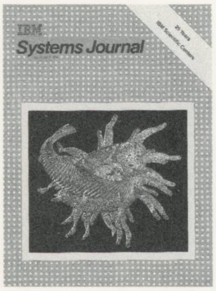
IBM

Systems Journal

Vol. 28, No. 4, 1989

25 Years
IBM Scientific Centers



The computer sculptures shown on the two covers are illustrative of the graphic tools used in support of three of the contributions to this special issue celebrating the 25th anniversary of the IBM Scientific Centers. These images have been chosen to illustrate some of the complexity and intricacy possible with those tools. Color, lighting, perspective, curvature, solidity, texture—techniques of photo-realism and computer graphics—combine here to give the illusion of reality to forms that exist only in the computer and our minds.

The cover art was created by William Latham at the IBM United Kingdom Scientific Centre in Winchester, England. Solid modeling and form evolution are used to produce forms that appear three-dimensional and realistic. Latham's ideas and techniques are more fully explored in a technical note in this issue. Specially designed software used for this purpose is also discussed in this issue.

The *IBM Systems Journal* is published quarterly by International Business Machines Corporation, Armonk, NY 10504. Officers: John F. Akers, Chairman of the Board; Jack D. Kuehler, President; Robert M. Ripp, Treasurer; William W. K. Rich, Secretary.

Subscription rate: $20.00 per calendar year (single copies $6.00). To order subscriptions or report change of address, write to IBM, P.O. Box 2076, Mahopac, NY 10541. Reprints of articles in this issue at $1.00 each may be ordered from IBM branch offices using the reprint order number on the last page of each article. Complete copies of this and other issues may also be ordered from branch offices using the order number on the back cover. Manuscript submissions and all other correspondence should be addressed to the Editor, *IBM Systems Journal*, Armonk, NY 10504.

Subscriptions may be entered or cancelled by IBM employees in the U.S.A. via VM/CMS by using the command JOURNALS, or by mailing the Journals Subscription Card (ZMO8-2203). Change of address for IBM employees is handled automatically by the IBM Corporate Employee Resource Information System and need not be reported to the *Journal*. IBM employees outside the U.S.A. may subscribe through their Country Literature Coordinators or local IBM libraries.

Reprinted from

IBM

Systems Journal

Vol 28, No 4, 1989

Technical note

Computer sculpture

by W. H. Latham
S. J. P. Todd

Technical note

Computer sculpture

by W. H. Latham
S. J. P. Todd

This technical note illustrates the graphic techniques used to generate the cover of this issue. It should be read in conjunction with the paper on WINSOM[1] which describes the computer program used to generate the computer sculptures.

Sculptures made by computers may be considered ghosts, in the sense that they exist only as computer data and not in physical form.

In the past, artists made sculptures from many different materials—marble, steel, bricks, and wood—in the workshop or studio. Our sculptures in comparison have no physical form; they are created in a virtual space viewed through the porthole of a computer screen. The forms can be rotated and viewed from any point, and visual attributes such as texture, lighting, and surface qualities can be simulated by photo-realist techniques.

The result is a highly-realistic representation of a sculpture that is imaginary. The three-dimensional realism is enhanced by the use of stereo projection and animation, yet the work of art itself remains a mystery, since it cannot be touched.

The true significance of this is not the irony of being unable to touch the sculpture, but the fact that by working in computer space we can create highly-complex forms that would otherwise be impossible to produce. The absence of gravity and material resistances enables us to explore and invent forms which had previously been outside our imagination. We call these forms *computer sculptures*. The systematic approach we have devised to generate the forms is called *form evolution*. There appear to be an unlimited number of forms that we can produce in this way—shells, eggs, antlers, slugs, and sea urchins—and, although we are creating forms that appear imaginary, poetic, and even romantic, our approach is structured and systematic.

Before he started to use computer graphics, artist William Latham experimented with a systematic approach to creating complex sculptures. While at the Royal College of Art in London, he hypothesized a design approach called the *evolutionary tree*, in which complex forms are created by a series of simple operations on basic shapes. Using this method, Latham created a hand-drawn chart of example evolutions measuring 10 metres long by 2 metres high, of which Figure 1 depicts a fragment. It became obvious that the computer could assist in this exploration of complex forms.

In 1987 the IBM United Kingdom Scientific Centre commissioned Latham to produce a series of computer sculptures. These were to use the WINchester SOlid Modelling (WINSOM) system and Extensible Solid Model Editor (ESME) computer program described elsewhere in this issue.[1] The results encouraged longer collaboration aimed at the use of the computer for faster form exploration and generation, thus widening a sculptor's creative scope. It became apparent that this work was also of interest to designers and architects who are similarly involved with problems of modelling complex forms.

The collaboration is focused around two aspects which we discuss in two main sections. The use of simple programmed operations, written in the ESME language, helps us explore complex forms; the use of the photo-realist techniques of WINSOM enables us to realise and communicate these forms.

Complex form generation

In this section we show how simple programming may be used to design a wide range of forms. Two functions provide the operations used to generate most of our complex forms.

The first of these is the *horn function*, that takes a form and transforms it many times. Depending on the original shape and the transforms used, a wide variety of forms may be generated as shown in Figure 2. Figure 2A shows a simple horn; Figure 2B shows the use of the horn function to generate a pumpkin form; and Figure 2C shows a horn in which each contributing primitive is another horn. The transforms that define a horn are described using connotative terms such as bend, scale, twist, grow, and stack. These are words that any sculptor would use talking to a technician while making a traditional sculpture in a workshop or studio.

The second function is the *branch function*. This takes a form and produces many copies of it radiating from a central point, as shown in Figure 3. Figure 3A shows a simple branch of cylinders; Figure 3B shows a branch of horns.

Combining forms generated from these simple functions permits a huge variety of more complex forms to be constructed. The range of generated forms is illustrated in Figure 4. The power to generate very complex forms is combined with sufficient constraint to focus the sculptor's ideas. While an infinite number of sculptures can be created, at any given moment we are restricted by the limited number of choices available to us; this has proved a good mixture for creative output.

Form realization

None of the forms we have generated at the UK Scientific Centre has ever existed as a physical object. Some are realized as high-resolution screen images or photographs, others as animations on videotape.

As a form develops, we use a variety of realizations. The simplest realization is a wire-frame display, as shown in Figure 5A, which is generated very quickly and may be rotated in real time on appropriate hardware. We use this to check the basic form and to choose interesting views. Many forms never progress beyond this state. Next a low-resolution version is rendered, as shown in Figure 5B, using WINSOM to see that there are no features hidden in a way that was not obvious from the wire frame. Finally, WINSOM generates a full high-resolution photo-realistic image, as shown in Figure 5C.

To achieve the photo-realist image, we have available a whole battery of special effects. These include three-dimensional solid texturing, shadows, colour, and surface qualities. To use these effects, the artist controls various parameters which determine how the sculptures should be lit, define a style of fractal texturing, or describe a special colour or particular bumpy surface quality. Some parameters are set interactively and some are set using descriptive words, but many still have to be typed in as numbers. Once created, the parameters for a set of textures, colours, or surfaces are easy to store and are used again.

Although photo-realist techniques are used, the intention is to give the forms a dream-like quality. Thus, forms float in a kind of twilight world, halfway between the real and the imaginary. And, like in a dream, they are lit with a strange eerie glow and have a curious clarity.

We can make the sculptures appear even more three-dimensional using stereoscopic projection. It is possible to use stereo pairs, with two projectors and polarizing filters. This requires a special screen. Alternatively, a red and a green image are combined on a single slide. This requires only one projector, but the colour of the image is lost. In either case, the viewer must wear the appropriate spectacles. Texture is particularly important for stereo viewing, as it permits the viewer to fix the depth at every point on a surface and not just at points where it intersects other surfaces.

Animations are much better at giving a viewer a full appreciation of the form of an object. In the simplest type of animation, the form is rotated to let the viewer see all sides. Figures 6A through 6D show sequences of a rotation. More complex animations lead the viewer around or even through a form, as shown in Figures 7A to 7C. The viewing path is generated from the same ESME program that generates the form. Finally, the power of animation permits the form itself to grow and become distorted in time (Figures 8A to 8D). This is not a facility available to conventional sculptors.

The combination of photo-realism and computer graphics appears to be popular with the general public and lends itself to mass reproduction and televised broadcast. As soon as sculptures are made from data, the artwork ceases to need to reside in an art gallery and can be transmitted "live" into the viewer's living room.

Conclusion

In the future, we expect to use more direct interaction in the design of forms. This interaction will still be constrained by the mathematics of form-generation functions and not take on the freedom associated, for example with paintbox systems. We will bring the power of the programmed functions back into the original concept of the evolutionary tree, and combine this with other ideas on evolution to permit a new form of user interface based on the selection of system-generated forms.

The form evolution approach has enabled us to create forms which had previously been beyond our imaginations and to present the results to the viewer. As holography improves, it will be possible holographically to project a life-sized sculpture into the viewer's living room. At that point, the ghosts of sculptures will truly appear.

Cited references

1. J. M. Burridge et al., "The WINSOM solid modeller and its application to data visualization," *IBM Systems Journal* **28**, No. 4, 548–568 (1989, this issue).

William H. Latham *IBM UK Scientific Centre, Athelstan House, St. Clement Street, Winchester, Hampshire SO23 9DR, United Kingdom.* William Latham initially trained as a printmaker, sculptor, and animator and obtained a B.F.A. in fine art from Oxford University, UK, and an M.A. from the Royal College of Art in London. In 1987, Mr. Latham became a Research Fellow in the Graphics Applications group at the IBM UK Scientific Centre in Winchester. There he has specialized in using three-dimensional solid modeling and computer photo-realist techniques to create computer sculptures. An exhibition of Mr. Latham's work is currently touring the UK, and his animations have appeared internationally on television and at film festivals. His recent film, *The Conquest of Form*, was shown at the 1989 SIGGRAPH Computer Graphics Theater.

Stephen J. P. Todd *IBM UK Scientific Centre, Athelstan House, St. Clement Street, Winchester, Hampshire SO23 9DR, United Kingdom.* Professor Todd studied mathematics at Oxford University, UK, from 1965-1971. In 1971, he joined the IBM UK Scientific Centre at Peterlee. He developed the Peterlee Relational Test Vehicle, one of the first relational database systems. He was also involved in research in image processing. He spent 1979 to 1981 at the IBM Research Laboratory in San Jose California, where he worked in text processing and coding theory. He rejoined the UK Scientific Centre in 1981. Since then, Professor Todd has researched a number of graphics areas, including picture generation from databases, languages to create solid models for a variety of applications, and the realistic rendering of these solid models.

Reprint Order No. G321-5382.

Figure 2 Examples of the horn function: (A) a simple horn; (B) use of the horn function to generate a pumpkin form; (C) a horn in which each contributing primitive is another horn

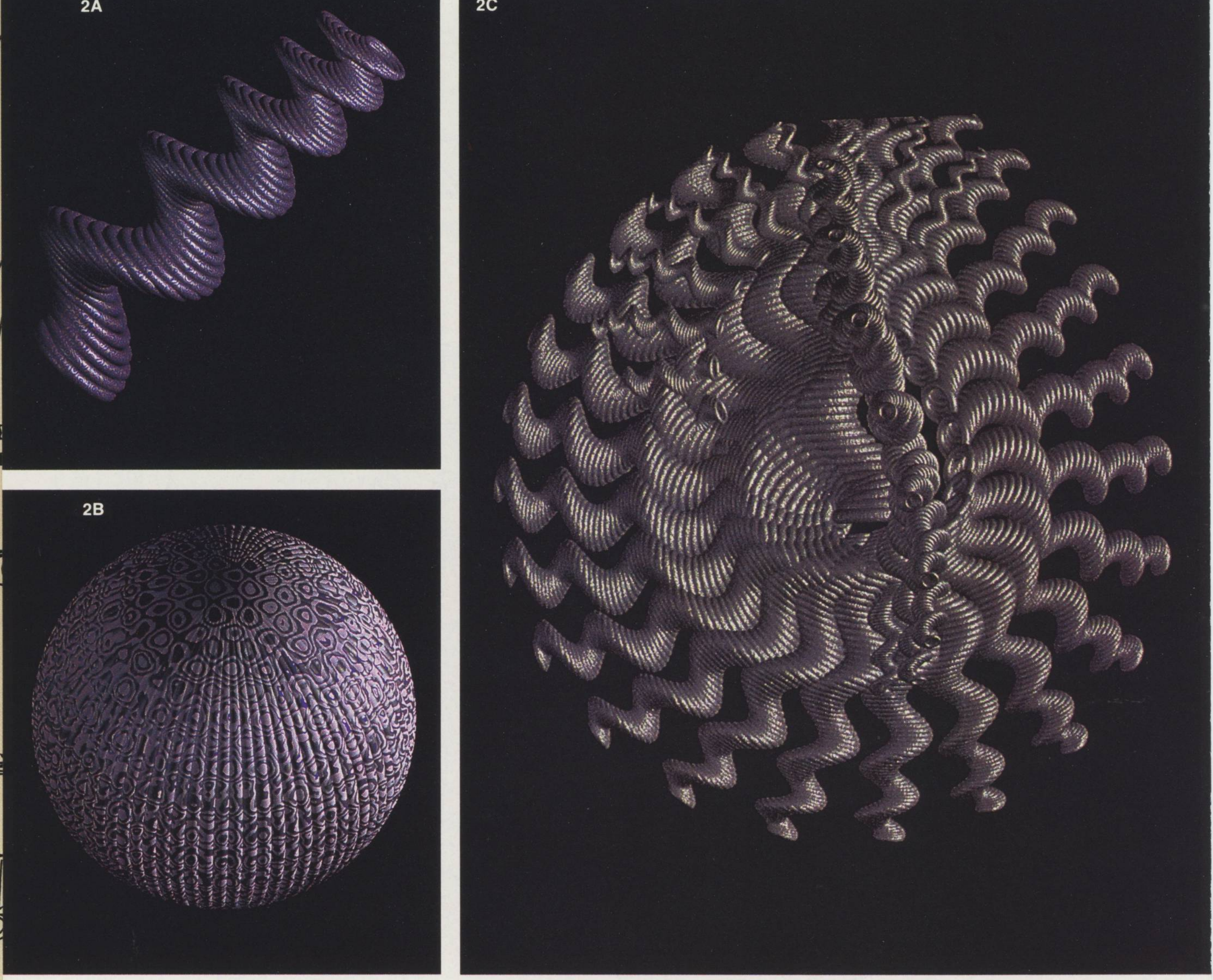
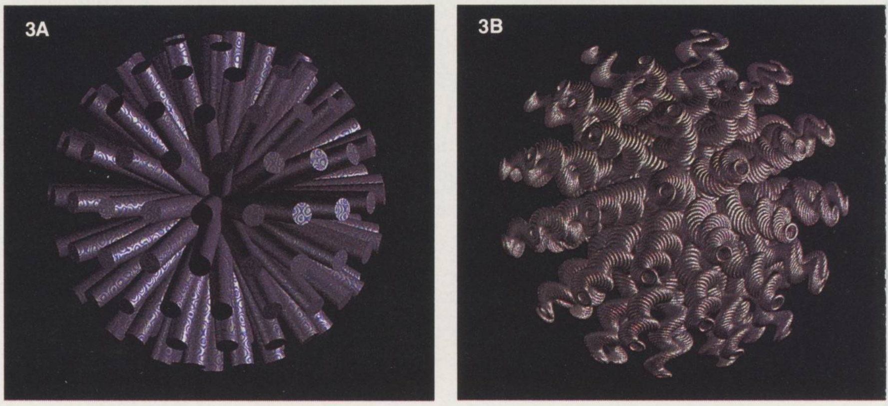


Figure 3 Examples of the branch function: (A) a simple branch of cylinders; (B) a branch of horns



LIFT, PLEASE

Figure 2 Examples of the horn function: (A) a simple horn; (B) use of the horn function to generate a pumpkin form; (C) a horn in which each contributing primitive is another horn

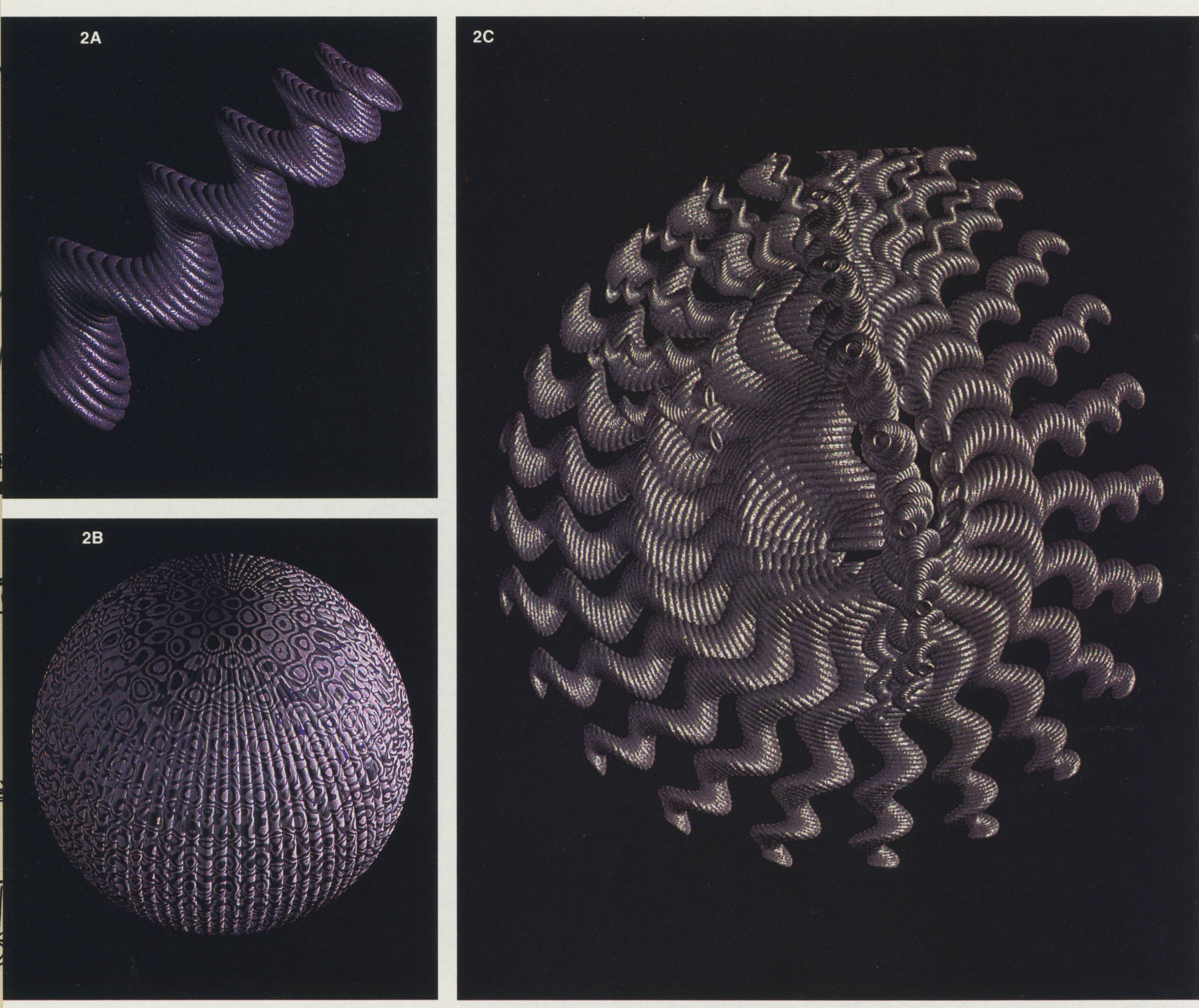
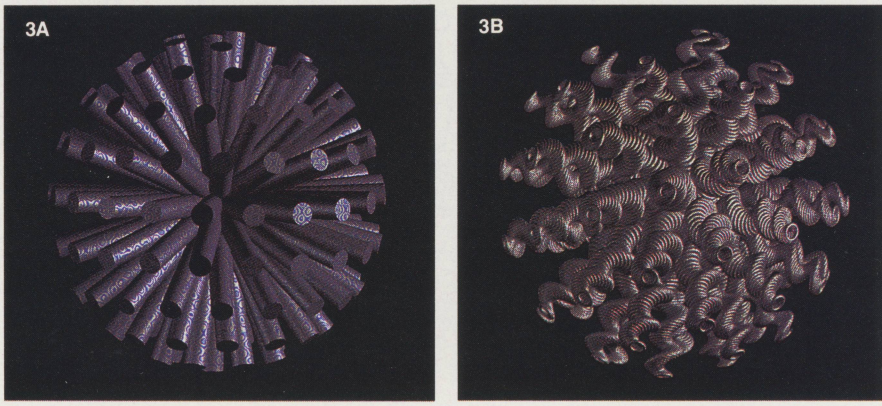


Figure 3 Examples of the branch function: (A) a simple branch of cylinders; (B) a branch of horns



LIFT, PLEASE

Figure 4 Examples of more complex forms

Figure 1 A fragment of the hand-drawn evolutionary tree of sculptures

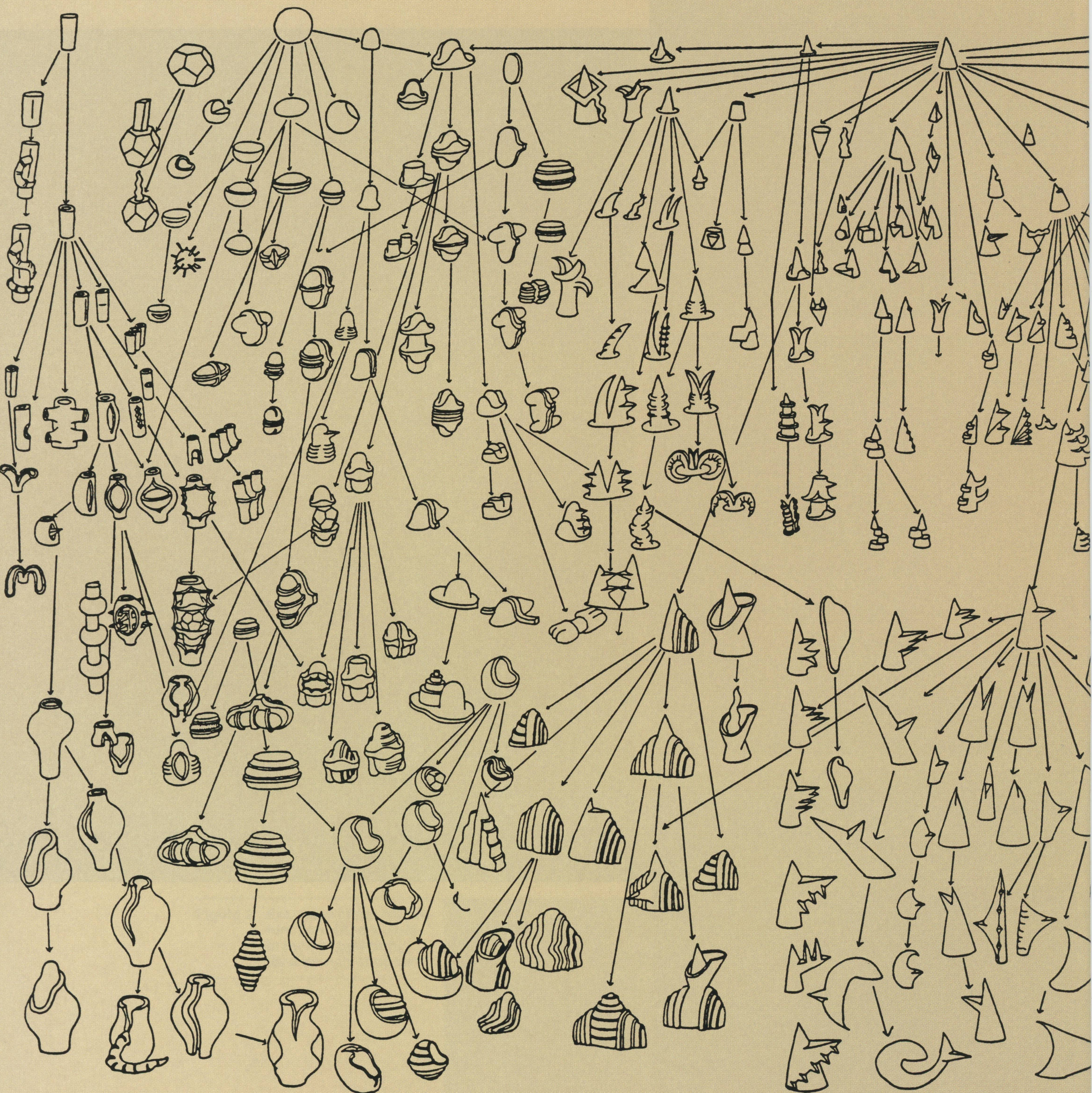
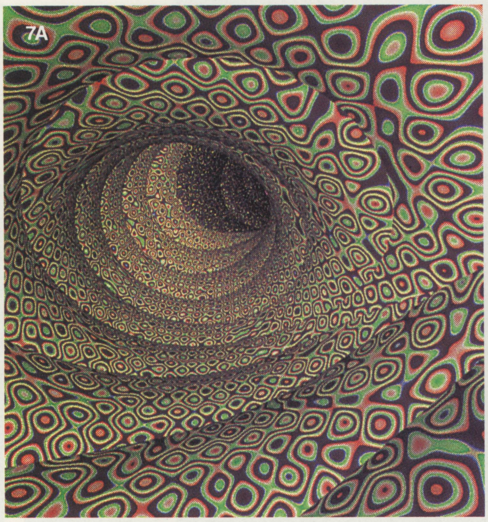
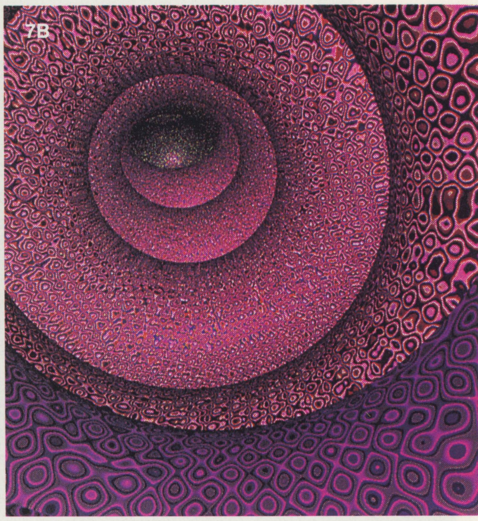


Figure 7 Three views from an animation flying through a form





LIFT, PLEASE

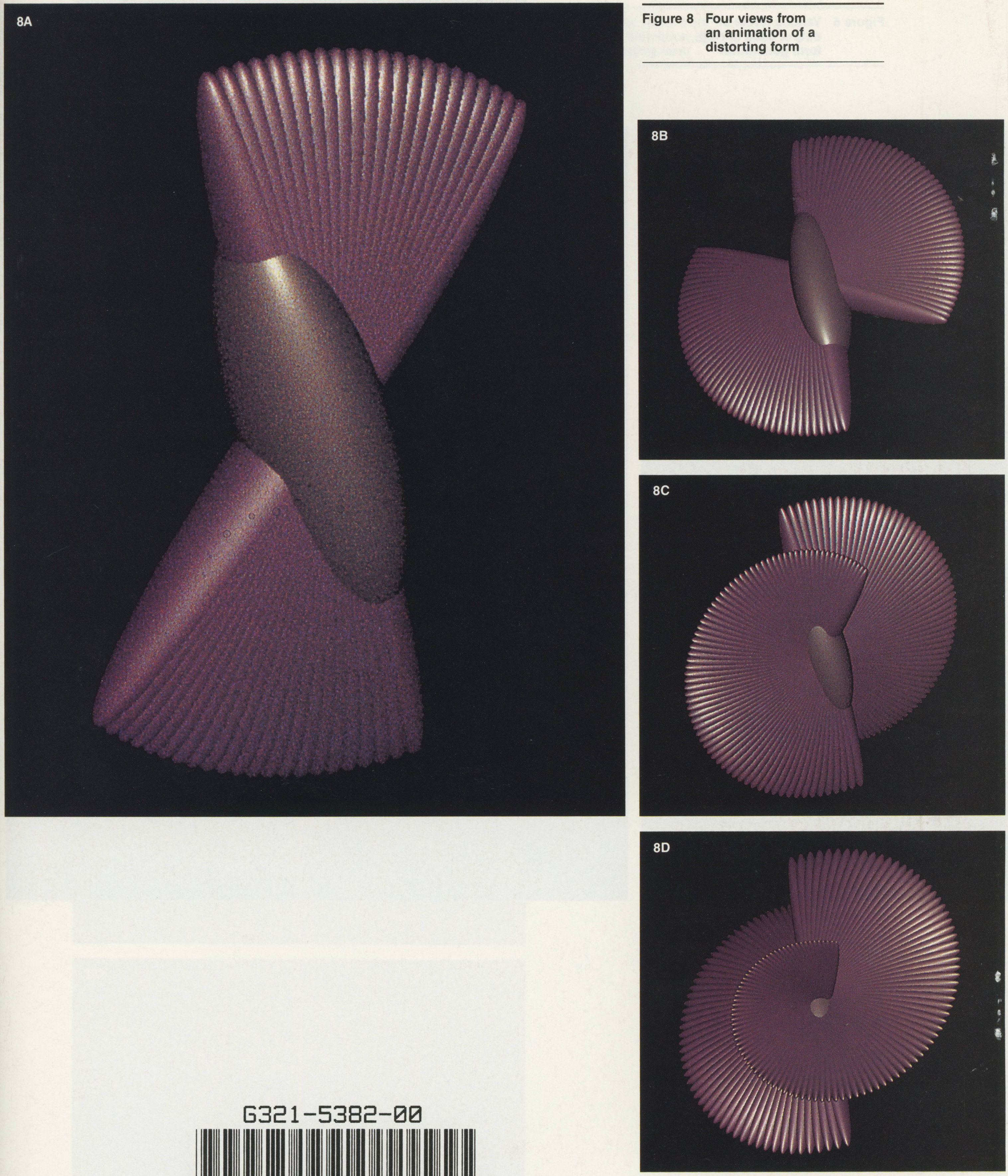
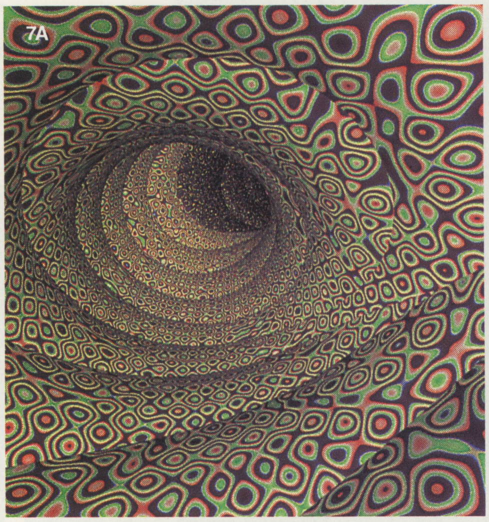
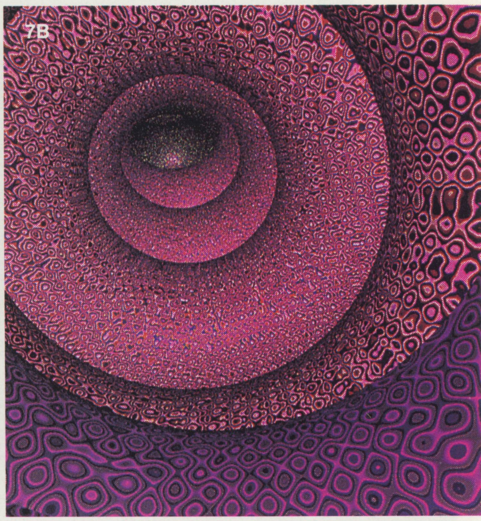


Figure 8 Four views from an animation of a distorting form

G321-5382-00

Figure 7 Three views from an animation flying through a form





LIFT, PLEASE

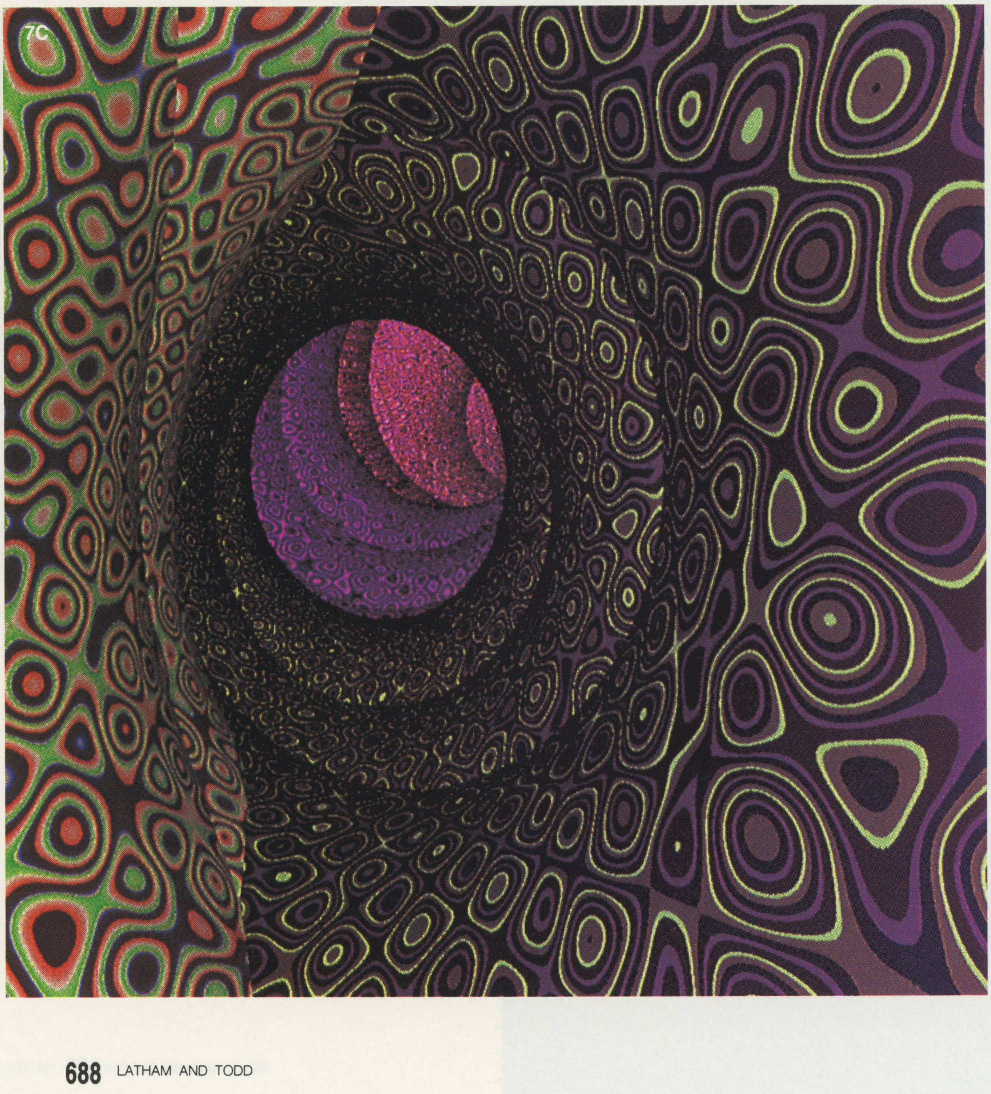
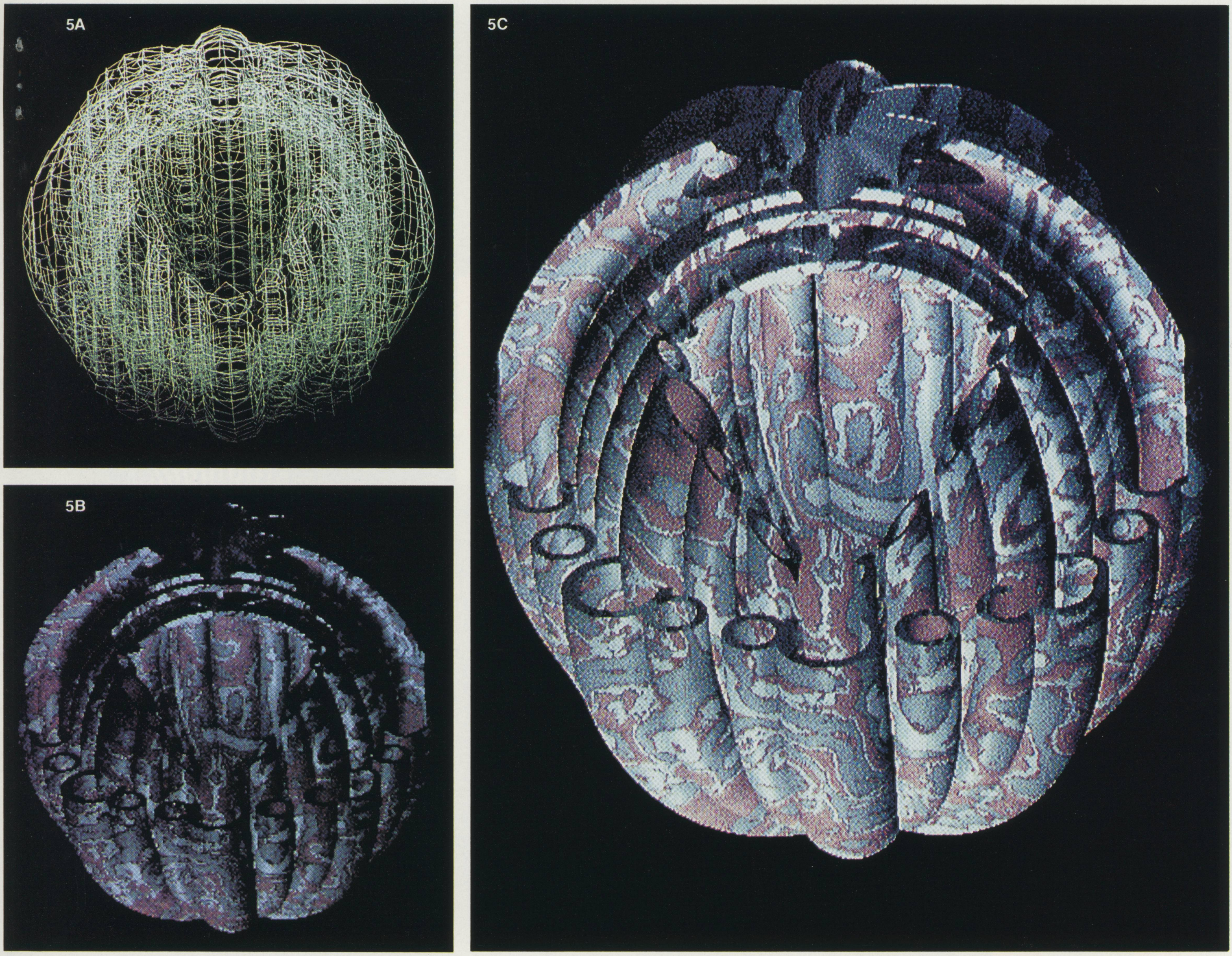


Figure 5 Various levels of output used during form generation



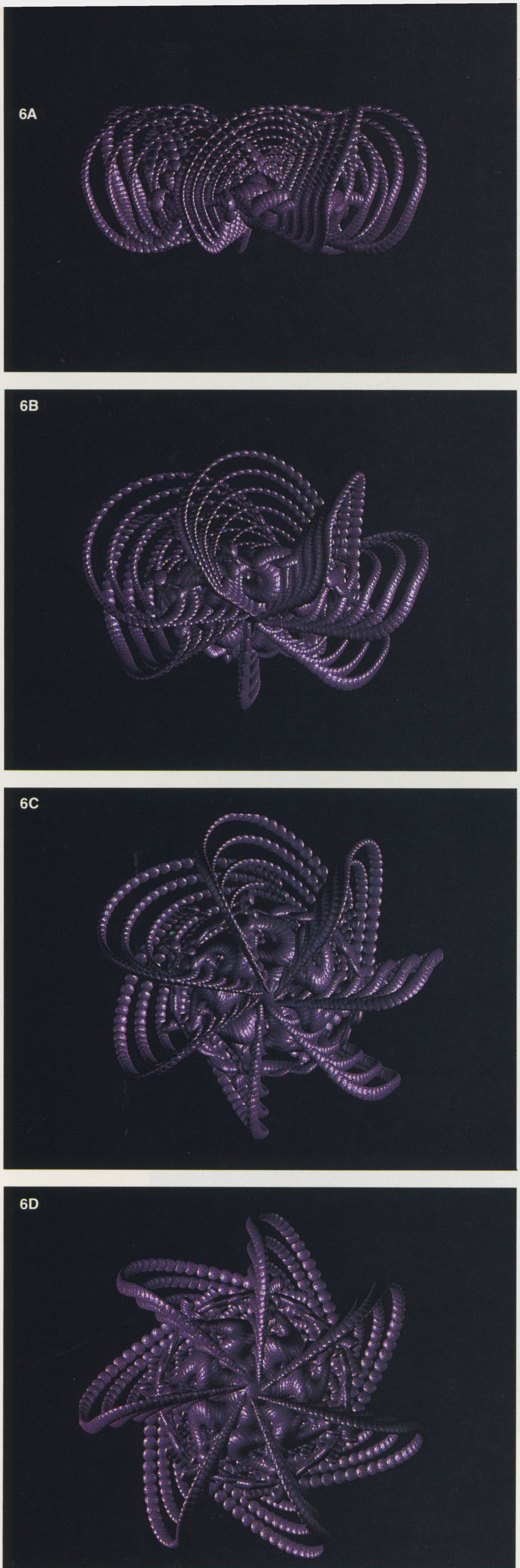


Figure 6 Four views from an animation of a rotating form