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EUGENE GARFIELD
INSTITUTE FOR SCIENTIFIC INFORMATION®
3501 MARKET ST., PHILADELPHIA, PA 19104

The Turtle: A Most Ancient Mystery. Part 2. Unanswered Research Questions

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Throughout history turtles have held a certain mystique. James J. Parsons, Department of Geography, University of California, Berkeley, notes that "people are instinctively attracted to these reptiles and have been since antiquity."[1] Some of their appeal may be due to the relatively large size of some turtles or because they outlive all other vertebrates, including humans. Turtles are unique in that they have changed very little during their existence on earth. By the middle of the Triassic period, some 200 million years ago, turtles were already in existence and had most of the characteristics they exhibit today.[2]

In the first part of this essay, we discussed the turtle's role in art, literature, and mythology.[3] In Part 2 we will explore some of the research questions that challenge the herpetologists, marine biologists, zoologists, and other scientists who study turtles. Many of these questions concern the uncanny navigational abilities of marine turtles and their complex nesting instincts.

Anatomy and Classification

Turtles are generally believed to have stemmed from the cotylosaurs, the primitive reptiles from which all other reptiles developed. Little, however, is known about the morphological evolution of the turtle because of a lack of early fossils. Archie Carr, graduate research professor of biology, University of Florida, Gainesville, wrote in 1952 that the most likely link between the cotylosaurs and the turtle was *Eunotosaurus africanus*, a reptile that lived during the Permian period in South Africa, about 250 million years ago. This reptile had a wide, flat body and broadened ribs. Some turtle genealogists once believed these characteristics evolved into the turtle's bony shell.[4] (p. 2) Peter C.H. Pritchard, Florida Audubon Society, Maitland, however, points out that this theory is no longer thought to be valid and that scientists do not know the stages the cotylosaurs went through in evolving into the earliest turtles, which were the Triassic turtles found in Germany and Thailand.[2]

One of the present problems faced by turtle biologists, according to Carr, is the classification of turtles.[5] The American Society of Ichthyologists and Herpetologists, Gainesville, Florida, in standardizing the names of reptiles in the US, assigned the name turtle to all members of the order Chelonia, which is sometimes called Testudines or Testudinata.[6] In the US, tortoise is used secondarily to describe some of the slow-moving, land-dwelling turtles. The term terrapin, an Algonquian Indian word meaning little turtle, is applied to certain edible varieties of turtle.[1] In the UK, turtle means only sea turtles. Terrapin is used to describe most freshwater turtles, and the term tortoise describes all other land-dwelling chelonians.[7] Australians refer to all chelonians as tortoises.[2]

There are more than 200 living species within the order Chelonia, which belongs to the class Reptilia and subclass Anapsida. They inhabit every continent except Antarctica. Although most of the species are aquatic or amphibious, some are entirely terrestrial. All have a bony or leathery shell that encloses the vital organs of the body and usually protects the head and limbs. This shell, which may be responsible for the evolutionary success of the turtle, consists of a top (the carapace) and bottom (the plastron), which are joined at the sides by a bridge. The strength of the carapace in hard-shelled species comes from the fusion of the backbone with a layer of bony plates covered by a layer of horny plates. Turtle ribs are broad and flat and are also fused with the shell. In some turtles, the shell has a moveable joint, usually in the plastron, enabling the shell to move up and down to a limited extent. This hinge is what enables some turtles to retreat completely.[8] (p. 19)

Taxonomists classify modern turtles according to the way in which they retract their heads into their shells. Most turtles belong to the suborder Cryptodira, which includes all turtles that retract their heads in a vertical plane. They bend their necks into an S-shaped curve to withdraw into the shell. This suborder includes soft-shelled, mud, and musk turtles as well as tortoises, cooters, and snapping turtles. Although it cannot retract its head, the leatherback turtle, a marine turtle that can weigh up to 1,000 pounds (454 kg) and reach lengths of 60 inches (152 cm), is included in this suborder. It is the largest of all living turtles.[9]

Also in this suborder are the sea turtles, including the green turtle, widely esteemed for its meat; the hawksbill, which is sought for its beautiful shell; the loggerhead; and the ridleys. The giant land tortoises of the Galápagos Islands belong to the Cryptodira. These may weigh up to 440 pounds (200 kg) and reach a length of about 40 inches (102 cm).[7] One of the largest recorded tortoises, now preserved in the Rothschild Museum at Tring, Herts, UK, weighed 593 pounds (269 kg) when alive.[9] Lord Lionel Walter Rothschild, who maintained a preserve for giant tortoises on his Tring estate, is pictured on the cover of his biography riding his favorite, a Galápagos tortoise named Rotumah.[10]

The suborder Pleurodira includes all turtles that retract their heads and necks in a horizontal plane by bending their necks sideways. Some terrestrial fossils have been found, but all living turtles in this suborder are aquatic.[2] Included in this suborder are the snake-necked turtles, whose heads and necks may equal half their total length.[7]

Finding Their Way Home

Perhaps the most mysterious aspect of turtle behavior is the remarkable navigational skill of marine turtles. Some species are known to swim 1,000 miles or more to lay their eggs on tiny beaches they presumably haven't revisited since they were hatched there 10 to 50 years before. Researchers are trying to determine how turtles know which beach is the proper breeding ground, why they bypass other larger and seemingly more appropriate nesting sites, and the techniques they use to migrate between their feeding and nesting grounds.

Pritchard suggests in a *BioScience* article by science writer Laura Tangley that the beaches chosen by turtles may have some unknown quality that makes the extra swim worthwhile or that turtles may chose a beach out of instinct. Their migrational habits may be vestiges of ancient behavior, from a time when feeding and nesting sites were closer or islands were larger. Carr suggests that one population of green turtles travels some 1,400 miles from its feeding grounds off Brazil to its Ascension Island breeding ground because islands closer to the mainland disappeared over geologic time. These turtles, initially accus-

tomed to swimming out to a relatively close island, may have been forced by the continental drift that widened the south Atlantic to swim farther and farther to reach their accustomed breeding beach.[11]

Another unanswered research question concerns the method used by marine turtles to locate their nesting beach. One widely accepted possibility is that the turtle hatchling imprints on the chemical characteristics of its natal beach. Imprinting is a learning process in which a very young animal focuses on the first object with which it has visual, auditory, or tactile contact and subsequently follows that object.[12] Carr has hypothesized that marine turtles are impressed at birth by olfactory cues from the sand and seawater. According to this theory, the chemistry of the turtle's natal beach is impressed upon its memory and traced in the seawater by the turtle when it reaches sexual maturity, some 10 to 50 years later.[11]

A number of experiments have provided evidence that turtle hatchlings imprint on their natal beach. David W. Owens and Yuki A. Morris, then of the Department of Biology, Texas A&M University, College Station, found that the level of corticosterone drops in loggerhead turtles after hatching and stays low until they emerge from their nests. Since birds imprint when their corticosterone levels drop, this suggests that imprinting may also occur with the loggerhead.[13]

Although scientists by and large accept the imprinting theory, most believe it is only one aspect of a turtle's navigational skill. Once turtles have detected the chemical characteristics of their nesting beach, they must determine in which direction to swim. Theories advanced to explain this navigational ability include an internal sun or star compass, navigation in response to the earth's magnetic field, and the ability to detect the direction of ocean-current flow.[11] It is also possible that turtles passively drift with the current or that, as John R. Hendrickson, Department of Ecology and Environmental Biology, University of Arizona, Tucson, proposes, virgin turtles simply follow more experienced turtles to the nesting ground.[14] Recent research on marine turtles' visual ability has shown that they have very poor eyesight above water, making it unlikely that they use a star compass. More promising, though, is the magnetic compass theory, since J. Kirschvink, Department of Geology and Planetary Science, California Institute of Technology, Pasadena, reported finding tiny magnetic particles called magnetite in the bodies of sea turtles.[15] More recently, Anjanette Perry, Department of Oceanography, University of Hawaii, Honolulu, isolated magnetic particles from turtle brains.[16]

Nesting

Whatever method is used, many researchers are convinced that marine turtles return to their natal beaches. Most sea turtles nest more than once in a breeding season—some may nest 3 to 10 times, usually at intervals of 10 to 14 days. The eggs laid during a season are not necessarily those fertilized during that season. Pritchard notes that the females of some turtle species can lay fertile eggs several years after they have had contact with a male.[8] (p. 63)

Once she has finished breeding, the female sea turtle crawls up the beach and, using her hind legs, digs an egg pit about two or three feet deep. She then deposits from 50 to over 200 leathery eggs. Throughout this process, the female turtle grunts and hisses and sheds tears. David M. Hudson and Peter L. Lutz, Rosentiel School of Marine and Atmospheric Science, University of Miami, Florida, report that the tears are the turtle's method of eliminating salt, bromide, magnesium, and other minerals from her body.[17] After hiding the site by flinging sand about, she lumbers around the beach, probably to disguise

the location of her nest, and then abandons the eggs forever.[4] (p. 13)

Hatching

After about two months, the eggs hatch, giving way to what Carr terms "sort of a little eruption" as the turtles break out of their shells and make their way to the surface. Once the hatchlings reach the surface, they lie quietly beneath the sand, "awaiting some signal to break out into the world."[18] (p. 76-7) Generally, the signal comes a few hours before dawn, probably from the lowered temperature of the sand. The hatchlings then emerge in a frenzied mass, thrashing along on their flippers, stopping only occasionally to get their bearings. Once they reach the wet sand, their speed increases, and crawling gives way to swimming as they enter the ocean and are lifted by the waves.[19]

Researchers generally agree that turtle hatchlings use visual cues—some characteristic of light over the open sea—to find their way to the sea. Since most marine turtles are too nearsighted on land to detect the ocean, researchers have been trying to determine what properties of light lead the hatchlings into the water. In a review of the literature on sea-turtle hatchling orientation, Paul W. Raymond, Department of Biological Sciences, University of Central Florida, Orlando, notes that turtles fitted with spectacles to blur their vision were still able to find the water.[20] David W. Ehrenfeld, Department of Zoology, University of Florida, Gainesville, and Carr found that young turtles are primarily dependent on light intensity for orienting toward the water.[21] N. Mrosovsky and S.F. Kingsmill, Departments of Zoology and Psychology, University of Toronto, report that sea turtles exhibit a phototropotactic mechanism for finding the sea. They compare light intensities at the horizon and balance the brightness entering both eyes to maintain an orientation toward light from an open horizon.[22]

Temperature-Dependent Sex Determination

In the past decade, researchers have found that the sex ratio of the hatchlings is dependent upon the temperature of the nest. In their paper entitled "Temperature-dependent sex determination in turtles," J.J. Bull, Laboratory of Genetics, and R.C. Vogt, Department of Zoology, University of Wisconsin, Madison, note that warmer temperatures tend to produce female map-turtle hatchlings and cooler temperatures produce males.[23] Bull and Vogt's paper is one of the five core publications in the research front on "Morphology, sex ratio, and sex determination in recent and fossil alligators, crocodiles, and sea turtles" (#84-3741). It is also one of the 10 core papers for the front on "Sex determination in reptiles and mammals" (#85-3478). These two ISI® research fronts are linked through two papers; one was published by Bull in 1980,[24] and the other was published in 1982 by Mark W.J. Ferguson, Department of Anatomy, Queen's University of Belfast, UK, and Ted Joanen, Rockefeller Wildlife Refuge, Grand Chenier, Louisiana.[25] We will discuss other research fronts pertaining to turtles later.

In a more recent paper, Vogt and Bull report that nests located among vegetation tend to produce all-male hatchlings, while all-female hatchlings are produced in nests in open sand that is exposed to the sun.[26] Research has shown that only the soft-shelled turtles[23] and the giant musk turtle, *Staurotypus*,[2] lack temperature-dependent sex determination.

Mystery of the Missing Year

One of the most recently solved mysteries of marine turtle behavior is what Carr describes as the "mystery of the missing year." It has long been known that, after hatching, turtles dive under the breakers and swim out to sea, where they can support themselves for some time on a residual supply of yolk in their bellies. But until recently, researchers had not been able to determine where

the turtles lived until they reached one year of age. Carr now reports that loggerhead, hawksbill, and green turtles swim as far as 50 miles out to sea, where they hitch rides on rafts of floating sargassum seaweed, which they eat. These rafts, which can reach lengths of up to 100 miles, are also home to small shrimp, crabs, and jellyfish on which the young turtles feed. Unfortunately, the same currents that bring together these large rafts also bring together styrofoam, oil, and tar. The young turtles ingest these pollutants, which can result in their death.[19]

Conservation

Most of the current research on turtles focuses on questions concerning their conservation. In a review of sea-turtle conservation problems, Pritchard explains that nearly all sea-turtle biologists eventually become conservationists because

> those who work in the field with sea turtles are inevitably distressed as the animals they study are slaughtered, often while actually on the nesting beach. The eggs too are all too frequently raided, either by man himself or by predators that in many cases have been introduced to the system by man or allowed to form unnaturally high population densities as a result of man's tinkering with ecological balances.[27]

Carr points out that nearly every omnivore and carnivore living near a turtle nesting beach preys on turtle eggs. He writes that these "range in size from ants and crabs to bears and Bengal tigers" and include wild dogs, buzzards, opossums, birds, pigs, and raccoons.[18](p. 75) On some nesting beaches, predators may destroy almost every egg laid.

Humans have contributed in many other ways to the turtle's demise. The widespread popularity of turtle meat and soup, the beauty of their shells, and the propensity of turtles to get caught in fishing nets have combined to decimate their population. Pollution has also played a role in the depletion of the marine turtle. According to Thomas H. Fritts of the US Fish and Wildlife Service in Denver, Colorado, dead leatherbacks have been found with plastic bags in their digestive systems, probably from mistaking plastic bags for jellyfish.[28] James M. McKim, Harbor Branch Foundation, Inc., Fort Pierce, Florida, and Kenneth L. Johnson, Center for Lake Superior Environmental Studies, University of Wisconsin, Superior, report high levels of polychlorinated biphenyls (PCBs) and pesticides in developing embryos of loggerhead turtles.[29] There is no evidence, however, that the PCBs harm these turtles.

The rapid development of beachfront property adjacent to nesting beaches has deprived some turtles of their breeding grounds. Road lighting near nesting beaches disorients hatchlings, who head toward the road, where they are run over by cars or perish from exhaustion or predation after many hours of confused searching for the sea.[18](p. 4-5)

The tortoise of the Mojave Desert in California is also the subject of some concern, since collectors have significantly reduced its population. The Bureau of Land Management recently set aside a portion of the Mojave Desert as a desert tortoise preserve.[1]

One of the primary means of marine-turtle conservation at present is removal of turtle eggs to special hatcheries, where the eggs are kept until the hatchlings emerge or until they are deemed relatively safe from predation. But this has its pitfalls. Pritchard points out that present techniques for moving eggs reduce the percentage of eggs that survive by 50 to 90 percent. Moreover, the relatively new knowledge of temperature-dependent sexual differentiation reveals that artificial incubation may have skewed the sex ratios of many species. Another problem here is that removing eggs to artificial hatcheries may deprive certain species of the ability to imprint on their native beaches, causing turtles to fail to migrate to the right place.[27]

However, as new information about imprinting and sex determination becomes available, scientists may experience more success in their efforts at artificial incubation. One such project, by Owens and colleagues, involves removing some 2,000 Kemp's ridley eggs from the beach at Rancho Nuevo, Mexico, and taking them to Padre Island, Texas, where ridleys may have nested many years ago. To ensure that these turtles imprint on the chemical characteristics of Padre Island, the hatchlings are allowed to enter the sea before they are caught and raised in captivity.[30] Similar projects are being sponsored by the US Fish and Wildlife Service and the US National Marine Fisheries Service at a number of turtle nesting sites throughout the US.[2] It will be at least five years before the turtles return to breed, so scientists will not know for many years whether these turtles have developed a preference for Padre Island and for the other sites at which they are being protected or relocated.[30]

Another potent approach to turtle conservation is a ban on the use of sea turtles and their products. Such bans, by closing the market for sea turtles, are expected to lower the demand and price of turtle products. Unfortunately, such bans are not always effective. Pritchard notes that when the US banned the importation of Olive ridley products, fishermen from Ecuador doubled their take of this species because they could sell only its meat, which went for a lower price than its shell.[27]

Organizations

Although hundreds of years of mismanagement have driven marine turtles to near extinction, much is now being done to conserve these species. According to Pritchard, marine turtles are classified as threatened or endangered through most of their range by the US Endangered Species Act.[27] Trade is controlled through the Convention of International Trade in Endangered Species. As is evident from the list of organizations in Table 1, a number of groups are dedicated to the conservation of turtles. The Caribbean Conservation Corpora-

Table 1: Selected list of associations providing information on turtles and tortoises.

American Society of Ichthyologists and Herpetologists
c/o Florida State Museum
University of Florida
Gainesville, FL 32611

British Herpetological Society
c/o Zoological Society of London
Regent's Park
London NW1 4RY, UK

Caribbean Conservation Corporation
P.O. Box 3048
Tallahassee, FL 32315

Charles Darwin Foundation for the Galápagos Isles
National Museum of Natural History
Tenth & Constitution Avenue, NW
Washington, DC 20560

Desert Tortoise Council
5319 Cerritos Avenue
Long Beach, CA 90805

German Society for Herpetology and Terrariatology
Senckenberganlage 25
D-6000, Frankfurt 1, FRG

Herpetologists' League
Department of Biological Sciences
Louisiana State University at Shreveport
8515 Youree Drive
Shreveport, LA 71115

International Union for Conservation of Nature and Natural Resources
Avenue du Mont-Blanc
CH-1196 Gland, Switzerland

National Audubon Society
950 Third Avenue
New York, NY 10022

National Marine Fisheries Service
1825 Connecticut Avenue, NW
Washington, DC 20235

Sea Turtle Rescue Fund
Center for Environmental Education
624 Ninth Street, NW
Washington, DC 20001

Society for the Study of Amphibians and Reptiles
c/o Milwaukee Public Museum
800 West Wells Street
Milwaukee, WI 53233

tion is credited with pressuring the governments of Mexico, Costa Rica, Venezuela, Brazil, and the US into passing laws protecting beach nesting areas from egg poachers.[31] This group also established a turtle research station in Tortuguero, on the Caribbean side of Costa Rica. Each year, thousands of green turtles are tagged at this site, which is one of the world's premier nesting beaches. Other groups that have been particularly active in sponsoring turtle research or conservation efforts include the US National Marine Fisheries Service, the World Wildlife Fund, and the Sea Turtle Rescue Fund, which is sponsored by the Center for Environmental Education, Inc.

Journals

Articles on turtles appear in a number of general science and natural history periodicals, including *Smithsonian*, *Sea Frontiers*, *Oceans*, and *BioScience*. Most research papers can be found in journals of herpetology, zoology, and ecology or conservation. Table 2, which lists the most prominent journals that report on turtles, was derived by a combination of online and manual literature searches using keywords, concepts, prominent authors, and papers on turtle research. The papers included those that are core and citing articles from current research fronts. The journals are covered in the *Science Citation Index®* (*SCI®*) and are listed with their 1985 impact factors. Another good source of information on marine turtles is the 11-year-old *Marine Turtle Newsletter*, published originally at the University of Toronto, Canada, and now at Mercer University in Macon, Georgia.

Table 2: Selected list of journals that report on turtles and tortoises. A=title, first year of publication, and publisher. B=1985 impact factor.

A	B
Australian Wildlife Research (1974) CSIRO, East Melbourne, Victoria, Australia	0.62
Biological Conservation (1968) Elsevier Applied Science Publishers, Barking, Essex, UK	0.69
Canadian Journal of Zoology (1929) National Research Council of Canada, Ottawa, Canada	0.89
Copeia (1913) American Society of Ichthyologists and Herpetologists, Gainesville, FL	0.73
Ecology (1920) Ecological Society of America, Tempe, AZ	2.60
Herpetologica (1936) Herpetologists' League, Shreveport, LA	0.93
Journal of Experimental Biology (1923) Company of Biologists, Cambridge, UK	1.87
Journal of Herpetology (1967) Society for the Study of Amphibians and Reptiles, Milwaukee, WI	0.61
Physiological Zoology (1928) University of Chicago Press, IL	1.38
Veterinary Record (1888) British Veterinary Association, London, UK	1.16

Research-Front Data

In addition to the two research fronts mentioned earlier on temperature-dependent sex determination, ISI has identified two other linked pairs of fronts. The front entitled "Avian and turtle eggshell structure and environmental effects on incubational development" (#84-1087) is linked to a 1985 front, "Thermoregulation in ectotherms" (#85-1402), by a paper authored by Mary J. Packard and colleagues, Department of Zoology and Entomology, Colorado State University, Fort Collins.[32] Other linked fronts are #84-2906 and #85-5278, which include papers on ecology and distribution of turtles. These are linked through two items, one an encyclopedia on turtles by Pritchard,[8] and the other a book on turtles in the US by Carl H. Ernst, Department of Biology, George Mason University, Fairfax, Virginia, and Roger W. Barbour, Department of Biological Science, University of Kentucky, Lexington.[33] Linkage of research fronts from one year to the next is established when core papers identified for one year continue to be cited in the next year's research fronts. Table 3 shows four 1984 and four

Table 3: The 1984 and 1985 *SCI®/SSCI®* research fronts on turtles and tortoises. A = number. The first two digits indicate the year of the research front. B = name. C = number of core items. D = number of published papers for the year indicated.

A	B	C	D
84-1087	Avian and turtle eggshell structure and environmental effects on incubational development	11	74
84-2680	Evolution of physiological adaptations in turtles, lizards, and other reptiles	4	16
84-2906	Swimming activity, distribution, and other aspects of freshwater and marine turtles	4	20
84-3741	Morphology, sex ratio, and sex determination in recent and fossil alligators, crocodiles, and sea turtles	5	35
85-1402	Thermoregulation in ectotherms	41	336
85-3478	Sex determination in reptiles and mammals	10	244
85-5278	Ecology, geographic variation, and behavioral aspects of turtles	2	17
85-8349	Analysis of scratch and spinal reflexes in turtles	2	10

1985 research fronts on diverse aspects of reptiles in general and turtles in particular.

Citation Classics

One *Citation Classic®* for the field of turtle biology is Carr's 1952 book, *Handbook of Turtles*,[4] which received 179 citations in the *SCI* between 1955 and 1985. Bull's 1980 article on "Sex determination in reptiles"[24] is also one of the most highly cited papers in this field, with 72 citations as of 1985. The citations received by these publications reflect the interest in turtles by a cross section of zoologists, ecologists, animal behaviorists, and conservationists. Some of these citations have also come from neurology, physiology, immunology, and other fields in which turtles are used as animal models.

Conclusion

Although the mysteries of turtle behavior are slowly being solved, many still remain. Since many turtles take so long to reach sexual maturity, it will be a number of years before scientists can determine if experiments in artificial imprinting are successful. Tagging operations to follow turtle migration, and to determine if they do in fact return to their natal beaches, have been fraught with problems. Metal tags, tow floats, and balloons attached to their shells fall off, and radio tracking equipment has produced weak signals or yielded only short transmission times. Sea-turtle biologists are hopeful that more sophisticated sonic and radio transmitters that have recently become available will be more successful.[11]

We cannot afford to let such a unique resource as the sea turtle dwindle away. Their ecological role may seem limited to such functions as feeding on the large crustaceans or jellyfish that other marine creatures do not eat or to cropping eel grass.[34] But turtles also have value as biological curiosities and as animal models.

Lutz and coauthors Myron Rosenthal and Thomas J. Sick, Department of Neurology, University of Miami School of Medicine, are using turtles in their work on cellular changes that occur in the brain as a result of oxygen shortages. Aquatic turtles have a great capacity to survive for long periods of time without oxygen while still maintaining brain function.[35]

Many turtle species have had the evolutionary savvy to outlive their Triassic peers. If the government and private institutions continue their research and conservation efforts, turtles may well be around for eons to come.

* * * * *

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REFERENCES

1. **Parsons J J.** Personal communication. 3 August 1986.
2. **Pritchard P C H.** Personal communication. 3 August 1986.
3. **Garfield E.** The turtle: a most ancient mystery. Part 1. Its role in art, literature, and mythology. *Current Contents* (39):3-7, 29 September 1986.
4. **Carr A.** *Handbook of turtles. The turtles of the United States, Canada, and Baja California.* Ithaca, NY: Cornell University Press, 1952. 542 p.
5. ----------. Secrets of the sea turtles. *Anim. Kingdom* 87(6):11-8, 1985.
6. **Riemer W J,** ed. *Catalogue of American amphibians and reptiles.* Bethesda, MD: American Society of Ichthyologists and Herpetologists, 1963.
7. Chelonia. *Encyclopaedia Britannica.* Chicago: Encyclopaedia Britannica, 1985. Vol. 26. p. 747-52.
8. **Pritchard P C H.** *Encyclopedia of turtles.* Neptune, NJ: T.F.H., 1979. 895 p.
9. Largest chelonians. *Guinness 1983 book of world records.* New York: Sterling, 1982. p. 74.
10. **Rothschild M.** *Dear Lord Rothschild: birds, butterflies & history.* Glenside, PA: Balaban, 1983. 398 p.
11. **Tangley L.** Sea turtle migration. Smelling their way back home? *BioScience* 34:353-6, 1984.
12. Imprinting. *Encyclopaedia Britannica.* Chicago: Encyclopaedia Britannica, 1985. Vol. 6. p. 275.
13. **Owens D W & Morris Y A.** The comparative endocrinology of sea turtles. *Copeia* 3:723-35, 1985.
14. **Hendrickson J R.** The green sea turtle, *Chelonia mydas* (Linn.) in Malaya and Sarawak. *Proc. Zool. Soc. London* 130:455-535, 1958.
15. **Kirschvink J.** Magnetic material in turtles: a preliminary report and a request. *Marine Turtle Newsl.* 15:7-9, 1980.
16. **Perry A.** Magnetite in the green turtle. *Pacific Sci.* 36:514, 1982.
17. **Hudson D M & Lutz P L.** Salt gland function in the Atlantic green turtle (*Chelonia mydas mydas*). *Physiologist* 28:343, 1985.
18. **Carr A.** *So excellent a fishe. A natural history of sea turtles.* Garden City, NY: Natural History Press, 1967. 248 p.
19. ----------. Mystery of the missing year. *Sciences* 24(4):44-9, 1984.
20. **Raymond P W.** *Sea turtle hatchling disorientation and artificial beachfront lighting.* Washington, DC: Center for Environmental Education, 1984. 72 p.
21. **Ehrenfeld D W & Carr A.** The role of vision in the sea-finding orientation of the green turtle (*Chelonia mydas*). *Anim. Behav.* 15:25-36, 1967.
22. **Mrosovsky N & Kingsmill S F.** How turtles find the sea. *Z. Tierpsychol.* 67:237-56, 1985.
23. **Bull J J & Vogt R C.** Temperature-dependent sex determination in turtles. *Science* 206:1186-8, 1979.
24. **Bull J J.** Sex determination in reptiles. *Quart. Rev. Biol.* 55:3-21, 1980.
25. **Ferguson M W J & Joanen T.** Temperature of egg incubation determines sex in *Alligator-Mississippiensis. Nature* 296:850-3, 1982.
26. **Vogt R C & Bull J J.** Ecology of hatchling sex ratio in map turtles. *Ecology* 65:582-7, 1984.
27. **Pritchard P C H.** The conservation of sea turtles: practices and problems. *Amer. Zool.* 20:609-17, 1980.
28. **Fritts T H.** Plastic bags in the intestinal tracts of leatherback marine turtles. *Herpetol. Rev.* 13:72-3, 1982.
29. **McKim J M & Johnson K L.** Polychlorinated biphenyls and p,p'-DDE in loggerhead and green postyearling Atlantic sea turtles. *Bull. Environ. Contam. Toxicol.* 31:53-60, 1983.
30. **Owens D W, Grassman M A & Hendrickson J R.** The imprinting hypothesis and sea turtle reproduction. *Herpetologica* 38:124-35, 1982.
31. **Beard J.** Archie Carr strives to make the world safer for sea turtles. *Sci. Dig.* 92(8):17, 1984.
32. **Packard M J, Packard G C & Boardman T J.** Structure of eggshells and water relations of reptilian eggs. *Herpetologica* 38:136-55, 1982.
33. **Ernst C H & Barbour R W.** *Turtles of the United States.* Lexington, KY: University Press of Kentucky, 1972. 347 p.
34. **Lutz P L.** Personal communication. 28 July 1986.
35. **Lutz P L, Rosenthal M & Sick T J.** Living without oxygen: turtle brain as a model of anaerobic metabolism. *Mol. Physiol.* 8:411-25, 1985.