



WOODS HOLE OCEANOGRAPHIC INSTITUTION

ADAPTEDNESS

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FOREWORD

The study that will be presented in the following pages brings up the question of what to count as the content of adaptedness, and its examples, various organisms and species. Should the warm-bloodedness of animals dictate that they are year-round active and so adapted in temperate regions, that they have the property of year-round adaptedness? And should the cold-bloodedness of other vertebrates dictate, contrastingly, that they are not year-round active and not adapted, that they do not have the property of year-round adaptedness? Should plants be considered to be adapted to the habitats and areas where they live, and should the habitats and areas be considered to be adapted to their plants – for the plants would not be there if the habitats were not adapted to them. And migrating birds – surely they are adapted to their northern breeding areas (which are adapted to them) and surely they are just as clearly adapted to their southern wintering areas (which are adapted to them). If features such as these are thought to be the appropriate contents of an adaptational enterprise, then what can be added to turn this content into a formed and structured whole? Thus structure will be the issue of concern throughout.

CHAPTER 1

Introduction

A structure for adaptedness will be sought in the following pages. In order to achieve structure for adaptedness, a basic feature is empirical observations. Empirical observations will include the following features.

First to be presented will be a few traits in the paleontology of land vertebrates in order to exemplify evolutionary adaptedness and the lack of it. In contrast, ecological adaptedness (and the lack of it) will be exemplified by the oyster-mussel temperature relation, by plankton-nutrient relations in the sea, and by the niche structure of the lizard *Anolis* in the Caribbean. On a different slant, spatial adaptedness will be exemplified by plant and habitat structures, and by animal species and their ranges of occurrence. Next, adaptedness will be sought in examples describing non-interaction between plankton species and interaction between littoral species. Then, continuing interaction, exemplifications of adaptedness will be found in pairs of interacting elements: two symbionts, plant and habitat (again), phytoplankton and nutrient, predator and prey, and

ciliate and algal cell. There will follow multiple adaptations as exemplifications of adaptedness in the heating of fish and, contrastingly and to gain wide coverage, in the various ways of CO₂ fixation. Finally, the growth rates of several algal species at various temperatures will provide examples, instances of both adaptedness and non-adaptedness. And after this small affair a description of the North American forest, a grand affair, will provide further examples, further instances of adaptedness and of non-adaptedness (the lack of adaptedness). And a few more examples will complete a rather heterogeneous array of empirical descriptions of adaptedness and the negation of adaptedness.

Already structure is apparent. There is the property of adaptedness, and in some situations the property of non-adaptedness. There are exemplifications, examples, instances of these properties.

Further structure is achieved by four principles of adaptation (Hulburt, 2002). First principle: if two quite different entities occur under the same condition, then one is adapted, has adaptedness, to the condition and the other is not adapted, does not have adaptedness, to the condition. Second principle: if one entity occurs under two quite different conditions, then the entity is adapted, has adaptedness, to one condition but is not adapted, does not have adaptedness, to the other condition. Third principle: if one entity is adapted, has adaptedness, to another entity, then this second entity is adapted, has adaptedness, to the first entity. Fourth principle: if two or more quite different entities occur under two or more quite different conditions, then each entity is adapted, has adaptedness, to its condition.

Structure will have a further gain by using logical validity. The logically valid structures contraposition, equivalence, and constructive dilemma will be used to rework the data and the four principles. No notation will be presented in the main text until near the end, in order to keep the reading manageable (though an appendix with notation is provided).

A philosophical approach will be adhered to in the presentation of data. The approach will be that of the metaphysical realist – one who endorses and holds dear the point of view that particular organisms and species possess the properties that compose them. The property of adaptedness is possessed by the organism that exemplifies it, that instantiates it. But not only properties but relations also will declare themselves as structural elements in the framing of adaptational structure.

Properties and relations lead to sets. And so set theory will be applied to observations and will be interwoven with properties and relations to structure the observations into an adaptational structure. Relations and functions of set theory will be found to be appropriate handmaidens to frame, with philosophical properties and relations, the empirical data of many biological portions of nature.

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CHAPTER 2

A Brief Review of Adaptation

So often adaptation and natural selection are considered in the same breath. Natural selection produces adaptation—the selected is better adapted – according to Williams (1966, pp. 25-27), to Sober (1993, pp. 171-208), to Stern (1970), to Mayr (2001, pp. 147-157), to Gould (2002, pp. 508-584) and to so many others. Thus Stern says “whatever has been produced by selection is to be designated as better adapted”. But consider the reverse: adaptation produces natural selection – the better adapted is selected. This is what Stern seems to say when “we were able to define an adaptation as any characteristic which caused its possessors to produce ... more offspring than they would in its absence”.

Is it interesting in what way such principles are presented? Let us see. Natural selection means having greater reproductive success, it should be noted. Employing the comparative idea of more, better, greater, etc., Brandon (1990, p. 11) says “If a is better adapted than b in environment E , then (probably) a will have greater reproductive

success than b in E ". Putting the matter in this two-part if-then format really is a clarifying procedure. But what is most interesting is what is not said. Why is it not said that if a does *not* have greater reproductive success than b , then a is *not* better adapted than b ?

The slender vista presented so far is expanded appreciably when Brandon reverses and changes slightly his description of the first paragraph. Thus the part starting with *if*, call it p , will be " a is better able to survive and reproduce in E than b ", and the part beginning with *then*, call it q , will be " a is better adapted than b in E ". And the whole affair is then q if p and q only if p , which is shortened to q if and only if p ¹. Brandon presents this shortened form, but he does this, as noted, in a quite different way: " a is better adapted than b in E iff [if and only if] a is better able to survive and reproduce in E than b " (p. 15). Another term for if and only if is 'equivalent to'. Why is this different? The form of presentation is an important difference, as will be seen later. But the striking difference is in the word 'able'. Able-to-survive seems so close to ability-to-survive, where ability is a property, a trait.

Munson (1971), in his discussion, introduces trait when he expands our view by going from "Trait T of organism O is adaptive in environment E " to " O has T and T is advantageous to O in E ". So one can see, in passing, that adaptive and advantageous overlap, they are true of many of the same organisms apparently. But trait, though an

¹If and only if means ' q if p and q only if p ', as noted. But ' q if p ' is the same as 'if p then q ' and 'if q then p ' can be expressed as ' q only if p ' – so that 'if p then q and if q then p ' reduces to ' q if and only if p '.

important ingredient, does not get attention in itself. Munson, impatiently, covers a medley of matters. There is an arresting switch in details when ‘in *E*’ changes to ‘to *E*’. Thus he says “Organism *O* is adapted to environment *E*”, “Species *S* is adapted to *E*”. One little word makes all the difference. For one single entity, organism or species, is adapted *to* one single entity, a certain environment. One could say succinctly: *x* is adapted *to y* – a tight connection.

But not forgetting the problem of what a trait is, what *T* is, what *T* is when *O* has *T*, Grant (1963, p. 95) gives a well crafted factual presentation: “The webbed feet of a duck set toward the rear of the body represent an adaptation for swimming; the strong sharp talons of an owl are an adaptation for clutching prey; the opposable front and rear toes of a warbler are an adaptation for perching on branches”, wherein duck *O* has webbed feet *T* and webbed feet *T* are (is) advantageous to duck *O*, which is to say, is adaptive *in* environment *E*, and, more cogently, is adapted *to* environment *E*. But what is trait *T*, webbed feet? This trait is the trait of adaptedness, exemplified in a duck, but exemplified also as an adaptation, for an adaptation is a property, exemplification of adaptedness..

Thus we have worked from the factual term adapted – true of many organisms – and its sister term adaptive – showing a tendency to become in fact true of many organisms – we have worked from these terms to the term adaptation. One adaptation is one entity, whereas adapted is true of many entities.

But to continue, Barash (1978, pp. 57-62) gives four traits for three species of marmots in North America. The eastern woodchuck *is* adapted to a low elevation habitat

and a long growing season and *has* these four traits, these four adaptations: dispersal of young at the end of the first year, sexual maturation during the second year, annual reproduction, solitary and aggressive social system. The Olympic marmot, by contrast, *is* adapted to a high elevation habitat and a short growing season and *has* these four traits, these four adaptations: dispersal of young at the third year, sexual maturation in the fourth year, biennial reproduction, colonial and tolerant social system. The yellow bellied marmot is intermediate in habitat and traits. Probably the last thing in the world that interests Barash is the switch from ‘is’ to ‘has’, from something is adapted to something else, x is adapted to y , to something has an adaptation, x has y and y is an adaptation. What interests Barash is the evolutionary change with the changing habitats. The traits as a bundle for each species are considered adaptive, the bundle for each species maximizing the fitness of each species – for throughout his book on sociobiology adaptive and maximizing fitness are regularly equated. The issue, one can vaguely discern, is not that there is some process of evolutionary change but that there is the accomplished fact of evolution in the three bundles of traits being adapted to three different environments, in the three species being adapted to three different environments.

But process is the central issue in Lewontin’s (1978) large scale portrayal when he says “the wholesale reconstruction of a reptile to make a bird is considered a process of major adaptation by which birds solved the problem of flight”. This wholesale reconstruction of a reptile includes the four traits or properties common to all birds: hollow, lightweight bone, increased size of sternum, change in integument to feathers for

flight and insulation, and increased forelimb. With the appearance of these traits evolution, *made* birds adapted to flight – solved the problem of flight, metaphorically speaking.

The accomplished fact of evolution and the process of evolution are expressed in another way (Levins and Lewontin, 1985, p. 68). “All extant species, for a very large part of their evolutionary histories, have neither increased nor decreased in number and range..... At the same time, the species is evolving, changing its morphology, physiology, and behavior. The problem is how a species can be at all times both adapting and adapted.” A point well taken.

This discussion has brought forward several features. Brandon provides if-then and if-and-only-if structure; these are logical structures. Munson provides trait; a trait is a property, an attribute, a universal. Munson relates the trait, the property, of being adapted to the environment. Instances of the property of being adapted are given by Grant: the webbed feet of a duck, the talons of an owl, the opposable toes of a warbler are property instances of adaptedness; they are adaptations. Finally the process and the accomplished fact of being adapted are important aspects of evolution for Barash, Lewontin, and Levins and Lewontin.

Now it is apparent what is wrong. The vista presented in the last three paragraphs is so unremittingly positive. It just can't be right. But three more cases are the following.

Let us consider the account of Kricher and Morrison (1989, pp. 141-143). They say that in the eastern woodchuck of the U.S.A., “the ability to hibernate.....is an adaptation”. The grey squirrel is pointed out because it lacks this adaptation. They want

us to believe, without a shred of evidence, that “In the past, probably millions of years ago, woodchuck ancestors possessing the ability....to sleep deeply for at least part of the winter, were the ones that survived best....and left most offspring in the overall woodchuck population.” They are concerned of course with the origin of an adaptation. Here the concern, instead, is the double question: Is the woodchuck adapted because it hibernates and is the squirrel *not* adapted because it does *not* hibernate? It is baffling that such an obvious contrast is not made. What they say is “an adaptation in one species is never guaranteed to evolve in all species, even if it would be advantageous.” Their thinking is confused.

A similar line of confused thinking is from Seger and Stubblefield (1996, pp. 99-102). A frequency distribution of clutch sizes for nearly 4500 clutches of great tits (*Parus major*) in Wytham Wood near Oxford (England) showed that “the most productive clutch is 12 but the commonest clutches are 8 and 9. Parents therefore appear to lay smaller clutches, on average, than those that would maximize their fitness.” If “maximize their fitness” is interpreted to mean “best adapted”, then it would seem that the commonest clutches are *not* the best adapted. But the authors’ effort is to explain both statistically and experimentally why the tits did not maximize their fitness. Their effort is to explain away the tits’ *not* being best adapted. Their thinking is confused.

A third case of confused thinking is provided by Gould and Vrba’s (1982) treatment of adaptation and exaptation: adaptations fit the organism to the environment and originate through natural selection, whereas exaptations fit the organism to the environment but do not originate through natural selection. One case of theirs is the

black heron of Africa. Their assumption is that feathers arose for insulation first, thence became part of enlarged arms as wings for flight. In the case of the black heron the wing is outstretched and shades the water, so that small fish can be seen and caught. This use of the wing was not selected in evolution, so the authors say “the wing per se is an exaptation in its current effect of shading”. What is confused here is that the wing’s being an adaptation is an assumption, but it is a matter of fact that the wing is adapted, is fitted, is suited to flying and also to shading. Both adaptations are simply factual matters. Adaptedness is exemplified in two ways, flying and shading. But to say one way came about by an assumed, imagined scenario and the other did not is to indulge in an unwarranted assumption – for one simply cannot know how the wing came about, how flying and shading came about.

But Dobzhansky (1968, p. 6) is perfectly clear in his thinking. He says “Man is not adapted to feed in pasturage, while horses and cows are so adapted; palms and bananas have no adaptedness to live in Canadian forests, while larches and spruces do have such adaptedness.....”

Whether Dobzhansky was aware of the importance of the distinctions he made is uncertain, but nevertheless his distinctions are vital. First, there is both affirmation and denial of adapted and adaptedness. Second, there is both the general term adapted and the singular, abstract term adaptedness. Third, there is the dyadic character, mentioned also by Munsen, of one entity adapted to another, of one entity having adaptedness to another. These three points will be included in the method of presentation.

CHAPTER 3

Method of Presentation

Two aspects of the method of presentation will be: using the general term *adapted* and using the abstract singular term *adaptedness*. The general term *adapted* is true of all and only those organisms or species that exemplify the property picked out by the abstract singular term *adaptedness* (Loux, 2003, p. 31). This is philosophically correct.

Philosophical correctness will be adhered to in the ensuing discussion. Thus what is the philosophical status of the term *adaptation*? If one endorses the view of the metaphysical realist (Loux, 2003; Moreland, 2001; Armstrong, 1989), the view that particular organisms possess the properties that compose them, then there are common properties that are repeated from organism to organism, from species to species. Such a property is *adaptedness*. This single property is exemplified, is instantiated in each duck, each owl, each warbler – and in each duck species, each owl species, each warbler species in Grant’s depiction in Chapter 2. These exemplifications of *adaptedness* in the various animals are whole body exemplifications. But when Grant says “The webbed feet of a duck set toward the rear of the body represent an adaptation for swimming”,

adaptation here is a *property* exemplification (instantiation) of adaptedness. Adaptation here is the representation of the property adaptedness in some morphological part of the organism.

The derivation of the viewpoint of the metaphysical realist (following closely Loux 2003, pp. 26-27) is as follows. Suppose it is said ‘the white spruce is adapted to Canada’. Corresponding to this *subject-predicate* linguistic structure is the real, external world structure of *particular-property*. The subject ‘the white spruce’ is a linguistic element and refers to a real element, a single though scattered entity, the white spruce. This entity is a particular, a particular broadly speaking. But the predicate ‘is adapted to Canada’ has referential force too in that ‘adapted’, a general term, refers to, picks out an abstract singular entity, adaptedness, and this single entity accounts for the fact that the repeated use of the general term has precisely the same effect.

When in this case the adaptedness to Canada is involved, pure adaptedness is excluded. Adaptedness to something makes adaptedness an impure property, an impure trait. Once this feature is admitted, it is an easy step to see x having adaptedness to y as a relation. And this parallels x is adapted to y , a relation between x and y .

Thus, summarizing, we have a property, adaptedness. This is “a multiply exemplifiable abstract entity that is a numerically identical constituent in each of its instances” (Moreland, 2001, p. 74). The use of ‘adaptation’ will be to refer to property instances, examples in the multitudinous, visible, concrete things that exemplify the single, abstract thing that may be deduced to be a numerically identical constituent from concrete thing to concrete thing. And this concrete thing is an instance, an example

whether it is a whole part of an organism, the whole organism, the whole species – or the whole habitat or area that the species occupies.

The structure of adapted-adaptedness is always relational: x is adapted y , x has adaptedness to y . Now there is nothing about this relation to prevent it from being reversed: y is adapted to x , y has adaptedness to x . But cases of non-reversibility and reversibility are important to consider.

A clear case of preventing such reversal is gotten by using Brandon's if-then two part structure: "if a is better adapted than b [has better adaptedness than b] in E , then (probably) a will have greater reproductive success than b in E ". It is impossible for b to be better adapted to a , when a reproduces better than b .

An equally clear case but for reversal is gotten by not having if-then structure, by having instead point-blank adaptedness, when: plant x has adaptedness to habitat y . The ground the plant stands on has adaptedness to the plant, otherwise the plant would not be there, so: habitat y has adaptedness to plant x .

So these two vital strands, non-reversibility and reversibility, will be a basic structure in the following enterprise. Their mixture will be a part of the enterprise.

CHAPTER 4

Evolutionary Adaptedness

Gould (2002) describes at length a unified theory of evolution, with adaptedness being an adjunct of the evolutionary process. Here there will be considered evolutionary adaptedness in the case of land vertebrates. It will be the view here that evolutionary adaptedness at the morphological level is *not* a unified process, because evolution would appear to be a haphazard, ununified process morphologically.

Moreover, as pointed out in Chapter 2, Lewontin (1978) says “The wholesale reconstruction of a reptile to make a bird is considered a major adaptation by which birds solved the problem of flight.” This is a misrepresentation of a part of vertebrate evolution. Vertebrate evolution is a chronically repeating process at the morphological level, as shown by the following features.

Amphibia began in mid-Devonian (early Paleozoic) and achieved their greatest development in the Carboniferous, 60 million years later. At this time the first reptiles began. Later, in the early Mesozoic, the Triassic, mammals split off by the smallest changes from reptiles, and later still at the end of the Mesozoic feathered birds began (see

Carroll, 1988, pp. 156-415; McFarland et al., 1979, pp. 291-453, for what is to come).

Paramount in land vertebrates is the common property of four legs (appendages) with single upper leg bone, two lower leg bones, and five toes (fingers). This property is subject to reduction. In amphibia aistopods (Carboniferous) and caecilians (present-day) there are no legs. In the lizard-snake (diapsid) part of the reptilia the burrowing *Amphisbaenia* have no legs – this group has a tight articulation of skull bones, separating it from the snake with its loosely articulated skull. Then there are snakes. So there are four completely legless groups, the *Amphisbaenians* and snakes occurring throughout the Cenozoic, but aistopods only in the Carboniferous and caecilians only present-day for sure.

Instead of leglessness, reduction in toes is prevalent. Instead of five, there are four toes on the fore feet of frogs and toads, occurring in the Cenozoic. There are four toes on the bipedal dinosaur *Ornithomimus* in the Cretaceous (late Mesozoic). And four toes, often three forward and one backward, are common in Cretaceous and Cenozoic birds. Finally, reduction to two toes occurs in ostriches, Eocene to present. In ungulates (mammals) toe reduction is repeated as four toes reduce to three to one in perissodactyls (four toes on front legs and three on back legs in titanotheres [Oligocene] and tapirs [present], three in rhinoceroses, and three then one from earlier to later Cenozoic horses). The reduction in ungulates is repeated again from four to two in artiodactyls (four toes in pigs, two toes in camels and deer, all with Cenozoic histories) (from Romer, 1959, pp. 256-278).

Repetitiveness, with very little correlation between the repeating features in geological time, is what has been seen so far. In addition to reduction of legs to no legs and five toes to two or one toe in a repeating manner, there is often the repeated feature of elongateness. Aistopods, caecilians, amphisbaenians, and snakes exemplify elongateness, but there are many examples of extreme elongateness among land vertebrates that return wholly to the water. Examples from major groups of amphibia and reptiles are given next. The groupings are made by the absence or presence of openings on the side of the head, fenestrae – no fenestrae, anapsid; one fenestra below squamosal and postorbital bones, synapsid; one fenestra above squamosal and postorbital, euryapsid; two fenestrae, diapsid. We get these groups and examples of elongateness (fig. 1).

1. Anapsids, amphibia – examples are embolomeres (Carboniferous) and nectrideans (Permian).
2. Synapsids – no examples.
3. Euryapsids, reptilia – examples are nothosaurs (Triassic) and plesiosaurs (Jurassic - Cretaceous).
4. Diapsids, reptilia – examples are *Askeptosaurus* (middle Triassic), *Hovasaurus* (upper Permian), pleurosaurs (Jurassic-Cretaceous), and mesosuchians (Jurassic).

These four groups are polyphyletic, so these occurrences of extreme longness are disconnected in an evolutionary sense. These occurrences are haphazard partially but not wholly because they are all wholly aquatic. Some of the animals are quite large, though most are not.

Large size is repetitive, as in mosasaurs (Upper Cretaceous), titanotheres (Eocene-Oligocene), rhinoceroses (Eocene to present), and elephants (Eocene to present).

Extremely large size occurs twice, dinosaurs (Mesozoic) and whales (Cenozoic).

Bipedality occurs in theropod dinosaurs, pterosaurs, feathered birds, and people. Flight is likewise repetitious in pterosaurs, birds, and bats. Toothlessness, with beaks instead, is repeated in turtles (Mesozoic-Cenozoic), the theropod dinosaur *Ornithomimus* probably (Cretaceous), and feathered birds (Cenozoic). Paddle-like feet occur in ichthyosaurs and plesiosaurs (Jurassic-Cretaceous) and seals (Pliocene-present).

As can be seen from this rehearsal, there is a chronic repetition of structures scattered through the non-fish vertebrate collage. It is hard to see how evolutionary change in morphology can bear on single evolutionary change in adaptedness. Mere morphology cannot be the basis for an all-inclusive adaptedness.

However, physiology can.

But wait – wait a moment – before going on, one may want to interject. We cannot ignore morphological traits as being adaptations, as exemplifications of adaptedness. We just do see them that way. We see many – but not all – morphological traits as adaptations.

When amphibia or lizards become legless, they are adapted to burrowing, to moving through leaf litter. When amphibia and reptiles remain always in the water, they surely are well adapted there, their paddle limbs are adaptations. Seals are surely adapted to the water, their paddle limbs are adaptations too. Webbed feet of ducks and frogs are surely adaptations: these adaptations exemplify the attribute of adaptedness –

these adaptations are property examples of the property of adaptedness. Turning next to the matter of toes and fingers, four toes in birds, three forward and one backward, seem just the adapted thing for perching, an adaptation par excellence, exhibiting the property of being adapted, the attribute of adaptedness. Then, as many ungulates become faster and faster by becoming more and more tip-toe with one or two hoofed toes, they surely got to be well adapted by their adaptations. This is all unremittingly positive, an unnuanced picture in one dimension, but strong and undeniable.

In addition to the many, many adaptations that land vertebrates have – morphological adaptations – there are the simple physiological adaptednesses of being warm-blooded or being cold-blooded. But warm-bloodedness, endothermy, what is it? What keeps a bird or mammal warm? The first fact, we are told, is the heat of metabolism. The metabolism of endotherms (birds and mammals) as ml. of oxygen consumed per gram of tissue per hour is six times higher than in ectotherms (amphibia and reptiles). This is shown in Figure 7-21 of McFarland et al. (1979, p. 267). The second fact is the regulation by the nervous system that keeps the endotherms' feather-hair-insulated body at a high and constant temperature. A few sample studies might include the following. Ransom, Fisher, and Ingram (1937) surgically produced lesions in the hypothalamus part of the brain in rhesus monkeys. The monkeys were kept at temperatures between 75°F and 80°F. Their temperatures decreased from a normal temperature of 101°F to temperatures in the low 90's F for a period of several weeks. But after three weeks they regained their normal 101°F temperature. This partial regulation of temperature is illustrated for birds when lesions were surgically produced in

Table 1

Deep body temperatures of some adult birds and mammals (from Bligh, 1973, p. 352)

Birds		Mammals	
Species	Temperature (°C)	Species	Temperature (°C)
Domestic duck	42.1	Mouse	37.9
Domestic goose	41.3	Rat	36.8
Domestic turkey	41.2	Rabbit	38.9
Chicken	41.9	Pig	38.6
Domestic pigeon	42.2	Cat	36.4
English sparrow	43.5	Dog	38.2
Brown pelican	40.3	Sheep	39.0
Downy woodpecker	41.9	Opossum	34.7
Bank swallow	41.4	Echidna	28.1
American magpie	41.8	Polar bear	37.6
Abert's towhee	42.0	Reindeer	38.8

the hypothalamus-preoptic region. In the case of house sparrows cooled hourly from 42°C to 11°C the sparrows decreased from their normal temperature of 42°C to 28°C (Mills and Heath, 1972). But in the case of the Pekin duck, similarly lesioned, almost no change of body temperature of about 42°C occurred when the ducks were exposed to temperatures from 30°C to -5°C (Hagan and Heath, 1980). So, in addition to hypothalamus-preoptic control, spinal cord control is apparent. These studies illustrate the general features of thermoregulation in mammals and birds, where “nearly normal thermoregulation appears after sufficient recuperation from preoptic lesions” in mammals and hypothalamus-preoptic or spinal cord control occurs in birds (Nelson, Heath, and Prosser, 1984). So the crucial features of high metabolism and neural, thermostatic regulation provide for the high core temperatures of mammals and birds in Table 1 (Bligh, 1973, p. 352), higher in birds than in mammals.

The temperature of mammals when hibernating may be just above the external temperature (Lyman and Chatfield, 1955) or in the case of the chipmunk may be 6°C above an external temperature of 0°C or in the case of the arctic ground squirrel may be between -2°C and 2.9°C when the external temperature is -15°C (Heinrich, 2003, p. 162).

Thus, the warm-bloodedness of birds and mammals is equatable to their warm temperaturedness except when hibernating. And the cold-bloodedness of some animals is equatable to their variable temperaturedness, as in Fig. 7. And these physiological properties stand in marked contrast, of course, to morphological properties. And it is the switch from the morphological to the physiological that will be analyzed next.

There are morphological adaptations which are chronically repetitive and haphazard, and there is the physiological adaptedness of warm-bloodedness and the physiological unadaptedness of cold-bloodedness. In the case of temperate land vertebrate evolution here is a plan to move from the morphological to the physiological. Remembering that adaptations are property exemplifications of adaptedness the plan starts out as 1., which is logically valid.

1. Morphological adaptations are haphazard. There is an adaptation which is not haphazard. Therefore, there is an adaptation which is non-morphological. A non-morphological adaptation is the warm-bloodedness of one single animal. But this occurs in the whole animal. So in general whole animals are examples, exemplifications, of non-morphological properties such as adaptedness and non-adaptedness, exemplified in the following general, logically valid descriptions by *all*..... Both 2. and 3. next are forms of the logically valid structure contraposition (see appendix I for explanation of 1., 2., and 3.).

2. All temperate land vertebrates, if warm-blooded, have adaptedness to year-round temperature – all, if not having adaptedness to any year-round temperature, are not warm-blooded.

3. All cold-blooded temperate vertebrates have adaptedness only to summer half of the year temperatures if and only they do *not* have adaptedness to *non*-summer half of the year temperatures.

In 2. is the first principle of adaptedness. The first principle is: each warm-bloodeder and each cold-bloodeder occur under the same temperature condition, one

adapted and the other not adapted – one exemplifying the attribute (property) of adaptedness and the other exemplifying the attribute of non-adaptedness. For any pair of animals from these two groups the logically valid contraposition is: if one animal's x is in a warm-blooded animal, then it, x , has adaptedness to year-round temperature – equivalent to; if x does not have adaptedness to year-round temperature, then x is not in that warm-blooded animal (so is in the other cold-blooded animal). There is one x in two animals. The x is an abstract constituent of each animal, like a property, but it is a trans-animal connector to warm-blooded from cold-blooded and is the connector in that evolutionary change; otherwise there would be no such thing as evolution in this important physiological sector.

There is further analysis. In 2. there are two classes, warm-blooded temperate vertebrates and physiologically adapted vertebrates. By the principle of extensionality these classes are identical because they have all the same members (Copi, 1979, p. 178; Lipschutz, 1998, p. 14) – so they are A. In 2. there are two more classes, cold-blooded temperate vertebrates and physiologically unadapted vertebrates, which are identical because they have all the same animals; so they are B. But if temperate land vertebrates are adapted year-round because they are active year-round, then the temperate land vertebrates are split differently into two classes. If the criteria for class membership are year-round-active vertebrate and behaviorally-adapted vertebrate, then these two classes are identical because they have all the same warm-blooded non-hibernating animals as members – so these classes are C. Likewise, if the criteria for class membership are not-year-round-active vertebrate and behaviorally-unadapted-vertebrate,

then these two classes are identical by having cold-blooded and hibernating warm-blooded animals as members – so these are D.

Finally, in 3. there is the second principle of adaptedness. The second principle is: each single cold-bloodeder occurs sequentially under two temperature conditions, adapted under one and unadapted under the other – exemplifying the attribute (property) of adaptedness in summer and later the attribute of non-adaptedness in winter.

In closing, structure has been achieved by empirical description as morphological and haphazard, by two of the four principles, by logical validity, by the trans-animal connector x , by the principle of extensionality, and always by the principle of exemplification of properties.

It is hoped that these structures seem the sort of thing to be taken seriously and to be reflected upon.

CHAPTER 5

Ecological Adaptedness

In contrast to evolutionary adaptedness there is ecological adaptedness. Maynard Smith (1993) gives various examples, usually of a superficial nature, such as the color of various animals to make them blend into their background and thus be less likely to be eaten by predators. Here a much deeper appreciation of ecological adaptedness will be presented in a description of the oyster-mussel relation, the phytoplankton-nutrient relation in the sea, and the niche structure of the lizard *Anolis* on several of the Caribbean islands.

The Oyster and the Mussel

Both the oyster (*Crossostrea virginica*) and the mussel (*Mytilus edulis*) open their shells slightly and pump large amounts of water through. In the case of the oyster, with the flattened shell removed and with the small end of the hollower shell held up, there are visible the wide marginal gills, which curve around the wide, lower end. Water comes in the opened shells primarily on the right edge, is made to cross the gills by their cilia, is collected into canals that empty finally at the lower left edge of the shells (Galtsoff, 1964,

Table 2

Average rates of water pumping, in cc. per hour, of groups of oysters subjected for approximately six-hour periods to temperatures ranging from 0.0° to 38.0°C.

Temperature intervals °C.	Number of oysters			Pumping rate	
	Total	Open	Pumping	Average	Maximum
0.0- 2.0	8	2	1	113	---
2.1- 4.0	52	22	1	863	1,020
4.1- 6.0	28	14	5	180	266
6.1- 8.0	20	12	6	495	1,197
8.1-10.0	36	21	16	763	1,594
10.1-12.0	36	24	22	2,914	4,303
12.1-14.0	32	25	22	3,902	5,409
14.1-16.0	28	27	26	4,344	5,787
16.1-18.0	21	21	21	9,083	11,583
18.1-20.0	33	33	33	7,020	9,773
20.1-22.0	42	42	42	9,802	13,341
22.1-24.0	24	24	24	7,795	10,802
24.1-26.0	14	14	14	9,537	12,635
26.1-28.0	20	20	20	9,366	11,569
28.1-30.0	24	24	24	12,983	15,155
30.1-32.0	19	19	19	11,813	16,253
32.1-34.0	20	20	20	8,948	12,856
34.1-36.0	17	17	17	2,785	4,201
36.1-38.0	4	4	4	2,449	3,884
Total	478	385	337	---	---

p. 68). During this transit phytoplankton is gotten to the mouth of the digestive tract near the upper end for the oyster's nutrition and oxygen and carbon dioxide are exchanged all along the gills. In order to get the amount of water pumped through, a rubber apron is glued near the left edge of the oysters' shells and is brought together as a tube to empty into a measuring apparatus.

Loosanoff (1958) measured the pumping rate of 337 oysters at a complete array of temperatures shown in Table 2. The Table shows that the rate of pumping was low though erratic from 0°-2°C to 8.1°-10.0°, was considerably higher from 10.1°-12.0°C to 14.1°-16.0°C, was still higher from 16.1°-18.0°C to 26.1°-28.0°C. This last large interval had an average of 8727 c.c. of water pumped per hour, very much higher than at temperatures below 10°C. Still higher pumping rates occurred for a few intervals above 28°C. In general the oyster responds to temperature in a cold-blooded manner. (This excellent study is just one of a variety of similar studies in the first part of the 20th century, reviewed by Galtsoff, 1964.)

The oyster responds in a cold-blooded manner but the mussel does not. Loosanoff (1942) studied the mussel in a different way. He found the time open of the shells did not change appreciably from -1.0°C to 24.9°C. The mussel was apparently unaffected by the wide range of temperature. The experimental responses of the oyster (with erratic valves removed) and of the mussel are compared in Fig. 2.

Thus the experimental observations show that the oyster has the attribute, the property of *not* responding fully to the year-round temperature range of the southern New England shoreline, which is about 0°-22°. So the oyster has the attribute, the property of

not being adapted to the full, year-round range of southern New England temperature.

But the mussel does have the attribute, the property of responding fully to the year-round southern New England temperature range, and so it has the attribute, the property of being adapted to that temperature range. The oyster, the mussel is all the oysters, all the mussels, a natural and usual inference from experiments.

The first principle of adaptedness is upheld by these observations, since two quite different entities, the oyster and the mussel, occur under the same environmental condition, and one is not adapted and the other is adapted to the condition. The situation can be reexpressed in a form of the logically valid structure, contraposition.

4. There is a y which is a part of the year-round temperature range, and: if x does *not* respond fully to y , then x is *not* adapted to y – equivalent to; if x is adapted to y , then x does respond fully to y .

The variable x is a constituent of, a piece of the oyster, each oyster or all the southern New England oysters in one heap, in the first part of 4. The variable x is a constituent of, a piece of each or all the mussels in the second part of 4. Same x throughout – a trans-entity x , bridging from one entity to the other, from one heap to the other heap, where one heap exemplifies unadaptedness and the other exemplifies adaptedness.

In 4. there is negation of the if-then structure in the first part of 4. followed by affirmation and reversal of the if-then structure in the second part of 4. This is a mark of contraposition, a logically valid structure. Looking back to the analysis of 2. there is affirmation of the if-then structure in the first part of 2. followed by denial and reversal of

the if-then structure in the second part of 2. The structures of 2. and 4. are mirror images. And both are contrapositions.

A further point, with x a constituent of one oyster or heap or mass of all oysters, is the following, in the logically valid form of contraposition.

5. x is adapted only to warmer temperatures if and only if x is *not* adapted to *non-warmer* temperatures (cold temperatures).

Here is the second principle of adaptation in logically valid form, which is: if one entity occurs under two quite different conditions, then it is adapted to one and not adapted to the other condition; it exemplifies adaptedness to one and not to the other.

The 'the' of 'the oyster' can refer to the species *Crassostrea virginica*. A species, of course, is a class, a set, to which each oyster belongs and determined by the properties which characterize each oyster. One single oyster is composed of a great many properties, in the view of the metaphysical realist or even common sense. If two or more oysters were composed of the same properties, they would be exactly alike, for by the principle of the identity of indiscernibles two entities with the same properties are identical (Loux, 2003, p. 112). And it is by the break-down of this principle that all the variously shaped oysters are accounted for. This remark introduces a new subject, a subject to be further elaborated upon in later chapters.

Thus there are various strands of interest and importance to be woven together to provide for the structure of adaptedness. Although these strands appear here to detract from the empiricity of this enterprise, next the empirical nature of the presentation will be emphasized.

Phytoplankton Nutrient Adaptedness in the Ocean

Whereas the oyster and the mussel exemplify unadaptedness and adaptedness with respect to temperature, in the case of the phytoplankton in the ocean exemplification of adaptedness and unadaptedness with respect to nutrient will be taken up. But first a brief description of the phytoplankton is given.

Four groups of single photosynthetic cells make up the phytoplankton of the ocean. The first group is very small. 1μ in diameter, and much more abundant than the others (Murphy and Haugen, 1985). It is the *Synechococcus* plankton. The other groups are $>7\mu$ and are classified as phyla (Margulis and Schwartz, 1988). They are called coccolithophores, dinoflagellates, and diatoms. These have (usually) the common property of having golden-brown chloroplasts. Their distinguishing traits, as seen under the light microscope at low or high power, are: coccolithophores – globular (usually) and covered by small plates; dinoflagellates – cell divided into two parts by a transverse groove; diatoms – with a visible shell for each cell, with cells having geometric shapes and often in colonial chains. Fig. 3. provides examples. These easy to see (microscopically) traits do not correlate with the trait of growth, the capacity to respond to nutrient. Instead there are two groups. There are two classes. Each class is defined in two ways. Class 1) is defined by its capacity¹ to respond only to impoverished nutrients and by its being a coccolithophore species (except *Emiliana huxleyi*) or its being a dinoflagellate species. Now one can see that these two definitions each determines a

¹ Capacity is a property.

class, so that there are two classes – but these two classes are identical because they have all the same member species (the principle of extensionality, Copi, 1979, p. 178; Lipschultz, 1998, p. 14). Then there is class 2), a class defined in two ways, one is the capacity to respond to improved nutrient (greater amounts or greater availability) and the other is being a diatom species (plus *Emiliania huxleyi*). And one can see that these two definitions determine two classes which are identical by having the same species as members. But this double layout reduces to the impoverished-nutrient-responding class and the improved-nutrient-responding class.

What nutrient is this? There are three nutrients in the sea that are very low in the surface water. These are nitrate, phosphate, and silicate. It is the slight to large fluctuations of these that make all the difference to the abundance and lack of abundance of the two classes, 1) and 2), of the phytoplankton – in the responses of these classes.

Support for the distinction of two classes of phytoplankton is provided, roughly, by Hentschel's extensive study of the phytoplankton of the South Atlantic Ocean from the Meteor Expedition (1932, 1933-1936, Fig's. 15, 16, 21, 22, 23, 24, 25, 35, 36). Hentschel shows the diatom phytoplankton to be much more abundant in the nutrient-rich water at latitude 60°S and in the upwelling along southwest Africa and off northwest Africa and sporadically beyond these areas where the thermocline comes close to the surface making nutrient available. The coccolithophore and dinoflagellate phytoplankton does not get more abundant in these locations.

The distinction into these two classes came about in two steps for the North Atlantic Ocean in extensive studies by the author. Fig. 4 taken from Hulburt (1982a)

shows the more frequent phytoplankton species in the winter from November to April in the years 1961-1972 in the western North Atlantic. The species are uniform in abundance and distribution, except *Emiliana huxleyi* which is somewhat more abundant northward. This Figure shows a few diatom species in slight abundance but some abundance near shore. All the other species are coccolithophores except *Oxytoxum variabile*, *Gymnodimon punctatum*, and *Katodinium rotundatum*, which are dinoflagellates.

But in 1982-1987 (Hulburt, 1990) on spring cruises to the western North Atlantic large abundances of the diatom occurred just in the northern part of this portion of the Atlantic (Fig. 5). Vertical profiles of temperature and one nutrient (Fig. 5) give the reason for the abundance of the diatom. There was a break-down northward of the near-surface temperature stratification in spring. This break-down allowed nitrate (and phosphate and silicate, not shown) to come close to the surface. This was nutrient improvement and produced the abundance of the diatom – whereas southward the extreme near-surface temperature stratification blocked any appreciable get-through of nutrient to the surface and as a result the diatom was meager. Though not shown, no growth of the coccolithophore-dinoflagellate phytoplankton occurred under nutrient improvement northward.

This rehearsal of facts leads to a conclusion in the manner of 4., but with the if-then structure reversed. The following, 6., is the logically valid structure of contraposition, like 4. and also 2. (See Appendix II for explanation.)

6. There is a y which is part of improved nutrient, and: if x responds by growth to y , then x is adapted to y – equivalent to: if x is not adapted to y , then x does not respond by growth to y .

Here the responding, adapted x is part of the diatom mass of material and the unadapted, unresponding x is part of the coccolithophore-dinoflagellate mass of material. Same x . Here all the species (and more) shown in Fig. 3 are put together as two heaps of bulk material, the diatom mass and the coccolithophore-dinoflagellate mass.

Thus two entities, the diatom mass and the coccolithophore-dinoflagellate mass – quite differently responding entities – are both exposed to the same spring condition (improved nutrients): first principle of adaptedness: and one is adapted (exemplifies adaptedness) because it responds, and the other is not adapted (exemplifies non-adaptedness) because it does not respond to this condition. And the two groups are integrated, held together by the same x , a trans-entity bridging constituent.

In addition to 5. the growth of the diatom northward but not southward in spring justifies 7.

7. The diatom (including x) is adapted only to the improved nutrient northward in spring; -- equivalent to: it (and same x) is not adapted to the non-improved nutrient southward in spring.

And Fig. 4 shows that the diatom is not adapted because non-abundant everywhere in winter. So here is the second principle of adaptation: if one entity occurs under two different conditions, it is adapted (exemplifies adaptedness) under one condition but is not adapted (exemplifies non-adaptedness) under the other condition.

The second principle provides no reason to think that one entity is adapted under one of the conditions. There is no reason for being adapted. Adaptedness is point blank adaptedness. Further, there is no switch from a physicalistic reality, growth response, to an interpreted reality, being adapted. This is the situation under the second principle, whereas under the first principle there is a reason for being adapted and there is a switch from the physicalistic to the interpreted, from growth response to being adapted.

The structure 7. can be shown to be contraposition and derivable from 6. in the following manner. 6. in expanded form is as follows.

8. For any y , if x , the diatom, is adapted to y , then y is part of improved nutrient in spring; -- and equivalent to: for any y , if y is not part of improved nutrient in spring, then x , the diatom, is not adapted to y .

Which is the following.

x is adapted *only* to improved nutrient in spring; -- equivalent to: for any y , x is not adapted to y , if y is not part of improved nutrient in spring.

Which is the following.

x is adapted *only* to improved nutrient in spring; -- equivalent to: x is *not* adapted to *non-improved* nutrient (southward) in spring.

Thus the first and second principles have the same basic logical structure. They are integrated by the sameness of structure. Therefore the logical structure shows a gain in structure over the purely discursive structure.

But more than this, logically valid structure in general achieves integration by the *if-then* connectives and the *equivalent to* connective in 5. and 7. Whether or not one is

willing to acquiesce in these connectives being real parts of a real nature at this point in this essay, this point of view will be steadfastly maintained throughout this essay. And this issue brings up a related issue.

Quine (1995, pp. 27-30) says “Whenever there is a raven, there is a black raven” which is “Whenever there is a raven, it is black”, which is “Everything, if it is a raven, is black”. The variable x is introduced to replace *it* and thus to connect the if-then structure. The variable x refers to one of the ravens when it is said linguistically ‘if x is a raven, then x is black’. The linguistic subject-predicate structure is paralleled by a particular-property structure, according to Loux (2003, pp. 26-32). But in particular-property structure x must, it is felt here, be a constituent, a piece of this raven, just as its blackness is a piece of it. And likewise, paralleling this partially, what is described in 6. is: if there is a diatom mass responsive to improved nutrient, then there is a diatom mass adapted to improved nutrient; if there is a diatom mass responsive to improved nutrient, then it, x , is adapted to improved nutrient; if x is responsive to improved nutrient, then x is adapted to improved nutrient. The further step of considering the converse is not one that Quine did. This further step is of paramount importance, for in everyday life we are perpetually concerned with converses. Thus the further step of the converse is that x must be a part of a different organic mass, the coccolithophore-dinoflagellate mass, if x is *not* adapted to improved nutrient. The variable x must be a trans-entity connector, must be a realistic x .

It is hoped that the development of 8. seems persuasive and clear.

The Niches of *Anolis* on Hispaniola

The concern here is to present some of the species of the lizard genus *Anolis* as they are related to their surroundings and to each other on the Caribbean island Hispaniola. The suitedness, the fittedness, the adjustedness, the harmoniousness of the lizard will be the concern of central importance in assaying their relations to their surroundings. Their surroundings are niche structure, part of adaptational structure.

The adjustedness of *Anolis* species depends on the detail with which they fit their surroundings. This is part of the plan of the following investigation. Another part is to present empirical details of situations where it seems difficult to decide whether species are adapted or not adapted. So the interpretive aspect of adaptedness will be considered.

The species of *Anolis* on the large Caribbean island of Hispaniola are distributed in the following way. Three species (Rand, 1962; Schwartz and Henderson, 1991, pp. 249, 254, 235), *Anolis cybotes*, *A. distichus*, and *A. chlorocyanus* occur over much of the island in open, often lowland situations. *A. cybotes* spends much of its time perching on tree trunks at heights up to 10 feet (3m.) above ground, with larger individuals above the smaller. It goes to the ground quite often. *A. distichus* overlaps considerably, perching at heights up to 10-15 feet (3-4.5 m) on exposed tree trunks like *cybotes*. It goes to the ground less frequently than *cybotes* and has larger individuals below the smaller, nearer the ground, so that where it overlaps *cybotes* its individuals are different in size from *cybotes* individuals (Moermond, 1979). Above these species is *A. chlorocyanus*, which perches on the tree trunk and into the tree crown. In addition to these three species is a large species found only in the tree crown (Williams, 1983), *A. ricordii*.

At lower altitudes the three species overlap two common species that extend above them to higher altitudes and into shaded forests: *A. christophei* and *A. etheridgei* (Thomas and Schwartz, 1967; Rand and Williams, 1969; Schwartz and Henderson, 1991, p. 237, 260). *A. christophei* is a trunk anole like *A. distichus* and is the same size; while *A. etheridgei* is the same size as both of these but is distributed somewhat lower on slenderer perches and onto the ground. This is the case in northern and central Hispaniola.

In southwestern Hispaniola (the Tiburon Peninsula), *A. coelestinus* replaces *A. chlorocyanus*; and *A. monticola* replaces *christophei* and *etheridgei*, is the same size as these, and has the same low structural habitat as *A. etheridgei*.

It would seem that these species are all dovetailed into each other and into their habitats, their niches.

More specifically, consider the four lowland species and their niches:

- First: *cybotes* - suited to ground-trunk niches,
- Second: *distichus* - fitted to trunk niches,
- Third: *chlorocyanus* - adjusted to trunk-crown niches,
- Fourth: *ricordii* - in harmony with crown niches.

This characterization is hopelessly positive. It leaves out the overlap of the species. It leaves out their competitiveness, their interference, which is the means by which the niche distinctions are maintained. So the following redescription is necessary. These redescriptions are all logically valid (see appendix III).

First. Let x be part of *cybotes*. Then we have 9.: x is better suited only to ground-trunk niches if and only if x is *not* better suited to any *non*-ground-trunk niches. Next, let z be part of *distichus*. Then we have 10.: z is *not* better suited only to ground-trunk niches if and only if z is better suited to any non-ground-trunk niches. This shows overlap and interference between *cybotes* and *distichus* in ground-trunk niches.

Now, non-ground-trunk niches are the same as trunk niches; we have two descriptions of the very same class of niches.¹ We move up from ground-trunk niches to trunk niches.

Second. Let z be part of *distichus*, as just noted. Then we have 11.: z is better fitted only to trunk niches if and only if z is not better fitted to any non-trunk niches. Next, let w be part of *chlorocyanus*. Then we have 12.: w is *not* better fitted only to trunk niches if and only if w is better fitted to any *non*-trunk niches. There is overlap and interference between these two species.

Now, non-trunk niches are the same as trunk-crown niches; we have two descriptions of members of a single class.¹ We move up from trunk niches to trunk-crown niches.

Third, we have 13.: w , in *chlorocyanus*, is better adjusted only to truck-crown niches if and only if w is not better adjusted to any non-trunk-crown niches. Then let u

¹ This is reminiscent of the basic tenet of set theory, the axiom of extentionality: if two classes (sets) have all the same members, the two classes are identical (Copi, 1979, p. 178, lines 15-16). The point is being made here that the only way to get two different classes is to have two different descriptions defining the two classes, which are identical because of sameness of members.

be part of *ricordii*, 14.: *u* is not in harmony with only trunk-crown niches if and only if *u* is in harmony with any non-trunk crown niches. Non-trunk-crown niches are crown niches.

Fourth. We have 15.: *u*, in *ricordii*, is in harmony only with crown niches.

In all four there is displayed the second principle of adaptation, which is: if one entity occurs under two quite different conditions, it is adapted to one condition but not adapted to the other condition, as in 3. Chapter 4.

Let us reflect on the descriptions *suited*, *fitted*, *adjusted*, *in harmony*. These are not synonymous. Each has a different connotation, a different feeling. For each person each of these has a distinct, perhaps undecipherable, feeling. Each is partly subjective. But each, too, is objective in that each can replace another. Each can replace or be replaced by *adapted*. These descriptive terms are quite different from the physicalistic synonyms *non-ground-trunk* and *trunk*, which describe all the same niches in two different ways. These ways have a minimum of subjective, interpreted content. *Non-trunk* and *trunk-crown* are synonymous in the same way. So there is a contrast in the structure of adaptedness between subjective, interpreted components and purely objective components.

Niche Expansion of *Anolis*

Lister (1976) sees the ecological characteristic of *Anolis* species as changing across several West Indian islands in response to competition. He is concerned with what happens from a species rich island to a single-specied island (Fig. 6). He approaches the issue as a case of competitor removal.

On Jamaica there are four other *Anolis* species coexisting with *A. sagrei*. On Exuma *A. sagrei* exists with three other competitor anoles. But on Abaco and Swan Island *A. sagrei* is solitary, without competitors. Fig. 6 “compares perch distributions for *sagrei*” on the islands. ...“Male, female and subadult male *sagrei* on Jamaica utilize the lowest and narrowest range of perch heights. The Exuma population shifts upward slightly but there is still complete overlap between females and subadult males.” On Abaco “females exhibit obvious expansion, occupying higher perches and overlapping less with subadult males,” though adult males “have not undergone the expected shift” “On Swan Island, however, all three size classes show an expansion in structural habitat”.....

Thus, with decreasing number of competitors, with competitive release, there is expansion in the structural habitat – there is structural niche expansion.

There is thermal niche expansion with competitive release, also. On Jamaica’s north central coast “*A. lineatopus* is found primarily in deeply shaded forest, *A. grahami* in habitats with intermediate insolation, and *sagrei* exclusively in open, sunny areas.” Body temperatures throughout the day of these species reflect their habitats, as shown in Fig. 6. “The absence of *sagrei* from habitats with even small amounts of shade is typical of the species ...throughout its range in western Jamaica. In the Bahamas, however, *sagrei* occurs without more shade tolerant competitors and has invaded habitats with low insolation. The thermal consequences of these habitat shifts are shown in Fig. 6. As one can see, *sagrei* populations on these islands have a range of body temperatures encompassing that of several species on Jamaica.”

Thus, with fewer or no competitors, with competitive release, there is expansion in the thermal habitat – there is thermal niche expansion.

With this background one feels justified in assessing, in judging, *sagrei* as well adjusted where it is not interfered with by competitors. It is well adjusted (well adapted) only to an expanded structural, thermal, competitorless niche. And of course it is not well adjusted (not well adapted) to any non-expanded niches on islands with interfering competitors. And of course these last paired statements make a logically valid whole and conform to the second principle of adaptedness.

The Undecidability of Adaptedness

Ruibal and Philibosian (1970) and Ruibal (1961) provide in their studies of *Anolis* on Dominica and on Cuba a comparison of temperature niches. On Dominica there is one species, *A. oculatus*. On Cuba in the provinces of Carmaguez and Oriente there are five common species, *A. allogus*, *A. lucius*, *A. homolechis*, *A. sagrei*, and *A. allisoni*. The investigators measured the body (cloacal) temperatures of lizards and the air temperature where each lizard was caught. Plots of *A. oculatus* body temperatures against air temperatures show in Fig. 7 that the lizards at Rosalie on Dominica were the same as air temperature in the shaded windbreak area but were warmer than air in the warm sunlit fence post area. All are in a warm part of Dominica, where the air temperature reached 30°C. Plots show the same thing for the deeply shaded Springfield area and the high (850 m.) Freshwater lake area, where the air temperature reached as low as 21°C. These plots show a range of body temperatures of 10.5°C and of air temperatures of 9.0°C. But on Cuba the 11° body range and 10°C air range are overlappingly partitioned by the five

species, shown in Fig. 7. The investigators say of *A. oculatus* on Dominica that it occurs in habitats ranging “from open agricultural areas where it perches on fence posts to cool rain forests high in the mountains of Dominica. This diversity is sufficient to demonstrate that the species occupies a broader ecological niche than any of the anoles of the Greater Antilles. In the absence of competitors *A. oculatus* successfully occupies an array of habitats which on Cuba or Puerto Rico (or Jamaica or Hispaniola) are occupied by different species By comparison to *A. oculatus* the Greater Antillean species are stenotopic and occupy smaller niches – whether measured as thermal (climactic) niches, structural niches, or general habitat.”

One cannot decide whether *oculatus* is adapted, because unrestricted, to the broader niche on Dominica and the species on Cuba are *not* adapted, because restricted, to the smaller niches on Cuba or instead *oculatus* is adapted to its broader niche on Dominica and the Cuban species are adapted, too, to their smaller niches on Cuba. One cannot decide between these two options because *oculatus* and the Cuban species do not overlap; they do not occur under the same condition together. For two, or more, differently behaving entities must occur under the same competitive conditions in order that the different behaviors prescribe one as adapted and the other as not adapted. Yet, here possibly, two or more entities (species) only behave differently because the competitive conditions differ. And this possibility would mean that the properties of the entities are not discernibly different and thus make the entities come out intrinsically adapted.

According to a version of the identity of indiscernibles all behavioral properties

of two or more entities must be the same for the entities to be behaviorally identical. But one cannot be sure whether the entities have the same behavioral properties or not. So one cannot decide whether they are all behaviorally adapted or not.

In the case of the species on Hispaniola it seems as though the species have different niche (perch) heights because they are physiologically and behaviorally different. But in the case of *A. sagrei* on Jamaica and the Bahamas it seems as though this species has different niche (perch) heights only because of competitors' interference. Then, between Dominica and Cuba it seems as though one cannot decide whether it's internal physiology or outside interference, whether *oculatus* on Cuba might have the capability to occupy the full 9°C niche in spite of competitors and each Cuban species on Dominica by itself fail to occupy the full 10°C – or whether *oculatus* on Cuba would be restricted by the other species as they are restricted by each other and each Cuban species by itself would be unrestricted and like *oculatus* on Dominica (see Hulburt, 1996, for a wholly different explanation but with the same outcome).

Thus the decision for adaptedness and for lack of adaptedness is clear in some cases, as on Hispaniola and in the Bahamas. But between Dominica and Cuba no decision can be made. So it is clear that adaptedness is interpretable.

Summary of Chapters 4 and 5

In summary, there are two possibilities: 1) the overlap of complete adaptedness and partial unadaptedness, and 2) the lack of overlap, the separation, of adaptedness and unadaptedness. 1) is illustrated by the complete adaptedness to a wide temperature range

by the warm-blooded (non-hibernating) vertebrate. 1) is illustrated too by the complete adaptedness to a wide temperature range by the mussel. In 1) partial unadaptedness to a wide temperature range is illustrated by the cold-blooded land vertebrate and by the oyster. 2) is illustrated by the phytoplankton because the diatom is adapted to improved nutrient by responding to it and because the coccolithophore-dinoflagellate is not adapted to improved nutrient by not responding to it. 2) is illustrated also by three lowland Hispaniolan *Anolis* species, because each species is adapted to a lower niche but unadapted to the niche above.

In the case of the Dominican and Cuban *Anolis* species the view is that it is an undecidable matter whether they are adapted or not. But the matter can be resolved by noting that this indeterminacy can be construed counterfactually (what would be the case were things other than they are). Thus *oculatus* would be unadapted on Cuba were it restricted like the other species there. And each Cuban species by itself on Dominica would be adapted were each unrestricted like *oculatus*.

This brings to a close cases that are unreversible, cases where x is adapted to y but not the reverse. From here on many cases will be reversible, x adapted to y and the reverse. Also this brings to a close cases where there is both affirmation and denial of adaptedness. In subsequent chapters cases of affirmation will be preponderant.

CHAPTER 6

Adaptation and Selection

Two accounts of adaptation and selection are given next because they illustrate the first principle of adaptedness. These accounts stand out as meager accounts of adaptedness. They are in total contrast to the many large-scale accounts of adaptedness that are the content of this book, wherein adaptedness is divorced from the assumption of natural selection and the assumption of directional selection. But the following accounts are factually based; there is factual basis for natural or directional selection and for this reason they are included. For again it is stressed that only factually based accounts of adaptedness are employed in this book.

The standard phraseology, adaptation and selection, is ill-defined by the principles of this book, because adaptation is a property instance or example of adaptedness. What must be born in mind is that an adaptation is concrete and particular and individuated, whereas adaptedness is abstract and deducible as a single constituent repeated from concrete organism to concrete organism.

Adaptedness and Natural Selection

Weiner's (1995) book, *The Beak of the Finch*, gives a case of natural selection. He recounts the accomplishments over two decades of a group headed by Peter and Rosemary Grant. They studied Darwin's finches in the Galapagos, on one of the small islands, Daphne Major (Fig 8). The following description is from Boag and Grant's paper (1981), "*Intense Natural Selection in a Population of Darwin's Finches (Geospizinae in the Galapagos)*", one of the many papers that are the basis of Weiner's book.

There was a drought on Daphne Major. From December through June in 1976 rainfall was 127 mm. From December through June 1978 rainfall was about the same, 137 mm. But in the same period in the intervening year, 1977, there were only 24 mm.s of rain. It is during this period that the plants of Daphne Major grow. And it is during this period that the finches, members of *Geospiza fortis*, build nests and have their young – the male doing the building and thus attracting a female (Fig. 8).

In 1977 no plants grew, and the previous years' small seeds decreased in abundance faster than large seeds due to the feeding of *fortis*. As a result, larger birds survived better on the larger seeds than the smaller birds. For the bird population decreased from over 1000 to less than 200. Averages of 642 birds before and 85 birds after 1977 were in weight (g.) 15.79 before and 16.85 after, in tarsus length (mm.) 18.76 before and 19.11 after, in bill length (mm.) 10.68 before and 11.07 after, and bill depth (mm.) 9.42 before and 9.96 after. These numbers show the decisive change from smaller to larger average size (though a seemingly small change). These numbers show a

decisive case of natural selection. In Weiner's words this "was the most intense episode of natural selection ever documented in action".

Such a statement leaves open what natural selection is, what its structure is, in this case. Natural selection could be this: at the end of the drought there were more bigger birds and fewer littler birds, bigger birds were selected and littler birds were not selected, bigger birds were better adapted and littler birds were not better adapted.

For during the drought any *fortis x*¹, if selected for bigger size, was better adapted to the drought; – equivalent to: if not better adapted to the drought, was not selected for bigger size. This again is the first principle: when two quite different entities, the bigger and littler birds, occur under the same condition (the drought), one entity is better adapted to the drought and the other is not better adapted to the drought; one has the property of greater adaptedness and the other the property of lesser adaptedness to the drought.

Adaptedness and Directional Selection

Textbooks present directional selection in just the opposite way from natural selection of *fortis* on Daphne Major. Directional selection relies on the binomial theorem, certainly an ironclad basis, and different results are gotten by different coefficients of selection *against* the frequency of the allele *a*, or perhaps the other allele *A*. Most of the combinations show successive changes of selection. These can be taken as changes in the amount of adaptedness. Thus before selection (before mating):

¹ *Fortis x* is one bigger, adapted bird before the colon but a different not adapted, littler bird after the colon. Two birds but one *x*. *Fortis x* must be read with *fortis* as an adjective.

if a has a *greater* frequency, then a confers lesser adaptedness; -- equivalent to (after mating, selection): if a does not confer lesser adaptedness, then a does not have a greater frequency.

The second of these two equivalents says that a *does* confer greater adaptedness only if a does *not* have greater frequency.

In order to see what is going on here, an example is given of selection from Wilson and Bossert (1971, pp. 53-55), wherein the recessive allele is considered to be completely eliminated in the homozygous form. The frequencies of the alleles AA , (Aa , aA), aa are given by the binomial formula, $p^2 + 2pq + q^2$. The frequency of aa , q^2 , is eliminated, because after one generation of mating with a selection sufficient s in $1-s$ as 1, the frequencies $p^2 + 2pq + q^2 (1-s)$ become $p^2 + 2pq$.

These frequencies, $p^2 + 2pq$, are exclusive (in different animals): either $p_0 p_0$ or $p_0 q_0$ or $q_0 p_0$ – for $p_0 q_0$ or $q_0 p_0$ tell equally well of the heterozygosity of $2 p_0 q_0$. At gamete formation chance dictates that the heterozygote frequency is (p_0 or q_0) in one gamete or (q_0 or p_0) in another gamete and this is validly equivalent to (if not p_0 then q_0) or (if not q_0 then p_0). Only the first parenthesis yields q_0 , to be rewritten q_1 , and this single allele yield from two heterozygotes is (assuming $p + q = 1$ and $p = 1 - q$):

$$q_1 = \frac{p_0 q_0}{p_0^2 + 2p_0 q_0} = \frac{p_0 q_0}{p_0 (p_0 + 2q_0)} = \frac{q_0}{p_0 + 2q_0} = \frac{q_0}{1 - q_0 + 2q_0} = \frac{q_0}{1 + q_0}$$

The subscript 1 indicates that one generation has passed, and so we have, recursively, for this and further generations:

$$q_1 = \frac{q_0}{1 + q_0}, q_2 = \frac{q_1}{1 + q_1}, q_3 = \frac{q_2}{1 + q_2}, \dots, q_m = \frac{q_{m-1}}{1 + q_{m-1}}$$

So the frequency of the recessive allele a becomes less with each generation, with each step of selection against a , with each step of *better adapted* to the left of the equals mark from *not better adapted* to the right of the equals mark. So a *does* confer better adaptedness when a does *not* have greater frequency to the left. With q of a as 0.5, after 10 generations, $q_{10} = 0.5/1 + 10(0.5) = 0.083$. This is a great increase in adaptedness since a has decreased so much in frequency. Albinism in Norway has a recessive a at a frequency of 0.01. One can imagine getting rid of this bad gene by very slow degrees, if albinos did not have children – if aa were completely selected against. This is to say that the Norwegian population would be better adapted without albinos. This is a hypothetical case, but certainly not a case of supposition. This case supports the first principle of adaptedness: if aa is selected against, then the organism is better adapted, left – equivalent to: if the organism is not better adapted, right, then aa is not selected against.

The selection coefficient, s , is a fraction and lies between 1 and 0 in $1-s$ or is 1. Thus the binomial frequency distribution for AA , (Aa, aA) , aa alleles would be $p^2 + 2pq + q^2(1-s)$ and for q_1 there would be (Ayala, 1982, pp. 92-97) (see footnote):

$$q_1 = \frac{q - sq^2}{1 - sq^2},$$

In the Biston moths of England, as everyone knows, fewer light moths survived on the dark trees than dark moths survived. 53% of released dark moths were recaptured. With this as a standard, the percentage recapture of light moths, 25%, is compared as $0.25/0.53 = 0.47$. This value, 0.47 is subtracted from 1 to give the selection coefficient $s = 0.53$

against the light moth's allele frequency. Starting with $q = 0.50$, the value of q_1 in one generation would be from the above formula:

$$q_1 = \frac{0.50 - 0.53 (0.50^2)}{1 - 0.53 (0.50^2)} = 0.424$$

In this way Ayala shows explicitly a hypothetical change in frequency from 0.50 to 0.424 as the allele for q is selected against. And for us this is an increase in adaptedness in the sense that the population of moths would be better off, be better adapted with fewer light moths on the dark trees (because less visible to predators). Again this is a hypothetical case, but certainly not a case of surmise. This case supports again the first principle of adaptation: if aa is selected against, $q_1 = 0.424$, then the organism is better adapted – equivalent to: if the organism is not better adapted, then aa is not selected against, $q = 0.50$.

So what is the moral of all this? Once one elects to choose (so to speak) a coefficient of selection that is a fraction between 1 and 0 (or 1) one has to select *against*. If the selected against gene is bad then adaptedness is conferred and all's well. On the other hand one may elect to select (so to speak) *for* something good, like bigger size of finches on Daphne Major; then adaptedness is conferred in this way.

Closing Comment

Since selection, in particular natural selection, has come up, some comment on natural selection is offered here. Two books which include a myriad of biological situations are Dawkins' (1996) *Climbing Mount Improbable* and Heinrich's (2003) *Winter World*. In the first the many observations are integrated to some degree by the assumption of natural selection. In the second the observations are presented just for

their intrinsic merit, without any natural selection assumption. The presentation of the present book takes a very different path from these books; the interest here is to search out a structure of the natural world. Here there is a point of view, the philosophical point of view of the metaphysical realist, the 20th century version of Platonism. However, a point of view including abstract entities (properties) about the world presently around us is a far cry from the assumption of the nebulous process of natural selection mixing into the physicality of organisms forever hidden in the biota of bygone geological ages.

Footnote

One must remember that frequencies are fractions. Thus corresponding to alleles (genes) AA , (Aa, aA) , aa are the basic frequencies $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{4}$, which are represented by $p^2 + 2pq + q^2$. These add up to 1. But when selection s in $1-s$ is introduced at q^2 the frequencies add up to less than 1, as seen next:

$$p^2 + 2pq + q^2 (1-s) = p^2 + 2pq + q^2 - sq^2 = (p^2 + 2pq + q^2) - sq^2 = 1 - sq^2.$$

To make the frequencies add up to one, these frequencies are divided by $1 - sq^2$:

$$\frac{p^2}{1 - sq^2} + \frac{2pq}{1 - sq^2} + \frac{q^2 (1-s)}{1 - sq^2} = \frac{p^2 + 2pq + q^2 - sq^2}{1 - sq^2} = \frac{1 - sq^2}{1 - sq^2} = 1$$

Then the frequency of the a allele after one generation of selection, q_1 , is gotten by adding the frequency of aa , $q^2 (1-s)$, to the frequency of Aa , pq , of the heterozygote (the other frequency qp is q or p equivalent to if not q then p and so does not appear in a given gamete). Thus we get:

$$q_1 = \frac{q^2 (1-s)}{1 - sq^2} + \frac{pq}{1 - sq^2} = \frac{pq + q^2 - sq^2}{1 - sq^2} = \frac{q(p + q) - sq^2}{1 - sq^2} = \frac{q - sq^2}{1 - sq^2}$$

CHAPTER 7

Spatial Adaptedness

Spatial adaptedness comes from the habitats and areas where plants or species are found. Mayr (1960, p. 60) points out that a species is adapted to its area. This much is surely right. But this is only part of the situation. For think of this simple case. You get your garden ready by clearing and fertilizing a patch of ground – you make the ground adapted. Then you plant the seeds or small plants. If they come up or do well, they are adapted to the ground. Thus the plants are adapted, have adaptedness to the ground, and it is adapted, has adaptedness to the plants. Likewise this two-step sequence is to be applied in the case of any plant and the ground it stands on, of any plant species and the habitat where it is found, of any such species and the locale of its habitats.

So Mayr is only half right. And so the full formula of the third principle is species having adaptedness to locale and locale having adaptedness to species. The full formula can be equally and correctly expressed as species having the property of being adapted to locale and locale having the property of being adapted to the species.

As pointed out in the method of presentation the general linguistic term ‘adapted’ by being true of many plants of one species has referential force, for ‘adapted’ refers to, picks out the abstract singular entity adaptedness because every use of the word ‘adapted’ has exactly the same descriptive effect in passing from one plant to the next within the species.

As pointed out in the method of presentation there is reversibility of x being adapted to y to y being adapted to x , when point blank adaptedness is involved, as here. And so this is a situation where the third principle of adaptation will frame and ensconce the observations to be presented.

Species and Habitats

The Woodland *Gilias*

The areas where the woodland *Gilias*, erect annual herbs, grow are shown in an article by Grant, V., and A. Grant (1954). From Washington to Baja, California, on the West Coast of North America there are five major species. Two of these, *G. splendens* and *G. caruifolia* differ morphologically and distributionally. *G. splendens* “has pink corollas with a long tube and slender tapering throat and short stamens inserted in the sinuses of the lobes; in *G. caruifolia*, by contrast, the corolla is pale blue-violet with a more campanulated form and has long exerted stamens attached to the middle of the short corolla throat” (Fig. 9). “*G. splendens* and *G. caruifolia* are wholly allopatric, the former species occurring in the South Coast Range and the San Gabriel, San Bernardino and San Jacinto Ranges, and the latter ranging from the Cuyamaca, Laguna and Palommor Mountains to the San Pedro Martin Range” (Fig. 10). Since their habitats are “similar

insofar as they consist usually of openings in pine woods”, the distinction is that the location of their habitats differ. And so each species is adapted, exemplifies adaptedness to the location of its habitats, and the location of its habitats is adapted, exemplifies adaptedness to each species.

Gilia australis has habitats which differ from those of the previous two species. Its morphology differs too. “*Gilia australis* is a smaller plant [than *G. splendens*] with simpler leaves and small whitish flowers.... It ranges from San Bernardino County, California, to the northern half of Baja, California (Fig. 10). It occurs in hotter and drier habitats than either *G. splendens* or *G. caruifolia*, namely in sandy marshes of the foothills and plains below the pine belt.” And this different species is distinct by being adapted (having adaptedness) to its different habitats, which are distinct by being adapted to it.

Then next is *G. leptalea*, which “differs most conspicuously from *G. splendens* in having leafy stems and in lacking a basal rosette. The leaves, moreover, are usually simple and linear instead of pinnately compound.” *G. leptalea*... “consists of three well-marked geographical races” – “(i) a race of relatively tall plants with simple linear leaves and a long slender corolla throat (*G. l. leptalea*...); (ii) a race similar to the foregoing except that the leaves are pinnate and bear 1 to 3 pairs of simple lateral lobes (*G. l. pinnatisecta*) and (iii) a race of smaller plants with a short corolla throat which is yellow instead of pink (*G. l. bicolor*,...)”. “*Gilia leptalea pinnatisecta* occurs in the North Coast Range of California; *G. l. leptalea* occurs in the Cascade Mountains of Oregon and northern California south through the Sierra Nevada and is known from Steens

Mountains in eastern Oregon; *G. l. bicolor* is restricted to the Sierra Nevada where it occupies an altitudinal zone above that of typical *leptalea*” (Fig. 11).

Gilia capillaris has a wide variety of form from a relatively tall plant to a dwarfish plant of the high mountains, with complete intergradation between the two extremes. It is the most widespread of the woodland *Gilia* species. Its distribution, shown in Fig. 11 is such that it occurs in the Cascade Mountains from Washington to northern California, occurs in the various mountain ranges of eastern Washington and eastern Oregon, occurs in the Sierra Nevada and on at least four peaks in southern California. Beyond this range there is no *G. capillaris*.

And so *G. leptalea* and *G. capillaries* are adapted to their habitats, adapted in turn to them

Three Conifers of North America

In Fig. 12 are presented three non-overlapping species of coastally restricted forests of North America (Laderman, 1998). In the coastal belt between southern Alaska and Washington state there is the Alaska yellow-cedar (*Chamaecyparis nootkatensis*). Though abundant in places and occurring in pure stands, it has declined. This decline started 100 years ago but is slight now. South of this species the coast redwood (*Sequoia sempervirens*) is abundant near the fog-shrouded coast from Oregon well into California. In spite of logging its regrowth shows it to be well suited to its present locale. Before the Pleistocene glaciation it was widespread in the West (Axelrod, 1976). Though it failed to regain its widespread distribution after the ice melted, still it seems well established in its present locale. The distribution of the Atlantic white cedar (*Chamaecyparis thyoides*) is

intermittent along the East coast and the Gulf coast. But it is a successful species, its net growth amply exceeding loss due to logging.

These non-overlapping species are instances (examples) of being adapted to their locales, which are instances of being adapted to them. It might be thought that only organic entities have properties; nothing could be further from the truth. Everything has the properties that compose it. And the unique, idiosyncratic properties that support a species throughout its range are constituents of the ground where each member species of the set stands.

The White Spruce After the Pleistocene

The white spruce (*Picea glauca*) of North America had a northward migration as the ice sheet moved northward after 18,000 years ago. The locations of the spruce forest, determined by pollen profiles in lakes, are shown at various times by carbon dating between from 18000 to 9000 years ago in Fig. 13 (Ritchie and MacDonald, 1986). In eastern North America its growth started in northeastern Pennsylvania at about 15000 years ago and amounted to 60% of the total pollen. The sudden appearance of white spruce pollen in various lake profiles was later and later going northward until it occurred between 3000 and 4000 years ago in northern Labrador. A faster northward progress of the sudden appearance of white spruce pollen occurred from 16,000 years ago in Wisconsin in central U.S.A. to 9,000 years ago in the extreme northwest corner of Canada. A southeast wind caused the rapid northward progress. This wind is deduced from the direction of sand dunes in southern central Canada (David, 1981). The hypothesis is that cold high pressure air to the northeast over the ice had warmer low

pressure air to the southwest; the wind wants to go from high to low pressure but the Coriolis force diverts it 90° to the right to give the southeast to northwest direction. Ultimately, the wind goes clockwise around the high pressure over the ice, as shown by the arrows. Thus, the location of the spruce forest was widespread and fast moving (geologically) behind the melting ice. The location of its habitats shows one shifting huge habitat. And surely the spruce exemplified the property of being adapted to this great habitat which exemplified the property of being adapted to the spruce. And surely the spruce exemplified the correlative properties of being fitted, suited, adjusted to the great habitat which exemplified the properties of being fitted, suited, adjusted to the spruce.

Conclusion

The cases of adaptedness of species to habitat and adaptedness of habitat to species are cases of the third principle of adaptedness, as was noted at the beginning of the chapter.

A longer and logically valid presentation is modified from Copi (1979, p. 40, rule 17) and from Kahane (1986, p. 68, rule 18). Their symbolic expressions are presented in words as follows.

16. If specie's x is adapted to habitat's y , then habitat's y is adapted to species's x ; and if habitat's y is adapted to specie's x , then specie's x is adapted to habitat's y – all this equivalent to: habitat's y is adapted to specie's x if and only if specie's x is adapted in habitat's y . (see Appendix IV for proof of this)

The complete formula is required if a logically valid structure is to be a part of the structure of nature. This requirement is essential to the point of view of this essay.

It may be wondered why the descriptions of the species of *Gilia* are provided. The point is that the *Gilias* present a case of the break-down of the principle of the identity of indiscernibles, wherein properties are so important; for if two or more entities have all the same properties, they are, arguably, exactly alike. And, of course, the *Gilias* by being different show the break-down of the identity of indiscernibles, just as individual oysters by being different from each other show break-down within the species (see chapter 5).

A further point is that the physical properties of *G. splendens*, for example, include having a pink corolla, a slender tapering throat, and short stamens in the sinuses of the lobes. The physical properties of *G. caruifolia* include a pale blue-violet corolla, a campanulate form, and long exerted stamens. These contrasting, corporeal, physical properties are matched with being located from South Coast Range to San Jacinto in the case of *G. splendens* and with being located from Cuyamaca to San Pedro Martin Range in the case of *G. caruifolia*. But the property corresponding to ‘being located’ is incorporeal, just as the property corresponding to “being north of” in ‘Edinburgh is north of London’ is incorporeal and abstract (Russell’s well known example, Russell, 1911, 1997). You can’t find being located in *G. splendens* or *G. carnifolia*. The property corresponding to the linguistic ‘being located’ is just as incorporeal as the property corresponding to ‘being adapted’.

Distributions and Their Adaptednesses

Necessarily the habitat is adapted to the species. If the species is adapted to the habitat, then the habitat *must* be adapted to the species. This is the most important of all ecological laws. If the habitat were not adapted to the species, the species would not be there. Likewise, if the area of occurrence were not adapted to the species, the species would not be there. If Canada were not adapted to spruces, the spruces would not be there.

The plan in the last section was to present organisms which do not move about, so that the areas where they occur are also areas adapted to them. The plan in this section is to present organisms which have several parts of their distributions, part where the animal breeds and another part where it does not. But the animal is adapted to each part, and each part is necessarily adapted to the animal.

Species That Migrate

And Their Distributions

Birds are the great migrators. In North America many species migrate usually south to north and back, except seabirds. Seabirds migrate out to sea. There are a minor number of species that do not migrate (National Geographic 1999). Among the migrators from south to north and back there are many similar species, each one with its breeding summer range and a different non-breeding wintering range. Each species is adapted to its breeding area and the breeding area is adapted to it, which is breeding-area-adaptedness; each species is adapted to its wintering area and the wintering area is adapted to it, which is wintering-area-adaptedness. Thus there is a combination of the

third and fourth principles of adaptedness, as presented next in the logical form of constructive dilemma (Copi, 1979).

17. (1) There is a breeding area or there is a wintering area.
- (2) If there is a breeding area, then there is breeding-area-adaptedness; and if there is a wintering area, then there is wintering-area-adaptedness.
- (3) Therefore, there is breeding-area-adaptedness or there is wintering-area-adaptedness.

Fig. 14 presents three sparrows, belonging to the genus *Spizella*, and their northern breeding ranges and their southern non-breeding wintering ranges (National Geographic, 1999, p. 404-405). These, of course, typify the combination of the third and fourth principle just presented.

The extravagance of bird behavior is most marked in the great migrations of some birds. In North America waterfowl have four flyways. One is from Cuba along the eastern seaboard and branching into northeast and into central Canada. The second is along the Mississippi River and widens out in northern Canada. The third goes up the Rocky Mountains and the fourth goes along the Pacific coast into northern Canada (Fig. 15). Other examples of the extravagant migration of birds are the scarlet tanager, the bobolink, and the Atlantic golden plover, with breeding areas in the northern United States and northern Canada and wintering areas in northern and middle South America (Fig. 16). The scarlet tanager's breeding range has a width of 1900 miles, but as the birds fly southward in fall their path of migration becomes more and constricted, until at the time of leaving the United States their path is only 600 miles wide (from Texas to

Florida) and after crossing the Gulf of Mexico their path of migration narrows to 100 miles in central America before widening out in South America. The bobolink, with thousands of birds of some 60 species, arrives in fall from its northern breeding area in Florida and Cuba and Jamaica. Only a few of the many species dare make the 500 mile flight across the Caribbean; the chief species to do this is the bobolink, which goes on to its wintering area well south in South America. The extravagant species are outdone by the adult eastern golden plover, which flies over the ocean from Nova Scotia to the Lesser Antilles, in fair weather its flocks passing Bermuda without resting. It flies south across South America to the pampas of Argentina where it stays from September to March before, unlike most birds, it makes a spring journey by a very different route, through Central America and slowly up the Mississippi Valley and on to the extreme north of Canada to its summer breeding grounds. This account is from Lincoln and Hines, 1950, pp. 41-69. The mountain ranges of Europe cut across the migration routes of migrating birds. Many do manage to do their migration but not to the extent of the American species (Berthold, 2001).

What is arresting is that these audacious migrations have such well defined terminal areas. These areas are so clearly excluding of each other: either there is a breeding area or there is a wintering area. Then two inferences seem just right: if there is a breeding area, then there is breeding area adaptedness; and if there is a wintering area, then there is wintering area adaptedness. Finally the conclusion is double: either there is breeding area adaptedness or there is wintering area adaptedness. And always the species is adapted to the area and the area is adapted to the species.

The double adaptedness of migratory bird species suggests further double adaptedness in marine species. We will consider sharks, turtles and seals.

Sharks

Instead of breeding area for birds, the corresponding term for sharks is a nursery area. Shark nurseries are discrete parts of a species area where the gravid females of most coastal sharks deliver their young or deposit their eggs, and where their young spend their first weeks, months, or years. A nursery is most often in shallow water where young find abundant food and have little predation from larger sharks. Nurseries are characterized by both gravid females and free swimming neonates. Neonates are young bearing fresh, unhealed placental scars in the case of placental species, or those at or near birth size in a placental species (Castro, 1993).

Fig. 17 illustrates a nursery area in northern Florida (U.S.A.). The bays and lagoons of this area vary from 1.9 m. in depth to 5.7 m. in depth. Fig. 17 presents the sizes and age distribution of the sandbar shark *Carcharinus plumbeus* caught between 1992 and 1997 (Carlson, 1999) in this nursery area. Beyond nursery areas are the open water where the adult sharks live. In the case of the sandbar shark these are continental shelf waters where an extensive fishery for the species exists (Heist, Graves, and Musick, 1995).

The double adaptedness of the sandbar shark, and presumably all other coastal species (Castro, 1993), is shown by the premise: either there's a nursery area or there's an offshore area – and conclusion: there's nursery area adaptedness or there's offshore area adaptedness. The full formulation is the same as 17.

Of course, anadromous fish have a similar distinction, spawning ground replacing nursery area as a term and showing a greater delineation as a fresh water reproductive area and separation from a salt water oceanic non-reproductive area – justifying the inference to adaptedness for each area.

Sea Turtles

The eggs of sea turtles are buried in the sand above high tide on the southeast coast of U.S.A. They hatch at night, at least in loggerheads, green turtles, and leatherbacks. Then there are three things: hatchlings go down the beach to the ocean; they swim against the waves away from the shore; and they stay within the North Atlantic gyre as they grow.

Hatchlings find their way to the ocean by crawling toward the brighter horizon seaward than landward, since the ocean reflects more starlight and moonlight than does the land (Lohmann and Lohmann, 1998; Mrosovsky, 1972). Once in the water they swim into the waves, both in the ocean in cages, whether the waves are from north, east, or south, and in wave simulators (Lohmann et al., 1990; 1995). Along the coast of northern Florida where the hatchlings are born and where the experiments were done, the waves are generally propagated perpendicularly to the shore by the prevailing easterly winds or turned perpendicularly to the shore by the effect of shallow water. If they swim far enough out to sea they will be caught by the Gulf Stream and then become incorporated into the North Atlantic gyre shown in Fig. 17. Then it is that they orient to the earth's magnetic field. In an experimental magnetic field arrangement hatchlings of loggerhead turtles could be made to swim eastward at intensities found along the western

side of the gyre and could be made to swim westward at intensities found along the eastern side of the gyre (Fig. 17) (Lohmann and Lohmann, 1996, 1998). Such directional swimming should help keep them in the gyre.

Here there are clearly three adaptednesses; the hatchling's adaptedness to light, and the light is adapted to the hatchlings; the hatchling's adaptedness to wave direction, which is just right for the hatchling; the hatchling's adaptedness to the magnetic field, which is the perfect thing for the hatchling.

Seals

Nine species of seals have an abundant underfur layer in their pelage; these are the fur seals. Their rookeries, where they mate and where later their young are born, are almost entirely on islands. The islands around Antarctica and off the southern parts of Africa, South America, and Australia – Amsterdam, St. Paul, Kerguelen, Heard, Crozet, etc. (Fig. 18) – these islands have rookeries or colonies of five species of fur seals. Northward along the west coasts of South and North America, Juan Fernandez Is., Isla San Felix, Galapagos Is., and Guadalupe Is. have colonies of other species of fur seals. The northern fur seal was first found on the Commander Islands in the Bering Sea in 1792. Four years later the first of the Pribilof Islands, St. George, was discovered with teeming rookeries of the northern fur seal. Then on Robben Is. and Kurila Is. off Russia were more colonies of this seal. Both on the Southern Ocean islands and on the Pribilof Islands fur seals haul out on beaches preparatory to giving birth and breeding to become pregnant. The immense numbers of seals supported mass harvesting for their skins.

Between 1786 and 1867 perhaps 2.5 million skins were taken from the Pribilof Islands. In spite of various restrictions, as these islands changed hands from Russia to the United States, the density of the Pribilof herd was reduced drastically, both by land killing and shooting of swimming seals, until in 1912 the Pribilof herd was about 300,000 seals. In the Southern Ocean seal hunting was intense from 1786 on. A peak on South Georgia was reached in 1800-01 when 17 British and American vessels took 112,000 skins, and “by 1822 James Weddel calculated that 1,200,000 furs had been taken at South Georgia and its seals were nearly extinct.” Ships put off landing crews in small boats, the men soaked to the skin in the surf, to kill and skin the seals and salt these skins for preservation upon supposed return of the ships to the landing positions – “one group left on the Snares Islands in 1810, was not picked up until 1817!” Thus the seal hunting dramatizes the shorebound part of seals’ lives.

A great deal of the shorebound life of a seal is concerned with breeding. In the case of the Antarctic fur seal most of the breeding bulls arrive in late October and establish territories by sitting upright with chest out and the head nearly vertical and a vocal threat of a high pitched whimper (some fighting occasionally happens). The cows arrive in the second week to the end of November, and make up a family of 11-16 per bull. Cows give birth about two days after arriving, a birth taking 30 seconds to 7 minutes and often assisted as the cow takes hold of the emerging pup and drags it toward her. There is a period of at least half an hour of mother-pup exchange of high-pitched whining. This duet is accompanied by sniffing the pup’s muzzle. These two methods of acquaintance apparently guarantee recognition of pup and mother for the next months.

But first after the birth is a period of eight days at the end of which the mother goes into oestrus and is mated by the bull of the territory she is in. After that for the summer period of about 110 days the mother is off feeding (to synthesize milk) for 3-6 days then returns to suckle her pup for three or so days. By February or March the pup is weaned and mother and pup swim away. By April the beaches are empty and the breeding period is over.

The non-breeding, oceanic life of the Antarctic fur seal is not known, except that next October they return to the beaches. Thus they have the double adaptedness of migratory birds and sharks, presented earlier in this chapter.

Although the oceanic life of the Antarctic fur seal is not known, the oceanic life of the Northern elephant seal is known in part. It breeds on Fallaron I., San Miguel I., Los Coronados Is., Guadalupe I., and Cedros I. on the west coast of North America. It was reduced to perhaps 20 animals in 1890 in a last stand on Guadalupe I. by sealers, but since then the population has increased to 125,000 as it expanded to the other islands. The oceanic life of these seals was studied by time depth recorders attached to six seals. These recorders over five months' time showed that average dive depths were 1148-1476 ft., that 86% of the seals' time was under water, that rarely more than 5 minutes of their time was at the surface between dives and that dive times averaged 21-25 minutes. Those seals were adapted to the ocean and the ocean to them, without a shadow of a doubt. And they exemplify the double adaptedness suggested by the Antarctic fur seal clearly, very clearly. And this double adaptedness can be framed in the structure of constructive dilemma at the beginning of the section.

18. Either there is shorebound breeding or there is oceanic non-breeding.

If the first, then there is shorebound breeding adaptedness, and if the second, then there is oceanic non-breeding adaptedness. Therefore, there is shorebound breeding adaptedness or there is oceanic non-breeding adaptedness.

This account is from Nigel Bonner's *Seals and Sea Lions of the World* (1999).

CHAPTER 8

The Symmetry of Adaptedness in Predominantly Asymmetrical Situations

Relations

Munson (1971), as pointed out in Chapter 2, puts traits, or properties, into adaptational structure. An organism has a trait, a property; it possesses this trait, this property. Properties thence compose the organism.

But the property of being adapted to a temperature range is an impure property. Throughout adaptedness has never been pure adaptedness. Adaptedness has been adaptedness to something, to some environmental feature. So this impure form of the property adaptedness may be isolated and emphasized as a relation. Munson has already foreshadowed this when he says “Organism *O* is adapted to environment *E*”, “Species *S* is adapted to *E*”.

In what follows there are five relations; helping, dominating, suppressing, preying on, and enslaving. These are wholly relational, but adaptedness is ambiguously relational. The distinction can be seen by comparing ‘The mother loves her baby’ with

‘The mother holds her baby’. Loving is a part of the mother, an attribute of the mother; whereas holding is not an attribute (or not clearly an attribute) of the mother.

There is a change from benign to unbenign in these relations. There is an abrupt change from helping to the other four. The first, helping – x helps y , y helps x – is symmetrical like species adapted to habitat, habitat adapted to species. The other four are not symmetrical. They are one-way relations, one entity dominates a second but the second can’t dominate the first (same for the others). The last relation is very different from the other four, which are fairly objective. The last relation, enslaving, is subjective. What follows is taken from Hulburt (1996).

Symmetrical Adaptedness Extended

The structure of symmetrical adaptedness is: if x is adapted to y then y is adapted to x . This is also the third principle of adaptedness. It can be extended by combining it with helping, if x helps y then y helps x . Helping is put first and being adapted second: if x helps y then y helps x ; if x is adapted to y then y is adapted to x . This is rephrased with the helping part an if part and the adapted part a then part as follows:

19. If x and y help each other, then x and y are adapted to each other.

Now, next, let us support the relation of helping and the relation of being adapted with some empirical data.

As extraordinary find of the 20th century is the giant tubeworm, *Riftia pachyptila* (Fig.’s 19, 20), in the hydrothermal vents of the sea floor. These worms are a dramatic example of symbiosis. These worms are up to 1.5 m. in length and 4.0 cm. in circumference. They live encased in tubes except for a feathery plume that can be

extended beyond the tube. Each worm has a well-developed, closed, hemoglobin containing vascular system, with heart-like structures to pump the blood from the plume to the posterior end and return (Arp et al., 1985). There is no gut. Instead 15% by weight of the major portion of the worm is composed of intracellular chemoautotrophic bacteria. The H_2S (and CO_2) in the water from the vents is absorbed by the blood in the plume; the sulfide in the blood is remarkably high, as high as 4 mM. The H_2S and CO_2 in the blood are transported to the bacteria. Various evidence indicates the bacteria to be CO_2 fixers, in the process oxidizing H_2S from the blood, as indicated, for example, by APS reductase, ATP sulfurylase, and thodanese in cell-free extracts of worm-bacterial tissue (Cavanaugh, 1985). Thus the bacteria are ' $CO_2 + H_2S + O_2 + H_2O \rightarrow [CH_2O] + H_2SO_4$ ' aerobic bacteria. And the synthesized material $[CH_2O]$ is available to the worm.

Thus the H_2S and CO_2 gotten by the worm with its plume and transported by the blood system help the bacteria, and the $[CH_2O]$ made by the bacteria helps the worm, and both features make them adapted to each other.

Moving next to the relation of dominating we may attach this property to the property of helping as an option:

20. If x and y help each other *or* x dominates y (but y doesn't dominate x)
then x and y are adapted to each other.

So next we may support the relation of dominating by the following observations.

The cobwebby *Gilias* studied by Grant and Grant (1956) are erect annual herbs occurring on the West Coast of North America. There are 17 species. Most of these species are divided into subspecies. There are three subspecies of one of the these

species, found only in southern California, which are separated as follows.

1. • Flowers small, 4-6 mm long; style maturing at orifice. Mojave Desert.
Gilia ochroleuca ochroleuca.
 - Flowers large, 8.0-13.5 mm long; style maturing beyond stamens. Mostly cismontane.
2. Corolla tube slightly exerted from calyx and slightly longer than throat. San Bernardino County to San Diego County. *Gilia ochroleuca exilis.*
3. Corolla tube shorter than throat and usually included in calyx. San Luis Obispo County to San Bernardino County. *Gilia ochroleuca bizonata.*

We have in (1) the small-flowered plants of *ochroleuca ochroleuca*, each plant adapted to a Mojave habitat adapted to each. We have in (2) the large-flowered plants of *ochroleuca exilis*, each with corolla tube exerted from the calyx and each adapted to a habitat in San Bernardino and San Diego County counties adapted to each. We have in (3) the large-flowered plants of *ochroleuca bizonata*, each with a corolla tube included in the calyx and each adapted to a habitat in San Luis Obispo and San Bernardino Counties adapted to each.

In the reworking of the key just presented adapted is a symmetrical connector between plant and habitat. Additionally each plant dominates its bit of ground and the plants of any locale dominate the habitat of the locale (dominate at least as compared to habitats beyond its locale). Certainly the habitat does not dominate its plants in any physical sense. So dominate is not symmetrical.

After helping and dominating comes the relation of suppressing. We attach this relation to the optionality structure:

21. If x and y help each other *or* x dominates y or x suppresses y
 then x and y are adapted to each other.

The description of phytoplankton and nutrient in the western North Atlantic in Chapter 5 shows the nutrient to be very low at the surface (Fig. 5). In the northern part of the area in spring in the upper 500 m. there is little stratification in temperature but marked stratification in nitrate. This nutrient (plus phosphate and silicate, not shown) is circulated by vertical turbulence from deeper down right to the surface and is inferred to be consumed by the abundant diatoms there. The surface, nutrient-depleted water is carried southward and westward by the gyre circulation (Fig. 5). The surface nutrient is suppressed thus locally in the spring and is carried into stratified, vertically nutrient blocking water and persists as a suppressed layer everywhere. In this way the brief occurrence of abundant diatoms suppresses all get-through of deeper nutrient to the surface. The abundant diatoms and meager coccolithophores and dinoflagellates both depend on nutrients from deeper down or in-situ, and in their varied manner are adapted to the nutrient distribution, which can certainly be said to be adapted to these phytoplankters' photosynthetic activity. And so phytoplankton suppresses nutrient but both are adapted to each other.

After helping, dominating, and suppressing comes the relation of preying on. We attach this property to the optionality structure:

22. If x and y help each other or x dominates y or x suppresses y or x preys on y , then x and y are adapted to each other.

Vermeij (1982) gives a great many cases showing the variation in efficiency of predation. Here are some excerpts from his study. “Fish-eating birds never achieve 75% efficiency after prey detection, and 3 of 10 species have efficiencies of 25%...”. “The oystercatcher *Haematopus ostralegus* kills 61% of the dogwhelks (*Nucella lapillus*) which it attacks...”. “Predatory mammals (lions, hyenas, wolves, frog-eating bats) in Africa, Central America, and North America usually have post detection predation efficiencies of less than 50%...”. “Efficiencies of 50% to 85% have been reported for wild dogs and chimpanzees in Africa... and for bobcats in North America...”. “The Floridian tree frog *Hyla cinerea* has a success rate of 42% in catching active houseflies...but catches only 18% to 21% of less active mosquitoes...”. “...the freshwater sunfish *Lepomis macrochirus* captures 50% of the *Diaptomis pallidus* which it attempts to capture, and 100% of the much slower *Daphnia magna* in laboratory aquaria. Another example of 100% capture efficiency... showed that the trout *Salvelinus mayaycush* in Alaska eats all *Daphnia pulex*, *Daphnia longiremus*...”. “Predaceous sea stars typically have very high failure rates. *Meyenaster gelatinosus* in Chile catches and eats less than 2% of moving chiton and gastropod prey... and *Leptasterias hexactis* in California meadows of the sea grass *Phyllospadix* has a success of 0% to 11% in catching and killing three gastropod species...”. There are many more cases given by Vermeij to show a varying failure of predation. This aspect of predation seems to tell that there is a reciprocal adaptation, though perhaps an uneasy one, between predator and prey. The predator is adapted to

prey because it does get enough to eat, on the average, and the prey is adapted to the predator because it supports the predator without getting wiped out, on the average.

The final relation, enslaving, may be added onto the others by *or*:

23. If x and y help each other *or* x dominates y *or* x suppresses y *or* x preys on y *or* x enslaves y , then x and y are adapted to each other.

It should not be forgotten that x is the same throughout and that y is the same throughout.

So 23. more fully is: if x in a worm and y in a bacterium help each other *or* x in a plant dominates y in a habitat *or* x in a plankton suppresses y in a portion of nutrient *or* x in a predator preys on y in a prey *or* x in a ciliate enslaves y in an algal chloroplast, then x and y are adapted to each other. Now to support the last relation, enslaving, there is the following.

The title of a paper by Stoecker et al. (1988/1989) is “Enslavement of algal chloroplasts by four *Strombidium spp.* (Ciliophora Oligotrichida)”. Table 3 shows results of some of the experiments, wherein algal food was given to the ciliates. The table shows that in the case of two of the species there was increasing growth, as measured by cell density and individual cell volume, with abundant food and increasing light intensity, more so for *S. capitatum* than for *S. chlorophilum*. The table shows that there was a little growth in the dark with increasing food concentration.

The table shows therefore that both food from the algae and photosynthesis from intact chloroplasts are required for best growth. The table’s data support the ciliate’s being adapted to the algae and the algae’s being adapted to the ciliate. The authors say “A

Table 3

Effects of algal food concentration and light flux on cell density (no./ml) and cell volume ($\mu\text{m}^3 \times 10^3$) of *Strombidium capitatum*, with an initial cell density of 1.1/ml, and of *S. chlorophilum*, with an initial cell density of 5.4/ml. 48 h incubation.

<i>S. capitatum</i>					Light Flux ($\mu\text{E m}^{-2} \text{ s}^{-1}$)			
Algal Conc. ($\mu\text{g C/l}$)	0	25	50	125	0	25	50	125
	Cell Density				Cell Volume			
0	0.5	0.5	0.9	0.9	26	40	44	42
10	0.5	0.7	1.4	1.6	37	40	45	64
100	1.5	2.8	4.0	4.6	47	50	57	54

<i>S. chlorophilum</i>								
Algal Conc. ($\mu\text{g C/l}$)	Cell Density				Cell Volume			
0	2.1	2.1	2.4	2.0	5.7	5.8	6.2	6.3
10	2.5	2.3	2.3	2.4	6.2	5.6	11.8	10.8
100	7.3	9.8	9.0	8.9	11.2	8.5	13.0	14.7

remarkable feature of the chloroplast-*enslaving* ciliates is their flexibility in use of photosynthetic organelles. Most of the ciliate specimens from our cultures *contained* one type of chloroplast, but careful examination of serial sections occasionally revealed single specimens or small numbers of other chloroplast types... the ability to *sequester* a range of chloroplast types seems to be a general feature of most plastidic ciliates". The italics are mine in this quotation to show the distinction between the subjective *enslave* and the physicalistic *contain* and *sequester*.

The varied observations so presented are related loosely by *or*, realistically conceived. They have been strung together by use of the variables *x* and *y*, realistically conceived. They all show one constant relation, the being adapted to each other of pairs of entities from the following excluding classes: worm and bacteria, plant and habitat, plankton and nutrient, predator and prey, ciliate and algal chloroplast. Each pair of entities has the relation of a worm helping a portion of bacteria, or the relation of a plant dominating a habitat, or the relation of a plankton suppressing a portion of nutrient, or the relation of a predator preying on a prey, or the relation of a ciliate enslaving an algal chloroplast.

Expressions 19.-23. describe these classes of pairs incompletely. But 19.-23. can be made complete by validity, like expression 16. of Chapter 7. The full description is then as follows. If *x* and *y* help each other or *x* dominates *y* or *x* suppresses *y* or *x* preys on *y* or *x* enslaves *y*, then *x* and *y* are adapted to each other; and if *x* and *y* are adapted to each other, then *x* and *y* help each other or *x* dominates *y* or *x* suppresses *y* or *x* preys on *y* or *x* enslaves *y*; -- equivalent to: *x* and *y* are adapted to each other if and only if *x* and *y*

help each other or x dominates y or x suppresses y or x preys on y or x enslaves y .

To get classes the part after the words 'equivalent to' is the starting point :
 x is a member of the class of entities adapted to y if and only if x is a member of the class of helpers of y or x is a member of the class of dominators of y or x is a member of the class of suppressors of y or x is a member of the class of predators on y or x is a member of the class of enslavers of y . All this is based on Langer (1967, pp. 150-151) and on the union axiom of set theory in Suppes (1972, p. 24 and 58-59). See appendix V.

And so it is seen that relations define classes and that this double structuring structures the adaptedness of the varied biota which exemplify the structuring.

CHAPTER 9

Reciprocal Adaptedness and Non-Interference:

Reciprocal Adaptedness and Interference

Reciprocal Adaptedness

If a perfectly clear case of reciprocal adaptedness is wanted, symbionts are a perfectly clear case. Symbionts help each other, produce each other, are required for each other's growth. Symbionts are fitted to each other, are suited to each other, conform to each other, in a figurative sense are designed for each other. Symbionts do not restrict each other, do not limit each other, do not interfere with each other. Thus, in three ways symbionts present themselves. They help, conform, don't interfere with each other. All three ways are included when it is said that they are adapted to each other. And to say that they are adapted to each other is to say that if one entity is adapted to a second, then the second is adapted to the first. This is the third principle of adaptedness.

Species that do not restrict each other, do not limit each other, do not interfere

with each other are like symbionts. Thus these species are like symbionts in being adapted to each other: if species x is adapted to species y then species y is adapted to species x , because they don't interfere with each other.

Why do we feel it appropriate to say the symbionts help, conform, don't interfere with each other? First, consider again the giant deep-sea worm *Riftia pachyptila* which has no gut: it procures CO_2 and H_2S with its elaborate anterior tentacles and these substances are transported by its blood system to posterior parts where encased chemo-synthetic bacteria convert them to organic matter for both worm and bacteria, so this is what the worm and encased bacteria actually do. But we describe expressively what they do as helping, conforming, not interfering with each other. We say, expressively, that they are fitted to each other, are suited, adjusted, adapted to each other. Further, whether one is adapted to the other or has adaptedness to the other, the issue is the same: adaptedness is an expressive part of physicality. In fact we can work wholly with the expressive describers, fitted, suited, adjusted, adapted. For this reason adapted describes directly from observation. Adaptedness is a direct describer too.

Symbionts are an extreme case where non-interference is mingled with other more cohesive attributes. But where the more cohesive attributes do not occur, where organisms are well separated from each other and only non-interference comes into play, we may say: if there is lack of interference between species, then there is adaptedness between the species; there is lack of interference – as will be shown next – and so there is adaptedness between them. We turn next to the coccolithophorid phytoplankton species of the ocean and the lack of interference between them. The observations are presented

to justify lack of interference, to justify the use of the descriptor non-interference. This justification in turn justifies the validity of the inference to adaptedness, a further descriptor.

What follows is taken from Hulburt (2001).

Non-Interference in the Sea

Catalogues of species abundances of the coccolithophorid marine plankton algae are from Hulburt (1983a). These are reproduced in Tables 3 and 4. The catalogues show averages of observed abundances of 15 samples Oct. 12-17, 1981, of 14 samples Oct. 17-21, 1981, at 36°N 66°W; of 19 samples Nov. 2-6, 1968, between Bermuda and the Straits of Florida; and of 15 samples Sept. 19-25, 1970, in the Mediterranean Sea. The even and very gradually decreasing abundances, the slight changes in the positions of the names from one catalogue to the next, and the fairly large number of species, about 20, comprised within a range of about 1-100 cells/l. – these three aspects indicate clearly the sameness, the stability of the dominant part of the phytoplankton in tropical ocean water. These three aspects indicate also the absence of interference between the various species, the absence of one species limiting another by making it much less abundant. These three thus indicate absence of interference in the sense that one species does not prevent another from existing or make another less abundant by restricting it in some way.

Table 3. Northern Sargasso Sea; at 36°M. 66°W/ Average concentrations of all coccolithophorids in cells/liter, except *Emiliana huxleyi* and *Gephyrocapsa oceanica*

12-17 October 1981		17-21 October 1981	
<i>Discosphaera tubifera</i>	92.2	<i>Syracosphaera pulchra</i>	74.3
<i>Syracosphaera pulchra</i>	76.7	<i>Discosphaera tubifer</i>	62.9
<i>Umbellosphaera tenuis</i>	57.2	<i>Cyclococcolithus leptoporus</i>	58.6
<i>Calptrosphaera oblonga</i>	42.9	<i>Umbellosphaera tenuis</i>	38.6
<i>Umbilicosphaera hulburtiana</i>	37.7	<i>Umbilicosphaera hulburtiana</i>	22.9
<i>Umbellosphaera irregularis</i>	29.9	<i>Calyptrosphaera oblonga</i>	18.6
<i>Cyclococcolithus leptoporus</i>	28.6	<i>Syracosphaera mediterranea</i>	15.7
<i>Thoracosphaera heimii</i>	26.0	<i>Helicosphaera carteri</i>	15.7
<i>Helicosphaera hyalina</i>	15.6	<i>Anthosphaera oryza</i>	15.7
<i>Helicosphaera carterae</i>	13.0	<i>Thoracosphaera heimii</i>	14.3
<i>Syracosphaera mediterranea</i>	11.7	<i>Umbellosphaera irregularis</i>	10.0
<i>Helladosphaera aurisinae</i>	11.7	<i>Halopappus adriaticus</i>	8.6
<i>Rhabdosphaera stylifer</i>	10.4	<i>Helicosphaera hyalina</i>	7.1
<i>Syracosphaera dentata</i>	5.2	<i>Syracosphaera dentata</i>	4.3
<i>Homozygosphaera spinosa</i>	5.2	<i>Deutschlandia anthos</i>	4.3
<i>Rhabdosphaera claviger</i>	3.9	<i>Helladosphaera aurisinae</i>	4.3
<i>Helladosphaera cornifera</i>	3.9	<i>Rhabdosphaera stylifer</i>	1.4
<i>Acanthoica acanthifera</i>	1.3	<i>Rhabdosphaera hispida?</i>	1.4
<i>Anthosphaera robusta</i>	1.3	<i>Michaelsarsia falklandia</i>	1.4
<i>Rhabdosphaera hispida?</i>	1.3		
<i>Ophiaster hydroideus</i>	1.3		

Table 4. Bermuda to Straits of Florida 2-6 November 1968; Mediterranean Sea 19-25 September 1970. Average concentrations of all coccolithophorid species in cells/liter, except *Emiliana huxleyi* and *Gephyrocapsa oceanica*

Bermuda to Florida		Mediterranean Sea	
<i>Umbilicosphaera hulburtiana</i>	148.0	<i>Umbellosphaera tenuis</i>	110.4
<i>Discosphaera tubifer</i>	116.8	<i>Calyptrosphaera sphaeroidea</i>	93.1
<i>Cyclococcolithus leptoporus</i>	72.0	<i>Cyclococcolithus leptoporus</i>	82.4
<i>Umbellosphaera irregularis</i>	54.4	<i>Calyptrosphaera oblonga</i>	57.2
<i>Umbellosphaera tenuis</i>	51.2	<i>Discosphaera tubifer</i>	30.6
<i>Calyptrosphaera oblonga</i>	38.4	<i>Helladosphaera cornifera</i>	29.2
<i>Syracosphaera pulchra</i>	35.2	<i>Rhabdosphaera hispida?</i>	23.9
<i>Syracosphaera mediterranea</i>	30.4	<i>Syracosphaera pulchra</i>	18.6
<i>Umbilicosphaera mirabilis</i>	20.8	<i>Syracosphaera bifenstrata</i>	15.9
<i>Syracosphaera dentata</i>	11.2	<i>Pontosphaera syracusana</i>	9.3
<i>Rhabdosphaera stylifer</i>	11.2	<i>Rhabdosphaera claviger</i>	9.3
<i>Helicosphaera carterae</i>	8.0	<i>Rhabdosphaera stylifer</i>	8.0
<i>Thoracosphaera heimii</i>	4.8	<i>Syracosphaera mediterranea</i>	8.0
<i>Helladosphaera cornifera</i>	4.8	<i>Syracosphaera dentata</i>	8.0
<i>Acanthoica acanthifera</i>	3.2	<i>Calyptrosphaera insignis?</i>	6.6
<i>Pontosphaera syracusana</i>	1.6	<i>Helicosphaera carterae</i>	6.6
<i>Acanthoica coronata</i>	1.6	<i>Rhabdosphaera multistylis</i>	6.6
<i>Halopappus adriaticus</i>	1.6	<i>Thoracosphaera heimii</i>	5.3
<i>Anoplosolenia brasiliensis</i>	1.6	<i>Helicosphaera hyalina</i>	4.0
		<i>Pontosphaera discopora</i>	1.3
		<i>Ophiaster hydroideus</i>	1.3

There are two species, also coccolithophores, which are often but not always much more abundant than those catalogued (Hulburt, 1979, 1983a, 1985a, 1985b). One of these, *Emiliana huxleyi*, is the dominant in the tropical and subtropical North Atlantic and was abundant in the two periods at 36°N 66°W with averages of 682 cells/l. and 1024 cells/l. compared to averages of all other coccolithophores of 517 cells/l. and 378 cells/l. in the two periods. Between Bermuda and the straits of Florida *E. huxleyi* was 1931 cells/l., the others 536 cells/l. But in the Mediterranean Sea *E. huxleyi* was 16 cells/l., the others 601 cells/l. The large change between the Mediterranean and the Atlantic in *E. huxleyi* but not the others indicates that *E. huxleyi* did not force the other coccolithophores to be less abundant when it was more abundant. Thus no interference between the dominant and other species occurred.

In the western North Atlantic in spring diatoms grow to abundance (Hulburt, 1990), but the diatoms' growth is a non-interfering growth, because fluid dynamics calculations show that there is no nutrient competition between phytoplankton cells (Hulburt, 1970).

Thus there is no interference between species. And so there is adaptedness of the species to each other. We can say further: if no interference then adaptedness and if adaptedness then no interference, which is: adaptedness if no interference and adaptedness only if no interference, which is: adaptedness if and only if no interference. Now the order is reversed: adaptedness first, no interference second.

Reciprocal Adaptedness and Non-Interference

The relation of reciprocal adaptation and non-interference comes from the preceding paragraph. Fully expressed the relation is:

24. If x is adapted to y then y is adapted to x : equivalent to: if x does not interfere with y , then y does not interfere with x .

This is shown in Appendix VI in the left bracket of (6), (7), and (8). More briefly we have:

25. One specie's x and another specie's y are adapted to each other if and only if one specie's x does not interfere with the second specie's y .

This says that x and y are reciprocally adapted if and only if they are uninterfering, never dreaming that they aren't. But dreaming that they aren't can be included, for 24. (and 25.) are equivalent to 26. This is a valid equivalence; it is shown in the appendix in the right braces of (8).

26. x and y are adapted to each other and don't interfere with each other, *or* x is adapted to y but y is not adapted to x and x doesn't interfere with y but y does interfere with x

Now the situation before *or* is found between the well separated cells of the sea's phytoplankton. And the situation after *or* is found between the crowded organisms near the seashore. In order for 24. and 26. to be equivalent the same x and the same y must go from the open sea to the seashore. The same x and y have to be part of a sea organism or species and then be a part of a seashore organism or species.

In 26. the part after *or* tells what to expect in the littoral. We need the following abbreviations:

- $Axy - x$ is adapted to y ,
- $\sim Ayx - y$ is not adapted to x ,
- $\sim Ixy - x$ does not interfere with y ,
- $Iyx - y$ interferes with x .

The Littoral

Among cheilostome ectoprocts (Bryozoa) on the undersurfaces of foliaceous corals at Jamaica, overgrowths of one species by another along edges of contact occur (Jackson, 1979). The dominant space occupier and the species with the largest win-lose ratio in overgrowths in unfouled parts of its surface, *Steginoporella sp.*, nevertheless loses large amounts of its surface coverage through deterioration of older parts of its colony. There are two species with very good overall win-lose ratios because of no deterioration of older parts but with less capacity to dominate because of lower win-lose ratios in the growing parts. Thus these last two species are adapted to *Steginoporella* because they are less aggressive and interferring, whereas *Steginoporella* is not adapted because more aggressive and interferring. So there are Axy and $\sim Ixy$ for the two species' x and *Steginoporella*'s y , and there are $\sim Ayx$ and Iyx for *Steginoporella* versus the two species.

Interference happens in 2 – specied systems in the case a) of *Postelsia* and *Mytilus* (Paine, 1979) and in the case b) of *Mytilus edulis* and *Mytilus californianus* (Harger, 1970-1971). Under a) the exposed, wave battered headlands of the U.S.A. west coast with 7.7% of the mussel (*Mytilus*) area denuded by winter storms have these denuded

patches regrown with the sea palm (*Postelsia*) during summer. But mussels encroach from the side and reduce the *Postelsia* stands – thus *Postelsia x* is adapted to *Mytilus y*, A_{xy} , in the sense that it is more long-suffering and not interfering, $\sim I_{xy}$, than *Mytilus y*, whereas *Mytilus y* is not adapted to *Postelsia x*, $\sim A_{yx}$, in the sense that *Mytilus y* is more pushy, truculent, and interfering, I_{yx} . The two senses occur in b) when clumps of *Mytilus edulis* and *M. californianus* on exposed pilings become 1 – specied, *M. californianus* winning, after several years of undisturbed growth. But half the clumps on pilings are equal mixtures of both species because partial mutilation of clumps by waves allows *M. edulis* to grow in freed space – or massive removal of clumps by storms allows 2 - specied clumps to start again (for only 2/3 of the pilings have clumps). Here it is *M. edulis* that is long-suffering, adapted, and uninterfering to *M. californianus*, A_{xy} and $\sim I_{xy}$, and the aggressive, pushy *M. californianus* that is unadapted and interfering to *M. edulis*, $\sim A_{yx}$ and I_{yx} .

In a study of subtidal organisms Dayton et al (1984) found that three kinds of kelp patches off southern California maintained their distinct structure up to 8-9 years, though their constituent species usually had life spans of about 3 years. Such local equilibria between the three kinds of patches with any one of them as x and any other as y , there is A_{xy} because of $\sim I_{xy}$. But such local equilibria could be easily broken by clearing areas adjacent but not an appreciable distance (2-30 meters) from the patch margins. Invasions from the adjoining patch typically produced a 1 - species peripheral area in a patch, so here $\sim A_{yx}$ and I_{yx} pertain.

Dayton (1971) describes the intertidal species of the Pacific coast of the northwest U.S.A. as undergoing biological interaction during the process of recruitment and growth. The settlement of barnacle larvae and subsequent first year growth to mature, full size is vastly more successful when the area under observation is shielded from predation by limpets, *Thais* snails, and the asteroid *Pisaster ochroceus*. But second and third year overgrowth of barnacles by *Mytilus californianus* indicates that predator exclusion does not block further interference. So here the scales are tipped very much toward lack of adaptation and interference by *Mytilus* y to the barnacles x , with $\sim Ayx$ and Iyx the predominant outcome.

Menge (1979) searches for the answer to the coexistence of the seastars, *Asterias vulgaris* and *A. forbesii*, which occur together temporally and spatially and which use the same food in the same proportions and do not engage in interspecific interference. His conclusion is that the two species are not in the grips of a chronic competition and do not vie with each other for food, because there are enough low level disasters from winter storms and disease. So here the scales are tipped very much toward Axy and $\sim Ixy$ when one at least of the species is x and the other is y . But there is the lurking possibility of quiet weather and lack of adaptation with interference between at least one species and the other, $\sim Ayx \cdot Ixy$.

Note in Conclusion

This small sample of littoral cases suggests a wider number of similar cases. For certainly the crowded littoral substrate would seem to be unavoidably interactive and

unstable. But this casual generality is superficial. What the analysis here unearths is the mixture of adaptedness and unadaptedness that ensues from such interaction.

What the analysis here unearths is, too, the possibility that instead of x is adapted to y there could have been x is tolerant to y . Thus the two less aggressive and interfering Bryozoan specie's x is tolerant to *Steginoporella's* y , Txy , matching their $\sim Ixy$, their not interfering with *Steginoporella's* y . Thus, likewise, *Postelsia* x is tolerant to *Mytilus* y , Txy , in the sense that it is more long-suffering and not interfering, $\sim Ixy$, than *Mytilus* y . The issue here is that the multi-faceted adaptedness can take under its wing still another facet, another describer, tolerance.

What the analysis unearths, above all, is the power of validity. Take 24., 25., and 26. Are they turgid and cumbersome? Are they just stumbling blocks? Perhaps. But the important point is the power they impart. The compellingness of validity seems inscrutable. But what it achieves, when sufficiently complex, is arresting. One could not have guessed that the sequence of 24. (25.) to 26. would yield the mixture of adaptedness and unadaptedness in the littoral. This sequence of validity is given in Appendix VI.

CHAPTER 10

Alternative Adaptedness and the Termination of the Evolutionary Process

A child there was, who was brought up on the expanding universe and who asked “How big is this universe?” The unforgettable reply was “Silly question. There’s so much matter in the universe that it bends the light and you can’t see out”. This was when relativity was new and dazzling. Since then other great breakthroughs have come about -- DNA, plates and the separation of continents, and chemosynthesis of carbohydrate using H₂S in the dark at the hydrothermal vents of the ocean bottom.

These are all physicalistic, objective breakthroughs, but they do not hold the world together for us. There are other elements that could be objective parts of the world and would then hold the world together. These elements are the logical connectives. *Not* is the first – and remember Dobzhansky’s use of *not* in *not adapted*. Next there is *if-then* – and remember Brandon’s use of *if-then* in defining adaptedness. But in simple fashion we may have: *if* there is an earring, *then* there is an ear – a tight connection which may be tightened further: everything, *if* it is an earring, *then* it is for an ear (as in chapter 5 in the

use of the ravens). A looser connection in simple fashion is knife *and* fork, connected by *and*, at a place setting at the table – a connection crucially employed in the third principle of adaptation: if species x is adapted to its locale, then its locale is adapted to x , *and* if its locale is adapted to species x , then x is adapted to its locale. And a still looser connection in simple fashion is by *or* as in Monday *or* Tuesday *or*..... The connective *or* has had star billing in Chapter 8. This will be continued in this chapter on alternative adaptedness, which requires an expansion of the fourth principle of adaptedness. What follows is based on Hulburt (1998).

Fourth principle expanded is: if two or more quite different entities occur under two or more quite different conditions, each entity is adapted to its condition. This principle is different from the first principle where two quite different entities occur under the same condition, one adapted and the other not adapted to the condition. This principle is different, too, from the second principle where one entity occurs under two different conditions, adapted under one condition but not adapted under the other condition. And all three of these differ from the third where one entity is adapted to a second and the second is adapted to the first.

What is the reason for putting the fourth principle off to the last? The reason is a theoretical reason. The fourth principle cannot, with any ease, be symbolized completely, whereas the first three can be completely symbolized with ease. In the fourth principle an entity is adapted to summer, which is: x is adapted to y and there is a y such that y is summer. This complication can be avoided by having: x is summer adapted. Likewise for other situations.

Multiple Pathways of Evolution in Non-Diapause and Diapause

It was said earlier that, morphologically, land vertebrate evolution was haphazard, because of the repetitiousness in leglessness, bipedalism, returning to water, flight, large size, and toe reduction. But physiologically, land vertebrate evolution was a *shift* from cold-bloodedness to warm-bloodedness (just when is anyone's guess). The gears of this shift got jammed, so to speak, so that cold-blooded and warm-blooded animals live side by side today.

The gears of evolution shifted cleanly and well to come up with diapause in temperate insects. In temperate regions a great variety of insects are active in summer. Their eggs are laid in a variety of ways; these develop into larvae in a great many ways; the larvae mature as pupae and metamorphose into insects (Howard, 1937). If this process goes through without cessation at any point, it is non-diapause and it is caused ancillary by the day-length of summer (Saunders, 1976, pp. 87-118). But in autumn short days cause arrested development, diapause, either at the reproductive stage or at the larval and nymphal stages or at the pupal stage (Beck, 1980, pp. 156-180). After winter diapause is broken by long day-length and morphogenesis occurs because of concomitant high temperature. This situation can be described validly as follows in the form of constructive dilemma.

27. (1) Either non-diapause prevails *or* diapause prevails.

(2) If non-diapause prevails then summer adaptedness ensues and if diapause prevails then winter adaptedness ensues.

(3) Therefore, summer adaptedness ensues *or* winter adaptedness ensues.

27. upholds the fourth principle of adaptation, because two quite different entities, non-diapause response and diapause response, occur under two quite different conditions, summer and winter; and each response is adapted to its condition. 27. describes the termination of the evolutionary process, because the responses and their summer-winter adaptednesses do not overlap, are exclusive of each other. 27. shows interpretive ascent from the physicalistic non-diapause to summer adaptedness and the physicalistic diapause to winter adaptedness. And finally, 27. shows the simplified form of summer-adaptedness instead of adapted to summer, winter-adaptedness instead of adapted to winter.

Let us consider a specific case. Even in the sea there is diapause. Marcus (1979, 1980, 1982a, 1982b) found for the planktonic copepod *Labidocera aestiva* that parent copepods exposed to long-day experimental regimes produced eggs that hatched right away at summer temperatures. She found that parent copepods exposed to short-day experimental regimes produced eggs that hatched only after being kept at 5°C for 40 days or more and then warmed to summer temperature. So the long-day, quickly hatching, subitaneous eggs of summer produced the continuously present plankton copepods from June to fall in coastal water (Woods Hole on the east of U.S.A.). And the short-day, diapause eggs of fall overwintered in the bottom mud and hatched during the warmth of June.

The structure of 27. is next done twice for one egg of *Labidocera aestiva*. The composition of this one egg, this philosophical egg, contains x . There are two ways to

achieve this philosophical egg: egg's x or egg x – the second, if said with the thought that egg is an adjective, means the same as egg's x . The second, egg x , will be used in 28., remembering that the x of egg x continues across *or*. See Appendix VII for proof of (1), (2), and (3).

28. (1) Egg x is subitaneous or egg x is diapause.

(2) If egg x is subitaneous then it, x , is summer-adapted, and if egg x is diapause then it, x , is winter-adapted.

(3) Therefore, egg x is summer-adapted or egg x is winter-adapted.

(4) If egg x is summer-adapted then it, x , is from parent copepods adapted to long-day photoperiod, and if egg x is winter-adapted then it, x , is from parent copepods adapted to short-day photoperiod.

(5) Therefore, egg x is from parents adapted to long-day photoperiod *or* egg x is from parents adapted to short-day photoperiod.

28. has two valid sequences, (1)-(3) and (3)-(5), the sequences of constructive dilemma. Though the second one is cumbersome to read, it brings out the interesting detail of the transmission of the day-length characteristic in the parent's cells to the single egg cell. Of course, a summer egg is a different egg from a fall egg. But there is a point between summer and fall when the parent has to make up her mind, so to speak, to produce a subitaneous or a diapause egg. This breaking point, so ambiguous to the reflective imagination, is remedied by the egg's x staying constant and the same despite the vacillating parent.

28. upholds the fourth principle of adaptation, since two quite different entities, a subitaneous egg and a diapause egg occur under two quite different conditions, summer and fall, and each egg is adapted. Two quite different parents, the summer parent and the fall parent, occur under quite different conditions, summer and fall, and both are adapted. The interpretive ascent from subitaneous or diapause to adapted is made at the outset, steps (1) to (2), and then maintained to the end.

Cases similar to non-diapause and diapause are annual plants and their seeds, perennial plants and their underground parts, leafy and leafless phases of deciduous trees.

Theoretical Interlude

Descartes, as anyone knows, said “I think, therefore I am,” “Cogito, ergo sum.” What he should have said (and maybe he thought this understood) is “I think, if I think then I am; therefore I am.” This is valid. This structure is called *modus ponens*. In 28. there are two of these *modus ponens*’s. Thus from 28.: Egg x is subitaneous, if egg x is subitaneous, then it, x , is summer adapted; therefore egg x is summer adapted. Likewise: Egg x is diapause, if egg x is diapause then it, x , is winter adapted; therefore, egg x is winter adapted. There could be any number of these *modus ponens*’s, hitched together in the initial and final parts by *or* and in the middle part by *and*. How this is accomplished analytically is given in Hulburt (1998).

**Multiple Pathways of Evolution in Dark, Light,
Heterotrophic, and Myxotrophic Nutrition¹**

The present termination of the evolutionary process is shown by pathways inherent in the following observations. These observations, too, uphold the fourth principle of adaptedness.

Hellebust and Lewin (1977) brought together much of the research up to that time on diatom species, mostly pennate, that grow in the dark on organic substances. The method is to use a nutrient medium consisting of nitrate, phosphate, trace elements and vitamins to which is added an organic compound both when growth in the dark is occurring and when growth in the light is occurring. Of the amino acids producing dark growth sodium glutamate is the most effective. It is effective alone for *Navicula pavillardii* but is most effective in combination with glucose for *Nitzschia angularis*. It is much less effective in the dark than in the light. Thus the large, slowly growing, pennate *N. pavillardii* has a doubling time of 65-75 hours in the dark with glutamate. It has a doubling time of 24 hours in the light (Lewin and Hellebust 1975). Next, the pennate *N. angularis* has a generation time of 78 hours in the dark with only glutamate, of 42 hours in the dark with glutamate and glucose, of 10 hours in the light (Lewin and Hellebust, 1976).

Although lactate is the preferred organic acid for dark growth, the pennate *Cylindrotheca fusiformis* utilizes lactate, succinate, fumarate, and malate. “The

¹ Pathway as a descriptive term is taken from Gould, 1989, pp. 311-316.

minimum doubling time in the dark on any of these substrates is about 30 hours as compared with about 13 hours” for growth in the light, Hellebust and Lewin (1977) found. Likewise they describe *Cyclotella cryptica*, a centric diatom. It has a doubling time of 27 hours in the dark with glucose and a doubling time of 17 hours in the light.

These diatom species grow both in the dark and in the light. If an inoculum of one of these four species is put in the dark in organic medium, it does divide and so is dark adapted. If the inoculum is put in the light, it divides better and is of course light adapted. Dividing is the first step. Being dark adapted or light adapted is the second step. A step of interpretation.

In a year-long study of ciliates at Woods Hole, USA, Stoecker et al. (1987) found a high proportion of oligotrich ciliates that have chloroplasts from the algae they have ingested. They are helped out in their carbon assimilation by marked photosynthetic fixation from the chloroplasts retained from the algae (Stoecker et al. 1988-1989) (Table 3, Chapter 8). At Woods Hole, “Over the year, an average of 45% (s.d. 27%) of the oligotrich cells had chloroplasts. In some of the summer samples, over 90% of the oligotrichs had chloroplasts. An average of 31% (s.d. 22%) of the ciliates (tintinnids and oligotrichs) were chloroplast retaining ciliates.” Cells without chloroplasts live on ingestion and assimilation, heterotrophy; cells with chloroplasts live by ingestion, assimilation, and photosynthesis, myxotrophy. A single cell may be heterotrophic, hence heterotrophically adapted; it may be myxotrophic, hence myxotrophically adapted.

Theoretical Interlude

We thread together the diatom and ciliate observations, because collectively they are closely allied in their concern with basic nutrition pathways, photosynthetic and non-photosynthetic and mixtures of the two. We thread these together via a single x , a single cell x . Interpretively the cell's x is dark adapted, or it is light adapted, or it is heterotrophically adapted, or it is myxotrophically adapted as shown next.

29. (1) Each cell's x is from one of the diatom growers or is a ciliate grower.
- (2) Each cell's x , if from one of the diatom growers, is dark adapted or light adapted and, if from a ciliate grower, is heterotrophically adapted or myxotrophically adapted.
- (3) Each cell's x is dark adapted or light adapted or heterotrophically adapted or myxotrophically adapted.

We thread together the diatom and ciliate observations by the single x in the valid form of constructive dilemma.

Multiple Pathways of Evolution in Fish Heating

The present termination of the evolutionary process is shown by pathways in the following observations. The observations, too, uphold the fourth principle of adaptedness.

Some large, fast swimming fish have parts of their bodies far above water temperature. Tuna and mackerel sharks are examples. Carey (1973) found a 10°C difference between the warmest mid region and the anterior and posterior regions of bluefin tuna. He found a 5°C difference in mako sharks. These fish have a different

arterial-venous arrangement from cool fish – large cutaneous vessels of these fish have lateral vessels branching profusely into dark muscle embedded in white muscle. Profuse blood vessel pairs form a heat exchanger, such that incoming arterial blood is warmed by interior muscle metabolism and outgoing venous blood, warmer than peripheral muscle tissue, loses heat back to this peripheral muscle. Thus heat accumulates. Such accumulation occurs primarily in the center of the body and it is there that muscle temperature far exceeds water temperature. Carey says this must speed up swimming and help in catching fast prey. Carey says “A major adaptive advantage of an elevated body temperature is greatly enhanced muscle power,” and this “must surely be connected to the advantage of increased swimming speed”.

Carey et. al., (1985) made temperature measurements of muscles of lamnid sharks right after they were brought aboard. These temperatures showed maximum elevations above water temperature from 0°C to 11°C, and these elevations were higher the lower the water temperature (Fig. 21). The species with no temperature elevation is *Isurus paucus*. *I. oxyrinchus* has none to considerable temperature elevation, and the last particularly in cooler water. *Lamna nasus* and *L. ditropus* have the highest temperature elevations and were caught in the coldest water. *Isurus* has one half the amount of axial red muscle of the other species, which have considerable amounts of axial red muscle, the result of a profusion of paired blood vessels that form a heat exchanger (the retia). The distributions of red muscle and temperature in cross-sectional areas along the length of the fish are shown in Fig. 22, emphasizing the importance of red muscle in heat production. Carey et al. say the following. “The anatomical information and temperature

data are consistent with ranking the sharks *Isurus paucus*, *I. oxyrinchus*, *Carcharodon carcharias*, *Lamna nasus* and *L. ditropis* in increasing ability to maintain an elevated temperature.... The sharks rank in the same order with regards to their occurrence in cold water. *Isurus paucus* is a warm water species from the near tropical waters of Cuba, the Gulf of Mexico, and the Gulf Stream.... *Isurus oxyrinchus* occurs in tropic waters, but also moves into temperate water....*Carcharodon* has a wide distribution throughout the oceans of the world...The *Lamna* species are cold-water forms which occur in water cooler than 16°C. *Lamna nasus* is found at 5°C in the North Atlantic. ...*Lamna ditropis*...has been reported as far north as 50 degrees in the Bering Sea....”

Carey (1982) found that the swordfish’s minuscule brain (0.002% of body weight) is warmed to 4.7°C above water temperature in caught dead or moribund fish but warmed to 10°C to 14°C above water temperature in a free-swimming fish in an acoustic telemetry experiment of 36 hr. duration. The brain is heated by thermogenic tissue. This is 50 times as heavy as the brain and is composed of brown tissue laterally and below the brain and of rete tissue below that which contains profuse arterial and venous blood vessel pairs. Swordfish migrate vertically during the day, going as deep as 600m. “In these vertical excursions water temperature may change as much as 19°C in less than 2 hours (Carey and Robinson, 1981). The large and abrupt changes that swordfish experience daily would chill the brain and affect central nervous system processes in most fish...”.

Thus there are three ways, three pathways, that are exemplified by these cases. One pathway is the presence of dark muscle with profusely branching blood vessels in

the body wall. A second pathway is the presence of axial red muscle. A third pathway is the presence of dark thermogenic tissue near the brain. These three pathways, though different anatomically and thus multiple, are duplicates in getting warm-bloodedness.

Theoretical Interlude

So there are three evolutionary pathways to heat adaptedness. And these may be presented in an expanded form of constructive dilemma.

30. (1) Pathways are by body wall dark muscle, or by axial red muscle, or by brown thermogenic tissue next to the brain.

(2) Pathways, if by body wall dark muscle, led to the adaptive advantage of fast swimming, and if by axial red muscle, led to the adaptive advantage of allowing northern distribution, and if by brain thermogenic tissue, led to the adaptive advantage of deep diving.

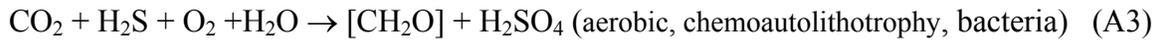
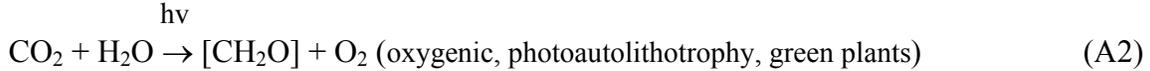
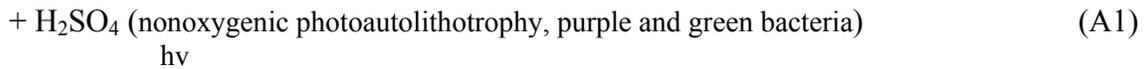
(3) Therefore, pathways led to the adaptive advantage of fast swimming or northern distribution or deep diving.

Multiple Pathways of Evolution in CO₂ Fixation

The present termination of the evolutionary process, as in nutrition and fish heating, is shown by the following observations. The observations, too, uphold the fourth principle of adaptedness. The observations conform to an expansion of constructive dilemma.

Multiple pathways of evolution are exemplified by the processes of CO₂ fixation shown by the following equations (Jannasch and Mottl, 1985):

$$2\text{CO}_2 + \text{H}_2\text{S} + 2\text{H}_2\text{O} \xrightarrow{h\nu} 2[\text{CH}_2\text{O}]$$



The first occurs terrestrially; the second occurs terrestrially and in seaweeds and the phytoplankton of the sea surface; the third and fourth occur in the hydrothermal vents of the sea floor. More simply, multiple pathways of CO₂ fixation are by bacterial photosynthesis, by plant photosynthesis, and two by bacterial chemosynthesis. More simply still, there are two pathways on the planetary surface and two pathways on the sea floor. Put in a logically valid form we have:

31. (1) Pathways are by (A1) or by (A2) or by (A3) or by (A4).
 - (2) Pathways if by (A1) are adapted to the lighted planetary surface and if by (A2) are adapted to the lighted planetary surface and if by (A3) are adapted to the dark sea floor and if by (A4) are adapted to the dark sea floor.
 - (3) Therefore, pathways are adapted to the lighted planetary surface or are adapted to the dark sea floor.

It is clear that this is large scale adaptedness. It is crucial, because adaptedness is to be looked upon as deeply permeating biological material and ecological structure. It is worldwide; it is totally covering.

CHAPTER 11

The Temperate Tropical Distinction

Emphasis has been placed on temperate adaptedness. Tropical adaptedness was considered only in *Anolis*. What is needed for a broader outlook is biological structures that go from temperate to tropical regions. The following are such structures – structures that bridge the temperate tropical divide.

The temperature adaptedness of marine, single-celled algae will be from data in Table 4 (Hulburt, 1982a). Three isolates from the temperate regions of U.S.A. (Massachusetts and Connecticut) have wide growth response ranges, a little wider than the annual temperature they are exposed to. One isolate is a little less wide than the annual range and one (from New York) has a very different growth response range. The three wide isolates show a temperate range of response of 2° - 25°C; one isolate grows at fairly low temperature; and one has a tropical response (the one from New York). The tropical response is exemplified by 14 isolates; the tropical response range is about 12° - 34°C. There is a match between response range and range of water, the isolates are

exposed to in the case of the three temperate isolates but not in the case of the New York isolate. There is a match between the response range of the four isolates taken from the Gulf of Persia and the annual temperature range of the water of 18° - 34°C. But the range of growth response of the seven isolates from off the coast of Surinam is roughly the wide tropical range; but the water has only a narrow range of 26° - 28°C. So there is no match between response and water range at Surinam. And at Bermuda and in the northern Sargasso Sea just north of Bermuda there is no real match between response range and the lesser range of the water of 18° - 27°C.

Matches between response range and water range will be interpreted to be instances of adaptedness. Disparities between response range and water range will be interpreted to be instances of unadaptedness. Since there are isolates with two quite different characteristics, response ranges, occurring under two quite different conditions, in temperate U.S.A. and in the Persian Gulf, this situation is covered by the fourth principle. Since adaptedness and unadaptedness are to be had in both temperate and tropical places, there is an expansion to the fourth principle. Since it is the place where the cells were isolated, not the species, that determines response range, the temperate tropical distinction is to be seen in the physiological attributes of the cells, not the morphological attributes – for some same species are common to both temperate and tropical places.

Table 4: Maximum growth rates in div./day at various temperatures of two species, upper part (methods given in Hulburt 1982a). Growth response range of isolates of species from various places, in °C. Water annual range for the various places.

Southern Massachusetts	1°	4.5°	7°	9°	11.5°	14.2°	17°	20.3°	25.7°	27.5°
<i>Thalassionema nitzschioides</i>	0.74	0.67	0.80	1.11	1.14	1.58	1.84	1.38	0.52	0
Bushehr, Gulf of Persia	11°	14°	17°	21°	28°	31°	34°	37°		
<i>Chaetoceros lorenzianus</i>	0	0.8	0.8	2.0	2.0	1.5	0.3	0		
Southern Massachusetts and Connecticut	0° - 22°			<u>Surinam</u>				26° - 28°		
<i>Asterionella glacialis</i>	1° - 25.7°			<i>Asterionella glacialis</i>				8° - 34°		
<i>Rhizosolenia setigera</i>	4.5° - 17°			<i>Biddulphia mobiliensis</i>				14.5° - 34°		
<i>Skeletonema costatum</i>	2.8° - 27.5°			<i>Chaetoceros didymus</i>				12.5° - 31°		
<i>Thalassionema nitzschioides</i>	1° - 25.7°			<i>Rhizosolenia setigera</i>				11° - 31°		
				<i>Skeletonema tropicum</i> , fall				12.5° - 34°		
<u>New York</u>	0° - 22°			<i>Skeletonema tropicum</i> , spring				17° - 31°		
<i>Nannochloris atomus</i>	10° - 30°			<i>Thalassionema nitzschioides</i>				14.5° - 31°		
Bushehr, Gulf of Persia	18° - 34°			<u>Bermuda</u>				18° - 27°		
<i>Amphiprora sp.</i>	14° - 31°			<i>Chaetoceros lorenzianus</i>				14° - 33°		
<i>Chaetoceros lorenzianus</i>	14° - 34°			<i>Men. 5</i>				13° - 34°		
<i>Coscinodiscus lineatus-excentricus</i>	14° - 37°			<u>Northern Sargasso Sea</u>				18° - 27°		
<i>Leptocylindrus danicus</i>	17° - 31°			<i>Chaetoceros lorenzianus</i>				14° - 33°		

Taking up next a very different case of the temperate tropical distinction there follows data in Table 5 justifying the attribution of adaptedness, and its denial, for predation on low intertidal rocky shore snails (Vermeij, 1978, pp. 57-60). The incidence and degree of shell characters that discourage shell crushing by predators increase toward the tropics. The percentage of species with toothed apertures, elongated apertures, inflexible operculum, and strong external sculpture is 3.58% from five temperate places and is 18.90% from six tropical places, Table 3. Additionally, the frequency of repaired shell injuries from predation is 0.07 for three snail species of the British Columbia coast but is 0.30 for three different species of the Costa Rican coast, for in spite of better defenses the Costa Rican species suffered more. So all these snails compose a single, scattered array and this entity is exposed to quite different predation conditions. So the snail array is better adapted only to temperate predation if and only if it is not better adapted to non-temperate tropical predation – is better adapted in part of its range and worse adapted in another part of its range. The snail array conforms to the second principle and the valid structure of contraposition.

One might think that toothed apertures, elongated apertures, inflexible operculum, and strong external sculpture are adaptations provided by a supposed and undocumented natural selection against predators. This would be an evolutionist's position. There is a different position. These features are a last ditch stand in the face of an overbearing predation, described in detail by Vermeij. They are a sign that the snails are *not* adapted to predation. But in temperate regions, with less predation, the unprotected snails are on easy street and are well adapted to the lesser predation. The situation here is the same as

Table 5. Latitudinal gradients in the incidence of some predator-related traits of low intertidal rocky-shore snails. Taken from Vermeij 1978, p. 60.

	Number Of Species	Percentage of species with –			
		Toothed apertures	Elongate apertures	Inflexible operculum	Strong external sculpture
Temperate:					
Vancouver Is., British Columbia	17	5.9	0.0	5.9	
Boothbay Harbor, Maine	5	0	0	0	0
Plymouth, England	12	8.3	8.3	0	0
Isla San Lorenzo, Peru	11	9.1	0	9.1	0
Montemar, Chile	20	5	0	10	10
		Average = 3.58			
Tropical:					
Playa de Panama, Costa Rica	15	40	47	20	20
Panama City, Panama	20	15	30	25	30
Port Point, Jamaica	15	13	20	20	33
Playa Chikitu, Curacao	10	20	10	30	0
Dakar, Senegal	13	15	23	7.7	7.7
Takorada, Ghana	7	0	0	14	14
		Average = 18.9			

will be described the North American forest, where spaced apart depauperate woody plants of the arid Southwest are not adapted to the arid conditions, for they signal the faltering hanging-in-there-by-the-skin-of-the-teeth aspect of an elsewhere undaunted luxuriant forest. But the pinon pine, creosote bush, etc. of the Southwest do hang in there, just as the gnarled, twisted tree on a windswept coast hangs in there as a mute spokesman of unadaptedness.

The partial plan of the evolution of land vertebrates, presented in chapter 4, comes under the first and second principles of adaptedness. In the first principle the warm-blooded animal and the cold-blooded animal both occur under the very widely changing annual temperature of temperate regions. One kind is active throughout the year and so is adapted; the other kind is not adapted and so is not active throughout the year. But in the always warm tropics both the warm-blooded and the cold-blooded animal kinds, if active throughout the year, are adapted and if adapted are active throughout the year – and thus they are adapted if and only if they are active, for this is the logically valid structure of equivalence. Thus in the tropics both kinds of animals support the third principle and both are adapted to the warm annual temperature.

So, finally, there is complete coverage of the vertebrate land animals' adaptedness to temperature. The whole world of their adaptedness to temperature is taken care of by the first and second principles in temperate regions and by the third principle in tropical regions. But the coverage extends to other attributes. The fur-feathers-insulation attribute may be put along side the warm-bloodedness attribute for they together define two identical classes of animals, and the lack of fur-feathers-insulation attribute may be put

with the cold-bloodedness attribute, for they define two identical classes of all the same animals. Except for hibernators, of course.

CHAPTER 12

Justification of the Four Principles

Of Adaptedness

The cases supporting the first principle are now reviewed. In Chapter 4 there is the pair, the warm-blooded and the cold-blooded vertebrate, the first responding to year-round temperature and thus adapted to year-round temperature, and the second not adapted to year-round temperature because not responding to year-round temperature (except hibernators). The same applies to the mussel and the oyster in Chapter 5. Also in Chapter 5 there is the pair diatom and coccolithophore-dinophycean, the first responding to improved nutrient and thus adapted to improved nutrient, and the second not adapted to improved nutrient because not responding to improved nutrient. In chapter 6 the pairs are the bigger and littler finches, the frequencies of q_1 and q_0 for albinos, and the frequencies of q_1 and q of moths. For the moths: when aa is selected against, $q_1 = 0.424$, then the organism is better adapted; when the organism is not better adapted, then aa is not selected against, $q = 0.50$. The four clauses in all of the comparisons are symbolized as follows, where p and q stand for clauses, where \supset goes between a clause beginning

with if and one beginning with then, and where \sim is not and where \equiv is equivalent to; in the familiar form of contraposition. Specifically for the warm-blooded cold-blooded pair we have : if x in the first responds to year-round temperature, p , then x (and the first animal) is adapted to year-round temperature, q ; – equivalent to: if the same x but incorporated into the second animal is not adapted to year-round temperature, $\sim q$, then x (and the second animal) does not respond to year-round temperature, $\sim p$:

$$32. (p \supset q) \equiv (\sim q \supset \sim p)$$

This symbolization incorporates the features of the first principle: when two quite different entities occur under the same condition one is adapted in q and the other is not adapted in $\sim q$ to the condition.

The symbolization just given incorporates too the features of the second principle: if one entity occurs under two quite different conditions, it is adapted under one condition and not adapted under the other. Cases illustrating this principle are the following. In chapter 4 the cold-blooded vertebrate is adapted only to warm-half of the year temperature if and only if it is not adapted to non-warm half of the year temperature. This is translated as: if the cold-bloodeder is adapted to y (q) then y is in warm-half of the year temperature (p); – equivalent to: if y is not in warm-half of the year temperature ($\sim p$), then the cold-bloodeder is not adapted to y , ($\sim q$): $(q \supset p) \equiv (\sim p \supset \sim q)$. Which has the same form as 32. Next, in Chapter 5, 32. applies to the diatom in the ocean, which is adapted only to improved nutrient if and only if it is not adapted to non-improved nutrient. And 32. applies to four species of *Anolis* on Hispaniola, for each is suited, fitted, adjusted, in harmony only with its niche if and only if it is not suited, fitted,

adjusted, in harmony with the niche above where it is interfered with by one of the other *Anolis* species. *Anolis sagrei* is adapted only to competitorless islands if and only if it is not adapted to non-competitorless islands.

The third principle of adaptedness is illustrated by examples in Chapters 7, 8, and 9. The examples from Chapter 7 all illustrate this important truth of ecological biology: if the species is adapted to locale, then locale *must* be adapted to the species. *Necessarily* locale is adapted to the species (otherwise the species would not be there). Examples from Chapter 7 are: species of the herbaceous genus *Gilia* and their localized small areas of occurrence on the west coast of North America, the redwood and its very limited locale in California, two species of cedars and their restricted locales in the west and the east of the U.S.A., the white spruce and its expanding locale with the retreating ice. Other examples from Chapter 7 are breeding and wintering locales or areas of migratory birds, nursery and pelagic locales of sharks, beach and ocean locales for marine turtles, and beach and ocean locales or domains for seals. The formula for all these cases, equivalence, is:

$$33. [(p \supset q) \cdot (q \supset p)] \equiv (p \equiv q),$$

if the species is adapted to locale (p), then locale is adapted to the species (q); and if locale is adapted to the species, then the species is adapted to locale – equivalent to: the species is adapted to locale if and only if (equivalent to) locale is adapted to the species. The species could be the species x , naming the species; or the species could be the species' x , indicating that x is a constituent of the species; or x could be put in place of the species. Same for locale and y .

The third principle is illustrated by cases from Chapter 8 on the symmetry of adaptedness. Where the symbionts worm and bacteria help each other, they are adapted to each other. Where plant dominates habitat, phytoplankton suppresses nutrient, predator preys on prey, and ciliate enslaves chloroplast the pairs nevertheless are adapted to each other. And we have an expansion of the preceding formula, where p is: x and y help each other; r is: x dominates y , s is: x suppresses y , ...; and q is: x and y are adapted to each other. The expansion is:

$$34. \{[(p \vee r \vee s \dots) \supset q] \cdot [q \supset (p \vee r \vee s \dots)]\} \equiv [q \equiv (p \vee r \vee s \dots)]$$

It is apparent, though, that this is structurally the same as:

$$[(p \supset q) \cdot (q \supset p)] \equiv (q \equiv p),$$

where $p \equiv q$ or $q \equiv p$ may be alternatively used.

But the above can be added onto, as was done in chapter 9:

$$35. [(p \supset q) \cdot (q \supset p)] \equiv (q \equiv p) \equiv [(q \cdot p) \vee (\sim q \cdot \sim p)]$$

Within $[(q \cdot p) \vee (\sim q \cdot \sim p)]$ the part to the left of \vee is: species x and y , are adapted to each other (for q) and species x and y don't interfere with each other (for p). The part to the right of \vee is: x is adapted to y but y is not adapted to x (for $\sim q$) and x doesn't interfere with y but y does interfere with x (for $\sim p$). See Chapter 9. A case for the left part is the coccolithophore species of the open ocean which are adapted to each other because they don't interfere with each other. Cases for the right part are species of Bryozoa, two adapted and uninterfering to a third which is not adapted because interfering to the first two. This situation is repeated for the sea palm and mussel, the first adapted to the second because it is more long-suffering and uninterfering to the second and the second

not adapted because more pushy and interfering to the first in occupying freed-up shore space. Further examples of the same sort of interaction include interactions between two mussel species, between equilibria and lack of equilibria in kelp patches, between first year and subsequent years growth of barnacles, and interactions between two seastars.

The fourth principle is supported by observations in Chapters 7 and 10. The double adaptedness of two different entities to two different situations of the fourth principle is found in winter adaptedness of diapause and the summer adaptedness of non-diapause. But in Chapter 7, there is the double adaptedness of northern summer breeding area and southern winter non-breeding area of migratory birds. There is, too, the double adaptedness of shallow nursery breeding area and offshore non-breeding area of coastal sharks, and the shore breeding areas of seals and their oceanic non-breeding areas. All these cases are included in the following structure of constructive dilemma:

$$36. p \vee r$$

$$(p \supset q) \cdot (r \supset s)$$

$$\therefore q \vee s,$$

for example: diapause or non-diapause, $p \vee r$; if diapause then winter adaptedness and if non-diapause then summer adaptedness, $(p \supset q) \cdot (r \supset s)$; therefore winter adaptedness or summer adaptedness, $q \vee s$.

The fourth principle includes triple adaptedness of some sea turtles in Chapter 7. It includes, in Chapter 10, the triple adaptedness of various warm fish to fast swimming, to northern distribution, and to deep diving. It includes, too, quadruple adaptedness of

algae and ciliates to photosynthetic, non-photosynthetic, heterotrophic, and myxotrophic nutrition. The greatest quadruple adaptedness comes from the four means of CO₂ fixation.

Finally, to go back to double adaptedness, specific physical entities are set aside as exemplifiers of adaptedness. Instead, physical entities will exemplify the property of tendency, which can be interpreted as a criterion for adaptedness. Thus aquatic plesiosaurs, pliosaurs, and ichthyosaurs of the Jurassic and Cretaceous and the spectacular mosasaurs of the Cretaceous had, in some cases at least, many-boned toes of their paddle limbs, Fig. 23. Whales (present) have many-boned fingers of paddle forelimbs. So there is a tendency toward many-boned digits of aquatic vertebrates. There is a tendency, too, in ungulates of the land toward toe reduction, from four to two toes, in artiodactyls, and from four to three to one in perissodactyls. And there is a similar tendency of toe reduction from five to the four of perching birds to two in ostriches. So if there is the tendency toward many boned paddle limbs, then there is aquatic adaptedness; and if there is the tendency toward toe reduction, then there is terrestrial adaptedness. For what else would epitomize aquatic or terrestrial adaptedness in non-fish vertebrates? And this is 36., if you can supply the missing premise.

The Integrated Reality of the Axiomatic Method

The four principles of adaptedness, as expressed in the logically valid 33. – 35., can be generated by application of the axiomatic method of symbolic logic. It would seem naïve to accept these principles purely on the basis of their mirroring the empirical detail that is said to justify them. Do the principles themselves have a source from which

they can be generated? The answer is that they do have such a source. Does this source generate by small, interconnecting steps the expressions 33. – 35.? The answer is that there are many interconnecting steps that generate the outcome seen in expressions 32. - 35. The source is the axioms of the axiomatic method, or propositional calculus, of symbolic logic.

First one must be prepared to accept the feature of structure. One must see what is same-structure in $\sim(\sim QP)$ and $\sim(\sim PP)$. But one must see in this sequence change in structure, too. What has happened, of course, is the substitution of P for Q in the sequence from $\sim(\sim QP)$ to $\sim(\sim PP)$. Substitution is a prime method of effecting the small, interconnecting steps that get from axioms to further expressions. A second method is the use of one, just one, argument form, modus ponens, which is: if this then that, given this; therefore that – $P \supset Q, P \therefore Q$.

It is the plan to have P and Q (and other letters) arranged and rearranged in an interconnecting, integrating manner, and thus an integrated structure will be gotten.

Among texts on mathematical logic such as Church (1956), Mendelson (1979), Kleene (1964), and Hamilton (1988) different axioms are given and a few proofs deriving further formulas are given. But Rosser (1953) gives 29 proofs and Hilbert and Ackerman (1956) gives 40 proofs. Copi (1979) reworks the Rosser system and the Hilbert and Ackerman system and presents for the Rosser system 22 fully portrayed proofs and 32 more theorems are indicated (proofs left to the reader). Nidditch (1962) has 11 axioms, the rest mostly 3 or 4. Nidditch presents 57 proofs, fully portrayed and completely annotated. But here the Rosser-Copi system will be followed, because its three axioms

require a close fitting sequence of proofs to gain the formulas of 32. to 35. In what follows 18 proofs will be given, totaling 112 steps, and thus an exhaustive delineation of interconnection is a clear intent.

Two kinds of proofs will be given. One is where axioms or previously proved formulas only are used to gain a further proved formula. The other is where assumed formulas are included to gain a further formula. The first is ‘proof of...’ and the second is ‘proof that...yields...’. Substitution of a letter remains constant throughout a single proof. By substitution and premise assumption the three axioms (next) generate and weave a remarkable wealth of interconnection, wherein each proof is necessary to the next. Part of the whole procedure is given next, the rest (the larger part) is in the appendix. First, though, a list of technical details is necessary.

A list of formulations is the following:

$P \supset Q, P; Q$ - modus ponens, rule 1. or R.1., where ‘ \supset ’ means ‘implies’,

‘if-then’ (if P then Q)

\sim - means ‘not’

\vee - means ‘or’

\cdot - means ‘and’

$P \supset Q$ - defined, df., as $\sim (P \sim Q)$, for $P \supset Q$ means getting Q if you get P and so not to get Q must be denied or barred initially in $\sim (P \sim Q)$.

$P \vee Q$ - defined, df., as $\sim (\sim P \sim Q)$, for barring not getting both P and Q amounts to getting one or the other or both.

df. - definition

pr. - premiss

The axioms are:

Axiom 1. $P \supset PP$

Axiom 2. $PQ \supset P$

Axiom 3. $(P \supset Q) \supset [\sim(QR) \supset \sim(RP)]$

Does it matter that the letters are in a certain order or that they are close together, in conjunction with each other? It does matter. Every rearrangement must be fought for by substitution and the use of modus ponens (R.1.).

Proof that $P \supset Q, Q \supset R$ yield $\sim(\sim RP)$

1. $(P \supset Q) \supset [\sim(Q \sim R) \supset \sim(\sim RP)]$ Ax. 3, with $\sim R$ replacing R

2. $P \supset Q$ pr.

3. $\sim(Q \sim R) \supset \sim(\sim RP)$ R.1. from 1. and 2.

4. $(Q \supset R) \supset \sim(\sim RP)$ df. of $\sim(Q \sim R)$ as $Q \supset R$

5. $Q \supset R$ pr.

6. $\sim(\sim RP)$ R. 1. from 4. and 5.

Proof that $P \supset Q, Q \supset P$ yield $\sim(\sim PP)$

7. $\sim(\sim PP)$ from 1.-6., replacing R with P

Proof of $\sim \sim P \supset P$

8. $\sim(\sim \sim P \sim P)$ from 7., replacing P with $\sim P$

9. $\sim \sim P \supset P$ df.

Proof of $(Q \supset P) \supset (\sim P \supset \sim Q)$

10. $(\sim \sim Q \supset Q) \supset [\sim(Q \sim P) \supset \sim(\sim P \sim \sim Q)]$ Ax. 3, $\sim \sim Q$ put for P , $\sim P$ for R

11. $\sim\sim Q \supset Q$ from 9., Q replaces P
12. $\sim(Q \sim P) \supset \sim(\sim P \sim \sim Q)$ R. 1., from 10. and 11.
13. $(Q \supset P) \supset (\sim P \supset \sim Q)$ df.

Proof that $\sim P \supset \sim Q$ yields $Q \supset P$

14. $(\sim P \supset \sim Q) \supset [\sim(\sim QQ) \supset \sim(Q \sim P)]$ Ax. 3, $\sim P$ put for P , $\sim Q$ for Q , Q for R
15. $\sim P \supset \sim Q$ pr.
16. $\sim(\sim QQ) \supset \sim(Q \sim P)$ R.1., from 14. and 15.
17. $\sim(\sim QQ)$ from 7., Q instead of P
18. $\sim(Q \sim P)$ R.1., from 16. and 17.
19. $Q \supset P$ df.

Each one of the last four proofs depends on what was proved in a previous proof, 7. depending on 1.-6., 8.-9. depending on 7., 10.-13. depending on 9. at step 11., 14.-19. depending on 7. at step 17. The next proof starts with $P \supset (Q \supset PQ)$ gotten by steps 50.-112. in the appendix. But P, Q yielding PQ can be P yielding $Q \supset PQ$, which can be $P \supset (Q \supset PQ)$. Reversing conclusion to premisses via implications is the deduction theorem, D.T. (see Nidditch, 1962, pp. 30-40 for many examples).

Proof that P, Q yield PQ

20. $P \supset (Q \supset PQ)$ from 50.-112. in the appendix
21. P pr.
22. $Q \supset PQ$ R. 1., from 20. and 21.
23. Q pr.
24. PQ R. 1., from 22. and 23.

Proof of $(Q \supset P) \equiv (\sim P \supset \sim Q)$

25. $(\sim P \supset \sim Q) \supset (Q \supset P)$ from 15. and 19. and D.T. (above)

26. $[(Q \supset P) \supset (\sim P \supset \sim Q)] \cdot [(\sim P \supset \sim Q) \supset (Q \supset P)]$ from 13. and 25 by 24.,
 where bracketed parts replace P
 and Q in 24.

27. $(Q \supset P) \equiv (\sim P \supset \sim Q)$

27. is defined by 26., where the left parenthesized part implies the right parenthesized part in the first bracket and the right part implies the left part in the second bracket. ‘ \equiv ’ means ‘equivalent to’. The tacit conjunction in PQ is changed from schematic to reality by *and*, \cdot , of step 26.

Proof of $[(P \supset Q) \cdot (Q \supset P)] \equiv (P \equiv Q)$

28. $P \supset Q$ pr.

29. $Q \supset P$ pr.

30. $(P \supset Q) \cdot (Q \supset P)$ from 28. and 29. by 24.

31. $P \equiv Q$ df. as in 26. and 27.

32. $[(P \supset Q) \cdot (Q \supset P)] \supset (P \equiv Q)$ pr.

33. $(P \equiv Q) \supset [(P \supset Q) \cdot (Q \supset P)]$ pr.

34. $\{[(P \supset Q) \cdot (Q \supset P)] \supset (P \equiv Q)\} \cdot \{(P \equiv Q) \supset [(P \supset Q) \cdot (Q \supset P)]\}$ 32., 33.,
 by 24.

35. $[(P \supset Q) \cdot (Q \supset P)] \equiv (P \equiv Q)$ df. as in 26. and 27.

Proof that $P \vee R, (P \supset Q) \cdot (R \supset S)$ yield $Q \vee S$

36. $P \vee R$ pr.
37. $P \supset Q$ assumption
38. $R \supset S$ assumption
39. $\sim Q \supset \sim P$ from 37. and 13. by R.1., P for Q , Q for P
40. $\sim S \supset \sim R$ from 38. and 13. by R.1., R for Q , S for P
41. $(\sim Q \sim S) \supset (\sim R \sim Q)$ from 40. and 53. in the appendix
42. $(\sim R \sim Q) \supset (\sim P \sim R)$ from 39. and 53. in the appendix
43. $(\sim Q \sim S) \supset (\sim P \sim R)$ from 41., 42., and 61.-70. of appendix
44. $[(\sim Q \sim S) \supset (\sim P \sim R)] \supset [\sim(\sim P \sim R) \supset \sim(\sim Q \sim S)]$ from 43. and 13.
45. $\sim(\sim P \sim R) \supset \sim(\sim Q \sim S)$ R. 1. from 44. and 43.
46. $(P \vee R) \supset (Q \vee S)$ df.
47. $Q \vee S$ R.1. from 46. and 36.
48. $(P \supset Q) \cdot (R \supset S)$ from 37. and 38. by 24.
49. $P \vee R, (P \supset Q) \cdot (R \supset S) \therefore Q \vee S$ from 36., 48., and 47., \therefore meaning ‘therefore’ and replacing ‘yield’

Step 27. is $(Q \supset P) \equiv (\sim P \supset \sim Q)$. But putting P for Q and Q for P this becomes $(P \supset Q) \equiv (\sim Q \supset \sim P)$. This is the same as expression 32. which contains the basic structure of 6 cases under the first principle and 7 cases under the second principle, as indicated in the first section of this chapter.

Step 35. is $[(P \supset Q) \cdot (Q \supset P)] \equiv (P \equiv Q)$, which is the same as expression 33. and contains the basic structure under the third principle of 6 cases of Chapters 8. and 9.

The further move of $[(P \supset Q) \cdot (Q \supset P)] \equiv (Q \supset P) \equiv [(Q \cdot P) \vee (\sim Q \cdot \sim P)]$ is where the right part as $(P \supset Q) \equiv [(P \cdot Q) \vee (\sim P \cdot \sim Q)]$ is in the appendix VIII, steps 113.-138.

Expression 33. jumps to 35. 35. is a development of 33. and its proof is given in the appendix. Expression 35. contains the structure of 7 cases of Chapter 9. It has the third principle.

Step 49. is $P \vee R, (P \supset Q) \cdot (R \supset S) \therefore Q \vee S$, which is expression 36. This has the structure, under the fourth principle, of 7 cases in Chapter 10.

Once the schematic formulas of steps 27., 35., and 49. are filled in with descriptive words, part of the reality that is aimed for in this enterprise has been gotten. A vital point is this: our words describing what is are as close to what is as we can get. Here no gap between description and what is being described will be indulged in. The linguistic 'x is a redwood and x is adapted' will be excluded. The 'x' of the linguistic 'x is a redwood' will be avoided. The spurious two entities of 'x' and 'a redwood' will be replaced by x as a part of the single redwood. All this was, of course, elaborated in the previous chapter. Were one to mention the North American forest as x being adapted only to moist environments, this would be explained as x is part of each twig, each plant, each association of the conglomerate entity the North American forest, this x integrating this single, broad, scattered thing. For x is real. As is the connective *and*, that was fought for by interconnecting proofs, a woven integrated reality. And especially to be included

are the other connectives, *if-then*, *or*, which are vital to the integrated reality which the sequence of proofs is.

The view here is of course that the connectives *if-then*, *and*, *or* are elements as real as the elements they connect. Same for *not*. The deduction theorem was just mentioned, saying that P, Q yielding PQ can be reversed to $P \supset (Q \supset PQ)$, that $\sim P \supset \sim Q$ yielding $Q \supset P$ can be reversed to $(\sim P \supset \sim Q) \supset (Q \supset P)$ – though only after the proof has been accomplished. But proof and reversal show the remarkable degree of connectedness, of integration, intended for adaptedness.

Is there a theory for combining *if-then*, *and*, *or*? Here the crucial $P \supset (Q \supset PQ)$ or $P \supset (Q \supset P \cdot Q)$ shows a tight hanging together. $P \supset (Q \supset PQ)$ can be definitionally expressed as $\sim[P \sim \sim(Q \sim (PQ))]$ – that is, one is barred from getting the initial P and not getting the $\sim(Q \sim (PQ))$ part and one is barred from getting the Q next and not getting the final PQ . So there is still a tight hanging together. But in the Hilbert-Ackerman system one finds that $P \supset (Q \supset PQ)$ is definitionally expressed by $\sim P \vee [\sim Q \vee \sim(\sim P \vee \sim Q)]$. The $\sim(\sim P \vee \sim Q)$ part to the right is barring not getting P or not getting Q ; in other words both are gotten, PQ (or $P \cdot Q$). And even though failing to get P or failing to get Q happens initially (to the left), getting both ultimately cannot fail (to the right). So the greater flexibility of the Hilbert-Ackerman system still has some semblance of the tightness of the Rosser system.

CHAPTER 13

The Four Principles of Adaptedness and Their Set Theory Foundation

Properties are a crucial part of what is presented next. Properties are collected together to compose, to make, to embody something (Loux, 2003, pp. 25-34), whether the something is a tight individual or a sprawling, diffuse land or ocean area. To be is to be a particular and to be a particular is to have properties. So a particular can be said to have the properties that compose it. Specifically we can get at the natural world by separating particular entities, particular organisms, particular species, particular pieces of ground and ocean from the properties they possess. We can have reality by invoking particular entities, 1), by invoking the response properties they have, 2), and by invoking the environmental facets the response properties are associated with, 3). In 3) it is seen that because properties are associated with environmental facets they are impure properties. But because of reversibility (Chapter 3) environmental facets can have idiosyncratic, unique support properties for the species that occupy habitats and areas.

Properties can determine sets, classes. For a set is all those things which have a certain property, which exemplify a certain property, which are therefore members which

belong to a set. There can be sets of things; there can be sets of properties. In fact, at the very outset we will take up a set of five properties; there will be a set of five division rates of single-celled algae. There will be sets of sets, for we will take up, next, the associations of the North American Forest, wherein an association is a set. There are 22 associations, each association a set, and these sets can be arranged in various further sets. There will be a set of three coastally restricted forest species as members already mentioned, a set of six North American cottontail rabbit species as members, a set of six Maine (U.S.A.) salamander species as members. There will be a set of six plant form properties such as leaflessness, leafiness, etc.. Two sets, one with two forms of photosynthesis as members and the other with two forms of chemosynthesis as members, will be presented again. And last a set of 14 bird species as members and a set of their 14 areas of habitation as members will be presented again in different guise.

What stands out about sets is that their members are numbered. The details of set theory are endlessly taken up by numbers. In fact, sets are various groupings of numbers. But numbers are infinite, and the set of conceivably countable, infinitely many numbers is labeled \aleph_0 (aleph). And the numbered members of finite sets are, it may be thought, merely the clothed, enshrouded parts of the infinite set of numbers.

So the delineation of adaptedness will have the structure of the four principles, the structure of validity the principles can be recast into, the structure of the properties that particulars of various sorts have, and the structure of sets that properties define and that particulars are members of.

Relations and the First Principle

Of Adaptedness

In the following presentation of the adaptedness model data will be used to substantiate the first principle of adaptation, which (it will be recalled) is this: if two quite different organisms occur under the same condition, then one is adapted to that condition and the other is not adapted to that condition. Put in a logically valid form this might be: if x in one organism responds to a given condition, year-round temperature, then it and organism is adapted to that condition; - equivalent to: if same x but within a quite different organism is not adapted to that condition, then it (and second organism) does not respond to that condition. Which is $(Rx \supset Ax) \equiv (\sim Ax \supset \sim Rx)$. (See appendices for the way symbolization is done.)

The shift from the discursive to the logical presentation emphasizes that the logic structure is a part of the reality that is supposed to be captured. But whether the format is discursive or logical the linguistic subject-predicate structure – i.e., ‘if x in one organism responds to a given condition’ – has a reality counterpart of particular-property structure, of empirical base of organisms and a property base of organisms’ responses to a given condition. This consideration leads to the next presentation.

In the presentation there are three constituents: 1) the empirical base of organisms that are prevalent in the ocean off southern New England, U.S.A.; 2) the response base of the growth responses of these organisms; 3) the environmental base of

the temperature of the ocean that the organisms respond to. In footnotes II and III are presented all three of these constituents. But in Table 6 are presented only 2) and 3) of these constituents. In Table 6 are given the experimental growth responses of several organisms (averaged) at various temperatures and experimental growth responses of a quite different organism at various temperatures. Also are given ocean water temperatures throughout the year where these organisms are prevalent (see footnote III).

We now turn to considering what a set is, so that set theory may be applied to the facts of Table 6, to the experimental growth responses and the ocean water temperatures.

What constitutes a set, a grouping, of growth responses is their numericalization in an ordered sequence with increasing temperatures. In Table 6 five growth rates or division rates of several unicellular algae (averaged) (see Fig. 3) are presented as a downward sequence. Five numbers themselves form a sequence (horizontally) in the following way (Lipschutz, 1998, p. 2):

$$1, 2, 3, 4, 5, \dots \quad 1)$$

This is an infinite sequence, as indicated by the dots. The one-to-one corresponding sequence of division rates, where only the subscripts effect numericalization and where no dots indicate a finite sequence, would be (Lipschutz, 1998, p. 119):

$$a_1, a_2, a_3, a_4, a_5. \quad 2)$$

1) and 2) form sets, expressed by enclosing the sequences in curly braces (Brewer, 1958, p. 6; Lipschutz, 1998, p. 1):

$$\{1, 2, 3, 4, 5, \dots\} \quad 3)$$

$$\{a_1, a_2, a_3, a_4, a_5\} \quad 4)$$

It is the view here that finite sets of growth rates or division rates, of things in general, are parts of infinite sequences. The set of positive numbers is an infinite

Table 6

Growth rates in divisions per day of pure cultures of the unicellular diatoms *Asterionella glacialis (japonica)* and *Thalassionema nitzschioides*, Fig. 1, at increasing temperatures, averaged as in the Appendix, set *A* (selected from Hulburt, 1982, p. 213). Ocean water temperatures at Woods Hole, southern Massachusetts, set *B* (from Schroeder, 1966).

Set <i>A</i>	Set <i>B</i>	<i>A</i> x <i>B</i>	<i>R</i>
Division rates, a_i	Ocean temperatures, b_i		
0.59 at 1° a_1	3° b_1	a_1, b_1	$a_1 R_1 b_1$
0.73 at 5° a_2	5° b_2	a_2, b_2	$a_2 R_2 b_2$
1.30 at 10° a_3	10° b_3	a_3, b_3	$a_3 R_3 b_3$
0.80 at 15° a_4	15° b_4	a_4, b_4	$a_4 R_4 b_4$
1.54 at 20° a_5	20° b_5	a_5, b_5	$a_5 R_5 b_5$
1.37 at 25° a_6			

Growth rates in divisions per day of a pure culture of the green alga *Nannochloris atomus* at increasing temperatures, Set *A* (from Ryther, 1954). Ocean temperatures off New York, Set *B* (from Schroeder, 1966).

Set <i>A</i>	Set <i>B</i>	<i>A</i> x <i>B</i>	<i>R</i>
Division Rates, a_i	Ocean temperatures, b_i		
(0.00 at 1° a_1) ¹	3° b_1 ²	a_1, b_1	$a_1 \text{ not} R_1 b_1$
0.00 at 5° a_2	5° b_2	a_2, b_2	$a_2 \text{ not} R_2 b_2$
0.14 at 10° a_3	10° b_3	a_3, b_3	$a_3 R_3 b_3$
0.65 at 15° a_4	15° b_4	a_4, b_4	$a_4 R_4 b_4$
0.80 at 20° a_5	20° b_5	a_5, b_5	$a_5 R_5 b_5$
0.71 at 25° a_6			
0.32 at 30° a_7			

¹ It is assumed that because *Nannochloris* grew very poorly at 10°C and did not grow at all at 5°C that it could not grow at 1°C.

² b_1 is matched with a_1 arbitrarily (and likewise above)

sequence; here the five division rates clothe a part of this infinite sequence.

But the finite part, the five division rates, of the infinite sequence of numbers has a parallel part in five ocean water temperatures. In Table 6 are presented set A of five division rates at various temperatures and set B of five ocean temperatures. Also is shown the product set of $A \times B$. The product set is all the ordered pairs of the constituents of A and B , wherein each member of the set A is a_i and each member of the set B is b_i . Thus each experimentally determined division rate at a particular temperature, a_i , is matched to the ocean water temperature, b_i , that it depends on (Lightstone, 1964, p. 50; Lipschutz, 1998, p. 65). We have:

$$A \times B = \{(a_1, b_1), (a_2, b_2), (a_3, b_3), (a_4, b_4), (a_5, b_5)\} \quad 5)$$

These are not all the ordered pairs (the Appendix I shows all of them). There are 25 ordered pairs in all, and these would constitute the complete product set $A \times B$. So there has been a great reduction in the number of ordered pairs in this case of applying set structure to the situation of inherent, experimentally determined division rates that are yet dependent on the external environment and its various temperatures throughout the year.

There are two presentations of ordered pairs (a, b) (Lightstone, 1964, p. 50, p. 58; Milewski, 1989, pp. 18-21; Lipschutz, 1998, pp. 64-65). Where $a \in A$ means *a belongs to the set A* and $b \in B$ means *b belongs to the set B* and where the colon means *such that* and \wedge means *and*, the first presentation is:

$$A \times B = \{(a, b) : a \in A \wedge b \in B\}. \quad 6)$$

6) says that the product set $A \times B$ equals the set of ordered pairs (a, b) such that $a \in A$ and $b \in B$. The second, where R is the relation of adaptation between A and B , is

$$(a, b) \in R. \quad 7)$$

Thus (a, b) belongs to R . Thence we say “ a is related by adaptation to b ,” that is, a is adapted to b , a has adaptedness to b : aRb . This is shown in Table 6 at the far right.

The five pairs of adaptednesses and water temperatures in Table 6 have the merit of dividing up the internal and external world explicitly. Further merit is the employing of a strategy of numericalization. This is important when we come to properties, the property of adaptedness as an example. We have adaptedness between division rate and an environmental particular : adaptedness as R_1 , between 1° rate and ocean’s 3°, adaptedness as R_2 between 5° rate and ocean’s 5°, adaptedness as R_3 between 10° rate and ocean’s 10°, and so on. Pure adaptedness is single; it is the common property here of several division rates and matching ocean temperatures. If these adaptednesses were extracted from the particular situations that ensconce them, the several adaptednesses would have no common property and would fail thus having the matrix to produce countably different things (aspects) united by a single common property (this will be treated more fully in the section on properties).

These considerations, although basic, have diverted us from the facts of Table 6. Thus the diatom conglomerate’s five division rates and the five ocean temperatures compose this set of five adaptednesses:

$$\{a_1R_1b_1, a_2R_2b_2, a_3R_3b_3, a_4R_4b_4, a_5R_5b_5\} \quad 8)$$

But the green alga did not grow at two of the low temperatures in pure culture so that it does not have adaptednesses (has no adaptedness) at these oceanic temperatures:

$$\{a_1 \text{not} R_1 b_1, a_2 \text{not} R_2 b_2\} \quad 9)$$

At the other temperatures in pure culture it did grow well and has the properties of several adaptednesses to the environmental temperatures experienced in the ocean:

$$\{a_3R_3b_3, a_4R_4b_4, a_5R_5b_5\} \quad 10)$$

Set 8) and set 9) plus 10) are on the one hand all adaptednesses and on the other hand partly unadaptednesses and partly adaptednesses, showing a clear and detailed accord with the first principle of adaptation – wherein the diatom conglomerate has only adaptednesses and the green alga does not have only adaptednesses to the very wide range of environmental temperature.

Relations and the Second Principle Of Adaptation

In the next presentation of adaptedness there is an elaboration of the second principle. This is (as pointed out repeatedly) that if one entity occurs under two conditions, then it is adapted to one condition and not adapted to the other condition. Put in a logically valid form this might be: some entity x is adapted only to a moist condition, say, if and only if entity x is *not* adapted to a *non*-moist condition. The shift to the logically valid form clarifies the second principle. (The symbolization of the logical form will be given at the end of the section.) But whether the form is discursive or logical the linguistic subject-predicate structure has a reality counterpart of particular-property structure, of empirical base of organisms and a property base of organisms' responses. This consideration leads to the next presentation of three constituents which show how *structure is the reality it captures*.

There are three constituents in the presentation of the first principal of adaptedness – but only two are used in Table 6. There are similar constituents in the presentation of the second principle of adaptation: 1) the empirical base of 22 associations (sets) of the North American forest; 2) the response base of eight sets of response properties of the North American forest; 3) the environmental base of the amount of rain, the moistness or dryness, of the environment of the North American forest. All three will be used at first, but in the end the second will be omitted and 1) and 3) will describe the North American forest.

What follows next is a long factual description of the North American forest, taken from Oosting (1948, pp. 234-299; which describes the associations of the forest very adequately). The reasons for this long account are two. First, the division of the forest into associations is par excellence a division into sets. The associations of the forest are very natural, totally uncontrived sets. Second, the reader will be asked to decide, by this description, what his view of being adapted is. In other words, if the reader considers that the associations of tall, densely packed species are ideally adapted to moist regions, then does he consider the associations of depauperate, spaced apart species are also ideally adapted to dry semi-desert regions. Or does the reader reason in a consistent way that the semi-desert species are *not* adapted to *little* water just as the moist region species *are* adapted to *ample* water.

The North American forest is composed of a number of associations of species. An association is (apparently) a set of species where several are picked out as representing the set and its geographical extent. The associations will be listed starting

with the mixed mesophytic association of southern Appalachia of 25-30 important species occurring with 60 inches of rain per year, 1. Extending northward two of these species, beech (*Fagus grandifolia*) and sugar maple (*Acer saccharum*), become increasingly important as the beech-maple association covering an area from New York to Ohio to Wisconsin, 2., Fig. 23. Northward of this association is a transition zone where hemlock (*Tsuga canadensis*) is important and a constant member in addition to beech and sugar maple. This association, the hemlock-hardwood association, 3., extends through the Lake states to Nova Scotia. Around the center of the mixed mesophytic association to the east, south, and west where precipitation becomes less, the drought resistant oak-hickory association occurs, 4., wherein four or five species of oak (*Quercus*) and hickory (*Castanea*) take part. In the coastal plain from New Jersey to Florida and along the Gulf to Texas a pine association occurs, maintained by fires, 5. Finally, in the mountains at 5000 feet in the Smokies, at 3400 ft. in the Catskills, at 3000 ft. in the Adirondacks, at 2500 ft. in the White Mountains, and at 500 ft. on Mt. Katadin there is a southward extension of the northern boreal forest, wherein red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*) are important, 6.

Thus the eastern and southern associations have been numbered outward from the first association in southern Appalachia. These are densely packed associations of tall trees in moist environments. They respond to moist environments by being densely packed and tall.

Further moist environments are associated with the northern boreal forest. This spans the continent from New England and Newfoundland westward touching the Great

Lakes then tending northwestward across Saskatchewan and along the Rocky Mountains to the Pacific coast in Alaska. The northern boundary is the tundra. Near the St. Lawrence the dominants, white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*), reach maximum size and grow in close stands and form an association, 7. The fir is absent at the northern border and in the west, so that an association, 8., has a single dominant species (the white spruce). At the north tamarack (*Larix laricina*) and black spruce (*Picea mariana*) are important and form an association, 9. These are densely packed, competitive associations because this is their response to their environment.

Next, the Rocky Mountain forest, from northern Alberta to the southern end of the Sierra Madre (*Mexico*) and from the Black Hills in the east to the Sierra Nevada and Cascades in the west, has five associations. From timberline downward for 2000 ft. there is an association of climax species, Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), which grow in dense stands, 10. Below this zone Douglas fir (*Pseudotsuga taxifolia*) is the climax dominant, growing in dense stands, though not without fir and spruce associates, 11. Below this zone is a belt in which *Pinus ponderosa* forms a relatively open climax forest that becomes savannah-like with decreasing altitude, 12., Fig. 23. Below this toward the south is an open forest of widely spaced small trees, the piñon pine-juniper association (*Pinus monophylla*, *Pinus edulis*, *Juniper osteosperma*), 13., Fig. 24. This association grades into the scrub bush associations of the semi-desert. Also there is a transition zone of broad-leaved scrub, the oak-mountain mahogany association, 14.

Thus there is gradation from tall, densely packed, competitive associations to small, spaced apart, uncompetitive associations, from associations of species with high growth capacity to associations with low growth capacity. The same trend will be traced next along the Pacific coast.

The climax dominant from Alaska southward to the Olympic Peninsula is Sitka spruce (*Picea sitchensis*), 15. On the Olympic peninsula in addition to Sitka spruce are western hemlock (*Tsuga heterophylla*), arborvitae (*Thuja plicata*) and grand fir (*Abies grandis*). In this region rainfall is 30-150 inches/year. Eastward Douglas fir becomes important and southward Sitka spruce is replaced by redwood (*Sequoia sempervirens*). All this is one association, 16. Inland in the southern Cascade mountains and the Sierra Nevada red fir (*Abies magnifica*) is the important climax species growing in dense stands and making up 80-90% of the forest. Several pines and white fir and hemlock, in small numbers, make up the association, 17. Rainfall is 40-50 inches/year but decreases downslope. There is one more association composed of broad-leaved, evergreen oaks and many evergreen shrubs in the coastal ranges of southern California and into lower California, with 10-30 inches of rain per year, 18. These associations have responses of tallness, dense packedness, and competitiveness to the abundant rain.

The desert region includes the Great Basin between the Rockies and Sierra Nevada where the sagebrush association is dominated by *Artemisia tridentata*, 19. Southward a shrubby association of shadescale (*Atriplex confertifolia*) and bud scale (*Artemisia spinescens*) dominates, 20. In the region of these two associations rain is 4-8 inches/year. In the Mojave Desert at higher elevations Joshua tree (*Yucca brevifolia*) is

conspicuous. With decreasing altitude the dominant creosote bush (*Larrea divaricate*) plus burro weed (*Franseria dumosa*) make up an association covering 70% of the Mojave Desert, which extends southward to the Gulf of California, 21. In the Chihuahua Desert, New Mexico into Mexico, a final association of ocotillo (*Fouquieria splendens*), creosote bush, and mesquite (*Prosopis julifera*) is widespread, plus a number of large succulents and leafless green-stemmed trees and columnar cacti, 22. These associations respond by being small, spaced apart, and uncompetitive because of slight rain.

These 22 associations are sets. Each association is a natural set. Each is an uncontrived set. Each is a set where the members, the elements, are species. Sometimes one association, one set, has only a single member. More often each association, each set, has several and sometimes quite a few species as members, as elements. Associations which are close to each other such as the beach-maple, 2., and the hemlock-hardwood association, 3., have several but not all species in common; thus these sets are said to intersect. The union of these sets would include all three dominant members, beach, maple, and hemlock. The southward extension of the northern boreal forest, 6., has no major members in common with the beach maple, 2., and so these associations are pairwise disjoint or mutually exclusive sets. Many pairs between the eastern and western forest formations are pairwise disjoint and thus partition associations 1.-6. from associations 10.-12. and 15.-18. The semi-desert associations, 19.-22. plus 13., are partitioned from the other associations. Although each association, each set, has these characteristics, each association is itself a member in a set of associations. These features and much more are well described in Langer (1967, pp. 112-156) and Lipschutz (1998,

pp. 4-11, p. 73, p. 117, pp. 155-156) and Suppes (1972, pp. 24, 37, 39).

This description of associations 1.-22. leads further. Let's look at the matter this way. Each association is a particular entity. Each such set is an entity. Entities have properties. When a number of entities (sets) have a common property, the property is a set defining property.

So there are four more sets: the set of associations having the response property of tallness, i ; the set of associations having the response property of dense-packedness, j ; the set of associations having the response property of competitiveness, k ; the set of associations having the response property of high growth capacity, l . Thence there are the four opposing sets: the set of associations having the response property of shortness, $\sim i$; the set of associations having the response property of spaced-apartness, $\sim j$; the set of associations having the response property of uncompetitiveness, $\sim k$; the set of associations having the response property of low growth capacity, $\sim l$.

Although the sets i , j , k , and l are very different in being defined by very different properties, they are identical in the sense that they all have the same members. Likewise the sets $\sim i$, $\sim j$, $\sim k$, and $\sim l$ are very differently defined by their properties but are identical in membership. These sets have set defining properties. This is a very important feature, stressed by Langer and overlooked in other accounts of set theory. Langer speaks of classes instead of sets, but her classes are sets exactly. And a class or set has its defining property.

There are two further sets, but only if the reader has decided on just one of the two policies about adaptedness mentioned in the beginning of this section. Let us

consider how a decision might be made. In spite of the often repeated idea that organisms adapt to harsh, adverse conditions, the fact is that harsh, adverse conditions make it impossible to lead the life of plenitude that organisms lead under non-adverse conditions. This is particularly the case of trees and bushes – and both are woody plants – when water is scarce. Woody plants may present extraordinary examples of pure, hanging-in-there-by-the-skin-of-the-teeth survival, as in the 11000 year old clones of creosote bush (Vasek, 1980), but this isn't adaptedness in the sense of 'adapted under non-adverse, plenitude conditions, under conditions when it's easy street, man, with cash in your pocket and a song in your heart.'¹ You look out across a valley floor in New Mexico at the poor miserable plants there, without a drop of water for months and months, put there by a perverse evolution, stuck there in their abject misery, unable to cope with fast growing trees to the north if they should go there or unable to profit by the pleasant conditions there so inured are they to a desiccated world that they do not care for and cannot escape from. You can't have it both ways, these plants adapted and the great trees to the north adapted too.

And you can't have it both ways – adapted to harsh, adverse conditions and adapted to plenitude conditions too – for this further reason. If a set of species is adapted, P , then it is in a moist region, Q – equivalent to: if a set is not in a moist region, $\sim Q$, then it is not adapted, $\sim P$.

¹ This just won't work with 'woman' instead of 'man'.

$$(P \supset Q) \equiv (\sim Q \supset \sim P)$$

The final P must be negated, otherwise the expression is not logically valid. This valid structure, it is the contention here, is just as much a real part of the forest as the trees, and species, and sets of species are real parts of the forest. So now there is a final set with one element all associations having the property of adaptedness to moist regions, e , and the second element all associations having the property of non-adaptedness to non-moist region, $\sim e$.

Now these sets can be arranged as five sets: where sets 1-18 (except 13) compose set A , are members of set A ; where sets 19-22 (plus 13) compose set B , are elements of set B ; where sets i - l compose, are members of set C ; where sets $\sim i$ - $\sim l$ compose, are elements of set D ; where the one element e and a second element $\sim e$ compose the final single set E (Lipschutz, 1998, p. 76, Fig. 3-7 in reverse). These five sets are related as follows:

A	C	E
1	i	
2	j	
3		e
·	k	
· -13		
·		
18	l	

<i>B</i>	<i>D</i>	<i>E</i>
19	$\sim i$	
20	$\sim j$	
21	$\sim k$	$\sim e$
22	$\sim l$	
13		

This diagram is a partial presentation, since the four connections of response relations should go from every element of A to every element of C , and the four connections of response relations should go from every element of B to every element of D . Then all the pairs of elements in the set of A and C , $A \times C$, and all the pairs of elements in the set of B and D ,

$B \times D$, are related – for surely each element of A is related closely to the four response properties it possesses as an element of C and each element of B is related closely to the four response properties it possesses as an element of D .

The next are the four relations connecting all the elements of the set C to one of the elements e of the set E , e being all the associations having adaptedness to moist regions. Then further are the four relations connecting the elements of the set D to the other element, $\sim e$, of the set E , $\sim e$ being the set of associations *not* having adaptedness to *non-moist* regions.

Finally, all of this may be summarized as relation R_1 connecting A to C and R_2 connecting C to E , defined as follows (Lipschutz, 1988, pp., 68-69) (a , c , and e are elements; o tells of the omission of the common element c):

$$a (R_1 \circ R_2) e \text{ whenever there exists } c \in C \text{ such that } aR_1c \text{ and } cR_2e.$$

All members of A , $a_1, a_2, a_3, \dots, a_{18}$ ($-a_{13}$), converge in the single member e of E ; thus all of A make up the one adapted member of E :

$$R_1 \circ R_2 = \{(1 \dots 18, -13), (e)\} \quad 11)$$

Likewise for members of B , which converge in the single member $\sim e$ of E ; thus all of B make up the one *unadapted* member of E :

$$R_3 \circ R_4 = \{(19 \dots 22, +13), (\sim e)\} \quad 12)$$

This constitutes an explicit portrayal of the adaptedness of the North American forest. We are now in a position to present this adaptedness in a logically valid description as follows, where the variable x is in any one of the associations 1-18 (-13) when x is adapted, and where the variable x , the same x , is in a different association, one of 19-22 (+13), when x is not adapted (one x but two associations). We have the following:

For every y , if x has adaptedness to y (x is adapted to y) then y is in a moist region – equivalent to: for every y if y is not in a moist region, then x does not have adaptedness to y (x is not adapted to y). Which is: $(y) (Axy \supset My) \equiv (y) (\sim My \supset \sim Axy)$. More briefly we have: x has adaptedness only to moist regions – equivalent to: for every y , x does not have adaptedness to y , if y is not in a moist region. More briefly still: x has adaptedness only to moist regions if and only if x does not have adaptedness to non-moist regions.

For the North American forest is adapted in part only to moist regions if and only if it is not adapted in part to non-moist regions. Thus the forest as a whole occurs under two quite different conditions and is adapted under one condition and not adapted under the other

condition – the second principle of adaptedness.

Returning briefly to the first part of this section, it was pointed out that there are three constituents of concern: the empirical base of 22 associations, the response base of eight associations, and the environmental base of two associations, one adapted to moistness and one not adapted to non-moistness. The reader should be aware that the trees of the empirical base and their response characteristics are physically not separate but are considered as quite separate, because the empirical base, the organism or species, is said to have the response properties that go into its composition. Is their precedent for this separation? There is; in fact, this separation is a standard procedure in analyses of phytoplankton structure of the ocean. For example, in Hulburt (1979, 1981) the structure is analyzed as samples having cells, samples having absorptiveness productive of cells; or analyzed as samples having cells, samples having a growth response preferred or good for cells. In Hulburt (1984) the phytoplankton has responsiveness; in Hulburt (1982) the phytoplankton has a growth capacity. In Hulburt (1990) the growth capacity of the phytoplankton or the growth capacities of its species show, still, a little separation.

Functions and the Third Principle of Adaptedness

In the presentation of the adaptational structure there is the third principle of adaptedness. This is of course: if one entity is adapted to a second, then the second is adapted to the first. More fully and in a logically valid form the third principle is: if one entity is adapted to a second, then the second is adapted to the first, $Axy \supset Ayx$, and if the second is adapted to the first, then the first is adapted to the second, $Ayx \supset Axy$; equivalent to: the first is adapted to the second if and only if the second is adapted to the

first, $Axy \equiv Ayx$. Gathering all this together provides $[(Axy \supset Ayx) \cdot (Ayx \supset Axy)] \equiv (Axy \equiv Ayx)$ (Chapter 12). Suppose there were no if-then connectives; we would have : one entity is adapted to a second, the second is adapted to the first. But the intended connection is made explicit by putting in if-then as ingredients in the capturing of the external world. Without the connectives the world would be unintegrated.

So we have a logically valid presentation of the principle, wherein not only the content but the logical structure are parts of the reality being captured.

There are three constituents in the presentation of the first and second principles of adaptedness. These three constituents will be used again in the third principle of adaptation. These constituents are: 1) the empirical base of species of trees, of rabbits, of salamanders; 2) the response base of *occupying* a certain area or locale; 3) the environmental base of area or locale. These three constituents will have data to substantiate them. The purpose in substantiating them will be to make possible the reality of the third principle as a structure of adaptedness. For the structure must reflect the reality it captures.

The first and second principles were encapsuled in the structure of relations of set theory. But the third principle will be presented via functions of set theory. What are functions? Here are two examples of functions from Lipschutz (1998, pp. 94, 95). “Consider the function of $f(x) = x^3$, i.e., f assigns to each real number its cube.” “Let g assign to each country in the world its capital city.” Now there are three basic features of functions, whether the functions are infinite, as in the first sample, or finite, as in the second example (see Lipschutz, 1998, pp. 98, 99, 142) – though even the finite set can be

construed as clothing part of the infinite set of numbers.

The first feature is that one element, a , of the set A is assigned to, aligned with one unique element b ; of the set B . This is one-to-one, is injective – as when one value of x is matched with one value of x^3 ; $x = 3$, for example, is matched with $f(x) = x^3 = 27$. Also, $x = -3$ has $f(x) = -3^3 = -27$. For the countries, $g(\text{France}) = \text{Paris}$, $g(\text{Denmark}) = \text{Copenhagen}$.

The second feature is that *every* element b_i of B is to be aligned with some element a_i of A . This is not one-to-one; this is onto, surjective. Examples illustrate this feature. Thus $f(x) = x^2$ yields for $a_i = -x = -2$ and for $a_i = x = 2$ the same number, $b_i = 4$. For the countries $g(\text{England})$ and $g(\text{Scotland}) = \text{London}$ ¹. There is convergence on 4 and on London.

The third feature is that when a function is both one-to-one and onto, like $f(x) = x^3$ and $g(\text{France}) = \text{Paris}$, the function is a one-to-one correspondence, is bijective. If a function is a one-to-one correspondence then it is invertible (reversible): $f: A \rightarrow B$ and $f^{-1}: B \rightarrow A$, wherein all elements, all members, of the sets A and B are considered. Again our examples are as follows, wherein the numbers indicate one-to-one correspondence and the countries onto alignment;

$$\begin{array}{rcc}
 A, x & \dots -3, -2, -1, 0, 1, 2, 3, \dots & \\
 & \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow \downarrow \uparrow & f: A \rightarrow B \\
 B, f(x) = x^3 & \dots -27, -8, -1, 0, 1, 8, 27, \dots & f^{-1}: B \rightarrow A
 \end{array}$$

¹ London is “the capital of the United Kingdom.” England is “the largest division of the United Kingdom.” Scotland is “a division of the United Kingdom.” (The Random House College Dictionary, 1975)

a_i	England	Scotland	a_i	b_i
b_i		London	England	London
			Scotland	

The application of functions to species and their locales is next. In Fig. 12 were presented three species of coastally restricted forests of North America (Laderman, 1998). All are conifers (evergreens). In the coastal belt between southern Alaska and Washington State there is the Alaska yellow-cedar (*Chamaecyparis nootkatensis*). South of this yellow-cedar region the coast redwood (*Sequoia sempervirens*) is abundant. The distribution of the Atlantic white cedar (*Chamaecyparis thyoides*) is intermittent along the East coast and Gulf coast.

These three species and their locales make up two sets of entities. Species and locale are bound together by being adapted to each other. There are two formulas for the binding together: 1), the function of adaptedness assigns to each species its locale; 2) the function of adaptedness binds each species to its locale. The function of adaptedness binds a_1 to b_1 , a_2 to b_2 , a_3 to b_3 – i.e., $f(a_1) = b_1, f(a_2) = b_2, f(a_3) = b_3$. This is one-to-one and onto; so this is a one-to-one correspondence, is bijective (see Table 7). But the locales seem well delimited in a unique, non-overlapping, idiosyncratic manner to their species and support their species fairly well. Thus the function of adaptedness is invertible, is left-right reversable in Table 7. The reversibility shows the function of adaptedness to be a one-to-one correspondence both ways.

In Fig. 25 are six of the set of eight North American cottontail rabbits belonging to the genus *Silvilagos* (Burt and Grossenheider, 1980, pp. 208, 209). Their distributions

Table 7. Species and areas.

Set <i>A</i>	Set <i>B</i>
Evergreen (Conifer) Trees	
Alaska yellow-cedar, a_1	Area of yellow cedar, b_1
Coast redwood, a_2	Area of redwood, b_2
Atlantic white cedar, a_3	Area of white cedar, b_3
Cottontail Rabbits	
Pygmy rabbit, a_1	Area of Pyg. r., b_1
Brush rabbit, a_2	Area of Brush r., b_2
Dessert cottontail, a_3	Area of Dessert c., b_3
Mountain cottontail, a_4	Area of Mountain c., b_4
Eastern cottontail, a_5	Area of Eastern c., b_5
Marsh rabbit, a_6	Area of Marsh r., b_6
Swamp rabbit, a_7	Area of Swamp r., b_7
New England cottontail, a_8	Area of New Eng. c., b_8
Maine Salamanders	
Spotted salamander, a_1	
Eastern newt, a_2	Eastern U.S.A., b_1
Blue-spotted salamander, a_3	
Northern redback salamander, a_4	Northeastern U.S.A., b_3
Four-toed salamander, a_5	
Northern two-lined salamander, a_6	Limited eastern U.S.A., b_5

are quite different from the conifer distributions. The rabbit distributions overlap considerably. Still each distribution seems unique to its species, so that the function of adaptedness binds each species to its distribution, its locale, $f(a_i) = b_i$, and the function of adaptedness binds each locale to its species, $f(b_i) = a_i$, in an invertible set of correspondences between sets A and B , as shown in Table 7.

The overlap of distributions of Maine salamanders, coming next, is very marked. Three pairs of species are presented in Fig. 26. There are two other species in Maine, but these six show the striking feature of overlap in their distributions both in New England and in North America. But first a few comments on their natural history are germane, taken from Hunter, Calhoun and McCollough (1999).

The spotted salamander (*Ambystoma maculatum*) breaks hibernation and appears in abundance from mid-March to April in vernal pools, where for several weeks the process of mating occurs, male and female closely contacting each other, followed by deposition on the bottom by the male of sperm-containing packets which are retrieved by the cloaca of the female with ensuing fertilization and laying of eggs several days later. This process is roughly the same in five of the other species. After breeding the salamanders leave the pools and disappear to secretive habitats under leaves, rotting wood, stones or in underground burrows of other animals and thus spend the summer, fall, and winter. The wide-spread distribution of the spotted salamander is virtually the same as the eastern newt (*Notophthalmus viridescens*), which, however, is quite different in that it spends much more time in the water, with a land stage (the eft stage) being omitted very often so that its whole life in these cases is in ponds and gentle streams.

The blue-spotted salamander (*Ambystoma laterale*) and the northern red-back salamander have very similar, overlapping distributions, restricted to the northern half of the eastern region where the previous two salamanders are widespread. The blue-spotted salamander has a breeding and post breeding life very much like the spotted salamander. However, the red-back (*Plethodon cinereus*) is very different; it is entirely terrestrial. Also it is very abundant – estimates as high as 10,000 individuals per hectare (almost 1/sq. yard) and having twice the biomass of birds (at the Hubbard Brook Forest Experiment).

The last two salamanders are the rare, small four-toed salamander (*Hemidactylum scutatum*), and the northern two-lined salamander (*Eurycea bislineata*) which is very abundant and inhabits fast streams and reproduces in fall, winter, or early spring.

All of these considerable differences in natural history produce an impression of uniqueness and idiosyncratic adjustment between these species and the areas where they live. For these reasons it is felt that the species do have the bond of adaptedness that ties them to their regions. But the bond does not work from region to species because the region is related ambiguously to two rather than one species. Thus the function of adaptedness does not assign to each species its unique region. But for each region there are one or more species assignable to it – in this sense each species can be surjectively mapped, by adaptedness, onto a region. This is shown by 2 species per one region in Table 7. Specifically, on the right $f(a_1) = f(a_2)$, but on the left $a_1 \neq a_2$ in Table 7; on the right $f(a_3) = f(a_4)$, but on the left $a_3 \neq a_4$; on the right $f(a_5) = f(a_6)$ but on the left $a_5 \neq a_6$. It is to be stressed that $f(a_1) = b_1$, that $f(a_2) = b_1$, too; likewise that

$f(a_3) = b_3$, that $f(a_4) = b_3$ too; and likewise that $f(a_5) = b_5$, that $f(a_6) = b_5$ too. See

Lipschutz (1998) p. 99 and p. 109.

Functions and the Fourth Principle of Adaptedness

The fourth principle of adaptedness is (as pointed out before): if two (or more) entities occur under two (or more) conditions, then each is adapted to its conditions. Consider diapause in insects : either there is diapause or there is non-diapause, $p \vee r$; if there is diapause then winter adaptedness ensues, $p \supset q$, and if there is non-diapause then summer adaptedness ensues, $r \supset s$; therefore, there is winter adaptedness or there is summer adaptedness, $q \vee s$. Altogether this is: $p \vee r, (p \supset q) \cdot (r \supset s), \therefore q \vee s$ as in Chapter 12. If the connectives or, if then, and, therefore were omitted from the description, the description would be unintegrated, describing a collage of separate parts. The point is not that the grammatical, linguistic presentation would lack coherence. The point is that the described reality would lack coherence, for there is no other reality than the described reality.

There are three constituents in the presentation of the first, second, and third principles. But only two constituents will be used in the fourth principle of adaptedness. These constituents are: 1) the response base of the property of overwintering, of spring-summer growth, of photosynthesis, of chemosynthesis; and 2) the environmental base of winter or summer adaptedness, of light or dark adaptedness. These constituents will have data to support them. And the goal in supporting them will be to elaborate a context for the fourth principle of adaptedness.

But the question is, what are the entities that take part in this realization, this capture of reality? We return to properties, for they should take part in the capture of reality. In the next analysis only properties will be employed; for particulars can be left out in the following analysis. Then, instead of a qualified, narrow functional relation as in *the function of adaptedness binds two particulars together*, we have an unqualified, broad functional relation, as in *there is a function which aligns one property with another property*, this other property being a qualified adaptedness. Thus, 1., there is a function which aligns the property of overwintering by bare limbs in deciduous trees with winter adaptedness. 2., there is a function which aligns the property of overwintering by seeds with winter adaptedness. 3., there is a function which aligns the property of overwintering by underground parts with winter adaptedness. Likewise, 4., there are functions which align the property of leafiness in deciduous trees, 5., the property of growth in annual plants, 6., the property of above-ground growth in perennial plants with spring-summer adaptedness.

Set A

1. The property of overwintering by bare limbs in deciduous trees
2. The property of overwintering by seeds in annual plants
3. The property of overwintering by underground parts in perennial plants

Set B

Winter adaptedness

4. The property of leafiness in deciduous trees
5. The property of growth in annual plants Spring-summer
adaptedness
6. The property of above ground growth of
perennial plants

There is a function that aligns set A with set B , $f: A \rightarrow B$; it is only one way (surjective), is only onto in the sense that the six elements of A are mapped onto the two elements of B . In more detail, on the right $f(1) = f(2) = f(3) =$ winter adaptedness, but on the left $1 \neq 2 \neq 3$. Likewise, on the right $f(4) = f(5) = f(6) =$ spring-summer adaptedness, but on the left $4 \neq 5 \neq 6$ (Lipschutz, 1998, p. 99, 109). This demonstrates that prime characteristics of temperate land plants have only a one-way adaptedness, wherein, however, two quite different traits, leafless overwintering and leafy growth, are aligned with two quite different properties, winter adaptedness and summer adaptedness, 1). Also, two quite different characteristics, seeds overwintering and plants' growth, are aligned with two quite different properties, winter adaptedness and summer adaptedness, 2). And last, two quite different attributes, underground overwintering and above-ground growth are aligned with two quite different properties, winter adaptedness and summer adaptedness, 3). And of course, these three pairs are cases of the fourth principle of adaptedness, in that two quite different entities are adapted to two quite different entities, winter and summer. The transformation to the logical format presented initially is easy (leaflessness or leafiness; if leaflessness then winter adaptedness, if leafiness then summer adaptedness; therefore winter adaptedness or summer adaptedness – as an example).

In Chapter 10 are given several, quite different examples of the fourth principle of adaptedness. One of them is the following. Multiple pathways of evolution are

illustrated by the set of four CO₂ fixation processes, 1. and 2. on the lighted planetary surface, and 3. and 4. on the dark sea floor (Jannasch and Mottl, 1985).

Set <i>A</i>	Set <i>B</i>
$1. \quad 2\text{CO}_2 + \text{H}_2\text{S} + 2\text{H}_2\text{O} \xrightarrow{h\nu} 2 [\text{CH}_2\text{O}] + \text{H}_2\text{SO}_4$ <p style="text-align: center;">(nonoxygenic photoautolithotrophy, purple and green bacteria),</p>	Light Adaptedness
$2. \quad \text{CO}_2 + \text{H}_2\text{O} \xrightarrow{h\nu} [\text{CH}_2\text{O}] + \text{O}_2$ <p style="text-align: center;">(oxygenic photoautolithotrophy, green plants, seaweeds),</p>	
Set <i>A</i>	Set <i>B</i>
$3. \quad \text{CO}_2 + \text{H}_2\text{S} + \text{O}_2 + \text{H}_2\text{O} \rightarrow [\text{CH}_2\text{O}] + \text{H}_2\text{SO}_4$ <p style="text-align: center;">(aerobic chemoautolithotrophy, bacteria)</p>	Dark Adaptedness
$4. \quad 2\text{CO}_2 + 6\text{H}_2 \rightarrow [\text{CH}_2\text{O}] + \text{CH}_4 + 3\text{H}_2\text{O}$ <p style="text-align: center;">(anaerobic chemoautolithotrophy, bacteria)</p>	

There is a function that aligns the property of photosynthesis by purple and green bacteria and by green plants and seaweed with the property of light adaptedness; i.e., $f(1) = f(2) =$ light adaptedness, but $1 \neq 2$. There is a function that aligns the property of chemosynthesis by H₂S consuming bacteria and CH₄ producing bacteria with the property of dark adaptedness; i.e., $f(3) = f(4) =$ dark adaptedness, but $3 \neq 4$ (Lipschutz, 1998, p. 99, p. 109). As for the salamanders and plants the functional relation $f: A \rightarrow B$ is onto, is surjective, because it does not assign to each CO₂ fixation property a unique property of the world. But for each property of the world there are one or more CO₂ fixation properties assignable to it and in this sense each property can be mapped surjectively onto a property of the world. All this may be redundantly summarized next.

There is photosynthesis or there is chemosynthesis; if there is photosynthesis then light adaptedness ensues, and if there is chemosynthesis then dark adaptedness ensues; therefore light adaptedness or dark adaptedness ensue. Like the insect situation at the beginning of the section, except that the insect situation is injective (one-to-one) and the situation here is surjective (onto).

Taking up again the bird migration of Chapter 7, we turn back to the previous, narrow, qualified use of function, wherein the function of adaptedness assigns or aligns or binds one entity, a species, to another entity, an area.

The Third and Fourth Principles Combined

The third and fourth principles of adaptedness can be combined. In the case of birds which migrate, it is best to divide any single species' life into a breeding time and a breeding area on the one hand and a non-breeding time and non-breeding area on the other hand, as done in Chapter 7.

Each breeding sparrow species occurs in a northern area and each non-breeding sparrow species occurs in a southern area (Fig. 16). So two different entities (breeding versus non-breeding) occur under two different conditions, and each is adapted to its condition, according to the fourth principle. But according to the third principle each entity is adapted to its area, which is adapted to it. To repeat, the breeding species is adapted to its northern breeding area, and the non-breeding species, same species but behaviorally very different, is adapted to its southern non-breeding area. But the northern breeding area is adapted to its species, otherwise the species would not be there. And the southern, non-breeding area is adapted to its species, otherwise its species could not

possibly be there.

For the scarlet tanager, the bobolink, the Atlantic golden plover and the Pacific golden plover the situation is the same, Fig. 16 (Lincoln and Hines, 1950, pp. 44, 56, 54), particularly because breeding area and non-breeding area are so far apart. By the fourth principle each breeding species is adapted to its breeding area and each non-breeding species is adapted to its non-breeding area. By the third principle each breeding species is adapted to its breeding area which is adapted to it; each non-breeding species is adapted to its non-breeding area which is adapted to it.

For these migrating species there is the set of species, set A , and the set of areas, set B . There is the function of adaptedness that binds a breeding species to its breeding area in a one-to-one correspondence (a bijective function), for example:

$$f(a_1) = b_1.$$

There is the function of adaptedness that binds the breeding area to its breeding species in a one-to-one correspondence (a bijective function), for example:

$$f(b_1) = a_1.$$

The function of adaptedness that binds a non-breeding species to its non-breeding area, $f(a_2) = b_2$, binds the non-breeding area to its non-breeding species, $f(b_2) = a_2$, the functions being two-way or invertible.

And likewise for the other species and areas of Table 8.

All of these comparisons can, of course be fitted into the logical formula constructive dilemma. Symbolically, the Atlantic golden plover's x has the property of breeding *or* has the property of non-breeding, $Fx \vee Hx$; *if* x has the property of breeding

Table 8. Species and areas.

Set <i>A</i>	Set <i>B</i>
1. Chipping sparrow (<i>Spizella passerina</i>), breeding, a_1	Breeding area, b_1
2. Chipping sparrow, non-breeding, a_2	Non-breeding area, b_2
3. Clay-colored sparrow (<i>S. pallida</i>), breeding, a_3	Breeding area, b_3
4. Clay-colored sparrow, non-breeding, a_4	Non-breeding area, b_4
5. Brewer's sparrow (<i>S. breweri</i>), breeding, a_5	Breeding area, b_5
6. Brewer's sparrow, non-breeding, a_6	Non-breeding area, b_6
7. Scarlet tanager (<i>Piranga olivacea</i>), breeding, a_7	Breeding area, b_7
8. Scarlet tanager, non-breeding, a_8	Non-breeding area, b_8
9. Bobolink (<i>Dolichonyx orizivorus</i>), breeding, a_9	Breeding area, b_9
10. Bobolink, non-breeding, a_{10}	Non-breeding area, b_{10}
11. Atlantic golden plover (<i>Pluvialis apricaria</i>), breeding, a_{11}	Breeding area, b_{11}
12. Atlantic golden plover, non-breeding, a_{12}	Non-breeding area, b_{12}
13. Pacific golden plover, breeding, a_{13}	Breeding area, b_{13}
14. Pacific golden plover, non-breeding, a_{14}	Non-breeding area, b_{14}

then it has adaptedness to a northern breeding area which has adaptedness to it, $Fx \supset Gx$, *and if* x has the property of non-breeding *then* it has adaptedness to a southern area which has adaptedness to it, $Hx \supset Ix$; therefore x has reciprocal adaptedness with a northern area or has reciprocal adaptedness with a southern area, $Gx \vee Ix$:

$$Fx \vee Hx$$

$$(Fx \supset Gx) \cdot (Hx \supset Ix)$$

$$\therefore Gx \vee Ix$$

The symbolism of the above description is very much truncated but the symbolism is enough to show the important connectives *or*, \vee , *if-then*, \supset , *and*, \cdot , \therefore . These connectives are considered, as mentioned before, as real as the parts of the description that they connect, as real as the variable x lodged in the entity the Atlantic golden plover.

Summary

It is clear that the relation of adaptedness between pairs of elements in two sets, that the function of adaptedness between elements of two sets, cannot be successfully delineated without set theory. We would not have had a clear idea in the achieving of adaptedness of cell division rates to year-round temperature by some algae but not by some other alga, if adaptedness had not been dissected into the numerically distinct adaptednesses of a set of five. But the direct, simple aspect of what a set is in the natural world is provided by the North American forest. We would certainly not have guessed at the aptness and discrimination afforded by set theory's functions. The function of adaptedness binds salamanders, plants, CO₂ fixation processes to environmental facets in only a half measure, in only a half way liaison – technically, in a surjective, onto manner.

But the versatility of function structure means that the function of adaptedness can connect totally tree species paired with regions, cottontail rabbits paired with their locales of occurrence, sparrow-scarlet tanager-bobolink-golden plover species paired with their northern breeding areas when in breeding condition and paired with southern, non-breeding areas when not in breeding condition. This total connection means that the connection is bijective, one-to-one and onto, and is reversible. Such connection is important in bringing into focus situations where adaptedness is reciprocal, where reversibility is the order of the day.

Infinity

So often we list things. A shopping list so often has no real order to it. Yet the items are numbered. So there is order to the list after all. *The tables in this essay are lists; they are numbered affairs.* Numbered lists really are very much a part of our lives. But normally we would not suspect that the numbers we use in lists and tables have been used by mathematicians in a dauntless venture to gain Olympus. One person above all, George Cantor, brought back infinity, as Prometheus brought back fire, and, like Prometheus¹, suffered tragically as a result.

¹ Prometheus, one of the three Titans hated by Zeus, created mankind from clay impregnated with divine particles in the image of the gods. He went to Phoebus first for ethereal flame for perfecting his human creation. He went again and brought back real fire in a hollow reed for human use. Zeus was enraged and had Pandora created and supplied her with her box of evils. She was presented to Prometheus. Prometheus sent her away and continued to perfect his race of humans. Finally Zeus had Prometheus chained to a rock on Mount Caucasus where a vulture fed all day on his liver which grew back at night. Pandora's box was opened by Epimetheus (one of the Titans). Ultimately Hercules, son of Zeus and Alcmena, freed Prometheus from his torment (Dwight, 1849, pp. 81-84).

Before Cantor were two important people, Galileo and Bolzano, in the story of infinity (Aczel, 2000). Galileo said that there are as many squares of numbers as there are numbers, if we count on to infinity. He said this because to each number we can assign its square. We have x and we assign $f(x) = x^2$ to x and count theoretically the x 's and x^2 's to achieve an actual infinity (rather than the potential infinity of infinitesimals). This was in 1638. Much later Bolzano too used a function to get a one-to-one correspondence but not between x and x^2 in an unrestricted world but within the confines of the interval 0 to 1 and 0 to 2. For the function $f(x) = 2x$ meant that any number such as $x = 0.5$ between 0 and 1 becomes $f(x) = 2x = 2(0.5) = 1.0$ in the interval between 0 and 2. So there are the same number of numbers between 0 and 1 and between 0 and 2 and both are infinite. This was in 1848 (Aczel, 2000, pp. 51-63).

Whether we use $\{1, 2, 3, \dots\}$ or $\{1, 4, 9, \dots\}$ or $\{1, 8, 27, \dots\}$ we can count them and we could conceivably count them all; they are countable; all of them were called \aleph_0 by Cantor. Cantor was born in 1845. What he did between 1874 and 1891 was to prove that we cannot count up all the fractions between 0 and 1 (or 1 and 0), if the fractions are expressed as infinite decimals and if numbers are created by a completely legitimate device that do not fit in with all the numbers exhibited as decimal fractions. So first take $n = 1, 2, 3 \dots$; then take the one-to-one correspondents $f(n) = 1/n = 1, 1/2, 1/3, \dots$. Then instead of the fractions use $0.999\dots, 0.499\dots, 0.333\dots$, for $0.999\dots$ would be the same as 1 at infinity, $0.499\dots$ would be the same as 0.5 or $1/2$ and $0.333\dots$ is the same as $1/3$. Also use $0.2499\dots$ for $1/4$, use $0.1999\dots$ for $1/5$, and use $0.1666\dots$ for $1/6$. Now these are put down as an infinite downward sequence to portray the content of the

interval 1 to 0 (Kamke, 1950, p. 10; Brewer, 1958, p. 27; Aczel, 2000, p. 115).

This is shown next, with inferred diagonals, too.

```

0.999 . . .
0.499 . . .
0.333 . . .
0.2499 . . .
0.19999 . . .
0.166666 . . .
. . . . .
. . . . .

```

The first diagonal has above it the number 0.993996. . . This number belongs to the set that the horizontal numbers belong to. But now a perfectly legitimate change is this: subtract 1 from each digit of the diagonal number to get 0.882885. . . This number is part of the set, but it would never be counted in any enumeration that went downward from 0.999. . . Now take the next diagonal number, 0.43996. . . and subtract 1 from each digit to get 0.32885. . . . This number is part of the set, but it would not be counted in any enumeration that went downward from 0.999. . . or from any other diagonal. So take the next diagonal, 0.3496. . . and subtract 1 to get 0.2385. . . and this one too would elude the counting procedure. And so on. So the moral of this devious presentation of the numerical content of the interval is that the interval harbors many numbers you cannot count. And the further moral is that we have come upon an infinity much larger than the simple infinity of counting numbers, \aleph_0 . This led Cantor to consider and prove many further infinities. Yet he could not prove them all. As a result he had longer and longer periods of depression. He continued to have his teaching position at the University at Halle in Germany. But in the end he died of depression (and emaciation) at the nearby Nervenlinik in 1918.

The Capture of Reality

Sets of things are as real as the things. Membership in a set as $a_i \in A$ wherein E , *belongs to*, is as compellingly real as a_i , which is the element, the entity that composes the set. And a_i is as close to what is as we can get, is all the reality we can have.

Suppose instead of ‘The chipping sparrow belongs to the set A of migrating birds’ we had ‘The chipping sparrow the set A of migrating birds’. The ungrammaticality is a trivial issue. Belongs to is what there is in nature. Nature is a junk yard perhaps. But nature has belongs to, organizing the junk to a considerable degree.

Of course the entities which are members of sets are varied, varying in size from an algal cell to an association of the North American forest. But the forest is a set, with a membership of many associations. And the subset of two sets is a product set, wherein relationship and function between paired members are as much parts of what we have as members, sets, and membership.

There are particulars, which are members. There is membership which holds particulars and sets together. What holds nature together? What holds nature together is structure, the coherence endowing structure of set membership.

Are particulars already numerical? Sure, why not. Each particular has its number, no matter how fleeting, how mercurially changing. Your left hand is to left of its right, and we number from left to right : 1, 2, . . . Numbers of things are numbers in things. If we can separate properties (division rate, for example) from particulars, we can separate numbers from particulars. Then numbers are infinite; when collected they are aleph, \aleph_0 . And so infinity is with us always, is in everything.

Footnote I

Ordered pairs from 5)

$(a_1, b_1), (a_1, b_2), (a_1, b_3), (a_1, b_4), (a_1, b_5)$

$(a_2, b_1), (a_2, b_2), (a_2, b_3), (a_2, b_4), (a_2, b_5)$

$(a_3, b_1), (a_3, b_2), (a_3, b_3), (a_3, b_4), (a_3, b_5)$

$(a_4, b_1), (a_4, b_2), (a_4, b_3), (a_4, b_4), (a_4, b_5)$

$(a_5, b_1), (a_5, b_2), (a_5, b_3), (a_5, b_4), (a_5, b_5)$

Footnote II

Maximum growth rates of two species selected from a group of species in Hulburt, 1982, p. 213. Average growth rates shown at right.

Experimental Temperature (°C)	Cell Divisions per Day		Average Div./Day
	<i>Asterionella glacialis</i>	<i>Thalassionema nitzschioides</i>	
1	0.45	0.74	0.59*
4.5	0.79	0.67	0.73*
7	1.28	0.80	1.04
9	1.51	1.11	1.30*
11.5	1.28	1.14	1.20
14.2	0.47	1.14	0.80*
17	1.84	1.58	1.71
20.3	1.23	1.84	1.54*
22	1.38	1.38	1.38
25.7	1.23	0.52	1.37*
27.5	0.00	0.00	0.00

* Selected for Table 1

Occurrence of species at Woods Hole, Massachusetts, in 1956-1957 and in 1978. These two years were selected from four given in Hulburt (1983). Numbers are number of cells per cm.³

1956	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-1957	14	7 28	11	15	17	7 8	29	20	5	2 29	30	30
<i>Asterionella glacialis (japonica)</i>	6	0 1	3	2	207	208	2 0	0	0	22 36	36	0
<i>Thalassionema nitzschioides</i>	19	33 7	7	1	4	0 17	4	0	4	6 0	38	48
1978	Feb	Mar	Apr	May	Jan							
	9	21 8	22	7 24	8 26	8						
<i>Asterionella glacialis (japonica)</i>	50	105	41	55	12	9	10	9	0			
<i>Thalassionema nitzschioides</i>	24	28	5	4	13	0	1	1	0			

Footnote III

Average surface temperatures at Woods Hole, Massachusetts, and off New York for each month of the year are given below. Temperatures are in °C. (from Schroeder, 1966)

At Woods Hole:

Off New York:

January	3°	*	4°	
February	3° - 4°		3°	*
March	3° - 4°		3°	
April	5° - 6°	*	7°	
May	10° - 11°	*	10° - 11°	*
June	14°	*	15° - 16°	*
July	18° - 19°		21°	*
August	19°		21° - 22°	
September	20°	*	21°	*
October	15°	*	16°	*
November	10° - 11°	*	11°	*
December	7°		7°	

* Selected for Table 1

CHAPTER 14

Properties and Adaptedness

Properties (universals) have been endorsed and relied upon in this essay. Late twentieth century critical arguments in favor of properties are those given by Jackson (1977), Loux (1970, 1976, 2003), Wotterstorff (1970), Armstrong (1989), and Moreland (2001). These have been relied upon.

Two basic schools of thought view properties, or universals, in two basically different ways. One school is the moderate nominalist or trope school. Here properties are confined to the particulars that have the properties, which in turn compose, constitute the particular. Here properties of similar particular things are similar; similar properties of similar things form a similarity set – the adaptedness of different organisms form a set of adaptednesses.

The other school insists that properties are not confined to particulars; this school is the metaphysical realist school. Here a single property, adaptedness say, is repeated from particular organism to particular organism. The adaptedness of flying is repeated, is instantiated in this bird or that bird, in this bird species or that bird species. Such a

numerically single property is instantiated, is exemplified not just in different organisms and species. A numerically single property, or characteristic, can be exemplified, by a species in different ways: there is adaptedness in division rate to ten different temperatures by two algal species (Chapter 13). There is multiple exemplifications of the numerically one property in numerically ten aspects of these species. And the question is: how can the realist see his way to their being this multiple exemplification? If the realist can accomplish this, the advantages are enormous. One entity, adaptedness, would integrate the multiplicity of biota and their processes into one whole.

Thus, if we rely on a full-blown realist view, what character would a property such as overwintering have? The answer is very simple. There is agreement among the organisms, the species, the groups that overwinter: they all have special features for getting through the winter (as noted in Chapter 13). Thus because many entities simultaneously overwinter, the realist is confident that one and the same universal is exhibited or exemplified by a multitude of plants and animals or by many species of plants and animals. But to champion this audacious scheme wholly, the realist is forced to avow a non-spatio-temporal view, because one thing cannot simultaneously be in several places – one universal, if it is physical, cannot occur in its entirety, in non-overlapping, discontinuous regions at the same time. But there is no difficulty with overwintering, because the character of overwintering, like adaptedness, is not spatio-temporal in itself. In itself it is incorporeal. Overwintering and adaptedness are incorporeal but enter into the things that have them, just as north of is incorporeal and abstract in itself but does enter into the cities in Edinburgh is north of London –

Russell's (1912, 1997) well-known example (as mentioned before). But physical properties can and should be treated as abstract, not just to be consistent but to promote an insight into the nature of a property. Then when such properties enter into particulars they are concrete exemplifications.

Thence a numerically single, unifying universal when entering into a particular, even a diffuse particular such as a species or a locale, dictates a structure for the particular. Suppose we consider one oyster; if it is like other oysters it pumps through its gill system 9 liters of water in one hour between 16° and 18°C (Chapter 5). This is an attribute, a property of oysters in general, this pumping rate. So on the one hand constituents such as gills, digestive system, shell, etc. are tied together by intercellular stickiness; on the other hand constituents such as pumping rate are tied into the physical stuff by a metaphysical glue. The rate in itself is as diaphanous and incorporeal as north of or adaptedness or overwinteringness or being located (*Gilia* in Chapter 7). And so there must be a metaphysical tie, a nexus, that ties together the instances of corporeal properties, such as being gills, and the instances of incorporeal properties, such as being a pumping rate. The nexus and properties are transmitted to all oysters, to the collection of all oysters, to the kind of thing that an oyster is, to the species the oyster, to the set the oyster.

Now there must be, one school of realists theorizes, an individuating principle to account for each oyster. There is no trouble in telling one oyster from another; of all animals they are the most easily distinguished from each other. But this distinguishability should be accounted for in constructing ontologically an oyster from

the basic materials of properties and nexus. And so we should have an individuating element, an element variously labeled bare substrate, bare particular, individuator – in the view of the substrate – attribute realist. This element is also a propertyless bearer of properties, for it is tied to the properties, to the instantiations of properties, to be exact. When we say that a particular has such and such properties, this is the element that does the having, the possessing of the properties.

But a certain possibility has to be guarded against, which is what the propertyless individuator does. Suppose man-made objects, like two samples of the same shade and brand of paint, are considered – these two samples by having the same properties (same shade, same chemistry) would be the same, would be one and not two, if it were not for the individuating propertyless bearer of properties. And it cannot be the case, the realist argues, that the samples are two by location, one to the left of the other, for example, for numerical difference must occur first in order for location difference to occur second. Of course, although we have managed by the device of the individuator to keep the two samples of paint two, they are totally alike; they are, to use a technical phrase, qualitatively indiscernible. A further point is the possibility that natural objects might conceivably be exactly alike; two plants of *Gilia* perhaps could be exactly alike, or qualitatively indiscernible.

The individuator is not the only way that something can have or possess properties. If a core collection of instantiations of properties is bound together by intercellular stickiness plus a nexus to hold on to the instantiations of the nebulous, incorporeal properties (rate of pumping, rate of growth, rate of cell division) this core

collection can be repeated. Each repeat, each organism, is a whole. Each can possess extra, ephemeral properties, which are accidental and contrast to the essential properties of the core. The variety of shapes of the oyster are accidental but the thick, bivalve shells are essential. But each whole, each repeat is a member in a set, which is a species. And species can be members in a further set, a genus. And genera are members in the set, family. And so on, to still larger taxonomic categories.

The way that initial taxonomic categories come about ontologically, is by the break-down of the identity of indiscernables. This principle requires properties, which includes the view of the metaphysical realist. The principle says that “if two things have the very same properties, then they are the very same thing” (Armstrong’s succinct words, 1989, p. 66). But as pointed out above in the case of the paint samples the two things can be kept two by an individuator, but they will be exactly alike. This happens in machine-made things. But natural things, the individuals of a species, seem usually not to be exactly alike. So a species is an initial taxonomic category and is obviously an identity of indiscernables break-down.

Summarizing as noted in Chapter 3, “a property is a universal construed as a multiply exemplifiable abstract entity that is a numerically identical constituent in each of its instances (Moreland, 2001, p. 74) Non-spatio-temporal is equatable with abstract, and both of these with incorporeal. Nexus is eminently philosophical; if you could breath life into the word ‘and’ and make it part of the structure of the world, you would have nexus. Individuator (bare particular, bare substrates) play a dual role of distinguishing between entities that are totally alike and thus qualitatively indiscernible and being the

anchor that properties (their instantiations) are hitched to.

One may wonder why a theory of the structure of a particular organism or species has been followed, in which properties, nexus, and individuator are required – this is the substrate attribute theory. Instead a theory having only properties might have been followed – this is the bundle theory. At first the nexus seemed to be required to glue the abstract, incorporeal attributes to the physical attributes. But now the bare substrate, the propertyless bearer of properties – the individuator – seems to be required in order to steer the identity of indiscernibles away from lapsing into ambiguity. The next three steps portray this ambiguity.

1) If the bundle theory is espoused, then it is not only true but necessarily true in the sense that every property of the bundle is an essential constituent in the structure of a thing. 2) And if it is impossible for two things to share all their properties because complete qualitative indiscernability entails numerical identity (Loux, 2003, pp. 112-113), then two things that conceivably do share their properties are not two but are one, are numerically identical. 3) But being one can be falsified by the logical possibility of two things that are exactly alike (Armstrong, 1989, p. 67), because two things exactly alike in empirically pure properties might differ by each having an impure property the other does not have, such as being identical with itself (Loux, 2003, p. 115). This ambiguous 2-1, 1-2 vacillation ought to be avoided. Thus an individuator would seem to be required, and the identity of indiscernibles can then be used in a further and exhaustive break-down to derive ontologically the taxonomy of species.

The reader is probably aware that the philosophical issues brought up in this brief

account are issues which have a number of arguments both for and against each issue.

For example, the substrate attribute theory and the bundle theory have approximately ten arguments for and against each, lucidly presented in Loux (2003, pp. 97-123). I have felt, as I think Loux does on the proviso of considering just the two theories, that the substrate attribute theory is the more consistent.

All this is fairly basic. But there does seem to be a lack of distinction between the corporeal, physical properties and the incorporeal properties. In the context of this book, what distinguishes the status of the properties adjustedness, suitedness, fittedness, harmoniousness? Are these like the incorporeal properties kindness, caringness, thoughtfulness, helpfulness that are virtues, that are properties of the property of being virtuous? It would seem that adjustedness, etc. are not properties of a property like kindness, etc., but are deducible from, interpretable from, and thus are related to properties such as rates that are closely tied in turn to the corporeal, physical properties that organisms and species obviously possess. Whereas virtuousness is a capping, end-point for the various virtues, there are a number of end-points for the properties of growth response, of division rate, of overwintering, etc. Adaptedness is the chosen end-point very often in irreversible contexts. But reversible contexts do away with other properties so that a species of *Gilia* is adapted, adjusted to its locale, which is adapted, adjusted to it.

CONCLUSION

This enterprise has flaunted its criticism of every consensus. Variables x and y are in things – they are not schematic letters that take values, as logicians put it. They are part of things, they structurally compose things, like properties. The connectives *and*, *or*, *if-then*, and *equivalent to* are as real as the things they structurally connect. Validity is not a plaything; validity is structure. And the metaphysician's hazy catalogue of properties has been distinguished as the corporeal and the incorporeal, and it is the second category that include the adaptedness that structures biological nature.

This enterprise is vastly different from the narrowly biological in that other disciplines have been deployed and blended in an explicit way. The method of doing this has been unapologetically redundant. Reiteration of principles and observations has been felt to be the only way to counter the insufficiencies in the disciplines deployed. The product is devoid of crass assumption. The product is straightforward, refreshingly different, and eminently adequate.

Appendix I, for Chapter 4

Expression 1. seems logically valid. And it is, as will be shown next. We have first (. – and ; \supset -- between *if then* parts) :

Morphological adaptations are haphazard.

This is a general description, meaning that: no matter what x is singled out, (x), if this x is in an adaptation, Ax , and this x is a morphological part of this adaptation, Mx , then this x is a haphazard part of it too, Hx . (x) is the universal quantifier. We have:

$$(x) [(Ax \cdot Mx) \supset Hx].$$

The second description:

There is an adaptation which is not haphazard is a factual description:

there is an x , ($\exists x$), such that, x is in an adaptation, Ax , and x is in a non-haphazard part of it, $\sim Hx$. ($\exists x$) is the existential quantifier. We have:

$$(\exists x) (Ax \cdot \sim Hx)$$

The logical deduction is this (Copi, 1979, pp. 63-150; Kahane, 1986, pp. 107-176);

1. $(x) [(Ax \cdot Mx) \supset Hx]$
2. $(\exists x) (Ax \cdot \sim Hx)$
3. $Ax \cdot \sim Hx$ 2, E.I.
4. $(Ax \cdot Mx) \supset Hx$ 1, U.I.
5. $\sim Hx$ 3, Simp.
6. $\sim (Ax \cdot Mx)$ 4, 5, M.T.
7. $\sim Ax \vee \sim Mx$ 6, DeM.
8. $Ax \supset \sim Mx$ 7, Imp.

9. Ax	3, Simp.
10. $\sim Mx$	8, 9, M.P.
11. $Ax \cdot \sim Mx$	9, 10, Conj.
12. $(\exists x) (Ax \cdot \sim Mx)$	11, E.G.

Step 12. is the final description: there is an adaptation which is not morphological (there is an x such that x is in an adaptation and x is a non-morphological part of it).

But when it is written that x is in an adaptation in the preceding parenthesis, x is part of an adaptation, a real part. Likewise, x is a real part of not morphological in the sense of non-morphological entity.

Now to start at step 3. we work consecutively downward.

Step 3. is the only step that is not logically valid. Step 3. is such that one x is arbitrarily chosen so that it, x , is in an adaptation, A , and is a non-haphazard part of it, $\sim H$. This step is Existential Instantiation, E.I.

Step 4. comes from 1., validly, because if all A and M are H in 1., then one of them is too in 4., Universal Instantiation, U.I. (x) is removed.

Step 5. comes from 3., validly, the way, Jane is happy, comes from, Jane is a happy child (Jane is happy and Jane is a child). This is Simplification, Simp.

Step 6. comes from 4. and 5., validly, because if x is in A and M then x is in H , 4.; but x is in non- H , 5.; so x is in non- A -and- M , 6. This is a form of contraposition called Modus Tollens, M.T.

Step 7. comes from 6., validly, because not being in both A and M at the same time is just the same as not being in one or not being in the other, $\sim A$ or $\sim M$: DeMorgan's Theorem, DeM.

Step 8. comes from 7., validly, because: if not $\sim A$ then $\sim M$; that is, if $\sim \sim A$ then $\sim M$, which is, if A then $\sim M$. This is because double negatives cancel out. Step 7. to 8. is Implication, Imp.

Step 9. comes from 3. by Simplification.

Step 10. comes from 8. and 9., validly, by Modus Ponens, M.P. Modus Ponens is what Descartes should have said. Instead of, I think therefore I am, he should have said: If I think then I am (like $Ax \supset \sim Mx$), I think (like Ax); therefore I am (like $\sim M$).

Step 11. comes from 9. and 10., validly, as in: if Jane is happy then if Jane is a child, then both Jane is happy and Jane is a child. If A of 9. then if $\sim M$ of 10., then A and $\sim M$ of 11. 63 steps are required for proof of this in chapter 17. This is a very important step. This is Conjunction, Conj.

Step 12. Finally, if x is in A and $\sim M$ in 11. then, validly, there is something x which is in A and $\sim M$. Existential Generalization, E.G.

Thus one can see that the whole deduction holds together by means of many varied small deductions. The haphazard structure of morphological evolution is an interpreted structure, an interpreted structure which is expressible as a cohering validity.

Expressions 2. and 3. are valid. So they add to the cohering validity of the whole of the description 1. - 3.

How about incorporating properties in this structure? This is easily done.

Step 1. would be: no matter what x is singled out, (x), if this x has adaptedness, Ax , and this x has morphologicalness, Mx , then this x has haphazardness, Hx :

Step 2. would be: there is an x , ($\exists x$), such that x has adaptedness, Ax , and x does not have morphologicalness, $\sim Hx$.

And so on downward. Just switch *is* to *has* (Quine, 1960, p. 119) and put *ness* on the end of the appropriate term (Quine, 1963, p. 76).

Step 1. could be put in a different way; whatever has adaptedness and has morphologicalness has haphazardness. Equally well 1. could be: whatever partakes of the property of being adapted and partakes of the property of being morphological too partakes of the property of being haphazard. *Partake* is from Plato, for in the Parmenides he says “great things become great, because they partake of greatness, and just and beautiful things become just and beautiful, because they partake of justice and beauty”. Plato started properties, as is well known. Equally well 1. could have *possess*, or *exemplify*, or *share*, or *embody* instead of *has*.

In step 1., if this x has adaptedness and this x has morphologicalness, then this x has haphazardness – $(Ax \cdot Mx) \supset Hx$, there is an incomplete symbolization. For x has adaptedness, we should provide: x has y and y is adaptedness – $Hxy \cdot Ay$. This last is what is understood by: x has adaptedness, Ax . In 2. we want: x does not have morphologicalness, $\sim Hx$, with not applying just to *have* – more fully, $\sim Hxy \cdot My$, rather than $Hxy \cdot \sim My$, is better. This distinction was not possible with *is*, as in : x is a non-morphological part of an adaptation.

7. is putting back the universal quantifier, Universal Generalization (U.G.). Step 1. implies step 7. ($1. \supset 7.$); step 7. implies step 1. ($7. \supset 1.$); and the conjunction of the two implications is equivalence – $[(1. \supset 7.) \cdot (7. \supset 1.)] \equiv (1. \equiv 7.)$. See end of Appendix II. So there is the following.

$$(x) [Wx \supset (\exists y) (Ty \cdot Ax)] \equiv (x) [(y) (Ty \supset \sim Axy) \supset \sim Wx].$$

Expression 3. is: for all cold-blooded vertebrates x , (x), and for all y , (y), if x has adaptedness to y , then y is in a summer half of the year temperature range – if and only if, if y is not in such a temperature range, then x does not have adaptedness to y (all are adapted only to summer temperatures, if and only they are not adapted to non-summer temperatures):

$$(x) (y) [(Axy \supset Sy) \equiv (\sim Sy \supset \sim Axy)].$$

See Appendix III of Chapter 5 for explanation of the brief expression in parentheses.

Appendix II, for Chapter 5

6. is symbolized using the following abbreviations:

$(\exists y)$ – there is a y such that (the existential quantifier),

Iy – y is part of improved nutrient (which is improved nutrient),

Rxy – x responds by growth to y ,

Axy – x is adapted to y ,

\cdot – and,

\equiv – equivalent to, if and only if

\sim – not,

\supset – connects a part beginning with if to a part beginning with then.

Putting these together we get the following:

$$(\exists y) Iy \cdot [(Rxy \supset Axy) \equiv (\sim Axy \supset \sim Rxy)],$$

which is: There is a y such that y is part of improved nutrient and: if x responds by growth to y then x is adapted to y – equivalent to; if x is not adapted to y then x does not respond by growth to y .

7. is symbolized using some of the same parts plus two new parts,

(y) – for any y whatever (the universal quantifier),

Wy – y is part of a warm temperature range.

We get:

$$(y) (Axy \supset Wy) \equiv (y) (\sim Wy \supset \sim Axy)$$

which is: For any y whatever if x is adapted to y then y is part of a warm temperature range – equivalent to; for any y whatever if y is not a part of a warm temperature range then x is not adapted to y .

In 6. $Rxy \supset Axy$ is like $p \supset q$. In 7. $Axy \supset Wy$ is like $p \supset q$. Under reversal and denial the whole $p \supset q \equiv \sim q \supset \sim p$ is logically valid because the parts on either side of \equiv come out both true under truth value analysis. Truth value analysis is presented next. In truth value analysis in expression 6. the part Axy is in reality true, T, to the left and then is imagined false, \perp , to the right, so that a dichotomy is set up. Then reductions are made using the following three rules (Quine 1972, pp. 28-32 gives a complete set of rules). The final outcome is T (true) everywhere, so $(Rxy \supset Axy) \equiv (\sim Axy \supset \sim Rxy)$ is the logically valid part of 6. The part $(\exists y) Iy$ is true as a matter of fact, so the whole of 6. is true. The part $(Axy \supset Wy) \equiv (\sim Wy \supset \sim Axy)$ of 7. has just one y and is logically valid; and if one y is valid, all y 's are valid. How to go from one y to all y 's, universal generalization, U.G., is given at the end.

Rules

- Rule 1. Reduce an if-then structure (a conditional) with T as a consequent (then part) or \perp as an antecedent (if part) to T. (A conditional with $T \supset T$, $\perp \supset T$, or $\perp \supset \perp$ is true as a whole).
 ($\sim T$ is \perp , $\sim \perp$ is T). As in 2. to 3. left; as in 3. to 4. far right.
- Rule 2. Delete T as an antecedent in a conditional. (The conditional is true or false as the rest is true or false; $T \supset T$ is true as whole, $T \supset \perp$ is false as a whole). As in 3. to 4. center.

Rule 3. $T \equiv T$ and $\perp \equiv \perp$ both reduce to T. As in 3. to 4. left and
4. to 5. center and right.

Truth Value Analysis

1. $(Rxy \supset Axy) \equiv (\sim Axy \supset \sim Rxy)$
2. $(Rxy \supset T) \equiv (\perp \supset \sim Rxy)$ $(Rxy \supset \perp) \equiv (T \supset \sim Rxy)$
3. $T \equiv T$ $(T \supset \perp) \equiv (T \supset \perp)$ $(\perp \supset \perp) \equiv (T \supset T)$
4. T $\perp \equiv \perp$ $T \equiv T$
5. T T

The rules show part of the structure of logic. For the conditional $T \supset T$ seems obvious for being true as a whole. And $T \supset \perp$ being the flat denial of $T \supset T$ should get a rating of false as a whole. But the other two, $\perp \supset T$, $\perp \supset \perp$, with denial of the antecedent, leave the case uncertain what to expect in the consequent and what to make of the whole. What has been settled on is just to lump these two with $T \supset T$ as being true as wholes.

Although not part of the above analysis, the following features are presented. The conjunction of $T \cdot T$ is sensibly true as a whole; $T \cdot \perp$, $\perp \cdot T$, $\perp \cdot \perp$ are all false as wholes. The disjunction, or-connected compound (*or* is \vee), is sensibly true when at least one part is true, otherwise false : $T \vee T$, $T \vee \perp$, $\perp \vee T$ are true as wholes; $\perp \vee \perp$ is false as a whole. $T \cdot T \cdot T \dots$ is true; $\perp \cdot T \cdot T \dots$ is false. $T \vee \perp \vee \perp$ is true; $\perp \vee \perp \vee \perp \dots$ is false. $T \cdot T$ is true as a whole in the sense that it takes both gasoline and electricity to make an engine go, to be true to its design. $T \vee \perp$, $\perp \vee T$, $T \vee T$ are true as wholes in the sense that one can make a million by plan A or plan B coming true and certainly if both plans come true.

The whole of logic is based on the characteristics presented in the last two paragraphs.

Universal Generalization and Equivalence in 7.

1. $(y) (Axy \supset Wy)$	Assumption
2. $Axy \supset Wy$	1, U.I.
3. $\sim Wy \supset \sim Axy$	2, Contra
4. $(y) (\sim Wy \supset \sim Axy)$	3, U.G.
<hr/>	
5. $(y) (Axy \supset Wy) \supset (y) (\sim Wy \supset \sim Axy)$	1-4, C.P.
6. $(y) (\sim Wy \supset \sim Axy)$	Assumption
7. $\sim Wy \supset \sim Axy$	6, U.I.
8. $Axy \supset Wy$	7, Contra.
9. $(y) (Axy \supset Wy)$	8, U.G.
<hr/>	
10. $(y) (\sim Wy \supset \sim Axy) \supset (y) (Axy \supset Wy)$	6-9, C.P.
11. $[(y)(Axy \supset Wy) \supset (y)(\sim Wy \supset \sim Axy)] \cdot [(y)(\sim Wy \supset \sim Axy) \supset (y)(Axy \supset Wy)]$	5, 6, Conj.
12. $(y)(Axy \supset Wy) \equiv (y)(\sim Wy \supset \sim Axy)$	11, Equivalence

Steps 1. and 6. are assumed, if is put before them. Steps 2. and 7. are using just one y , an instance of the general descriptions in steps 1. and 6., Universal Instantiation, U.I. Steps 3. and 8. are contraposition, Contra. Steps 4. and 9. are putting back the universal quantifier, (y) , U.G. Steps 5. and 10. are linking the assumed descriptions with the final descriptions, the if descriptions with the then descriptions, in a conditional, if-then proof, C.P. Step 11. is putting steps 5. and 10. together with and (\cdot) , Conjunction, Conj. Step 12. is reexpressing this conjunction as equivalence, so that the reversed order of the conditionals of step 11. is a definitional presentation of what equivalence is, (Copi, 1979, pp. 110-112).

Appendix III, for Chapter 5

For 9.: x is better suited only to ground-trunk niches, equivalent to, x is *not* better suited to any *non*-ground-trunk niches; we have:

$$(y) (Sxy \supset Gy) \equiv (y) (\sim Gy \supset \sim Sxy),$$

where (y) is : for every y ,

where Sxy is : x is better suited to y ,

where Gy is : y is in a ground trunk niche

where \equiv is : equivalent to, if and only if

9. is like 3. in Chapter 4. and like 5. in Chapter 5. All three are based on example 12. p. 117 and example 6. p. 119 in Copi (1979). The crucial word *only* occurs within the first clause, for no matter what y may be if x is suited to it, then it is G (ground-trunk) – so x is suited only to G . The second clause is: no matter what y may be, if y isn't G then x is not suited to y – or instead – x is not suited to y , if y isn't G ; which is: x is not suited to any non- G .

Appendix IV. for Chapter 7

Where the following abbreviations are:

Axy – species' x is adapted to habitat's y ,

Ayx – habitat's y is adapted to species' x ,

The previous presentation, 16., is:

$$19. [(Axy \supset Ayx) \cdot (Ayx \supset Axy)] \equiv (Ayx \equiv Axy).$$

Here, if Axy then Ayx is the same as Ayx if Axy . Also, if Ayx then Axy can be Ayx only if Axy . Then we have Ayx if Axy and only if Axy , or briefly Ayx if and only if Axy . If and only if is \equiv in the last parenthesis. Also, \equiv is equivalent to, as between the bracketed part and the final parenthesis part.

16. is logically valid, that is, true by truth value analysis. Next is its truth value analysis. The three rules in Appendix II are repeated and one more is added.

Rule 1. Reduce a conditional with T as a consequent or \perp as an antecedent to T.

As in 2. to 3. left and center right, and 5. to 6. extreme right.

Rule 2. Delete T as an antecedent in a conditional. As in 2. to 3. extreme left and

5. to 6. center right.

Rule 3. Delete T from a conjunction – it is T or \perp as the rest is T or \perp

As in 3. to 4. left right.

Rule 4. $T \equiv T$ and $\perp \equiv \perp$ reduce to T, $T \equiv \perp$ and $\perp \equiv T$ reduce to \perp . As in 5. to 6.

center and far right, and in 6. to 7. everywhere.

1. $[(Axy \supset Ayx) \cdot (Ayx \supset Axy)] \equiv (Ayx \equiv Axy)$
2. $[(T \supset Ayx) \cdot (Ayx \supset T)] \equiv (Ayx \equiv T)$ $[(\perp \supset Ayx) \cdot (Ayx \supset \perp)] \equiv (Ayx \equiv \perp)$
3. $(Ayx \cdot T) \equiv (Ayx \equiv T)$ $[T \cdot (Ayx \supset \perp)] \equiv (Ayx \equiv \perp)$
4. $Ayx \equiv (Ayx \equiv T)$ $(Ayx \supset \perp) \equiv (Ayx \equiv \perp)$
5. $T \equiv (T \equiv T)$ $\perp \equiv (\perp \equiv T)$ $(T \supset \perp) \equiv (T \equiv \perp)$ $(\perp \supset \perp) \equiv (\perp \equiv \perp)$
6. $T \equiv T$ $\perp \equiv \perp$ $\perp \equiv \perp$ $T \equiv T$
7. T T T T

A dichotomy is set up in 2. with Axy as it really is, T, left and as it can be imagined to be, \perp , right. A second dichotomy is set up in 5. with Ayx as it really is, T left and as it can be imagined to be \perp , center and as T center and \perp right. The outcome in 7. is T everywhere.

So 19. is true by truth value analysis, is valid.

Appendix V, for Chapter 8

The principle of symmetrical adaptedness, if x is adapted to y then y is adapted to x , is not logically valid. But it can be extended. Thus consider this sequence:

If (if x helps y then y helps x) then (if x is adapted to y then y is adapted to x).

The sequence just shown can be put as:

If x and y help each other, then x and y are adapted to each other,

And more briefly this can be put as:

If p then q .

Now what we do is reverse this and put the unreversed and reversed parts together:

If p then q and if q then p ,

which was done in Chapter 7, expressions 16. This sequence can be symbolized as:

$(p \supset q) \cdot (q \supset p)$.

Now this is equivalent to (as in Chapter 7):¹

$q \equiv p$,

which is to say:

19. $[(p \supset q) \cdot (q \supset p)] \equiv (q \equiv p)$

¹ (If p then q) is the same as (q if p). (If q then p) can be (q only if p). Thus (if p then q and if q then p) is: (q if p and q only if p), or (q if and only if p), or $q \equiv p$. (If and only if) is the same as (equivalent to). But order makes no difference in equivalence: $q \equiv p$ can be rewritten as $p \equiv q$.

And 19. is logically valid, a case of validity without negation (as in chapter 8).

It says: if x and y help each other then x and y are adapted to each other and the reverse: equivalent to: x and y are adapted to each other if and only if x and y help each other.

The optionality structure is an extension of 25.:

$$23. \{[(p \vee r \vee s \vee \dots) \supset q] \cdot [q \supset (p \vee r \vee s \vee \dots)]\} \equiv [q \equiv (p \vee r \vee s \vee \dots)],$$

which is: if x and y help each other or x dominates y or x suppresses y or ..., then x and y are adapted to each other; and if x and y are adapted to each other, then x and y help each other or x dominates y or x suppresses y or ...: equivalent to: x and y are adapted to each other if and only if x and y help each other or x dominates y or x suppresses y or ...

The full delineation and proof of 26. is given in Hulburt (1996).

Classes

Class membership is shown by \in . Classes are shown by capital letters. Thus $x \in H$ is: x is a member of the class of helpers. The subscript y means for $x \in H_y$ that x is a member of the class of helpers of y . First, the general formula for class (set) union (Suppes, 1972, p. 24) is:

$$(1) (\exists C) (x) \{(x \in C) \equiv [(x \in A) \vee (x \in B)]\}$$

There is the class C , $\exists C$, possessing any thing x if and only if x is a member of at least class A or class B . We equate the class C to A_y , the class of entities adapted to y . We get the following array of classes (Langer, 1967, pp. 150-151):

$$(2) (\exists A_y) (x) \{(x \in A_y) \equiv [(x \in H_y) \vee (x \in D_y) \vee (x \in S_y) \vee (x \in P_y) \vee (x \in E_y)]\},$$

there is the class of entities adapted to y such that for any x , x is member of the class of entities adapted to y if and only if x is a member of the class of helpers of y , or x is a

member of the class of dominators of y , or x is a member of the class of suppressors of y , or x is a member of the class of predators of y , or x is a member of the class of enslavers of y .

The converses y is adapted to x , y helps x are not included. Only the one directional x -to- y relation has been taken up because this is common to all five classes. The one directional x -to- y relation may be rephrased as the ordered pair.

A different presentation is the following. Classes which are relations are given by the ordered pair $\langle x, y \rangle$, which is defined as (Suppes, 1972, pp. 57-59):

$$(3) \quad xAy \equiv \langle x, y \rangle \in A,$$

x is adapted to y if and only if x and y are members of the class A of adapted entities.

More explicitly, there is the domain, D , of a relation which is identical to the class of all things x is such that $(x : \dots)$, for some y $(\exists y)$, $\langle x, y \rangle \in A$, expressed in this way:

$$(4) \quad DA = [x : (\exists y)(xAy)].$$

Paralling (2) instead of $(\exists C) (x) (x \in A_y)$ we get $x : (\exists y) (xAy)$, and to the right of \equiv the five classes (sets):

$$(5) \quad \{x : (\exists y) (xAy) \equiv [(\exists y) (xHy) \vee (\exists y) (xDy) \vee (\exists y) (xSy) \vee (\exists y) (xPy) \vee (\exists y) (xEy)]\}$$

This says: the class of entities x is such that x and y are members of the class of adapted entities if and only if x and y are members of the class of helpers, or x and y are members of the class of dominators, or x and y are members of the class of suppressors, or x and y are members of the class of predators, or x and y are members of the class of enslavers.

Because xAy , etc., are read as x and y are members of the class

(set) of adapted entities, etc. – whereas in 2) x is a member of the class of entities adapted to y , etc. Both stress the ordered pair relation but in different ways.

Appendix VI, for Chapter 9

Going back to the previous Appendix, V, we have the following development:

$$(1) p \supset q,$$

$$(2) (p \supset q) \cdot (q \supset p),$$

$$(3) [(p \supset q) \cdot (q \supset p)] \equiv (q \equiv p).$$

(3) is valid. It can be added onto (Copi, 1979, p. 40, rule 17):

$$(4) [(p \supset q) \cdot (q \supset p)] \equiv (q \equiv p) \equiv [(q \cdot p) \vee (\sim q \cdot \sim p)].$$

(4) can be shortened to the valid:

$$(5) (q \equiv p) \equiv [(q \cdot p) \vee (\sim q \cdot \sim p)],$$

Next q and p are replaceable:

$$q - Axy \supset Ayx,$$

$$p -- \sim Ixy \supset \sim Iyx,$$

and, further, $Axy \supset Ayx$ is replaceable by $\sim(Axy \cdot \sim Ayx)$ – that is: *If this then that* is replaceable by: *It is not the case that this and not that*. Same for $\sim Ixy \supset \sim Iyx$. Double negatives cancel. We get:

$$(6) [(Axy \supset Ayx) \equiv (\sim Ixy \supset \sim Iyx)] \equiv \{[(Axy \supset Ayx) \cdot (\sim Ixy \supset \sim Iyx)] \vee$$

$$[\sim(Axy \supset Ayx) \cdot \sim(\sim Ixy \supset \sim Iyx)]\},$$

$$(7) [(Axy \supset Ayx) \equiv (\sim Ixy \supset \sim Iyx)] \equiv \{[(Axy \supset Ayx) \cdot (\sim Ixy \supset \sim Iyx)] \vee$$

$$[\sim\sim(Axy \cdot \sim Ayx) \cdot \sim\sim(\sim Ixy \cdot \sim\sim Iyx)]\},$$

$$(8) [(Axy \supset Ayx) \equiv (\sim Ixy \supset \sim Iyx)] \equiv \{[(Axy \supset Ayx) \cdot (\sim Ixy \supset \sim Iyx)] \vee$$

$$[(Axy \cdot \sim Ayx) \cdot (\sim Ixy \cdot Iyx)]\}.$$

Now the parts in the far right brackets of (8) are these:

Axy - x is adapted to y ,

$\sim Ayx$ - y is not adapted to x ,

$\sim Ixy$ - x does not interfere with y ,

Iyx - y interferes with x .

Appendix VII, for Chapter 10

In 28. (1), (2), and (3) are written out horizontally so that (1) and (2) together imply (3): (egg x is subitaneous or egg x is diapause, $Sx \vee Dx$, and if egg x is subitaneous then it, x , is summer-adapted, $Sx \supset A_sx$, and if egg x is diapause then it, x , is winter-adapted, $Dx \supset A_wx$) implies (egg x is summer-adapted or egg x is winter-adapted, $A_sx \vee A_wx$). We have:

$$\{(Sx \vee Dx) \cdot [(Sx \supset A_sx) \cdot (Dx \supset A_wx)]\} \supset (A_sx \vee A_wx)$$

The first dichotomy, with A_sx as it really is, T, to the left and as it can be imagined to be, \perp , to the right, is:

$$\{(Sx \vee Dx) \cdot [(Sx \supset T) \cdot (Dx \supset A_wx)]\} \supset (T \vee A_wx)$$

$$\{(Sx \vee Dx) \cdot [(Sx \supset \perp) \cdot (Dx \supset A_wx)]\} \supset (\perp \vee A_wx)$$

We develop the left hand part of this grand dichotomy:

$$\{(Sx \vee Dx) \cdot [(Sx \supset T) \cdot (Dx \supset A_wx)]\} \supset (T \vee A_wx)$$

$$[(Sx \vee Dx) \cdot T \cdot (Dx \supset A_wx)] \supset T$$

T

Thus the left hand part of the grand dichotomy is true in three steps.

Next, we develop the right hand part of the grand dichotomy:

$$\{(T \vee Dx) \cdot [(T \supset \perp) \cdot (Dx \supset A_wx)]\} \supset (\perp \vee A_wx)$$

$$[T \cdot \perp \cdot (Dx \supset A_wx)] \supset A_wx$$

$$\perp \supset A_wx$$

$$\perp \supset T \quad \perp \supset \perp$$

$$T \quad T$$

$$\{(\perp \vee Dx) \cdot [(\perp \supset \perp) \cdot (Dx \supset A_{nx})]\} \supset (\perp \vee A_{nx})$$

$$[Dx \cdot T \cdot (Dx \supset A_{nx})] \supset A_{nx}$$

$$[Dx \cdot (Dx \supset A_{nx})] \supset A_{nx}$$

$$[T \cdot (T \supset A_{nx})] \supset A_{nx} \quad [\perp \cdot (\perp \supset A_{nx})] \supset A_{nx}$$

$$A_{nx} \supset A_{nx}$$

$$\perp \supset A_{nx}$$

$$T \supset T \quad \perp \supset \perp$$

$$\perp \supset T \quad \perp \supset \perp$$

$$T \quad T$$

$$T \quad T$$

A further point about this validity analysis, as well as those in Chapters 5 and 7, is whether taking some term such as $A_s x$ as T to the left and \perp to the right is just an imaginary game or is a linguist scheme or is a part of world reality. Usually the second is chosen. This allows a statement to be true or false. This is a prime aspect of logic. You make a statement; call it true, or call it false. How could the situation be otherwise? But this is wrong in applied logic. The logic of textbooks is not applied logic. In this book, logic is applied logic. Suppose there were only the biology of biology researchers – this would be pure biology. But there is the biology of medicine – this is applied biology. So in order to have applied logic in truth value analysis a statement, such as $A_s x$, describes what there really is and so $A_s x$ is true, T, to the left. For a statement, our words, are as close to what there is as we can get; thus $A_s x$ is true. But because we are not the simple souls who cannot appreciate things as otherwise then they are, we can imagine $A_s x$ as false to the right. So we start with world reality, what there is, with T to the left and then switch to an imagined world of what is otherwise with \perp to the right.

Appendix VIII, for Chapter 12

The proof 20.-24., which joins two compound statements by *and* in 26., starts with $P \supset (Q \supset PQ)$, gotten by steps 50.-112. These steps are based on Copi (pp. 227-250), except steps 82.-99., which are based on Rosser (pp. 64-65).

Proof that $P \supset Q$ yields $RP \supset QR$

- | | |
|---|---|
| 50. $P \supset Q$ | pr. |
| 51. $(P \supset Q) \supset [\sim(QR) \supset \sim(RP)]$ | Ax. 3 |
| 52. $\sim(QR) \supset \sim(RP)$ | R. 1. from 50. and 51. |
| 53. $RP \supset QR$ | from 15. and 19., $\sim(QR)$ of 52.
replacing $\sim P$ and $\sim(RP)$ of 52
replacing $\sim Q$ in 15. |

Proof that $\sim P \supset \sim Q$ yields $P \supset P$

- | | |
|--|--|
| 54. $\sim P \supset \sim Q$ | pr. |
| 55. $(\sim P \supset \sim Q) \supset [\sim(\sim QP) \supset \sim(P \sim P)]$ | Ax. 3., P replacing R , and $\sim P$ and $\sim Q$
put for P and Q |
| 56. $\sim(\sim QP) \supset \sim(P \sim P)$ | R. 1., from 55. and 54. |
| 57. $\sim(\sim QP)$ | from 6., with $\sim Q$ for $\sim R$ |
| 58. $\sim(P \sim P)$ | R. 1. from 56. and 57. |
| 59. $P \supset P$ | df. |

Proof of $RP \supset PR$

- | | |
|---------------------|---|
| 60. $RP \supset PR$ | from 59. and 53. Rule of thumb 1.;
surround $P \supset P$ with R |
|---------------------|---|

Proof that $P \supset Q, Q \supset R$ yield $P \supset R$

61. $P \supset P$ from 59.
62. $P \supset Q$ pr.
63. $Q \supset R$ pr.
64. $(P \supset P) \supset [\sim(P \sim Q) \supset \sim(\sim QP)]$ Ax. 3, putting P for P and $Q, \sim Q$ for R
65. $\sim(\sim QP)$ R. 1. done twice, as in 2. to 6.
66. $\sim R \supset \sim Q$ from 63. and 13. by R. 1., R for P
67. $(\sim R \supset \sim Q) \supset [\sim(\sim QP) \supset \sim(P \sim R)]$ Ax. 3, $\sim R, \sim Q$, and P for P, Q , and R .
68. $\sim(\sim QP) \supset \sim(P \sim R)$ R. 1., from 67. and 66.
69. $\sim(P \sim R)$ R. 1., from 68. and 65.
70. $P \supset R$ df. Rule of thumb 2: Q 's cancel in
 $P \supset Q, Q \supset R; P \supset R$

Proof that $P \supset Q, P \supset R$ yield $P \supset QR$

71. $P \supset Q$ pr.
72. $P \supset R$ pr.
73. $PP \supset RP$ from 72. and 53., P for R, R for Q
74. $RP \supset QR$ from 71. and 53.
75. $PP \supset QR$ from 73. and 74. by reasoning of 62., 63., to 70.
76. $P \supset PP$ Ax. 1
77. $P \supset QR$ from 76. and 75. by reasoning of 62., 63., to 70.

Proof that $R \supset S$ yields $PR \supset PS$

78. $R \supset S$ pr.
79. $PR \supset SP$ from 78. and 53., with R and S for P and Q ,
with P for R
80. $SP \supset PS$ from 60., with S put for R
81. $PR \supset PS$ from 79. and 80. with reasoning as in 62.,
63. to 70.

Associativity proofs, 82. - 99.

Proof of $(PQ)R \supset P$

82. $(PQ)R \supset PQ$ Ax. 2, with PQ put for P , R put for Q
83. $PQ \supset P$ Ax. 2
84. $(PQ)R \supset P$ from 82. and 83. by reasoning of 62., 63., to 70.

Proof of $(PQ)R \supset Q$

85. $(PQ)R \supset PQ$ Ax. 2, with PQ put for P
86. $PQ \supset QP$ from 60, with P for R and Q for P
87. $(PQ)R \supset QP$ from 85. and 86., reasoning as in 62., 63., to 70.
88. $QP \supset Q$ Ax. 2
89. $(PQ)R \supset Q$ from 87. and 88., as in 62., 63., to 70.

Proof of $(PQ)R \supset R$

90. $(PQ)R \supset R(PQ)$ from 60., putting PQ for R and R for P
91. $R(PQ) \supset R$ Ax. 2., putting R for P and (PQ) for Q

92. $(PQ) R \supset R$ from 90., 91., as in 62., 63., to 70.

Proof of $(PQ) R \supset P (QR)$

93. $(PQ) R \supset QR$ from 89. and 92. by reasoning as in 71., 72., to 77.

94. $(PQ) R \supset P (QR)$ from 84. and 93. by reasoning as in 71., 72., to 77.

Proof of $P (QR) \supset (PQ) R$

95. $P (QR) \supset (QR) P$ from 60., (QR) put for P , P put for R

96. $(QR) P \supset Q (RP)$ from 95., like 94., outer parentheses like 94.'s outers

97. $Q (RP) \supset (RP) Q$ from 96., like 60., (RP) for P and Q for R

98. $(RP) Q \supset R (PQ)$ from 97., like 94., outer parentheses like 94's outers

99. $R (PQ) \supset (PQ) R$ from 98., like 60., PQ for P

Proof of $[(PQ) \supset R] \supset [P \supset (Q \supset R)]$

100. $P \sim \sim(Q \sim R) \supset P (Q \sim R)$ from 81., $\sim \sim(Q \sim R)$ for R , $Q \sim R$ for S

101. $P (Q \sim R) \supset (PQ) \sim R$ from 95.-99., $\sim R$ for R

102. $P \sim \sim(Q \sim R) \supset (PQ) \sim R$ from 100. and 101., as in 62., 63., to 70.

103. $\{[P \sim \sim(Q \sim R)] \supset [(PQ) \sim R]\}$ from 102., bracketed parts replacing

$\supset \{\sim[(PQ) \sim R] \supset \sim[P \sim \sim(Q \sim R)]\}$

104. $\sim[(PQ) \sim R] \supset \sim[P \sim \sim(Q \sim R)]$ from 103. and 102. by R. 1.

105. $[(PQ) \supset R] \supset [P \supset (Q \supset R)]$ from 104., df.

Proof of $P \supset (Q \supset PQ)$

106. $P \supset P$ from 59.

107. $Q \supset Q$ from 59., Q put for P
108. $PQ \supset QP$ from 107. and 60., P for R , Q for P
109. $QP \supset PQ$ from 106. and 60., Q put R
110. $PQ \supset PQ$ from 108. and 109., as in 62., 63., to 70.
111. $(PQ \supset PQ) \supset [P \supset (Q \supset PQ)]$ from 105., PQ replacing R
112. $P \supset (Q \supset PQ)$ from 111. and 110. by R.1.

Thus from the repeated use of steps 53. and 60. (Rule of Thumb 1.) and from the reasoning of steps 62., 63., to 70. (Rule of Thumb 2.) and by the laborious derivation of associativity in 82. to 99. and the dazzling substitution in 100., the final result of the simple and crucial 112. is achieved.

Proof of expression (4)., right part in appendix VI

Proof of $(PQ) \supset (P \equiv Q)$

113. PQ pr.
114. P
115. Q
116. $P \supset (Q \supset P)$
117. $Q \supset (P \supset Q)$
118. $P \supset Q$ 117, 115, R.1
119. $Q \supset P$ 116, 114, R.1
120. $(P \supset Q) \cdot (Q \supset P)$ 118, 119, by 24
121. $P \equiv Q$ 120, def.
122. $(PQ) \supset (P \equiv Q)$ 113, 121, D.T.

Step 114.: (*Ax . 2 .*) $PQ \supset P, PQ, P$. Step 115.: $PQ \supset QP, QP \supset Q, PQ \supset Q, PQ, Q$.

Step 116.: (from 105.) $P \supset (Q \supset R), P \supset (Q \supset P)$. Step 117.: (from 116.) Q for P ,

P for Q .

Proof of $(PQ) \supset [(PQ) \vee (\sim P \sim Q)]$

123. $P \supset (P \vee Q)$

124. $(PQ) \supset [(PQ) \vee (\sim P \sim Q)]$ 123, (PQ) for P , $(\sim P \sim Q)$ for Q

Step 123.: (*Ax . 2*) $P \sim Q \supset P, P \supset (\sim Q \supset P), P \supset \sim(\sim Q \sim P), P \supset (Q \vee P),$ (*Ax . 3*)

$(\sim Q \supset \sim Q) \supset [\sim(\sim Q \sim P) \supset \sim(\sim P \sim Q)], \sim(\sim Q \sim P) \supset \sim(\sim P \sim Q), (Q \vee P) \supset (P \vee Q),$

$P \supset (P \vee Q)$.

Proof that $P \supset Q, P \supset R, P$ yield $Q \supset R$

125. $P \supset Q$ pr.

126. $P \supset R$ pr.

127. P pr.

128. Q 125, 127, R.1

129. R 126, 127, R.1

130. $Q \supset R$ 128, 129, D.T.

Proof of $(P \equiv Q) \equiv [(PQ) \vee (\sim P \sim Q)]$ Right part, expression (4) appendix VI

131. $(PQ) \supset (P \equiv Q)$ like 125

132. $(PQ) \supset [(PQ) \vee (\sim P \sim Q)]$ like 126

133. PQ like 127

134. $P \equiv Q$ like 128

$$135. (PQ) \vee (\sim P \sim Q) \quad \text{like 129}$$

$$136. (P \equiv Q) \supset [(PQ) \vee (\sim P \sim Q)] \quad \text{like 130}$$

$$137. [(PQ) \vee (\sim P \sim Q)] \supset (P \equiv Q)$$

$$138. (P \equiv Q) \equiv [(PQ) \vee (\sim P \sim Q)]$$

Step 137: Reverse order of 128 and 129 to give $R \supset Q$ and mimic to get 137. Step 138.:

Put 136 and 137 in conjunction to get 138 by def., which is like the right part of (4)

appendix VI.

But expression (4) can be analyzed by truth value analysis when it is in the form $P \supset Q, P \supset R, P$ yielding $Q \supset R$. By the deduction theorem this form is $(P \supset Q) \supset [(P \supset R) \supset (P \supset (Q \supset R))]$. This is valid by truth value analysis, as follows:

$$(P \supset Q) \supset [(P \supset R) \supset (P \supset (Q \supset R))]$$

$$(T \supset Q) \supset [(T \supset R) \supset (T \supset (Q \supset R))] \quad (\perp \supset Q) \supset [(\perp \supset R) \supset (\perp \supset (Q \supset R))]$$

$$Q \supset [R \supset (Q \supset R)]$$

$$T \supset [T \supset (T)]$$

$$T \supset [(R \supset (T \supset R))]$$

$$\perp \supset [(R \supset (\perp \supset R))]$$

$$T \supset T$$

$$R \supset R$$

$$T$$

$$T$$

$$T$$

All 18 proofs have been checked by truth value analysis for validity.

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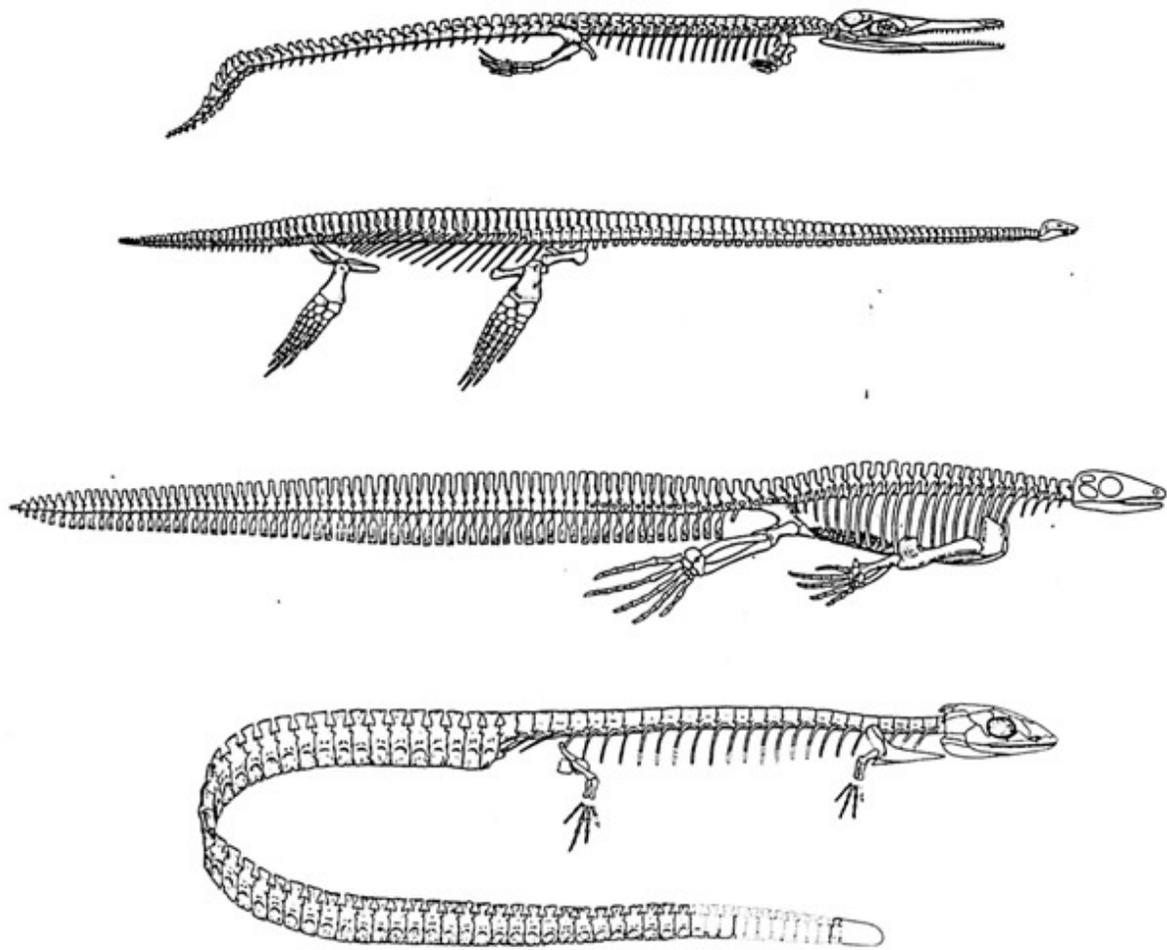


Fig. 1. Examples of extreme elongateness from the late Paleozoic and the Mesozoic. Lowermost figure: the neotridian amphibian *Ptyonias marshii*, Permian, 20 cm. Next to bottom: the diapsid eosuchian reptile *Hovasaurus*, upper Permian, 50 cm. Next to top: the euryapsid plesiosaur reptile *Hydrothecrosaurus*, Jurassic, 12 meters. Topmost figure: the mesosuchian crocodile *Geosaurus*, lower Jurassic

(from Carroll, 1988).

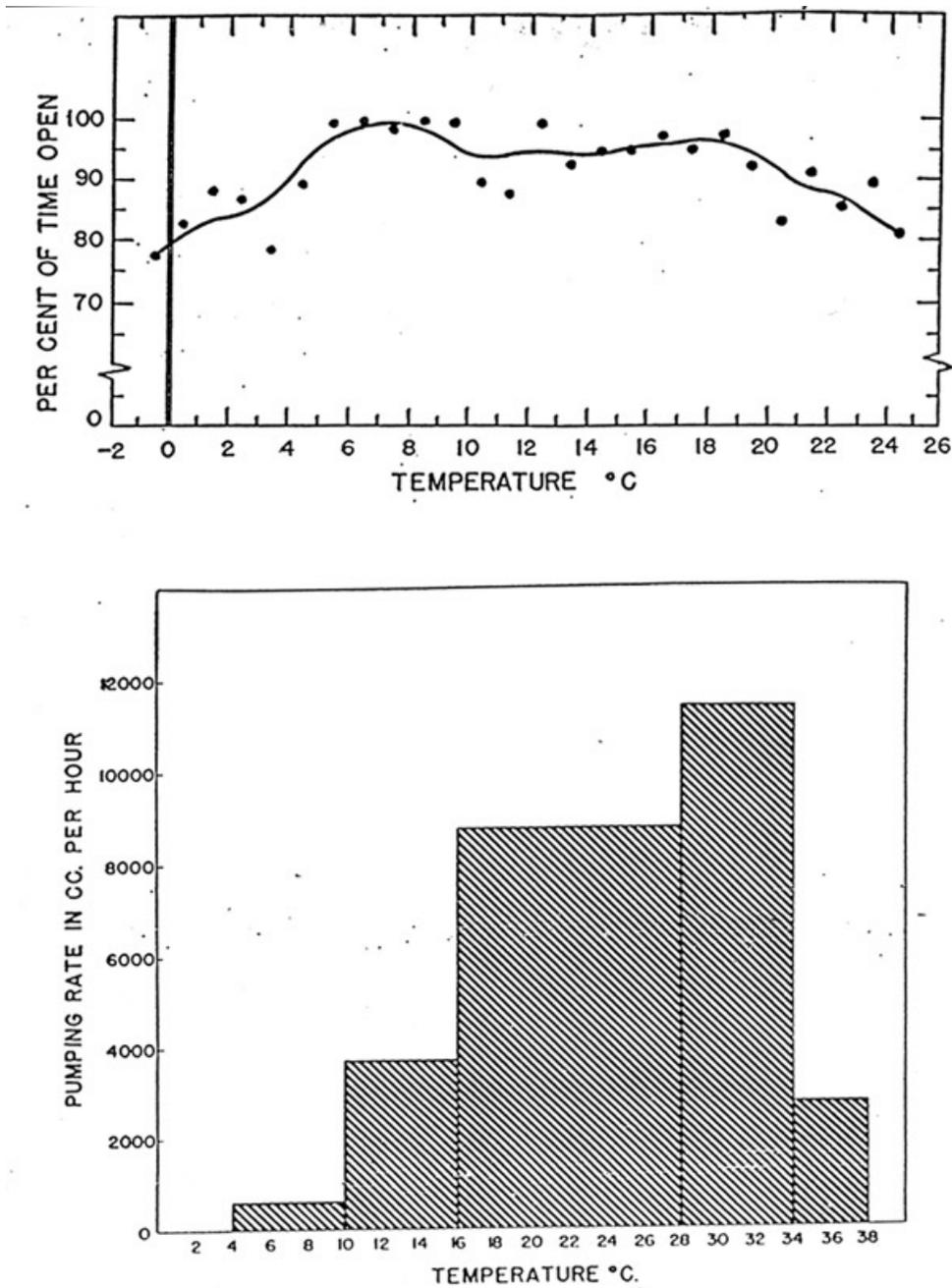


Fig. 2. Upper figure: percentage of time shells of mussels remain open during 24-hour periods at different temperatures ranging from -1.0°C to 24.9°C (from Loosanoff, 1942). Lower figure: mean rate of water pumping by oysters at five homogeneous temperature levels (from Loosanoff, 1958).

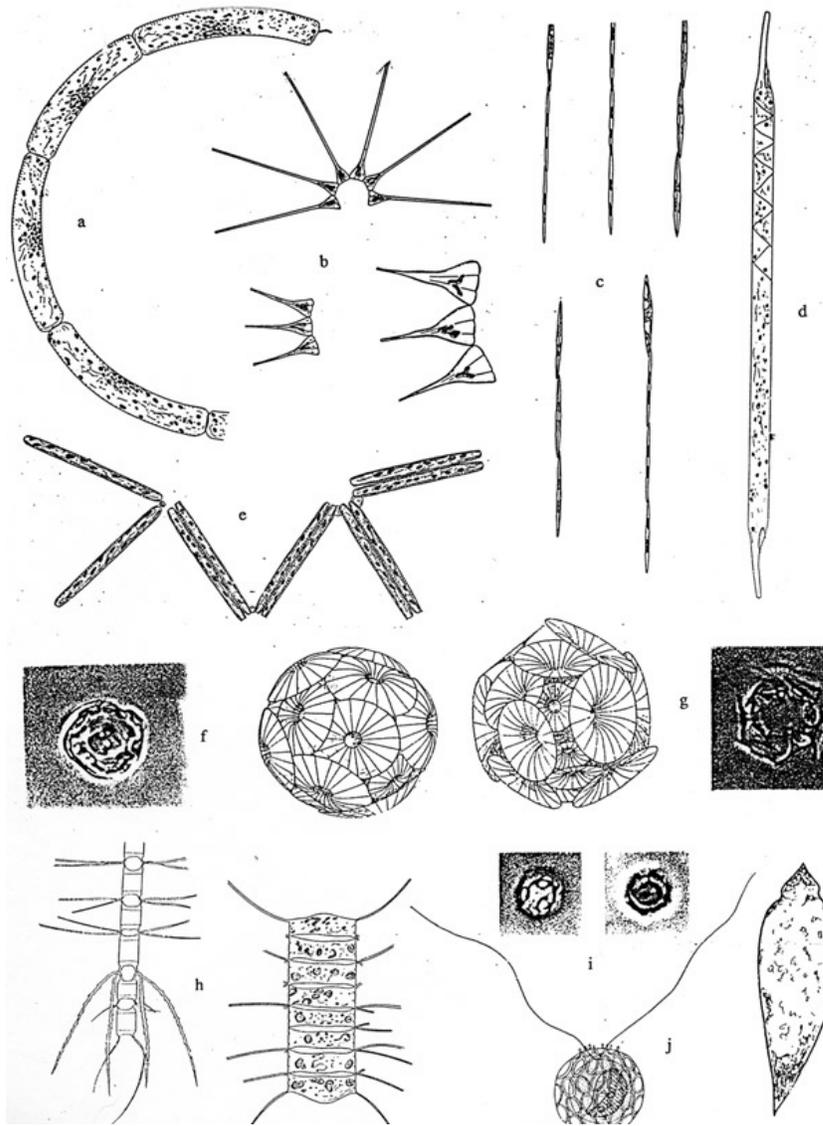


Fig. 3. Some phytoplankton species . a – d, and h are diatoms. f – j are coccolithophores. k is a dinoflagellate. a is *Rhizosolenia stolterfothii*, diameter 20 u . b is *Asterionella glacialis (japonica)*, length of colonies 110 u , 42 u, 58u, c is *Nitzschidelicatissima*, length of cells 63 – 65u. d is *Rhizosolenia alata form gracilluna*, diameters 6u 0u 7u , length about 100u. e is *Thalassionema nitzschioides*, cell length 42u. h is *Chaetoceros compressus*, cell width 7u, 6u. All the diatoms are from Cupp, 1943. f is *Umbellosphaera tenuis*, g is *Umbellosphaera irregularis*, both microphotographs 1500x, from Markali and Passache, 1955. I is *Emiliana (Coccolithus) huxleyi*, about 7u, from Gaarder and Hasle, 1971. j is *Syracosphaera mediterranea* 1300x, from Schiller, 1930. k is *Oxytoxum* variable, length 20u, from Rampi and Bernhard, 1980.

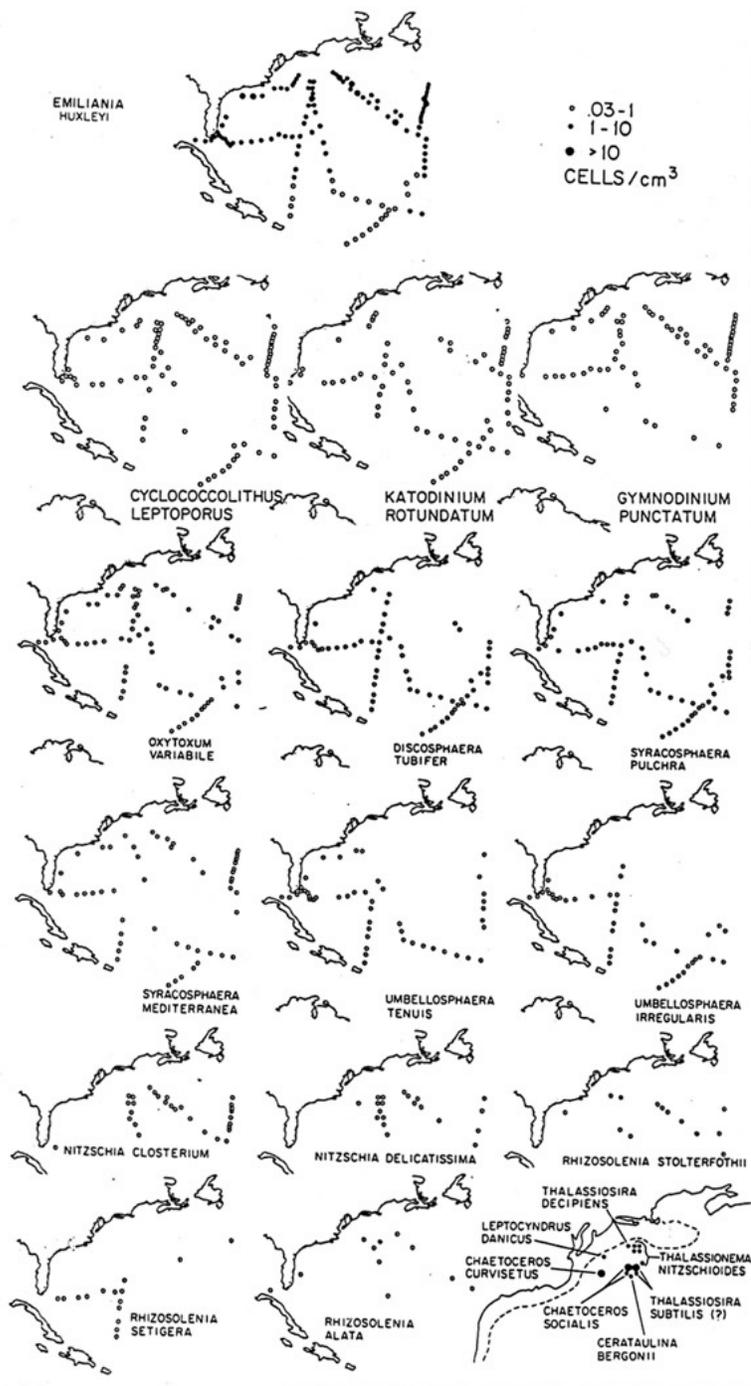


Fig. 4. The near-surface distribution of phytoplankton species that occur in the western North Atlantic in 33 or more of the locations shown in complete number for *Emiliana huxleyi* and visited from November 1961 to April 1972. (From Hulbert, 1982a)

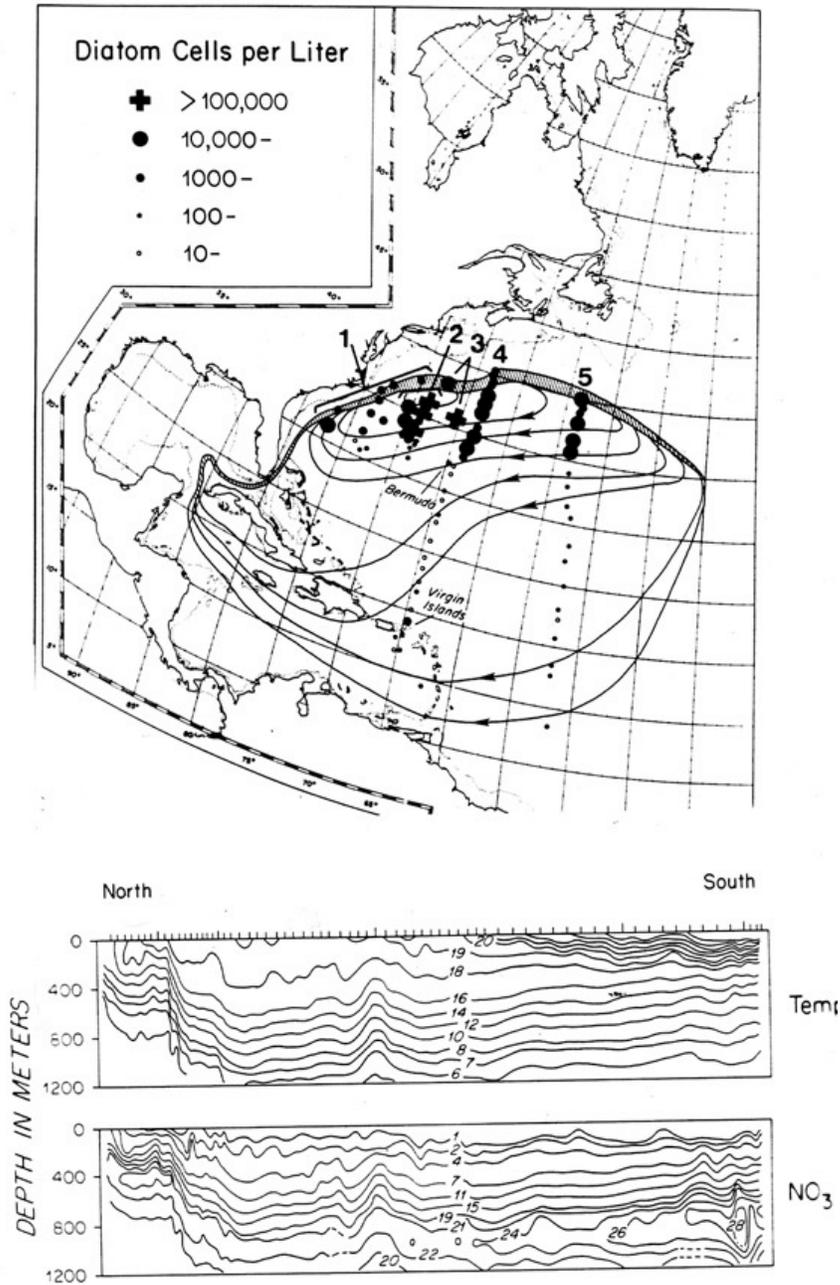


Fig. 5. Upper figure: circulation of the surface layer of the western North Atlantic and total diatom concentration. Track 1 was from March 25 to April 8, 1987; Track 2 April 1-5, 1982; Track 3 April 25-26, 1984; Track 4, where diatoms are $>1000/ \mu\text{l}$, April 21-27, 1985; Track 5, where diatoms are $>1000/ \mu\text{l}$, May 13-15, 1983. Each streamline equals $5 \times 10^6 \text{ m}^3 \text{ s}^{-1}$ water transported. These are average transports and do not indicate the meandering of the Gulf Stream and the formation of rings in the northern part of the gyre. (Adapted from Worthington, 1976.)

Lower figure: temperature and nitrate profiles along longitudes 63°W and 64°W April 13-26, 1985. Nitrate values are in $\mu\text{g-atl}^{-1}$ of N. (From Hulbert, 1990.)

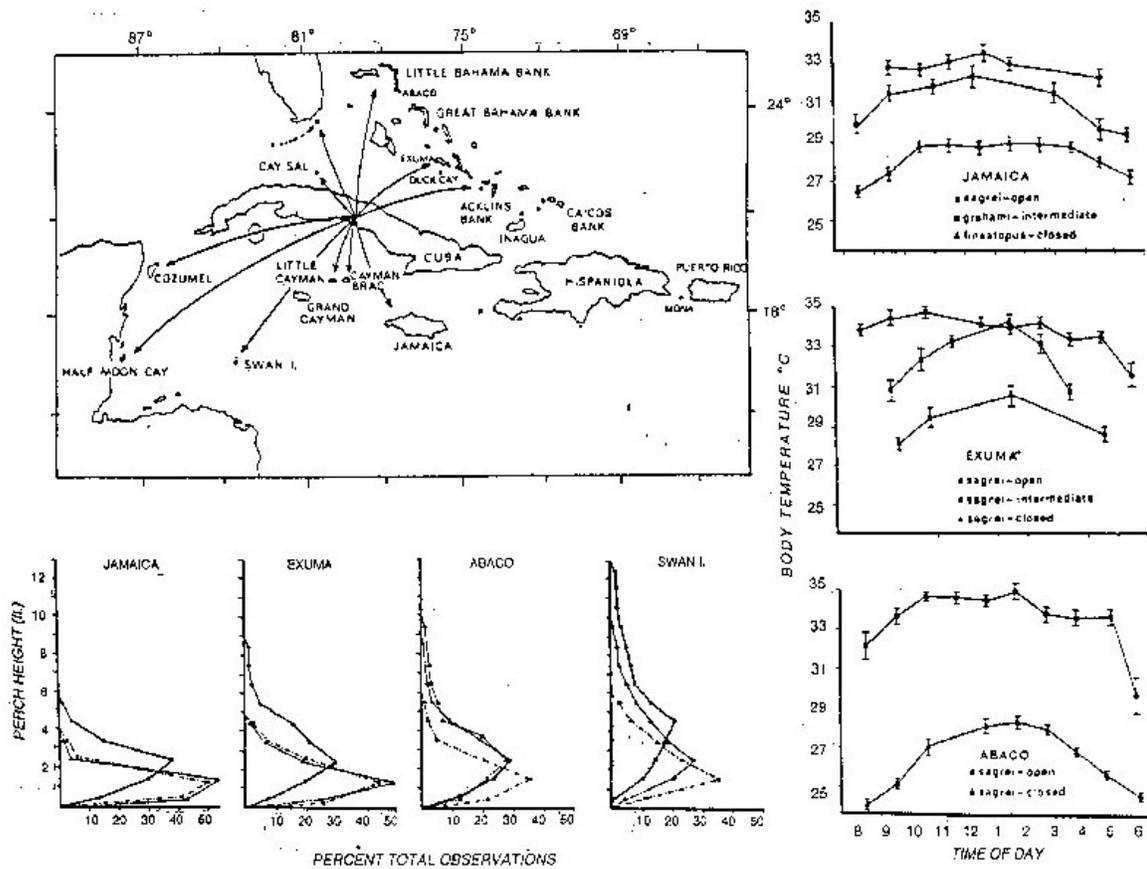


Fig. 6. The islands and banks colonized by *Anolis sagrei* from its source island, Cuba, upper left. Perch height distributions for adult male (solid line), adult female (dotted line), and subadult male (broken line) *sagrei* populations on Jamaica, Exuma, Abaco, and Swan Island, lower left. Average hourly body temperatures of *sugrei*, *grahami*, and *lineatopus* occurring in habitats with different share conditions near Discovery Bay, Jamaica, compared with *sagrei* populations on Exuma and Abaco. (From Lister, 1976.)

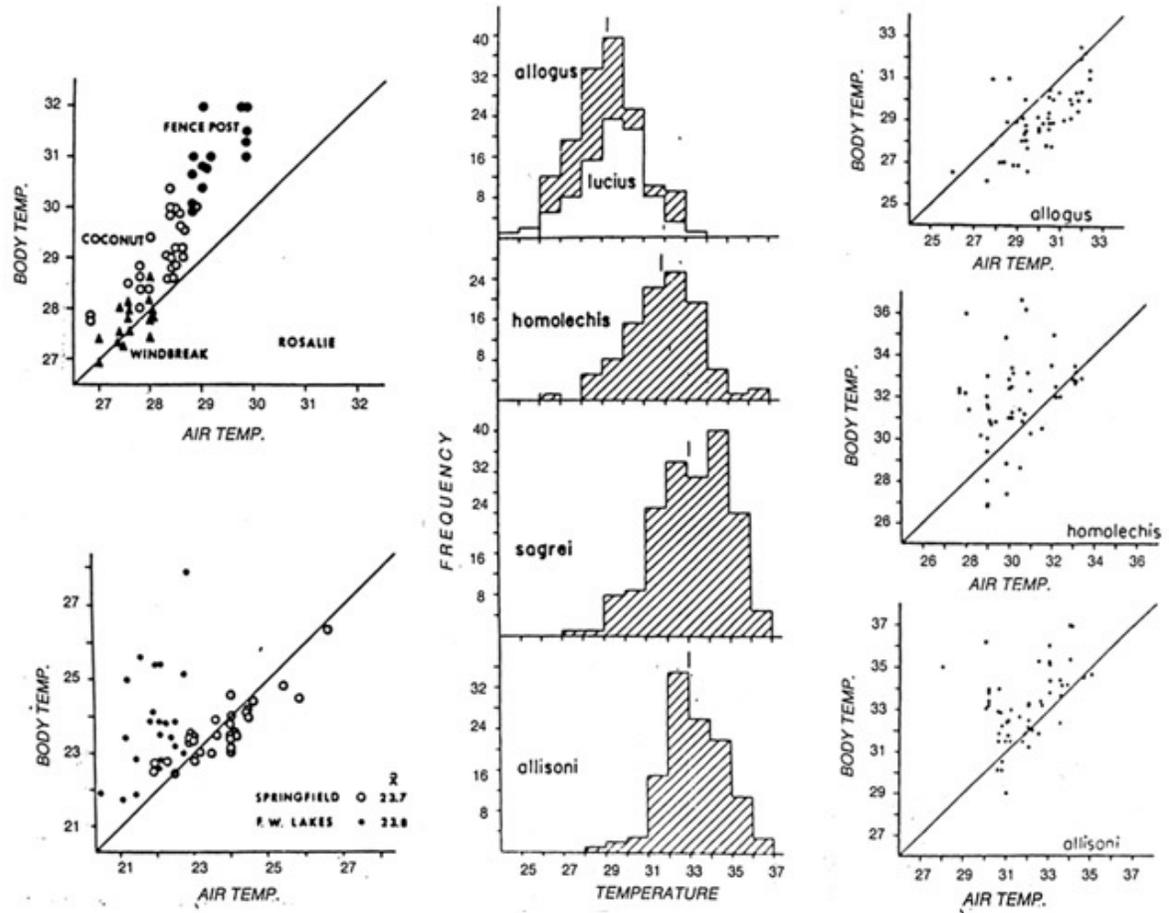


Fig. 7. The relationship of body temperature of *Anolis oculatus* to air temperature on Dominica in the two graphs at the left. The histograms of body temperatures in the center and body-air temperature plots at the right are for five common *Anolis* species on Cuba. (From Ruibal and Philibosian, 1970, and Ruibal, 1961.)

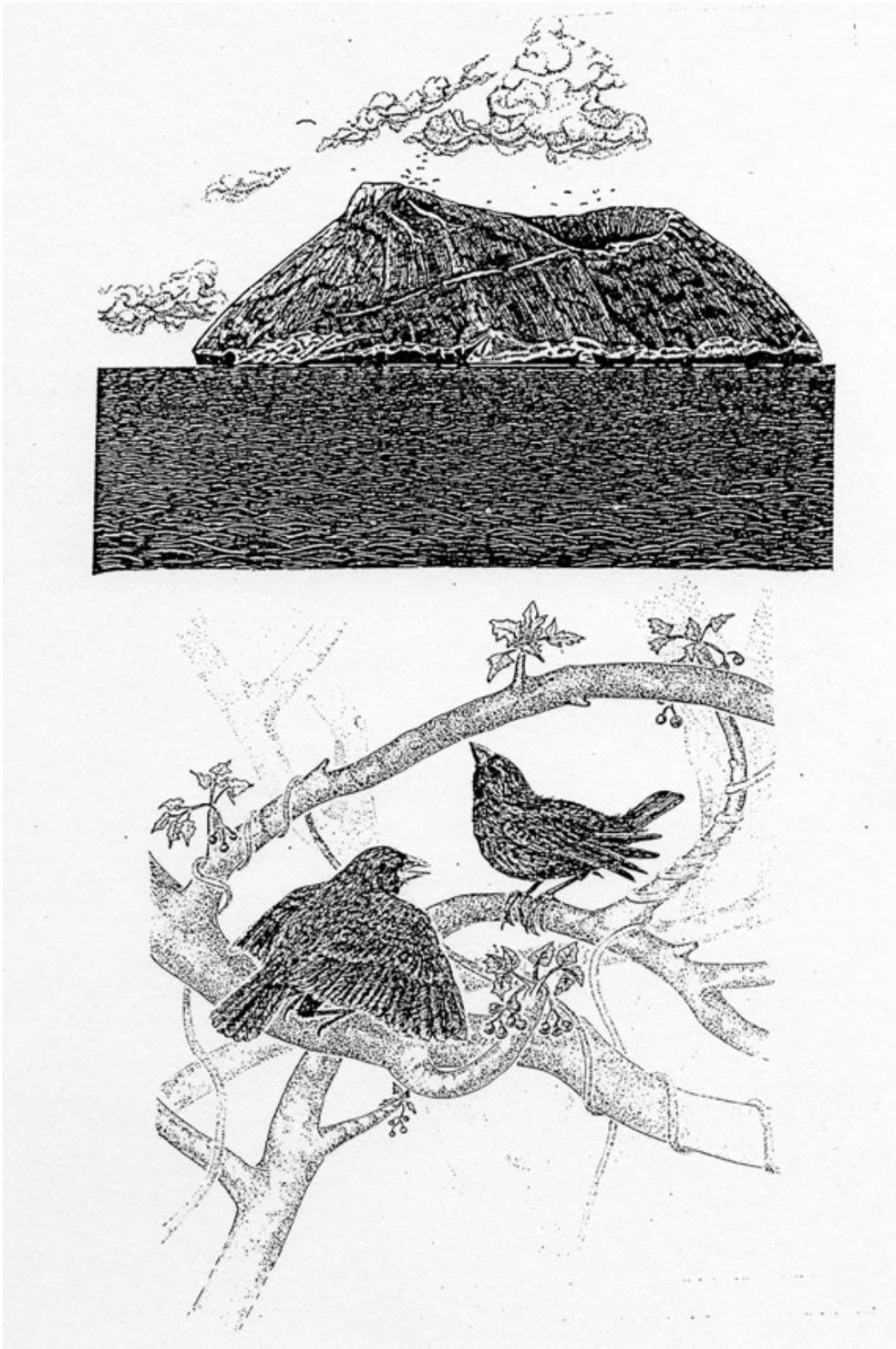


Fig. 8. Upper figure: Daphne Major, one of the islands of the Galapagos archipelago. Lower figure: finches courting – he shakes his wings, she raises her beak into the air, a sign of interest. (From Weiner, 1995.)



Fig. 9. *Gilia splendens* (left) and *Gilia caunifolia* (right). (From Abrams, L., 1951.)

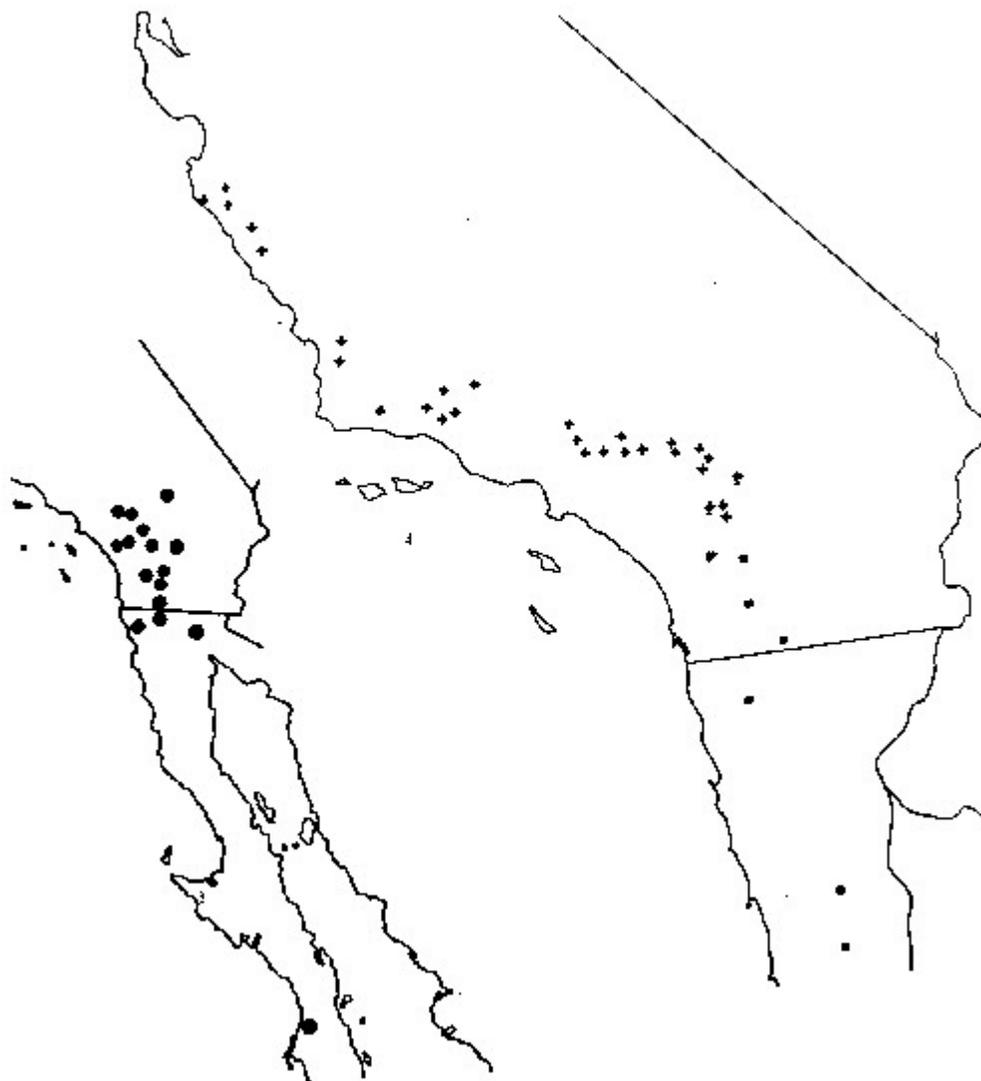


Fig. 10. Right: Geographical distribution of *Gilia splendens* (+) and *G. caruifolia*. (From Grant, V., and A. Grant, 1954.)
Left: Geographical distribution of *Gilia australis*. (From Grant, V., and A. Grant, 1954.)



Fig. 11. Geographical distribution of *Gilia leptalea* and *G. capillaris*. The range of *G. leptalea pinnatisecta* is indicated by open circle. The region within the dotted line is a mixture of *G. leptalea leptalea* and *G. leptalea bicolor*. (From Grant, V. and A. Grant, 1954.)

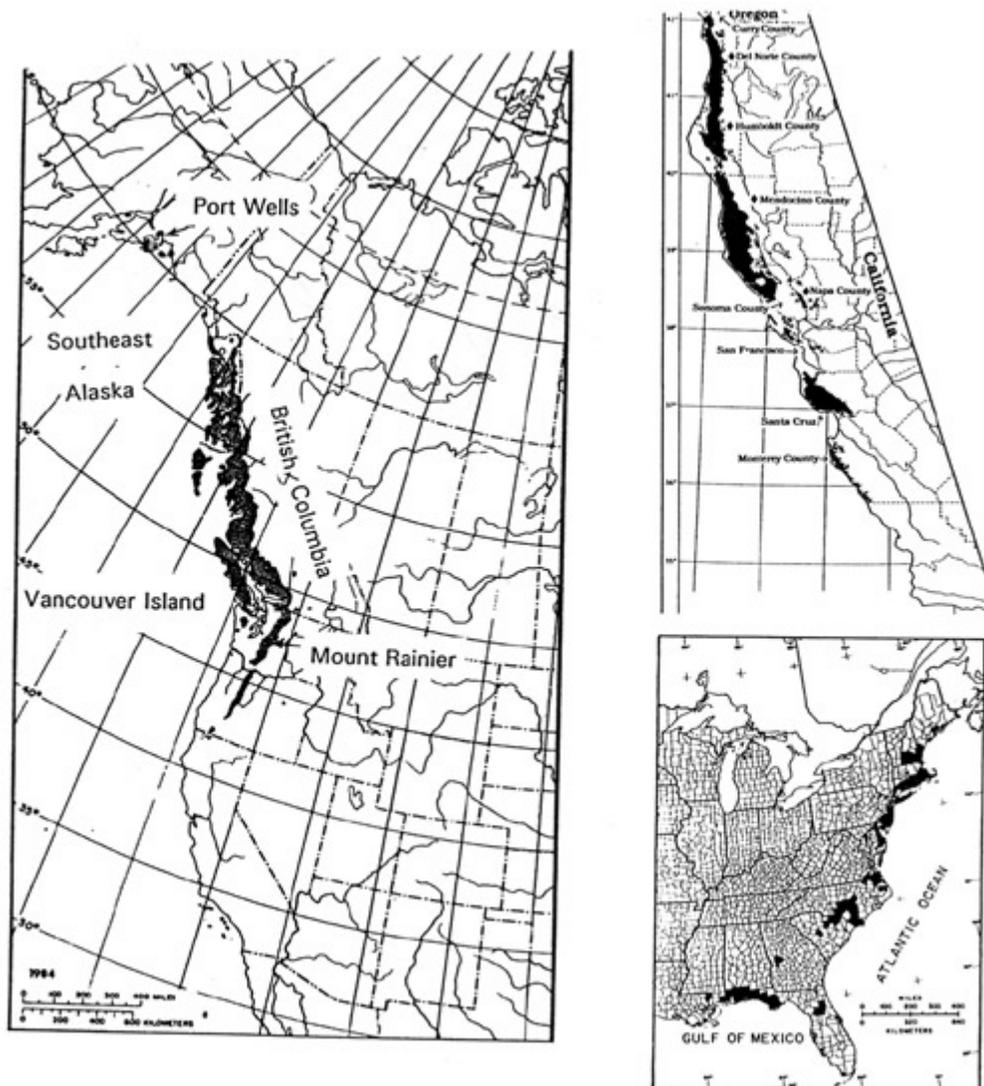


Fig. 12. Left panel: range of the Alaska yellow-cedar (*Chamaecyparis nootkatensis*). Upper right panel: range of the coast redwood (*Sequoia sempervirens*). Lower right: range of Atlantic white cedar (*Chamaecyparis thyoides*). (Laderman, 1998, pp. 56, 222, 112.)



Fig. 13. The aerial distribution of the white spruce, *Picea glauca* 12,000 years ago. Lower figure, and 9000 years ago, upper figure, (from Ritchie and MacDonald, 1986) and the proposed (David, 1981) and hypothesized wind circulation.



Fig. 14. Breeding range, north, and non-breeding range, south, of chipping sparrow (*Spizella passerina*) on the left, of clay-colored sparrow (*S. pallida*) in the middle, of Brewer's sparrow (*S. breweri*) on the right. (National Geographic pp. 404,

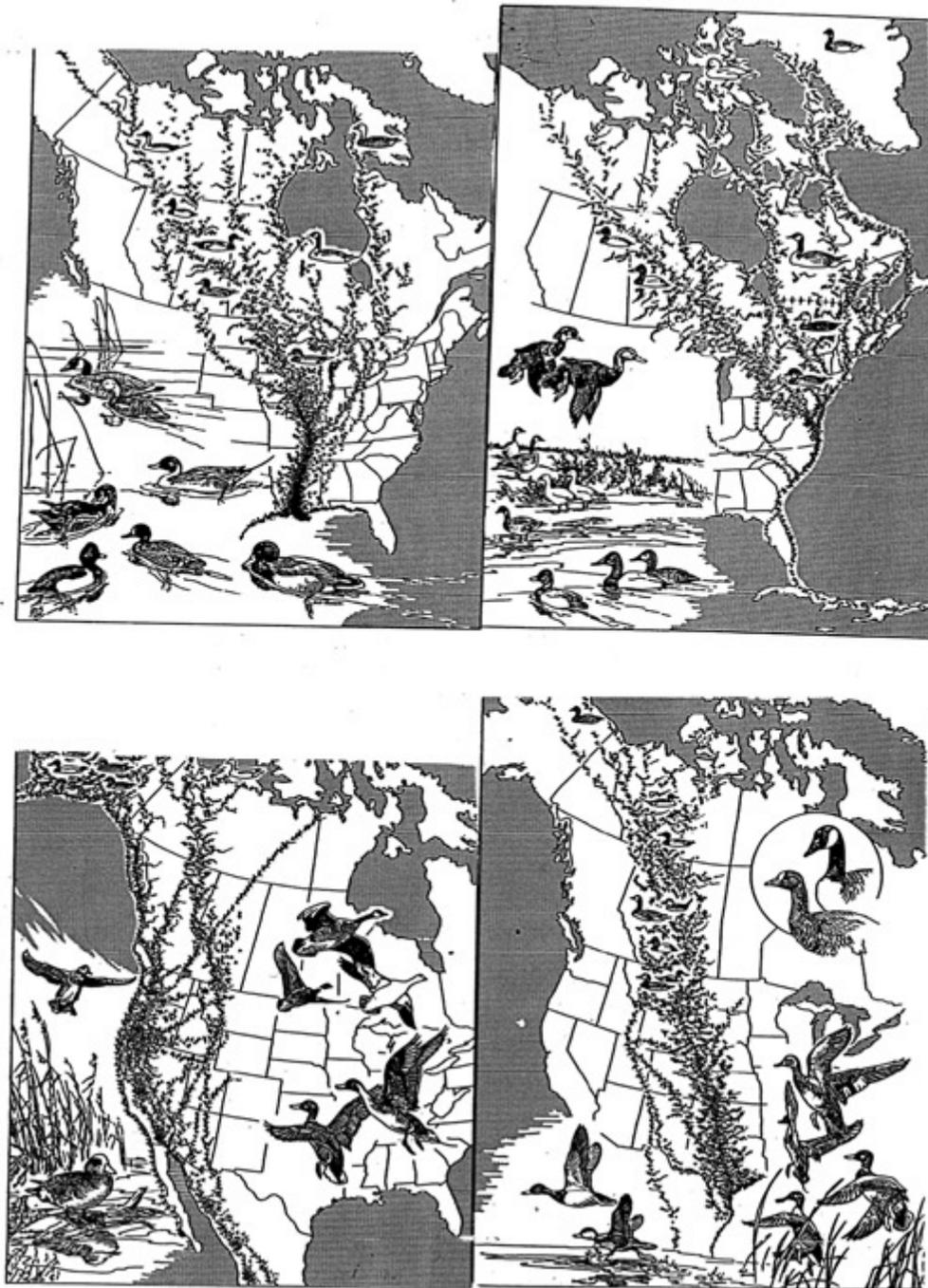


Fig. 15. The migration flyways of waterfowl in North America. Upper left, the Mississippi flyway. Upper right, the Atlantic flyway. Lower left, the Pacific flyway. Lower right, the Rocky Mountain flyway. (From Lincoln and Hines,

1950.)

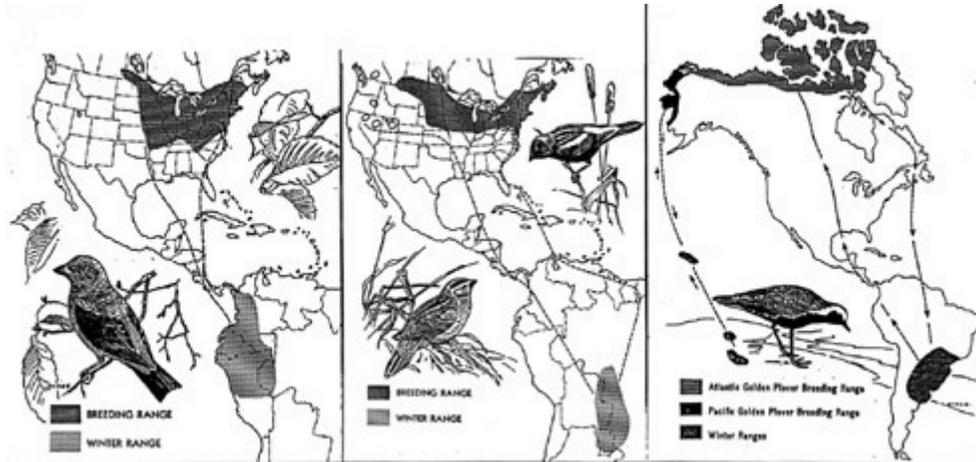


Fig. 16. Migration routes and breeding and wintering ranges of the scarlet tanager (*Piranga olivacea*), left, of the bobolink (*Dolichonyx orizivorus*), center, and the golden plover (*Pluvialis apricaria*), right. (From Lincoln and Hines, 1950.)

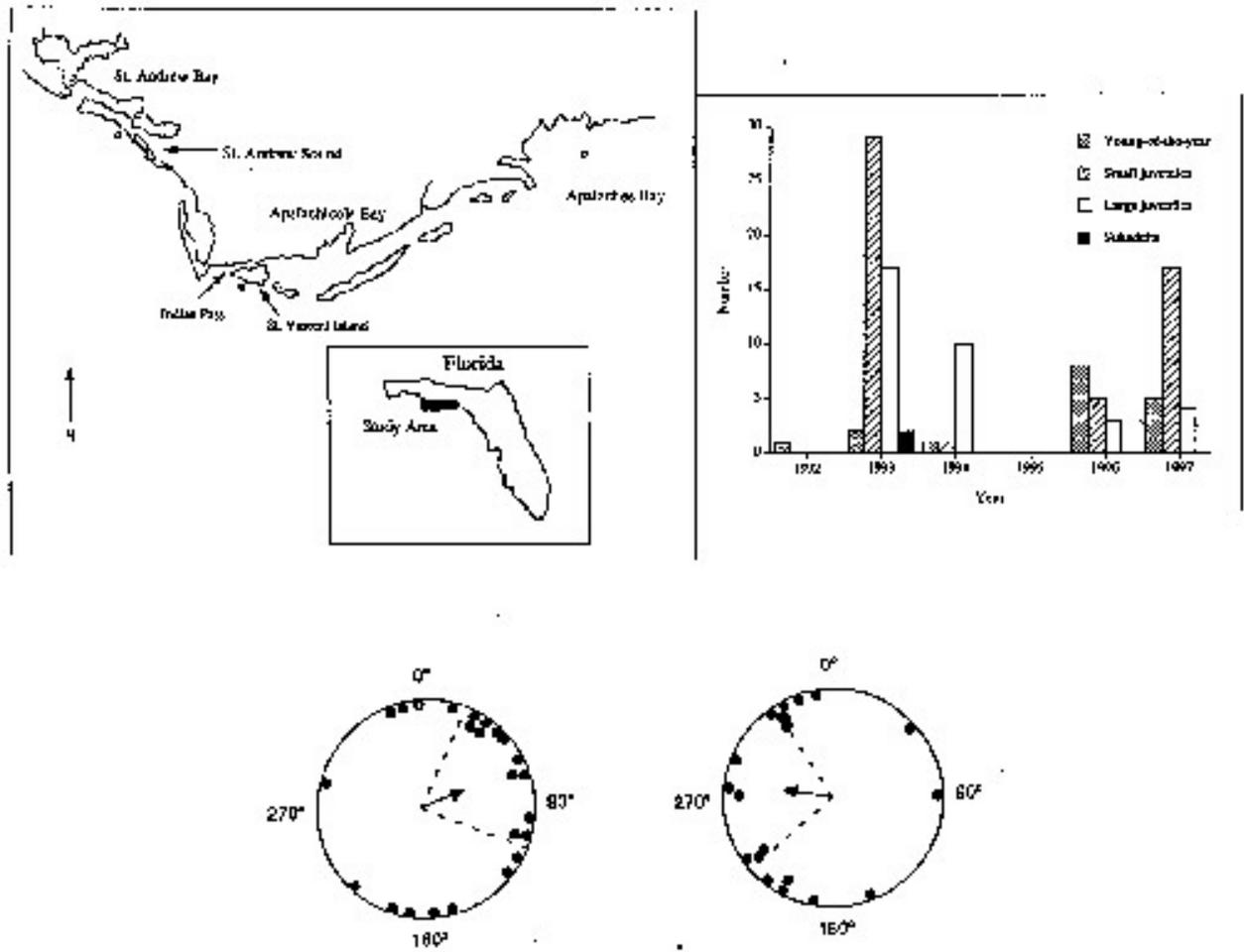


Fig. 17. Upper two presentations are the Florida nursery area and age distribution of the sandbar shark *Carcharinus plumbeus* (from Carlson, 1999). Lower presentation of the orientation of turtle hatchlings, wherein left diagram shows effect of magnetic field in making hatchlings swim eastward and right diagram the effect of swimming westward (from Lohmann and Lohmann, 1996, 1998). The hatchlings and loggerhead turtles (*Caretta caretta*).



Fig. 18. The distribution of the islands about Antarctica and the distribution of the southern fur seal (from Bonner, 1999).

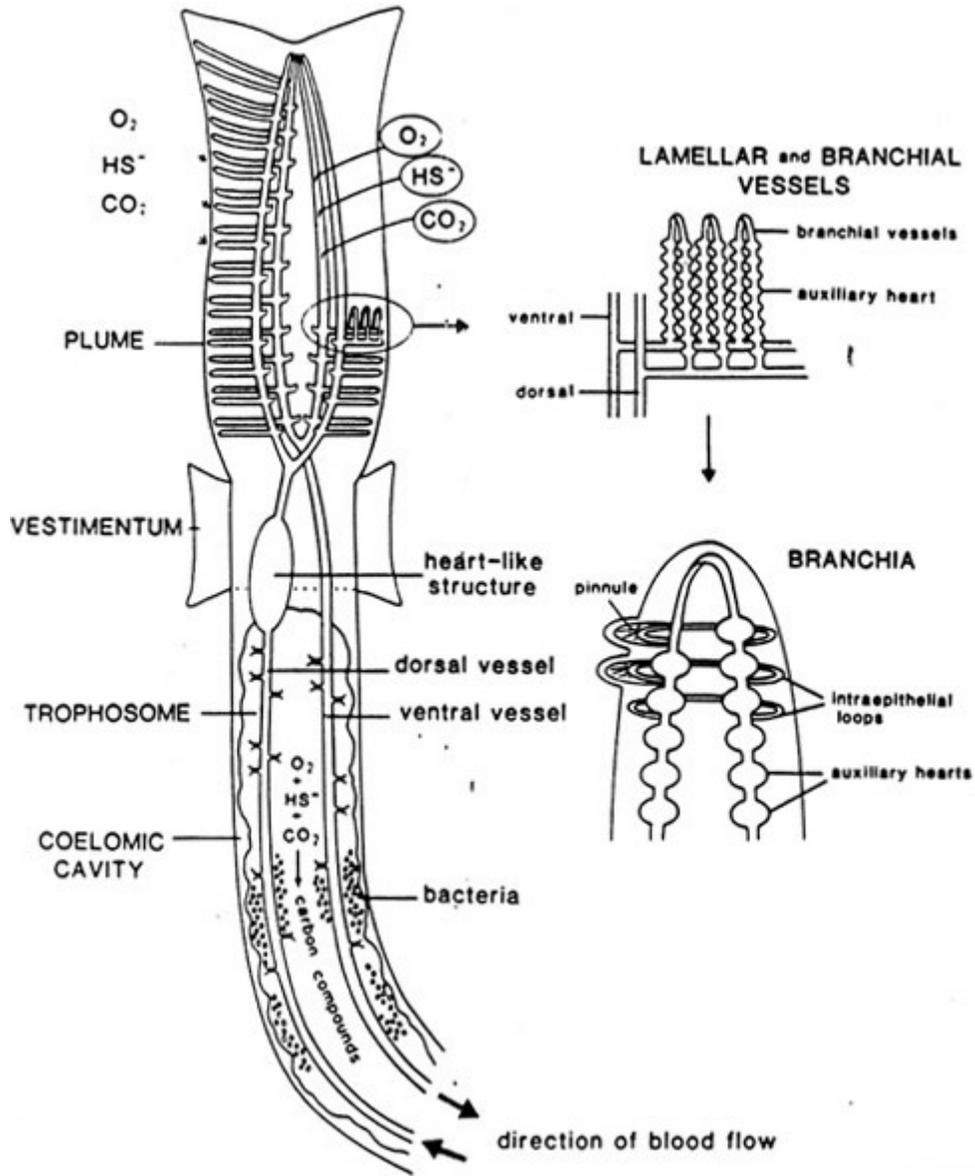


Fig. 19. Internal anatomy of *Riftia pachyptila*. (From Arp, et al., 1985).

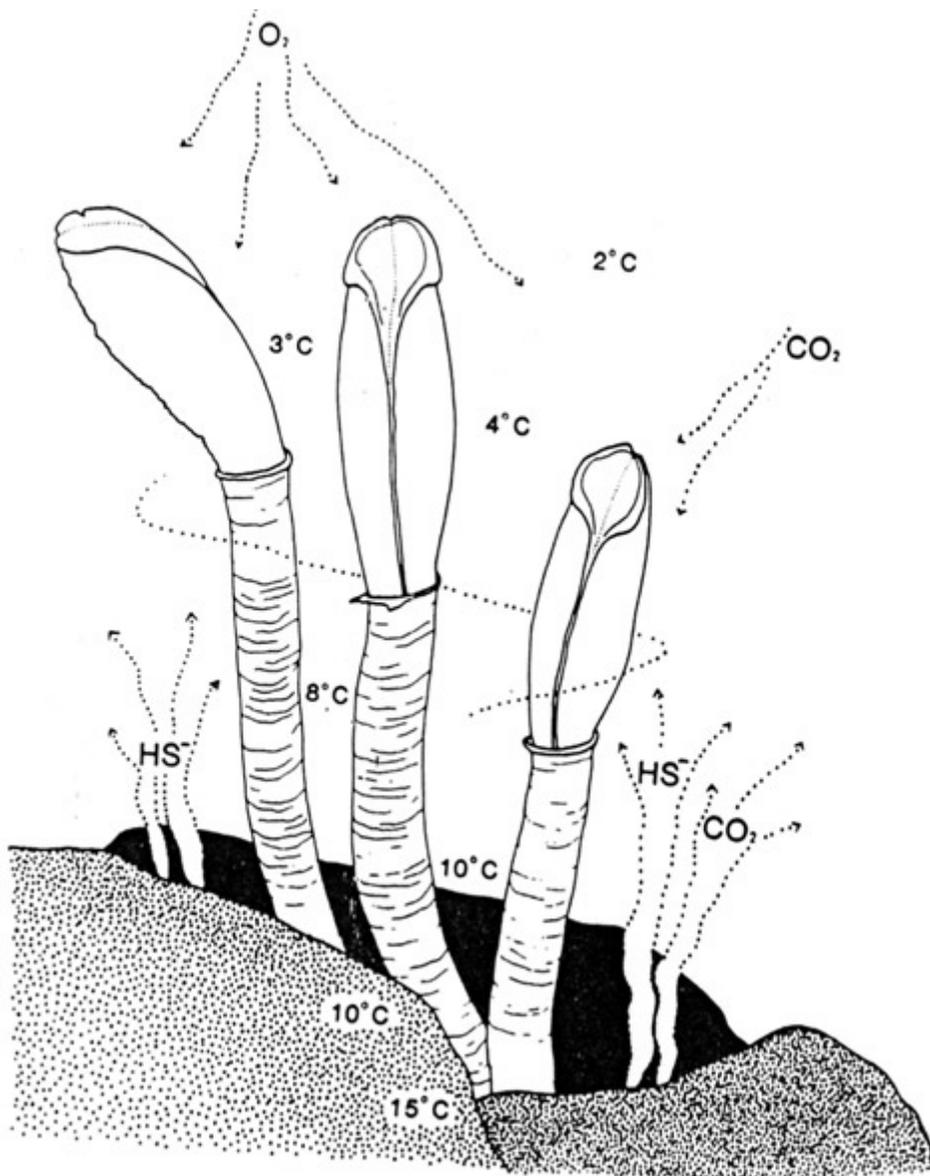


Fig. 20. The habitat of *Riftia pachyptila*. (From Arp, et al., 1985.)

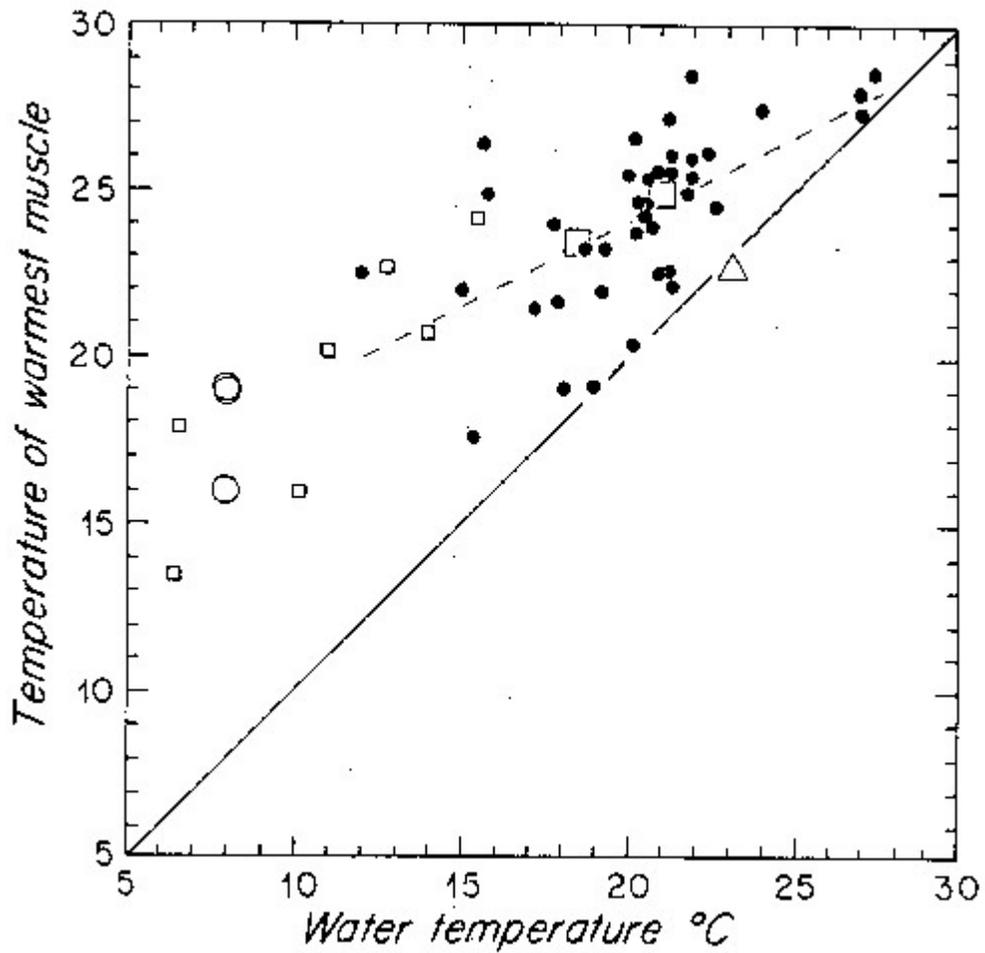


Fig. 21. Temperature of the warmest muscle of lamnid sharks compared to water temperature. Diagonal line gives position of zero temperature elevations. (Δ) *Isurus paucus*. (O) *I. oxyrinchus*. (\square) *Carcharodon*. (\square) *Lamna nasus*. (O). (From Carey, et al., 1985.)

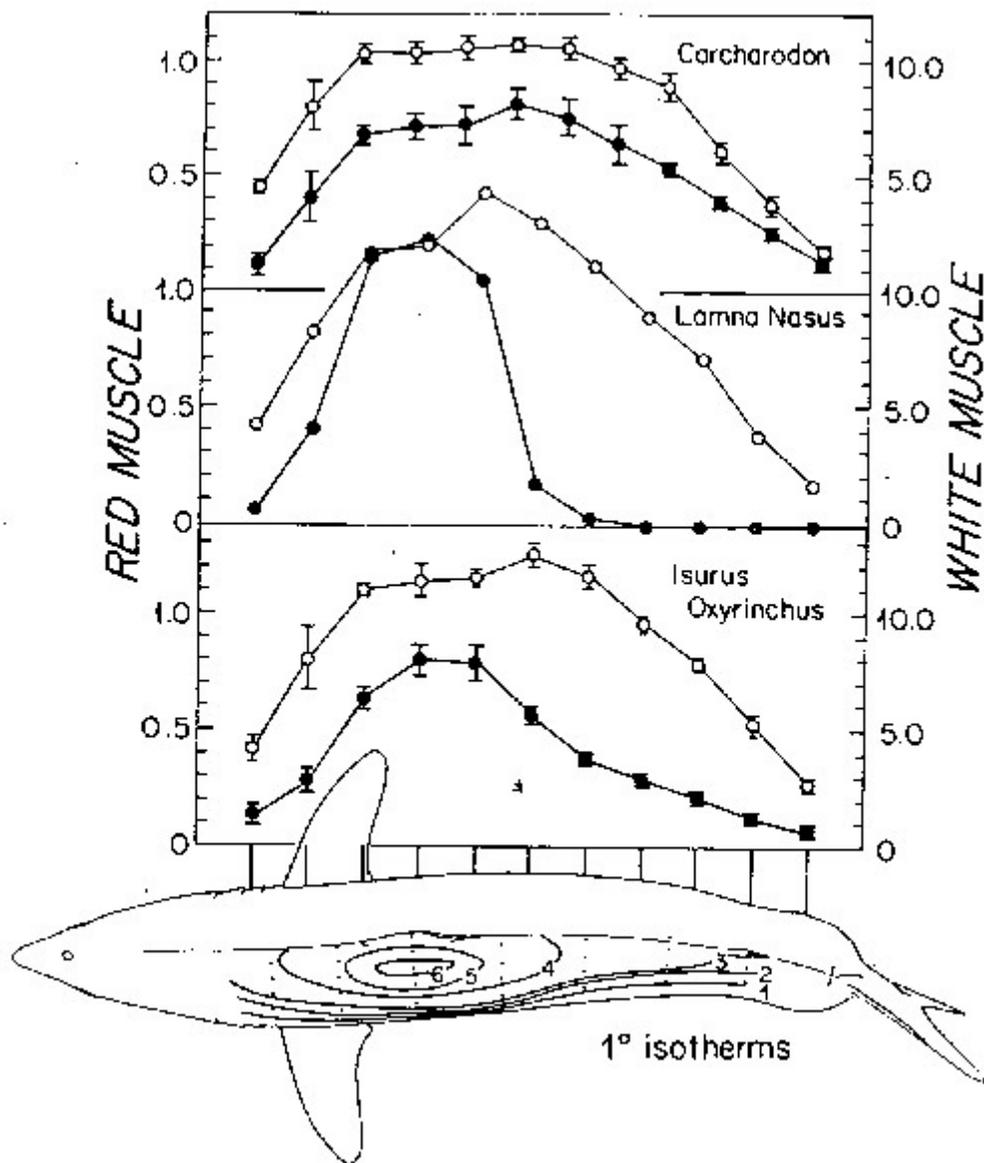


Fig. 22. Longitudinal distribution of white muscle, O, and red muscle, ●, at about 5% intervals along the length of three shark species. The isotherm distribution in *I. oxyrinchus*, shown at the bottom, closely approximates that of red muscle. (From Carey, et al., 1985.)

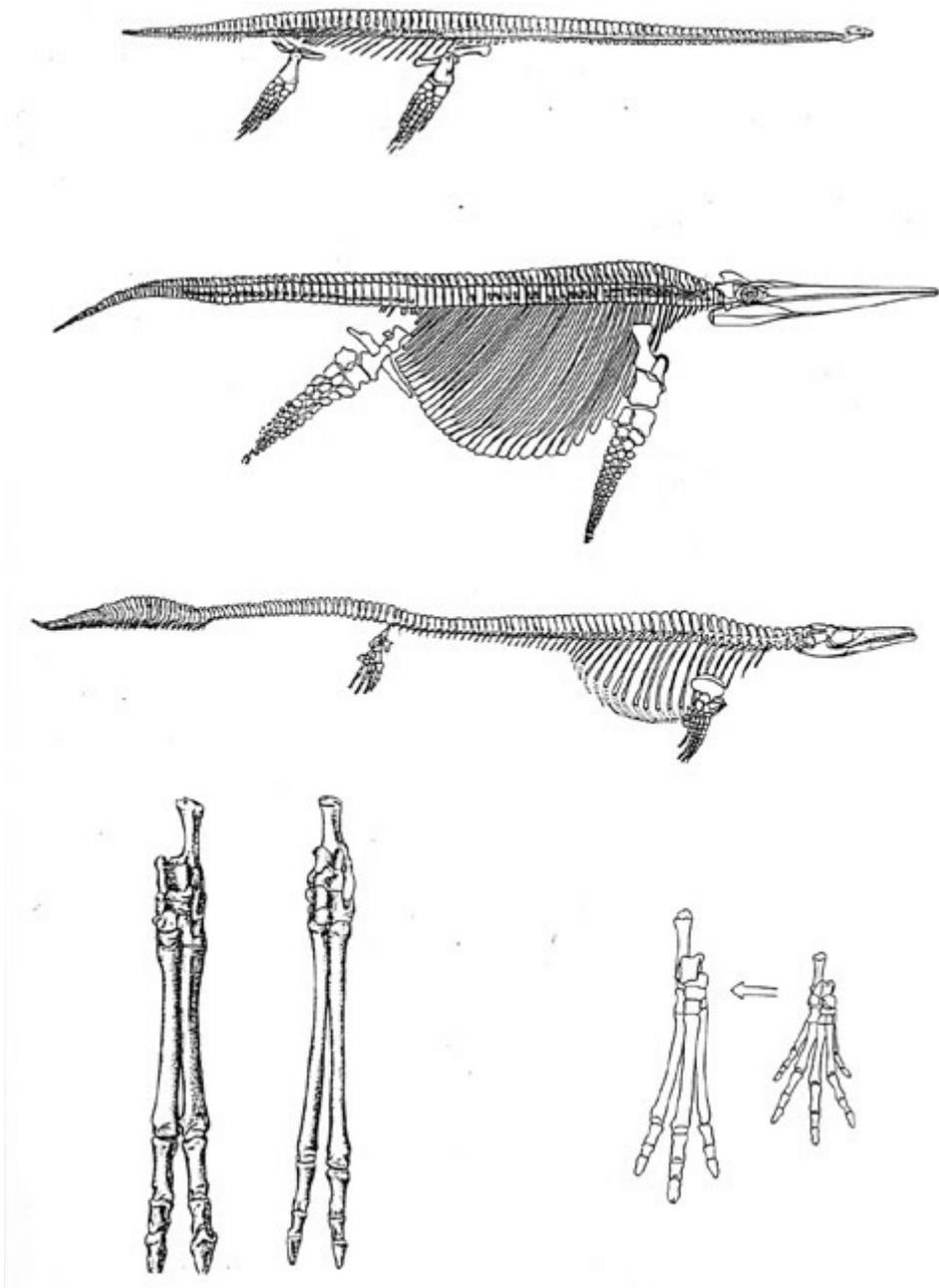


Fig. 23. The plesiosaur *Hydrothecosaurus*, Jurassic, 12 m long. Next to the top figure. The ichthyosaur *Shonisaurus*, Upper Triassic, 15 m long. Middle figure. The mosasaur *Plotosaurus*, Upper Cretaceous, 10 m long. Bottom figure. Left pair, the artiodactyls *Proebrotherium* and *Protoceras*, Oligocene. Right pair, the perissodactyls *Hyracotherium* (left) and *Tetraclaenodon* (right). Lower Eocene (from Carroll, 1988, pp. 248, 256, 234, 5125 and 529).



Fig. 24. Upper panel: sugar maples (*Acer saccharum*), 160-200 years old, in a beach-maple association in Pennsylvania. Middle panel: climax forest of ponderosa pine (*Pinus ponderosa*) in a typical open stand, montane zone, Arizona. Lower panel: characteristic open stand of piñon-juniper (*Pinus monophylla*, *P. edulis*, and *Juniperus osteosperma*). (Oosting, 1948, pp. 246, 266, 267.)

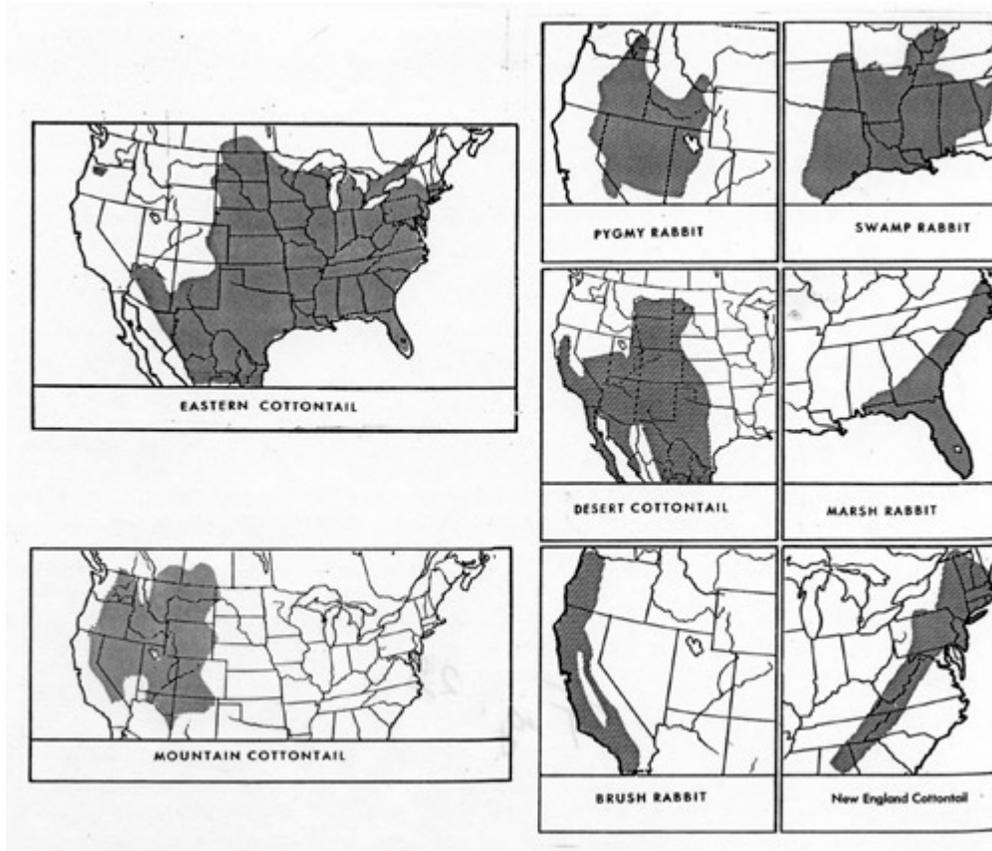


Fig. 25. Ranges of cottontail rabbits. Eastern cottontail (*Sylvilagus floridanus*) and mountain cottontail (*S. nuttalli*), left panel. Pygmy rabbit (*S. idahoensis*) and swamp rabbit (*S. aquaticus*), upper right. Desert cottontail (*S. auduboni*) and marsh rabbit (*S. palustris*), middle right. Brush rabbit (*S. bachmani*) and New England cottontail (*S. transitionalis*), lower right. (Burt and Grossenheider, 1980, pp. 208-210.)

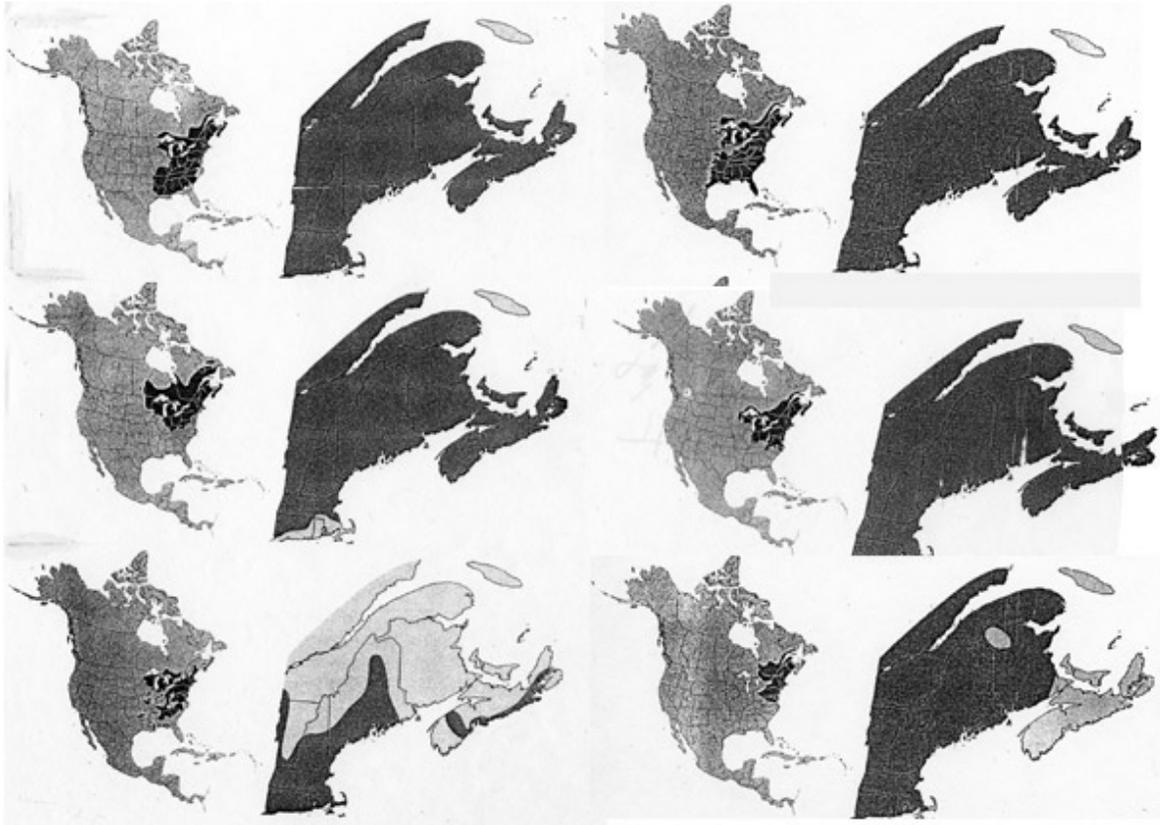


Fig. 26. Salamanders of Maine (U.S.A.), where the map of North and Central America gives the whole region where the species occurs, and where the New England-Canada map shows its presence there. Upper row: left, spotted salamander (*Ambystoma maculatum*); right, eastern newt (*Notophthalmus viridescens*). Middle row: left, blue-spotted salamander (*Ambystoma laterale*); right, northern red-back salamander (*Plethodon cinereus*). Bottom row: left, four-toed salamander (*Hemidactylium scutatum*); right, northern two-lined salamander (*Eurycea bislineata*). (Hunter, Calhoun, and McCollough, 1999, pp. 45, 50, 40, 68, 63, 57.)