way? Caste determination may well be "coarse-tuned"—two or three castes constitute a very blunt instrument to be adjusted to the numerous environmental contingencies, even with the finer tuning provided by age-related responses and individual differences in pace. I doubt whether caste determination is unique in this bluntness.

The questions that we can ask about strategies are necessarily myopic: we cannot say anything about what might evolve in the long term or know much about the problems that have been solved and are no longer problems. To ask about optimization at all is to presuppose that the necessary genetic variability is available to carry the species to at least a local optimum. But suppose the capacity is simply not there and the solutions we see are only workable ones? Fitnesses are relative, not absolute, and as long as no better competitor appears the suboptimal may survive perfectly well. Competitive exclusion would never happen in nature if all species were the best (rather than just good or average) at doing what they are supposed to do. More than any other book I have read, *Caste and Ecology in the Social Insects* lays bare the problems of applying optimality theory to ecology and evolutionary biology, devoting the whole of chapter 8 to explicit and penetrating self-criticism. The authors are clearly optimists; otherwise, knowing what was to appear in the eighth chapter, they would never have written the previous seven. It is far too early to tell whether this optimism is justified; but without doubt they have created some mighty and fascinating problems where before there were only ants.

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Chemical Coevolution

Biochemical Aspects of Plant and Animal Coevolution. Proceedings of a symposium, Reading, England, Apr. 1977. J. B. HARBORNE, Ed. Academic Press, New York, 1978. xviii, 436 pp., illus. $50.90. Annual Proceedings of the Phytochemical Society of Europe, No. 15.

This symposium volume reviews aspects of an exciting and rapidly expanding subject that is already finding important applications in agriculture and silviculture and promises to do so to a much greater extent in the future. During the last 20 years there has been a growing realization that many of the chemical constituents of plants function not so much in basic metabolism as in ecological interactions with plant enemies and mutualists. These "secondary substances," previously the province of natural products chemists and pharmacologists, appear to constitute the main defense of plants against herbivores, pathogens, and other plants and also are of great importance in attracting pollinators and seed dispersers.

I found all the chapters in the book interesting. They contain much new information, and there is a healthy proliferation of new hypotheses and attacks upon old ones. T. Swain assails the ecological selectionists, claiming they have mistakenly assumed that a description of biochemical or other aspects of present-day ecological interactions can explain changes that have taken place in the remote past. In fact, most selectionists have so far not concerned themselves with the remote past but have attempted to discover the underlying principles maintaining patterns in contemporary plant and animal interactions and have used them to create testable predictions concerning related present-day interactions. When these basic principles have been discovered they will, one hopes, prove useful in understanding the course of evolution in the remote past, since it is reasonable to assume that selective influences maintaining contemporary patterns have also been important in their evolution. The cast may change but the plot should be similar.

Swain and other contributors to the book champion the historical approach to understanding biochemical coevolution, with an emphasis on phylogeny that borrows heavily from the techniques of paleontology and chemotaxonomy. Unfortunately, there is little fossil evidence concerning plant and animal coevolution, particularly, and not surprisingly, in the case of chemical aspects. Thus the schemes developed by historical coevolutionists have themselves been largely based on properties of living species thought to be similar to ancestral forms, and Swain is guilty of the same shortcoming he attributes to selectionists. While one school has highlighted the importance of selective influences in evolution the other has highlighted ancestry. It is a truism that both are intimately involved. We now need a combination of the two approaches. Swain's scenario of plant defensive chemical evolution from the Paleozoic onward is fairly plausible, but its authoritative air belies its speculative nature. There is a great need for further fossil chemical evidence.

It has been proposed that the amount and type of defense evolved in various plants should be related to the risk plants face from enemies. S. McNeil and T. R. E. Southwood think that a major defensive adaptation against insects in high-risk (long-lived, common) plants may be to render their nitrogen unavailable, as has been previously suggested. D. H. Janzen, himself a confirmed selectionist, warns against applying the risk hypothesis to interactions between seeds and seed predators because we do not yet know enough about the natural history of seed predators. He apparently believes that an assessment of resource risk must take enemy properties into account. I believe that the definition of risk should exclude reference to particular enemy properties in order to avoid circular reasoning in unraveling coevolution.

E. A. Bernays and R. F. Chapman find that feeding by two species of acridoid insects, both of which naturally eat only grasses, is much less inhibited by grass extracts than by extracts of nonhost-plant species. Surprisingly, they interpret this to mean that grasses are relatively free of defensive substances and, on the basis of this dubious assumption, propose a scheme of evolutionary change in the feeding habits of Acridoidea from polyphagous ancestors. Using analogous methods it might easily be concluded that any chosen group of plants is free of defensive substances. H. F. van Emden concludes from his studies of aphids, which tend to be mobile, reproductively prolific, and host-specific, that most insect species with restricted host range may be "*r*" selected and, conversely, that insects with many hosts may be "*K*" selected, which seems unlikely.

D. A. Jones, R. J. Keymer, and W. M. Ellis find only limited support for the hypothesis that polymorphism for cyanogenesis in clover and birdsfoot trefoil populations is maintained by a combination of selective grazing on acyanogenic individuals when herbivores are present and lower fitness for cyanogenic plants when herbivores are absent. Their results can be explained if the plants are also polymorphic, or exhibit variance, for other defensive systems and both plant species contain candidate substances. Similarly, W. C. Burnett, S. B. Jones, and T. J. Mabry report that a sesquiterpene lactone added to an artificial diet deterred feeding and depressed growth and survival of insects but that in

field tests plants containing this compound experienced heavier grazing than a member of the same genus depauperate in sesquiterpene lactones, suggesting the presence of another defensive system in the lactone depauperate plant.

Taxonomically dissimilar animals deal with dietary toxins by remarkably similar metabolic pathways (P. Millburn). Disappointingly, differential mechanisms or detoxification potencies among coevolutionarily relevant groupings, such as herbivores versus nonherbivores or host-restricted herbivores versus generalized herbivores, are not discussed, and resistance mechanisms other than those involving chemical modification of the toxin are not covered.

M. Rothschild has so far obtained little evidence for her hypothesis that dietary carotenoids may potentiate olfactory and auditory perception and hormonal changes in animals. *Ophrys* orchid fragrances attract male insects, which transfer pollen while endeavoring to copulate with the flower, but attempts to associate the fragrances with insect sex pheromones have proved unsuccessful (G. Bergström). Bergström believes that the interaction probably evolved from a stage in which the orchids produced nectar to one in which the insects benefit by collecting volatile secretions from the flowers for use in swarming behavior. Seed toxins and insect carotenoids are discussed by E. A. Bell and J. Feltwell, respectively, to conclude the section on plant-animal interactions.

E. I. Newman concludes that allelopathy occurs, but he thinks this effect may be merely fortuitious, not due to natural selection acting on competing plants, and that allelopathy is not the primary function of the substances involved. Doubtless, these conclusions will be challenged. According to J. B. Harborne and J. L. Ingham, postinfectional production of phytoalexins is the most important mechanism by which plants resist fungal infection. Harborne and Ingham compare phytoalexins produced by various plant taxa, but unfortunately no comparisons are made among ecologically relevant groups such as trees, shrubs, and herbs.

Evidence has been accumulating to suggest that many plants, perhaps most, can actively increase their levels of defensive substances over time periods ranging from hours to years in direct response to attack by herbivores, analogously to their responses against pathogens. This effect may be of great importance as an analytical tool in herbivore population dynamics and, potentially, for pest control. The absence of any reference to this phenomenon is a failing in a book claiming to cover the most significant developments in ecological biochemistry of the last five years. The book should be read by all those in the field, but more complete and condensed introductory summaries are available for the general reader.

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Techniques in Field Theory

Relativistic Quantum Fields. C. NASH. Academic Press, New York, 1978. x, 224 pp. $31.

Relativistic quantum field theory has become a tool used daily by the high energy physicist. It is now widely believed that non-Abelian gauge field theories give the fundamental dynamics of the strong interactions as well as furnishing the framework for the unification of the weak and electromagnetic interactions. In particle physics the fundamental issue of our time has centered on attempts to understand the interaction of non-Abelian color gauge fields with quark fields. The application of quantum field theory has not been limited to particle physics, however. The great advances that have recently been made in our understanding of the scaling laws in second-order phase transitions have come about through a study of the long-distance behavior of zero-mass quantum field theories.

There is a notable lack of books for students dealing with modern quantum field theory. This short volume by Nash discusses a number of recently developed techniques in field theory in a manner intended to be comprehensible to postgraduate students. In particular the book deals with functional integration, dimensional regularization, infrared behavior in quantum electrodynamics (QED), the Wilson expansion, and the Callan-Symanzik equation. Each topic is illustrated by many well-chosen examples, though there are hardly any physical applications given. By and large ϕ^4 theory and QED are the field theories discussed, with some results quoted for non-Abelian theories.

About a quarter of the book is devoted to a discussion of dimensional regularization. The examples in this section are especially well chosen. A reader familiar with the basic properties of Feynman diagrams should be able to obtain a good working knowledge of dimensional regularization. I think this is the most successful part of the book.

Renormalization of ϕ^4 theory and QED is done mostly by means of examples. A general subtraction procedure, such as that of Bogoliubov, Parasiuk, Hepp, and Zimmermann, is not given. This makes the discussion of the Wilson expansion little more than the statement of a set of rules. In deriving the Callan-Symanzik equation the very elegant method of Symanzik is used. However, without a thorough knowledge of a subtraction procedure this method is virtually impossible to comprehend.

Relativistic Quantum Fields is written in a crisp, lucid style. Many of the topics discussed in the book are not covered in any other book intended to be used by students. If the reader is willing to refer to some of the original papers while reading this book, he or she should be able to obtain a good foundation in modern quantum field theory without an undue amount of pain.

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