with increasing size. Table 2 shows the general relationship. When the firms are small the ratio is somewhat misleading, since there is an almost irreducible minimum of management no matter how small the total. Using a table similar to that given for first-line supervisors, the decreasing ratio is clear. Management grows in size as the total grows, but more slowly than the total, and it is an increasingly smaller part of the whole. The strength that management provides does not need to be increased more than proportionately as the company grows. Contrary to the argument that diminishing returns come from a pinch at the top, in the range of sizes studied here, the top seems perfectly adequate.

The rise of the clerical function

Parkinson has made us all self-conscious about the clerical function in modern organization. To look at this, a special tabulation was kept in these four firms of all the people who were primarily paper handlers of one sort or another. The total number of clerical workers does increase as the company increases. In general, as the companies went from forty to eighty employees, the clerical staff doubled, and the doubling of total size and clerks roughly continued. The

Table 3

Clerical Workers as a Percent of Total

Size of Company	Percent of Clerks
20–50	12
50–100	15
100–200	12
Over 200	14

table shows some variation, but not the alarming growth one might expect. The curves in Figures 17–20 show the same story: growth, but not runaway growth of the clerical function. Figures 21–24 show the growth of the clerks not as a function of size, but as a function of time. As a company ages, the tendency to acquire a larger percentage of clerks appears. Part of this may be the staying power of the staff mentioned earlier. Or, in part, it may be a kind of agglutinative accretion, as when a line promotion requires a new secretary because there is no room for salary increase. In any case, the number and proportion of clerks tends to grow and grow.

The clerks have been treated separately from the staff for the present study because of the timeliness of the interest. They belong to the staff, however, and, as such, it is worthwhile considering their function for a moment. They are part of the general function of control, coordination, and communication which increases rapidly as the size increases. These functions are the responsibility of the line, but they are largely implemented by the staff. We saw that the staff in-

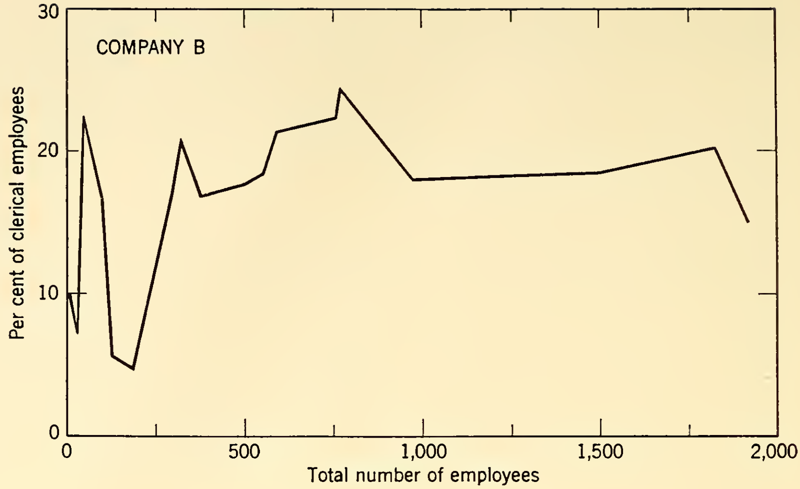


Figure 17

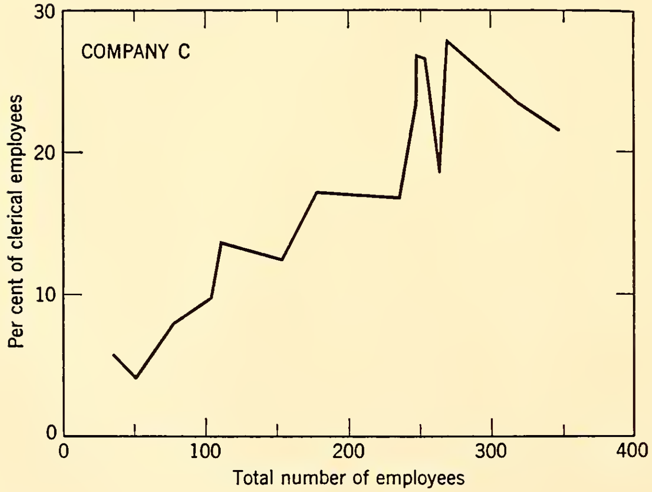


Figure 18

▲ ▶

Clerical workers as a per cent of total.

◀

creased by a factor of six when the line first doubled; the steady growth of the clerical function gives another clue to what is happening. The clerk's job is largely concerned with information—recording, duplicating, disseminating, keeping, and finding information—to support the integrative function.

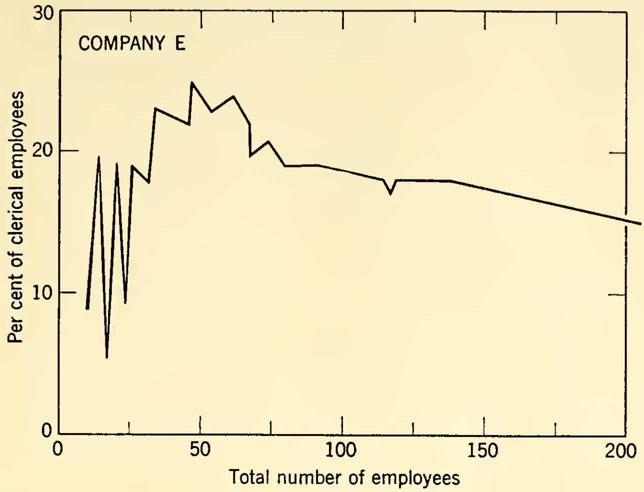


Figure 19

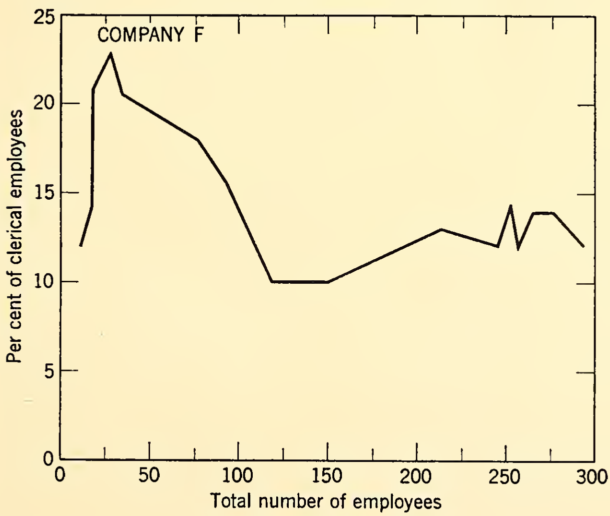


Figure 20

In the biological organism there is the same pressure for information in the interest of integration. Part of it is answered by the growth of the nervous system into a more complex network. Part of it is met by a simple increase in the speed of the transmission of the signal. For example, in a sea-urchin egg, without a proper nervous

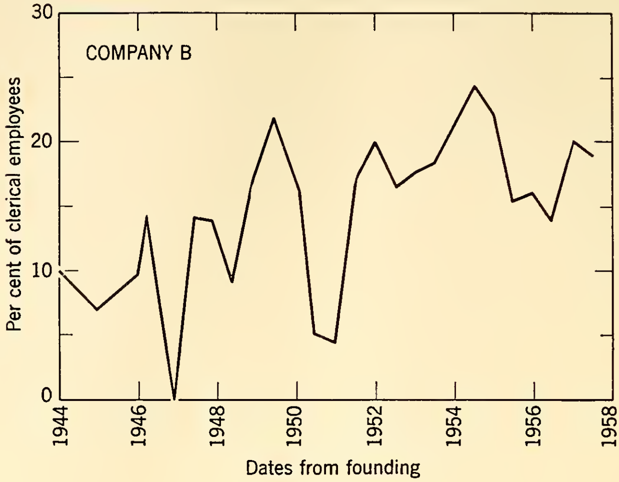


Figure 21

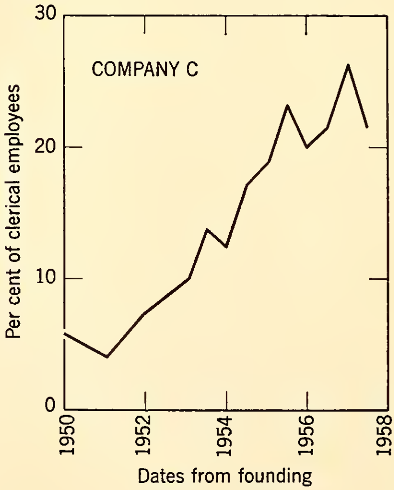


Figure 22

Per cent of clerical workers through time.

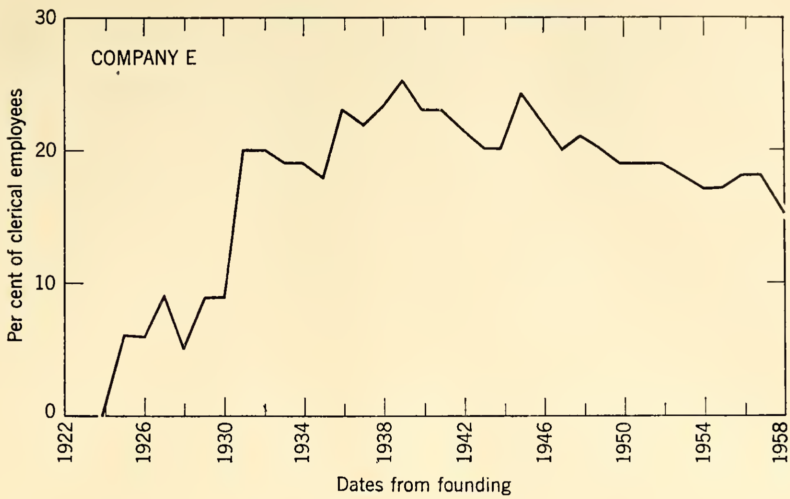


Figure 23

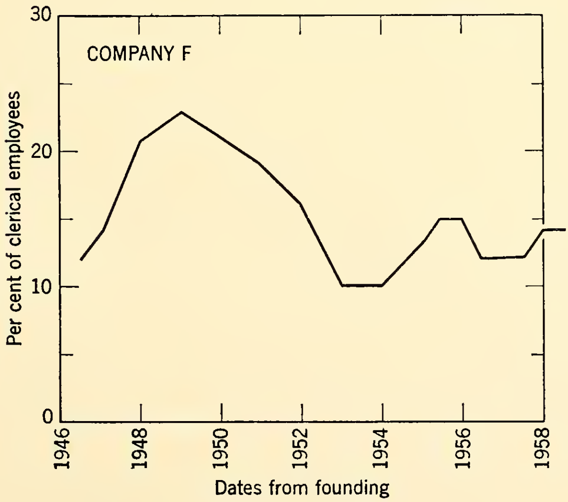


Figure 24

system, a signal barely moves along the membrane at a centimeter an hour; in the sponge it is already up to a centimeter a minute. A differentiated communication system—a nervous system—greatly improves the situation. In a jellyfish a signal goes 10 cm/sec—in a worm about ten times as fast. The arthropods step up the rate by another factor of ten, and finally the anthropods—including man—again show a tenfold increase to something like 100 m/sec. Two things might be noticed—one, that in larger and more complex organisms there is a marked increase in transmissive capacity and hence in adaptive response; and two, in very complex organisms two specialized branches develop—one for internal adjustments (the autonomic nervous system), and one for handling external information (Redfield, 1942).

In social organisms we cannot do much to speed the actual transmission of the nerve impulse, but we can and do develop, like the biological model, separate specialized functions for internal and external adjustments. Instead of increasing the actual transmission speed, there is one thing which we can do. It is a truism in communication engineering that it is always possible to trade band-width for time. If a message takes a channel of x frequencies to travel in y time, one can usually use $2x$ frequencies, and, by simultaneous transmission, achieve $\frac{1}{2}y$ time. This is essentially what happens in the combined staff-clerical function. Unable to speed up transmission, we duplicate messages and transmit simultaneously, achieving a measure of the desired speed.

It seems worthwhile going into this point in a little detail to show the communication role of the staff-clerical function. The first reason is somewhat immediate and practical, while the second is more basic. With the great deal of attention currently paid to the rise of the staff, it will perhaps make us happier with it if we realize its true role. The tendency to refer to staff as "non-productive workers," "overhead personnel," or "burden personnel" expresses a frustration that is quite common, but it represents a bookkeeping fiction more than it does a factual reflection of the true organizational role of the function.

The second reason for considering the issue lies in the organizational problem itself. As the organization grows, the force that seems likeliest to destroy it is the centrifugal force arising from the fact that the members are individuals and tend to fly off on tangents toward their own goals. It seems strange to me that the function of holding the organization together is not more heavily weighted in job descriptions of executives. Usually we read that they collect information, make decisions, see that the decisions are carried out, and the like. Observing executive behavior, it seems to me that most time and effort is spent in holding the thing together as a single working unit. Most organizations, properly started, will largely direct themselves except for periodic, crucial decisions. In terms of importance, decisions catch our eye. In terms of time and effort, and perhaps of equal importance, the holding-together has slipped by us.

In speaking of the reason small firms survive in spite of the advantages of large-scale production, N. S. Ross (1952–1953) finds the answer in the pressure on the executive's coordination. Coordination must be the act of a single center, he reasons, and cannot be delegated. Thus, an increase in size increases the chain of command, and hence the costs of coordinating eventually exceed the declining economies flowing from large-scale production. The histories of the growth of these firms seen both to agree and disagree with Ross. Certainly the cost of coordinating does increase (as shown by the increase in staff not only in absolute terms, but at a faster rate), but, while it may be impossible to delegate coordination, the very phenomenon of growth in the staff-clerical function seems to show that a great deal of support can be supplied to ease the job of coordination and integration. Whether the curve of costs is steeper than that of savings, seems to be a point for empirical determination. Indeed, a rough empirical test exists in the firms studied here, and in many others which have grown much larger.

In view of the central importance of this centrifugal force tending to destroy the organization, it is a wonder we don't have more empirical studies of the engineering structure needed to resist it. These studies show the rapid growth of staff as size increases. A few others offer leads. The basic studies of cohesion in groups offer promise, but at the moment they seem largely confined to the laboratory and are a little removed from the industrial problem. In industry itself, Sune Carlson, studying how Swedish executives spend their time, contributes a point (Carlson, 1951). Asked to indicate what they did, executives reported that about ten percent of their time was spent making decisions and giving orders. More than fifty percent was spent on "getting information" and "advising and explaining." Within these last two categories there may be a good deal of the function of holding the organization together. Unfortunately, Carlson's data do not show the behaviors as a function of size. Other studies could easily test the hypothesis that a larger and larger part of executive behavior falls in this integrative function as size increases.

Another type of study is that illustrated by Weiss and Jacobson's sociometric analysis of a plant (Weiss and Jacobson, 1955). They identified liaison people who were holding the groups together. Of a population of about two hundred, eighteen percent were identified as having this function. Again, this study does not make it possible to study the holding-together as a function of size, but it does show the phenomenon and indicates that the growth study is operationally possible. The informal liaison people make an especially interesting study, since they differ from the recognized staff. The staff is established as a result of a conscious decision to support the integrative function. The liaison individual, on the other hand, is an example of the spontaneous homeostatic economy of the social organism strengthening its structure in the face of disintegrative pressures. The two—the deliberate and the spontaneous—may vary inversely, compensating for one another in terms of the organism's protection, but with very different implications for managerial control.

Summary and Conclusion

We began by looking at a biological model for organizational growth, and went on to look for some things that might flow from it. We spoke of lawful processes in growth, their grounding in forces internal to the organization, the relation of the organization to the environment, and the interdependence of size, shape, and function. Let us look back briefly and see what has come out.

Some suggestion of lawful processes appears in the descriptions possible of the growth of firms. Their total growth can be described by relatively simple growth-equations of a kind useful in population studies and other disciplines. The simplicity and regularity of the process lends support to the idea that the growth is lawful and that it is fruitful to search for general principles. The fact that it is possible to describe growth with only a two-factor equation means that we may search for rational bases for the factors. It is clearly possible to describe any function with enough variables in the equation. The gain here seems to lie in describing a superficially complex process with rather simple parameters.

The regularity of the inside-outside functions also suggests lawfulness and a reasonable prospect of understanding the process. It also provides a lead to the geometry of the space within which the organization exists, just as the growth curves tie its growth to the ecological equilibrium between the organization and its environment. It is suggested that the geometry is capable of study with concepts and techniques presently available.

The changes within a firm during growth showed a variety of facets. In early years, the staff grew rapidly and reached a stable level. In time, the clerical function grew, too, though not as fast as the staff as a whole. It is suggested here that the physical model provides a useful clue to organizational growth. A brace is strongest where the force tending to destroy the structure is strongest. As organizations grow, the bracing material will grow where the destructive forces are focused. The staff growth suggests that this is in the areas of coordination and control. In addition to this, the centrifugal tendency of individuals in organizations is suggested as one of the main forces influencing shape as size changes. A framework for describing growth of staff and line in terms of a module of an individual's contribution is suggested.

These few paragraphs sum up, in a sense, the material which is reported here. It would not be proper, however, to fail to emphasize one further point. This material is based on two widely different things, and two things notably lacking in organization theory: conceptual frameworks broadly based in the logic of science in general; and empirical data painstakingly collected from actual growth. Much of the writing in the field consists of anecdotal, descriptive generalizations which fall midway between the two. They are neither based on careful, empirical research nor related to a general, theoretical framework. The present trends in the field are away from this tradition, and it seems likely that the eventual understanding of the organization of industrial operations will flow only from these new approaches.

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