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PART I: Information

Chapter 1:
Various manifestations of information

Here are some examples of complex systems, about which the question must be asked: What is the reason that this system can function in such a remarkable way?

1.1 The Spider's Web

Figure 1 shows a section of the web of a *Cyrtophora* spider. The mesh size is approximately 0.8 mm x 1.2 mm. The circle in the lower picture indicates the part that has been highly magnified by an electron microscope to provide the upper picture. The design and structure of this web is exquisite and the spider uses the available material quite economically. Required rigidity and strength—stronger, weight-for-weight, than steel or indeed any other man-made fibre including Kevlar—are obtained with a minimal amount of material. Spiral threads do not merely cross the radials and the two sets are not attached at the points of intersection only. Instead, they run parallel over a short distance and then they are tied or 'soldered' together with very fine threads.

This spider's web gives the appearance of skilled architectural planning and proficient weaving. The spider's body chemically synthesizes the silk it uses for spinning the web using a computer-like controlled manufacturing process. Where did this apparent architectural, engineering and chemical ability come from? How were these instincts instilled into the spider? Where did the information come from? Most spiders are also active in recycling: they eat their own web in the morning and chemically process the material for re-use in manufacturing a new web.

If we want to answer these questions, we have to be willing to look at the possibility that information plays an essential role.

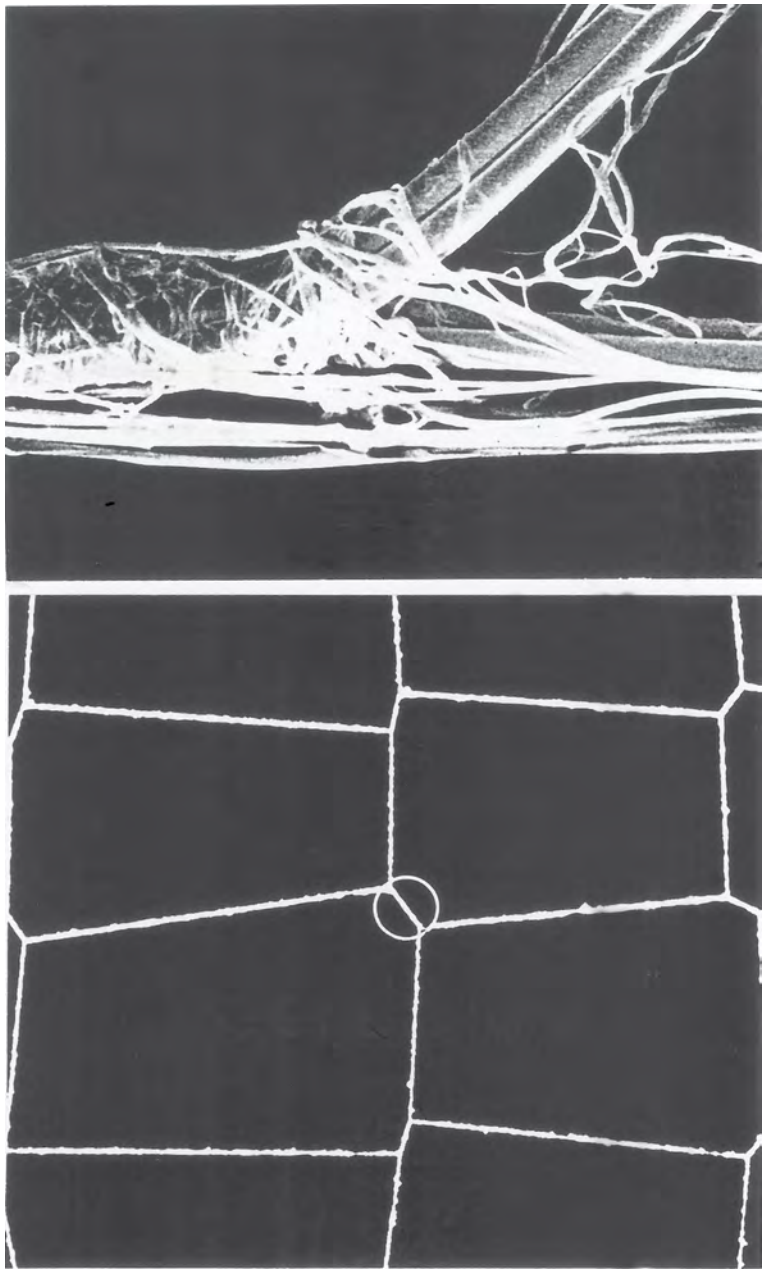

Figure 1: The web of a *Cyrtophora* spider

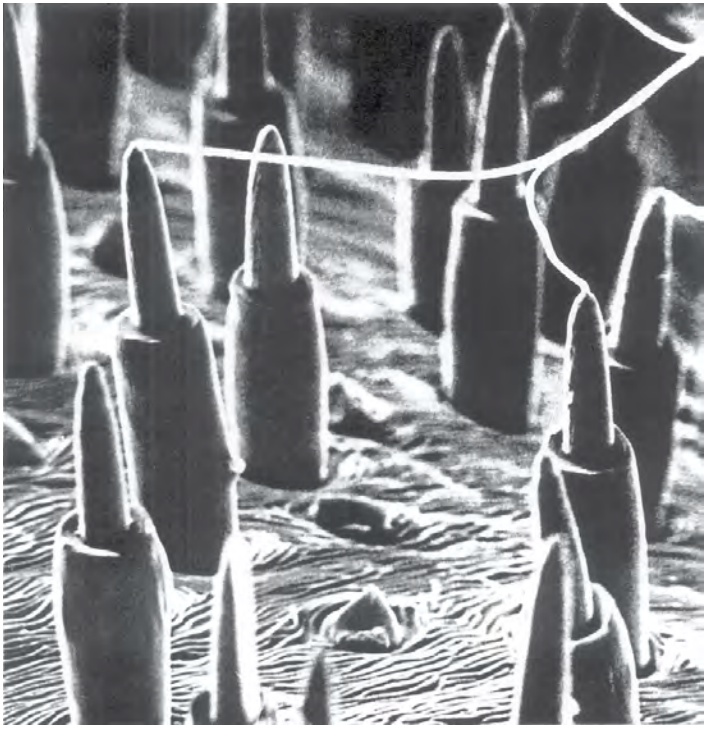

Figure 2: The spinnerets of *Uroctea*

1.2 The Spinnerets of *Uroctea*

The spinning spigots of *Uroctea* spiders are shown in Figure 2 under high magnification. The female has 1,500 spinnerets, only a few of which appear in Figure 2, where threads can be seen emerging from two of them. Silk having the required tensile strength is produced in the 'factories' located directly below the spinnerets. These complex processes have a computer-like control and, in addition, all the required equipment is highly miniaturized. How is it possible that such a complex and minutely detailed manufacturing process can be carried out without mishap? It is because the system contains a controlling program that has all the required processing **information** (see Section 5.9, Operational Information).

1.3 The *Morpho Rhetenor* Butterfly

The South American butterfly *Morpho rhetenor* is depicted in Figure 3 under various magnifications so that the detailed structure of its wing scales can be seen

(*Scientific American*, Vol. 245, Nov. 1981, p. 106). The wings exhibit marvelous colorful patterns, metallic blue above (top left) and brown underneath (top right). The wings were analyzed for pigmentation but none was found. How then can this colorful beauty be explained?

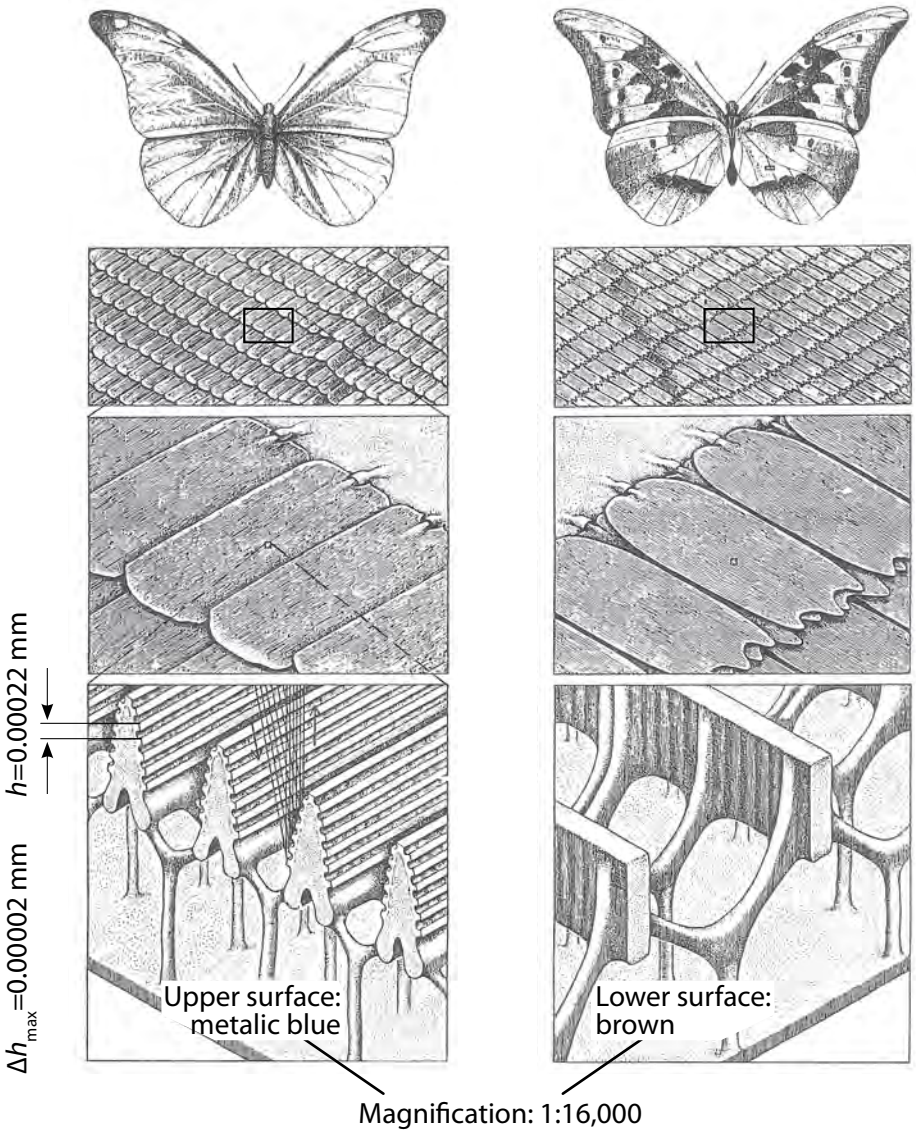

Figure 3: The South American butterfly *Morpho rhetenor* with wing surface sections under different magnifications.

The detailed structure of the wings becomes apparent at 40x, 280x, and 16,000x levels of magnification. At the lower magnifications the structure resembles roof tiles, but at magnification 16,000x the secret is revealed. The structure is quite extraordinary: on the left side of Figure 3 is a regular grid of precisely constructed wedge-shaped ridges spaced at intervals of about 0.00022 mm. This pattern is repeated so accurately that the maximum deviation is only 0.00002 mm. What is the purpose of this marvelous structure, which would be impossible for us to manufacture with this precision?

A certain physical effect is utilized here in a marvelous way. It can be explained in terms of a simple example: when one drops two stones into a pool, concentric waves spread out from each point of impact. At some points of contact these waves cancel out and at other points they enhance one another. This effect is known as wave interference and it is this effect on light waves that results in the observed colors. When the sun's light rays strike the stepped grid, called a *diffraction grating*, some colors are cancelled out and other colors are enhanced. The grid spacing and the wavelengths of the incident light are precisely tuned to one another.

Furthermore, the deep black edges are caused by another fine structure: the scales are covered with pits about 0.001 mm across, with a high refractive index. Almost all light entering this pit is not reflected to an observer, but back into the material, so it appears almost completely black—blacker than any paint.

Another butterfly, *Lamprolenis nitida,* has two blazed diffraction gratings interspersed on single scales, which give two main color signals.

Did this simply happen accidently, where everything is precisely formed to produce a special physical effect? That stretches credibility. It appears that, once again, the answer is most likely linked to **information**! (see Section 5.9, Production Information).

1.4 The Development of Human Embryos

What happens during the nine months of human gestation is incredible. During the first four weeks of the new life, billions of cells are formed and they arrange themselves according to an apparent plan to shape the new human being. Around the fifteenth day the first blood vessels appear. A few days later, within the tiny breast of the 1.7-mm-long embryo, two blood vessels join to form the heart, which begins to pump blood through the minuscule body before the end of the third week. The tiny new heart provides the developing brain with blood and oxygen. In the fourth month the heart of the fetus[1] is already pumping 30 liters of blood per day; at birth this volume will be 350 liters.

1. **Fetus:** After 12 weeks no new organs begin to form. When organogenesis (embryogenesis = the growth and differentiation of cells at the sites of new organs during the first 12 weeks) is concluded, the embryo is referred to as a *fetus* (Latin for 'offspring') and its further growth is known as fetal development.

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