Growth, Structural Coupling and Competition in Kinetic Art

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ABSTRACT

The author considers systems capable of growth within the framework of the aesthetics of kinetic art and George Rickey's morphology of movement. He explains fundamental growth types as the kinetic aspects of a class of structurally coupled autonomous systems. Two paradigms are treated with examples: the settling of clans competing for space and the concurrent sprouting of up to three plants. The author uses and explains his method of morphography, which generally requires of the artistically inclined scientist the design and usage of computer-generated figures called morphograms.

Rickey's Morphology of Movement and the Viewpoint of Morphography

This article deals with growth based on two different paradigms: the settling of clans competing for space and the concurrent sprouting of up to three plants. Clearly, the accompanying figures suggest the phenomenon of *spreading* or even *proliferation* [1]. This phenomenon is shown in Fig. 1 and, more evidently, in the four-fold Fig. 2, the sections or panels of which display consecutive phases of growth. As a matter of fact, any of the figures accompanying this article may be considered as a frame or a quartet of frames from a complete film, which would place them in the field of *kinetic art.*

According to George Rickey, the history of kinetic art began in 1920 [2] when the brothers Naum Gabo and Antoine Pevsner not only claimed kinetic rhythms as the most important elements of art, but experienced them as the basic forms corresponding to the human sensitivity to time. Starting from these principles, Rickey developed his morphology of motion as a comprehensive theory of shape movement. Rickey categorized the following categories of kinetic art: (1) optical phenomena, e.g. changing moiré patterns; (2) transformations, e.g. the mutation of objects in a picture as the viewer looks at it; (3) mobile objects whose parts viewers may often be allowed to influence; (4) machines, generally driven by motors; (5) variable light projection [3]; and (6) movement itself, caused by the most efficient mechanical means available. To this last class, Rickey subsumed not only Calder's mobiles but his own works [4].

Rickey himself never considered a kinetic art of growth. However, we can conceive such a category of art as a synthesis of Rickey's above-mentioned fourth and sixth groupings. In my search for this category, I am striving for a modification of Rickey's morphological position via the idea of *morphography.* Morphography entails investigating any visual sign without elevating its status to a work of art, in the spirit of the initial sense of the Greek term *aisthetikos* as the exploration of the perception of the extant for its own sake. Thus, my goal is the observation of growth as such. At the same time, I follow the principle of *unlimited aesthetification*: everything can become an aesthetic object and, of course, a work of art as well. However, what should be understood as the intrinsic and creative *heresy of morphography* is this basic rule:

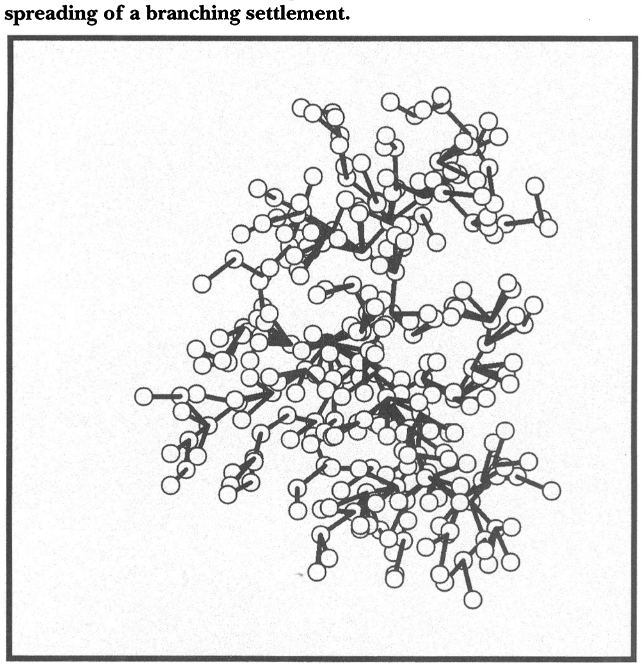
The aesthetician or artist/scientist must make his or her stand via pictures called *morphograms.*

In other words, the true morphographer speaks chiefly by devising morphograms. He or she does so in order to minimize the vagueness inherent in every syllabic language [5]. Clearly, the intricacy of many morphograms makes the use of computers absolutely unavoidable. In this sense, this article deals simply with a computer-aided exercise in motion-oriented morphography [6].

Autonomous Systems and the Motive of Simplicity

Rickey's theory of kinetic art remains a useful concept today, more so because many objects from individual morphological classes have proven to be computerizable. Autonomous sys-

Fig. 1. The entirety of the small panes represents the settlement of a clan. Each individual pane, representing one member of the clan, is linked to its predecessor by a small bar. The position of every member is calculated by a random-number generator. However, each member's incorporation into the clan is determined by rules of behavior. As a result, growth manifests itself in the spreading of a branching settlement.



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tems—defined as units that hold their ground by moving in their environments according to their inherent laws [7]—are just such objects. The phenomena of *structural coupling* and *competition* are necessary consequents of system autonomy.

The accompanying figures show morphograms that resemble vegetal growth. Is one entitled to include extremely simple as well as highly complex organizations of this type with autonomous systems? Any farmer enraged by rampant poppy growth in his or her cornfield would probably answer positively.

Because this kind of discourse necessitates stringent concepts, we must now introduce some basic definitions. At first, every system *S* must fulfill the following conditions:

1. *S* is made up of one or more parts.
2. Every part of *S* may itself possess parts that are in turn also parts of *S*.
3. Relationships may exist between parts of *S*.

In addition, I define a *structure* as a representation of the construction of a certain system *S* from the parts and internal relationships of *S*.

The following definition represents a refined understanding of autonomous systems:

1. Every autonomous system *A* is also a general system.
2. The behavior of *A* follows a set of rules.
3. Some autonomous systems retain a data memory.

From this explication we may draw the following conclusion: when using the storage space of a suitable computer *CA* as the host for the memory of an autonomous system *A*, and if one moreover describes the behavioral rules of *A* via a program that suits *CA*, then *CA* is, in principle, able to simulate *A*.

Although I will avoid formal languages in my description of simulation processes, I will nevertheless try to apply as rigorous a diction as possible. The formulations I choose are fundamentally independent of the growth processes found, for example, in biology, even if I use botanical terms. Indeed, these growth scenarios apply not only to assemblages of cells, but also to zoological and ethnic groups as well as buildings and cities. Moreover, the question remains: What are the most primitive behavioral rules possible on which autonomous systems capable of growth can be based? This problem characterizes a major motivation for the present study.

The Growth Principle of Settling

The object in Fig. 1 is clearly recognizable as the representation of a particular autonomous system, providing one can find corresponding behavioral rules and, perhaps, a memory. The illustration shows small, circular panes that accumulate into chains, which in turn branch out in some places. I use an ethnological metaphor in order to explain the formation of this system: Fig. 1 shows the settlement of one clan *C*, with each individual pane representing a member of *C*. As a result, growth turns itself out as the spreading of a settlement. New members are added constantly, like parachutists falling into the picture and landing in coincidental places, their ultimate positions calculated by random-number generators. Hence, an elementary growth rule results in the form of an instruction to an individual member:

> Only settle near one of your fellow clan members.

However, this rule turns out to be too general. One will gain deeper insight by use of an anthropomorphic approach that lets one conceive the clan *C* as represented by a certain system *R1* that operates by a complete set of rules:

> R1a: A group of members coalesces into a settlement.
> R1b: Potential members (applicants) land at coincidental places in the settlement area.
> R1c: Any applicant *F1* that does not land very close to a member *F0* that is already incorporated into clan *C* is refused.
> R1d: Any applicant that lands close to an incorporated member *F0* is linked automatically to *F0*.
> R1e: Members in clan *C* are thus incorporated until a specific number is reached.

From these rules several facts follow: the system *R1* starts with a single growth germ or a small cluster of germs. In Fig. 2, only one germ can be discerned as a black dot at the center of the picture. Furthermore, *R1* retains in its memory system the topographical data of each of its members. Finally, *R1* is authorized to stop the growth process at any time. These details are translated into a computer language via the construction of a list of data from the memory. The computer looks up the list in cycles, thereby evaluating the behavioral rules step by step. This process can be displayed graphically on the computer screen.

A closer investigation of Figs 1 and 2 reveals that every member now overlaps or touches no more than exactly one of its precursors, which definitely implies another autonomous growth system *R2* different from *R1*. This fact can be characterized by a modification of rule R1c:

> R2c: Any applicant *F1* that does not land very close to exactly one member *F0* that is already incorporated into clan *C* is rejected.

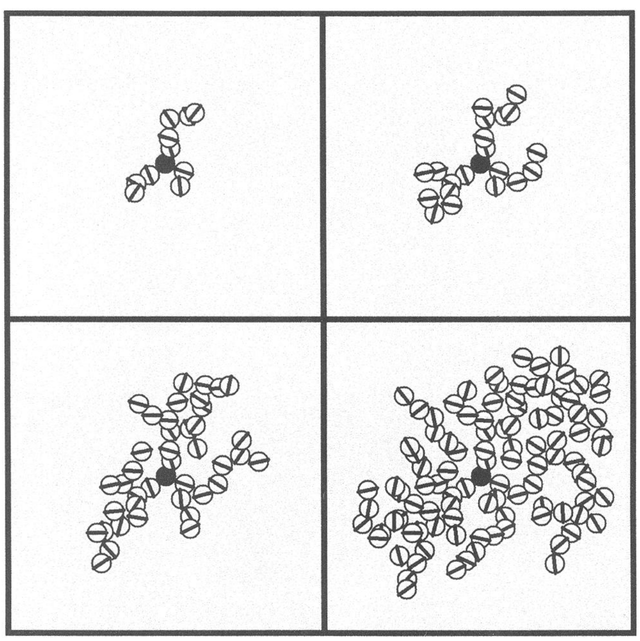


Fig. 2. Settling, displayed in four phases, under the condition that every applicant is refused unless it lands very close to exactly one clan member. The result is a three-pronged partition into subsystems.

In Fig. 2, the growth germ constitutes the center of a three-pronged partition into subsystems. Certainly, the systems in Figs 1 and 2 present a branching that results from the local admission of one or more new members close by a previous one. These "local qualities" generate the typical visual shape of the system as a

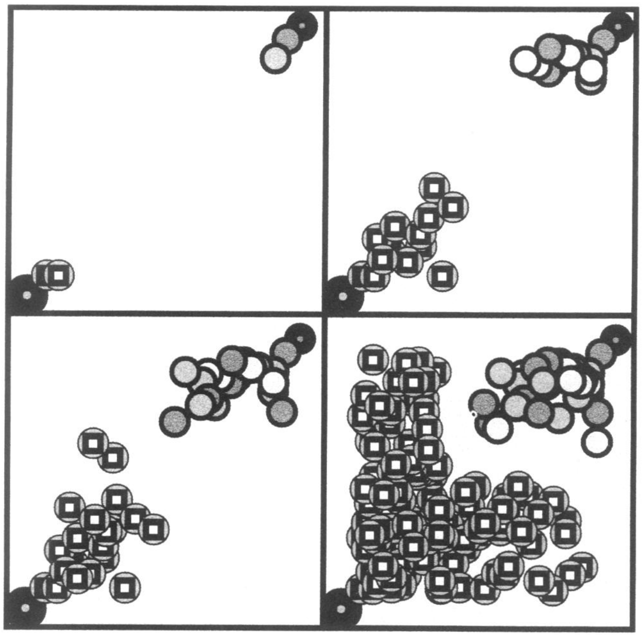


Fig. 3. Competitive settling of two co-existing clans, under the control of a demiurge or super-system. The clans, or subsystems, are structurally coupled by the condition of keeping some distance from one another. Subjective interpretations, e.g. observing a mutual interest of the clans in panel 3, to be substantiated by the spectator.

whole and present a prototypical case of the evolution of global visual features from local particularity [8].

Structural Coupling

More interesting than the behavior of an individual autonomous system is the cooperation of several of them. How would two different clans *C0* and *C1* manage their coexistence if any one member could only belong to one clan? We may provide perhaps the simplest solution to this problem by slightly amending our former universal growth rule:

> Only settle near a fellow clan member. By all means, keep away from foreign clans.

Thus, these two clans would now compete for available space. If we retain the metaphor of applicants raining from the sky, then we should assume that applicants to both clans land with equal frequency. However, because both clans originate from specific germs according to rule R1a, the clans can prosper only if every newcomer can be accommodated in one of the two neatly separated settlement areas. This consideration leads to the following addition to behavioral rules R1a and R1c:

> R1a2: A group of objects forms a settlement a safe distance away from foreign objects.
> R1c2: Any applicant *F1* is rejected unless it lands very close to a clan member *F0* and not less than a certain distance away from the other clan.

One will realize immediately that the system *R1* must in some sense be able to "see," "feel" or otherwise locate members in its area. Of course, *R1* relates now to both clan *C0* and *C1* with equal right. Hence, a ticklish problem arises: an arbiter or demiurge is now needed that would be responsible for the welfare of a fitting supersystem *W* that comprises both *C0* and *C1*. We assign this demiurge (DEMI) the following obligations:

> W1: To create the germ clusters for both clans *C0* and *C1* and to begin populating them.
> W2: To allow both *C0* and *C1* the option to break off growth autonomously after reaching a certain size.

Figures 3, 4 and 5 show that system *C1* sometimes stops expanding after a number of propagation cycles while *C0* continues to propagate. This is due to their respective structures and behaviors as controlled by their supersystem. To distinguish the systems with this dynamic particularity, I use the concept of *structural coupling,* which I borrow from the research field of biological constructivism [9]. In doing so, one must keep in mind the immense distance in complexity between my very elementary autonomous systems and those of biology, in which, for example, the mutual control of movement in a swarm of insects is a case of highly organized structural coupling.

Nevertheless, many dynamic attributes of almost all autonomous systems are reducible to structural coupling. Furthermore, competition itself is an aspect of structural coupling, because no entity can compete with another without encountering resistance. With regard to the generality of the meaning of "self-organization," the applicability of this concept at least to our color illustration surely is not questionable.

Figures 3 through 5 reflect results of the diligence of DEMI. Each panel of Fig. 3 shows on the lower left the germ of clan *C0* and on the upper right that of clan *C1*. Emanating from the germs, the development of the shape of growth depends exclusively on both the clan's behavioral rules and chance as realized by random-number generators. Although the course of progress is gradual, some spectators' sense of psychokinetic organization may lead to the following interpretation: The clans extend little by little; in panel 3 of Fig. 3, one could even read a mutual inter-

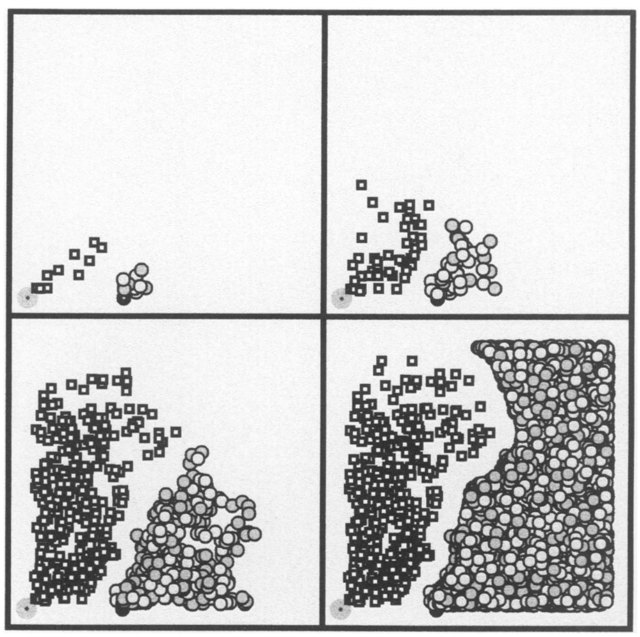


Fig. 4. Settling of two clans as in Fig. 3, but starting from germs situated near each other. In both Figs 3 and 4, the distance each clan member must keep from members of foreign clans eventually results in the formation of a separating canyon between the settlement areas of the two clans.

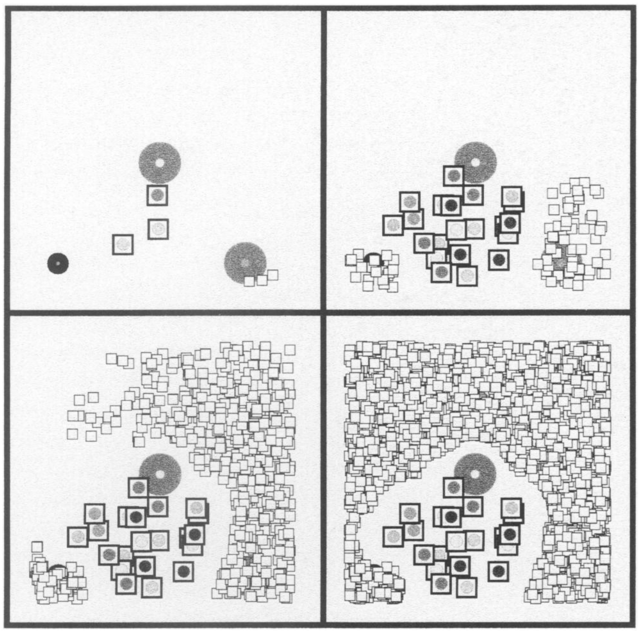


Fig. 5. Settling of two clans as in Figs 3 and 4. By intentionally positioning the germs and stopping the growth of one clan, a demiurge can shape the separating canyon into a ring. The picture may be interpreted as an arrangement of buildings.

forms, let us consider Fig. 6. The picture contains homogenous elements that resemble petals, which we may designate as sprouts. Prominently positioned near the center is a large primary sprout. This present example of a sprouting process entails that the primary or first-order sprout generates seven second-order sprouts, or "daughters," around itself. The figure depicts one of the second-order sprouts generating a complete set of seven third-order sprouts. However, with another second-order sprout the same course of events breaks off after the generation of four daughters. This breaking off is by choice of some demiurge; the generation of ever tinier daughter-sprouts could continue for a very long time. However, nothing speaks conceptually against the possibility of uniting all sprouts visible in Fig. 6 in one *plant.* Also useful is the notion of the *growth front* of these artificial plants, by which I mean the entirety of all sprouts of any order as representative of growth. In this sense, the first ring of seven daughters in Fig. 6 represents the first stage in the advance of the growth front.

est of the clans. In panel 4, although clan *C0* contains more members than clan *C1, C0* appears to hold out at rest as opposed to the more aggressive *C1.* Although these subjective interpretations depend on the sensibilities of the viewer, there is nevertheless a lesson to learn here: simple behavioral rules can improve the predictive abilities of some viewers, which would explain the commercial success of even unsophisticated computer games. Of course, DEMI itself can be transformed into an interactive game by delegating the constellation of the germs to some players.

In Fig. 4, the germs of the subsystems are closer together, and the resultant growth yields another interpretation—cooperation. What was suggested in Fig. 3 now becomes very clear: The respectful distance that each member keeps from its foreign counterparts finally results in the formation of a canyon between the settlement areas of the two clans. As Fig. 5 shows, this canyon can assume the shape of a ring. Incidentally, the course of events in Fig. 5 results from the existence of an additional germ of clan *C1,* visible in the lower left corner of panel 1. Panel 4 of this figure suggests an urbanistic interpretation: rather than a siege of clan *C0* by *C1,* one can imagine a design of speculative architecture. Certainly, the tenacious output of a global canyon gestalt as the result of the concurrent growth of two clans, controlled by DEMI, appears to be a rather universal attribute of this kinetic type of process.

Color Plate B No. 3 demonstrates a link-up of two clans by bridge connections across the canyon among several closely neighboring members. The interlocking, symbolized by red strokes, is caused in this case by a final action from DEMI based on its ability to access the system's memory.

The Growth Principle of Sprouting

Let us now move from the metaphor of the clan and its members to that of a plant and its sprouts, i.e. sprouting trees that eventually produce branches and boughs. In order to analyze the principle of sprouting in one of its simplest

Our attempt to understand the plant in Fig. 6 as an autonomous system leads again to the question of adequate rules of behavior, especially in regards to the deterministic form of growth with plants, as opposed to the aleatoric growth of clans. The seven daughter-sprouts, in combination with the overall circular pattern, reflect an outstanding symmetrical quality in Fig. 6 as a whole. In order to grasp the laws of sprouting and the administration of the structure of plants, one can again use both the instruments

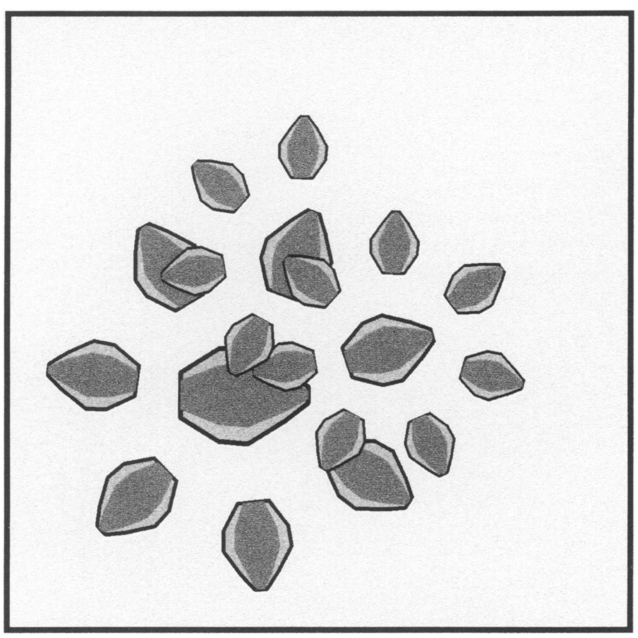


Fig. 6. The sprouting of one plant. The picture shows homogenous elements that resemble petals and are designated as "sprouts." Prominently positioned close to the center is a large primary sprout. In this example, any first-order, or "mother," sprout can, even if it need not, generate seven second-order, or "daughter," sprouts around itself.

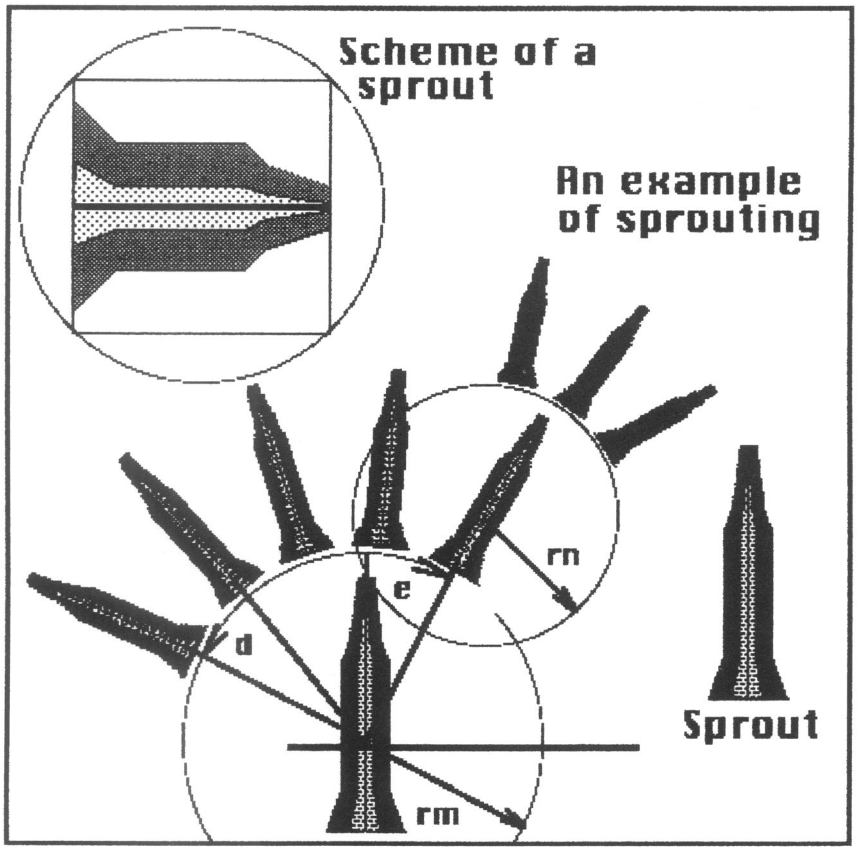


Fig. 7. The general schematic mechanism of sprouting. Upper left: a scheme of the possible sprout-forms. Lower right: an individual sprout-shape derived from the general sprout-form. Lower middle: A section from the advancing pattern of the fronts of growth. Note that *rm* represents the initial or momentary radius of the protective circle, as does *rn; d* equals the constant angular difference between two neighboring daughters; *e* represents the constant angle of displacement of the momentary growth front against the angle of the preceding one. The data of the sprouts engaged in the growth process are handled by queues.

of memory and list. However, one must distinguish the visual representation of a sprout from the sprout's role as an item in memory. The actual difficulty lies in finding an appropriate methodical representation of the growth front. A specific list format, in the form of a *queue,* offers a solution to this problem. In a queue at a bank counter, we can refer to the position of the first in line as the *head* of the queue and that of the last as the *tail.* Since bank customers would more likely be arranged in sprouts rather than queues, we may characterize the principle of sprouting by the following imperative rule:

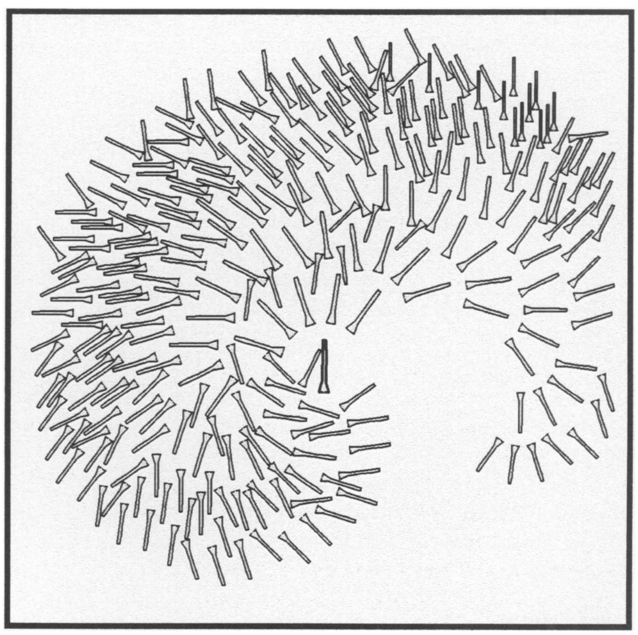
> A clan member shall surface as a sprout by going to the head of the queue.

The sprouting process can be explained via the scheme in Fig. 7. As above, we may formulate the rules of growth anthropomorphically:

GA: The queue *Q* is created by positioning the germ *s0* at the head: *Q* = *s0.*
GB: Five daughters of *s0* are incorporated into *Q,* and supplied with geometrical data derived from their mother *s0*: *Q* = *s0, s1a, s1b, s1c, s1d, s1e.*
GC: The mother *s0* is dismissed from the queue: *Q* = *s1a, s1b, s1c, s1d, s1e.*
GD: Step GB is repeated to incorporate five daughters *s2aa* to *s2ae* of *s1* into the queue: *Q* = *s1a, s1b, s1c, s1d, s1e, s2aa, s2ab, s2ac, s2ad, s2ae.*
GE: Each daughter is afforded five daughters via the equation: *Q* = *sm . . . sna, snb, snc, snd, sne* where *n* = *m* + 1 and where the sprouts *sna, snb, snc, snd* and *sne* retain data memory derived from their mother *sm,* who is eventually dismissed from the queue
GF: The cyclical course of events ends when enough sprouts are visualized or a special condition B becomes true.

In order to understand the concept of *geometrical data* used in the above rules, let us compare Figs 7 and 8. One will recognize in Fig. 8 the more schematic features of Fig. 7, which presents in its upper left corner a scheme of the possible visual presentations of the sprouts in Fig. 8. We can easily determine a particular symmetrical sprout design by specifying some of its coordinates and using distinct colors to designate its external and internal components. From this scheme, the final shape of the sprout—as represented in the lower right of Fig. 7—is derived by multiplication with two scale factors. A visualization of the stepwise emerging pattern of the plant as a whole begins with the initial positioning of a germ. In Fig. 7, the germ is set at an angle of 90° from the horizontal axis. The really important values begin with the radius *rm* of a protective circle concentric to and encasing the germ. The value of the generation number *m* is equal to 1 in the case of the installation of the germ. We can also see the sprouting situation sketched in Fig. 7 as already representing a section or substructure of the sprouting generations *m* up to *m* + 2. The initial circle ra-

Fig. 8. An example of sprouting where the overlapping of sprouts does not occur. This is an operative result of the following rule of ground suitability, or ground shunning: A sprout is manifested if and only if the ground is suitable. "Suitability" in this case means the absence of colors belonging to sprouts themselves.



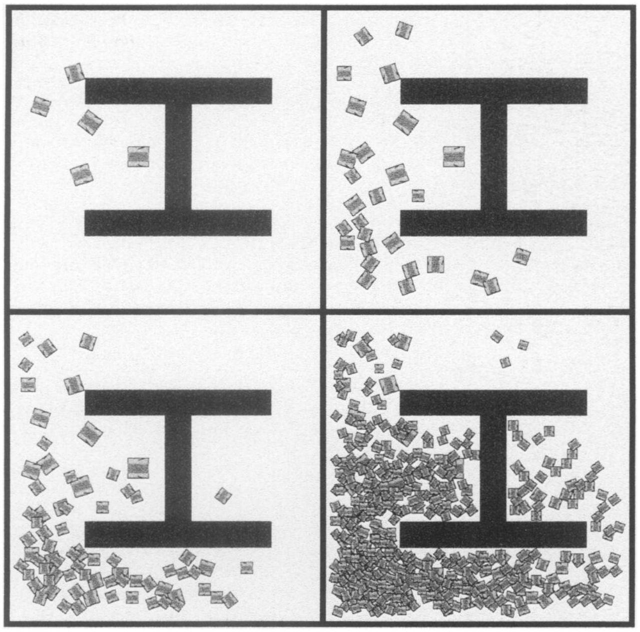


Fig. 9. The sprouting process can handle obstacles. This is accomplished by ground shunning: Visualization is suppressed when coincidence with any color of an obstacle happens. Because the data of a suppressed sprout is, nevertheless, present in its administrating queue, "sneaking" beneath obstacles can occur, as panel 3 demonstrates.

pattern of growth by a purposeful control of the individual sprouting chances granted to each plant. This is done via the creation of a supersystem that I will call FORTUNA. We can let FORTUNA play the natural equivalent of a wheel of fortune with three variably sized sectors. If the wheel of fortune lands on the n-th sector, then the n-th plant is conceded exactly one full sprouting cycle through rules GB to GD. Fig. 10 shows the cooperation—or contra-operation—of three different plants. In this case, each of the two plants growing from the corners was given a 30% chance, while the plant in the middle was given a 40% chance. Certainly, the total shape depends not only on chance but also on the placement of the germs. One can perhaps say that the central plant masters the area.

In the case of Fig. 11, three plants were granted equal chances. While the plant on the far left flourishes on its own, the other two seem to be locked in battle.

Obviously, many of the figures in this article present patterns developed with care, each of which possess a singular character. Of course, the essential reason for my theoretical neglect of these individual—though pattern-supporting—features is that I have handled the pictures as morphograms (i.e. methodical entities) in order to focus on investigating extremely primitive types of growth. The meaning of "morphography" as it applies here can be expressed by two rules:

1. Morphography puts form before gestalt; the topic itself is more important than any possible visual representation of the topic.

dius *rm* or *r1* is complemented by a similarly constant factor *fr* that determines the change in radius from one generation to the next. In Fig. 7, a value of 0.7 is assigned to *fr*. One may also choose a minimum radius that will automatically stop the growth process. Indeed, this is one of the special conditions B that are mentioned in rule GF. Furthermore, a constant factor *fi* is required to put the daughters in the front of growth relative to their mother sprout. The factual distance between mother and daughter is then increased by multiplying *fi* with the current sprout radius *rm*. One more factor needed is the angular difference *d* between two neighboring daughters, which remains constant from generation to generation. Finally, *e* represents a constant angle of displacement of the momentary growth front against the angle of the preceding one. In Fig. 7, the value of this angle is –30°.

Figure 8 shows no overlapping of sprouts, an operative result of the following rule of *ground suitability* or *ground shunning*, which can be considered a supplement to rules GC and GE:

A sprout is created if and only if the ground is suitable.

This rule is useful when the ground shows—or fails to show—specific colors, e.g. the colors of already manifested sprouts. One might say that a potential sprout carried along by a queue bears a cloak of invisibility. Fig. 9 presents a special case of ground shunning, namely the handling of obstacles. Panel 3 of this figure shows an individual sprout that has obviously been sneaking beneath the obstacle by using the above mentioned cloak of invisibility.

Form and Shape, Paradigm and Metaphor

Concurrent with the interaction of several structurally coupled clans is the sprouting of more than one plant on the same bed via the simultaneous administration of the complete set of queues assigned to each of a set of plants. The next step is to influence the developing

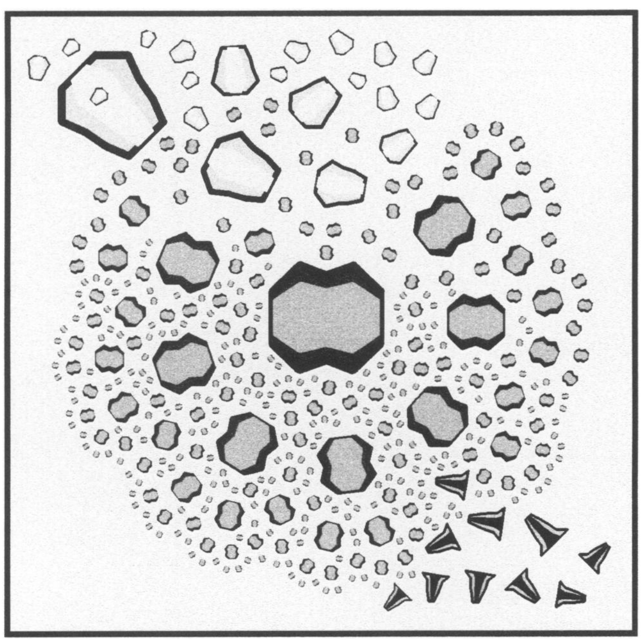


Fig. 10. Competitive sprouting of three plants. The chance of one particular plant to sprout is controlled by a "wheel of fortune" with three variously large sectors. If this wheel of fortune lands on the *n*-th sector then the plant is allowed to advance its growth-front. The principle of ground suitability is applied.

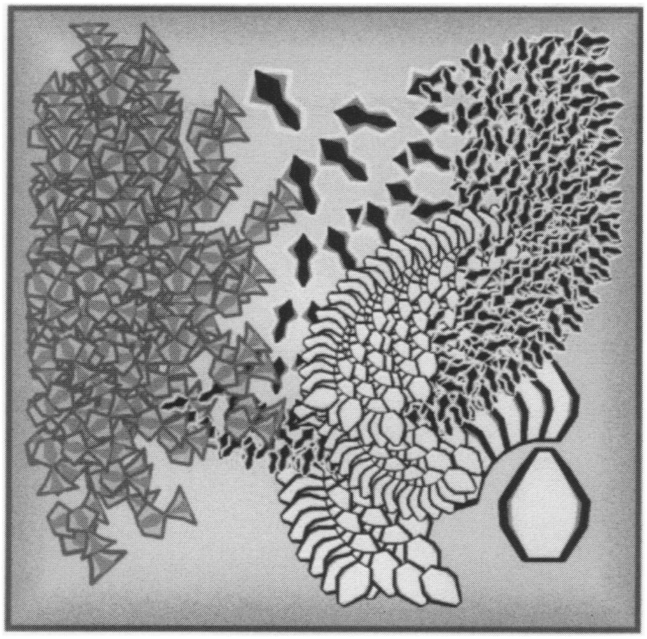


Fig. 11. Competitive sprouting of three plants without ground shunning. The same chance is given to each of the plants. Surely, the picture encourages subjective reading.

2. Morphography searches for paradigms. For example, growth is a paradigm that, on one hand, subordinates itself to the greater paradigm of movement and, on the other, comprises such sub-paradigms as settling, sprouting and, presumably, many more.

These static rules are meant to spur a striving towards essential generalizations of our topic. For example, we may conceive of primitive spreading systems that generate new subsystems both out of themselves and by use of formal elements from their material, sensual and mental environment.

Acknowledgment

This article is dedicated to George Rickey.

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