# The Organization of Arthropod Cuticle:

## *A Modified Interpretation*

**A. Glenn Richards**

*Division of Entomology and Economic Zoology, University of Minnesota*

IT IS GENERALLY CONSIDERED THAT THE exoskeleton of insects, crustacea, arachnids, and other arthropods is composed primarily of a polysaccharide called chitin, with or without the additional statement that other substances such as lime, pigments, proteins, and an external waxy layer are present. In fact, textbooks usually characterize these cuticles simply as "a chitinous exoskeleton." A few papers and the well-known textbook by V. B. Wigglesworth are noncommittal. A reanalysis of the situation, including new data, has led the writer to the view that the phrase "chitinous cuticle" is misleading if not actually fallacious. A more detailed analysis is being published elsewhere, but because of the desire to present the shift in viewpoint to the wider audience of general biologists, a digest of the facts is presented here.

The cuticle of arthropods is the secreted ("nonliving") layer covering the exterior surface of the body, the cuticular appendages such as setae, scales, and sense organs, and also the corresponding surfaces of certain invaginated parts such as the fore and hind guts, the genital ducts, apodemes, and tracheae—all of which show the same type of structure and organization, though there are obvious variations in thickness, hardness, and color.

The evidence for calling these cuticles "chitinous" seems based on the remarkable chemical stability and insolubility of chitin, the retention of recognizable structure after removal of other components, the presumed general occurrence of chitin, and perhaps the fact that chitin is the best known chemically. Chemical stability, insolubility, and information on structure can be summarily dismissed as irrelevant to the question of what are the basic components of arthropod cuticle. The retention of structure after purification is not valid evidence, both because chitin is insoluble in the agents used for purification and because newer methods show that only the grosser structure is retained. The idea that chitin is of general occurrence has numerous exceptions (which are usually ignored!). Insect tracheae and butterfly scales, and even different tracheae or scales of a single individual, may be found either with or without this substance. Also, the epicuticle (outermost layer of the cuticle) is said always to lack chitin. Even membranes which give positive tests for chitin may contain extremely low percentages of this substance. Chitin is recorded as usually accounting for 20–40 per cent of the dry weight of the cuticle, but although the amount may in a few cases rise to as high as 60 per cent, it may also drop to as low as 1–2 per cent. With such a range of quantitative determinations already available, it seems likely that we must eventually say that the chitin content of different cuticles varies from 0–60 per cent.

It seems to the writer difficult to view the arthropod cuticle as primarily chitinous when these highly specific structures retain similar structure, even in electron micrographs, whether chitin is present, nearly absent, or completely absent. In view of the above facts the present writer feels forced to conclude that the evidence in favor of calling the arthropod cuticle chitinous is not convincing, and that either there is no chemical constancy to the basic pattern of arthropod cuticles or the constancy must be due to something other than chitin which is always present in reasonable percentage.

Since it has been pointed out above that insolubility is not a valid reason for calling arthropod cuticle "chitinous," it follows that the basic framework does not have to possess this quality. In re-examining the components in this light, one is impressed with the fact that the cuticular proteins fit all the requirements for being the basic component of the cuticular membranes of arthropods. There are no known examples of cuticular membranes which lack these proteins. Irrespective of the percentage of chitin, the percentage of protein is always high. While little is known about the composition of these proteins (there is only one preliminary paper), a sufficiency of data attests their general occurrence. Of course, it is not possible to say that cuticular membranes lacking proteins will never be found; if such are found, we will have to conclude that there is no chemical constancy to the cuticular framework. At present it seems more reasonable to assume both that these proteins are always present, necessarily plasticized, and that they form the basic molecular framework which is variously modified by other substances (usually including chitin) to produce the various recorded subtypes.

Biologists will recognize that the above argument is based on the type of thought used in comparative anatomy. The concepts affected involve mostly our orientation toward further analysis of the molecular architecture of cuticle and our interpretation of the development of these membranes. The analysis of arthropod cuticle is still in such a state of infancy that it seems unwise to hazard any guesses as to the eventual

effects of such a change of concept for membrane properties and permeability. The obvious effect on anatomical thinking is to abolish the concept of the cuticle being a chitinous sheet with a fundamentally different layer on the outside (epicuticle). This concept is replaced by that of a continuous protein layer, usually modified by the addition of waxes on the outer surface and chitin and, less often, other substances in the inner region.

Quite likely, an extended polemic about a single "basic" component would be futile. The arthropod cuticle is obviously a highly complex organization. All that can safely be said at present is that the known manifestations are consistent with the view that arthropod cuticles are variously modified protein membranes and are not consistent with the view that they are basically chitinous.

# NEWS *and Notes*

**Two bills providing for a National Science Foundation** were introduced into the Senate on Friday, February 7. The first bill, now numbered S. 525, was introduced by Senator Elbert D. Thomas of Utah and is identical with S. 1850, which passed the Senate in the 79th Congress, but which died in a House Committee.

The new bill introduced by Senator H. Alexander Smith of New Jersey is a compromise measure, which Mr. Smith believes avoids the controversial features of the Kilgore-Magnuson bill (S.1850) of the last session and S.525 of this. Senator Smith, who is a Republican, said that he was directed by Robert A. Taft of Ohio, majority leader of the Senate, to prepare a bipartisan bill in an effort to get a National Science Foundation established in this session. Accordingly, Senators Warren G. Magnuson and J. W. Fulbright, who are Democrats, and Republicans Guy Cordon, Chapman Revercomb, and Leverett Saltonstall joined with Senator Smith in introducing the new bill.

Both bills were referred immediately to the Senate Committee on Labor and Public Welfare, of which Senator Taft is the chairman.

The new Smith Bill provides for the creation of a National Science Foundation composed of 48 "outstanding men and women who are recognized leaders in the fields of the fundamental sciences, medical science, engineering, education, or public affairs" to be appointed by the President. This body is authorized to develop and encourage scientific research in the interest of national welfare and defense, including the award of scholarships and fellowships and global interchange of scientific information.

The 48 members of the National Science Foundation would delegate broad powers to an executive committee of 9 members, who would select the director and deputy director of the Foundation. These positions would be full-time jobs at $15,000 and $12,000 annually.

The bill provides for the immediate establishment of 5 divisions: medical research, physical sciences, biological sciences, national defense, and scientific personnel and education. The inclusion of the social sciences is left to the judgment of the Foundation.

The new bill does not estimate the annual cost of the program, but authorizes such sums as may be necessary to carry out the provisions.

On Friday, February 7, Senator Smith said that the number of persons suggested in the bill, 48, bears no relation to the number of states and may prove to be unwieldy. Presumably, a smaller number, perhaps 24, might ultimately be decided upon. Senator Smith also said that in his opinion the Foundation would have jurisdiction over atomic research of a nonmilitary nature. The new bill does provide for the distribution of funds by states. This was one of the controversial features of the earlier bills introduced into the last session, and, according to Senator Smith, any attempt to introduce this feature into S. 526 will not be acceptable to the sponsors of the measure. He said: "The sponsors of this legislation are aware of the fact that they are pioneering in a new field. They are convinced that, if this experiment is to be a success, the greatest possible latitude must be given to the scientific experts throughout the United States to determine what research in basic science is entitled to and is in need of Federal support, and who are the most promising younger members of the profession who are entitled to scholarships or graduate fellowships to complete their education." He went on to say ". . . that the development of the Foundation should be by the trial-and-error method with amendments to the basic act from time to time as the experiment proves necessary."

As has previously been announced in *Science*, the AAAS is planning an Inter-Society conference on the National Science Foundation on February 23, at which time it is expected that the new bills will be compared and analyzed.

Leaders in the Congress who have been concerned with a National Science Foundation have been invited to spend Sunday evening with more than a hundred delegates to the Inter-Society conference. In next week's issue of *Science* the complete text of the new S. 526 will be published.

**Maj. Gen. H. S. Aurand, director of Research and Development,** War Department, spoke before 1,500 physicists at the joint annual meeting of the American Physical Society and American Association of Physics Teachers at Columbia University on January 30.

During World War II, he said:

. . . The military man's respect for the scientist was greatly increased. Those of us who had the opportunity to work with scientists during World War II were amazed at your vision, your intense devotion to your work, and your calm assurance of purpose. Time after time, when the chips were down, the scientists came through with the answers.

Here at home, in your laboratories, you