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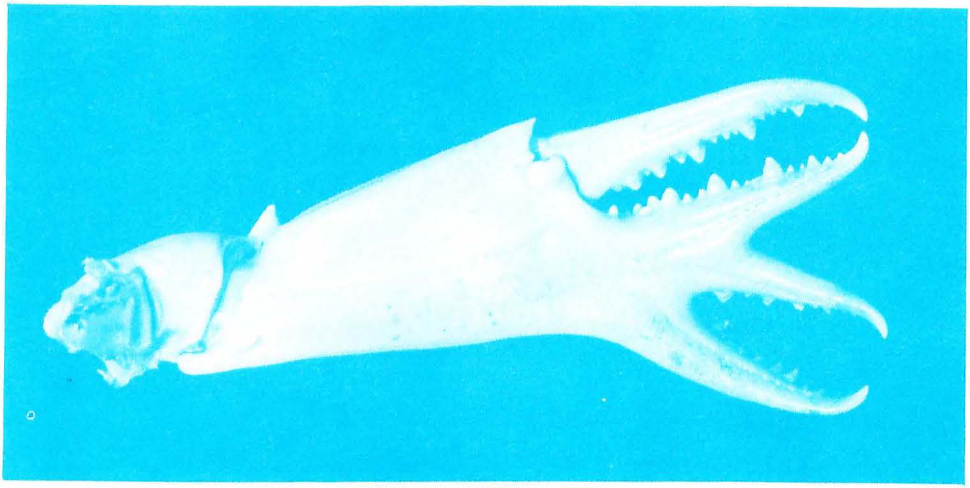

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A COMMENTARY ON

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Throughout history mankind has probably reacted to all natural phenomena by some degree of either attraction or repulsion. Certainly the same objects or phenomena are not viewed exactly alike by all. The rhythmic, as contrasted with discordant, motion, or symmetrical verus non-symmetrical patterns of structure may elicit various feelings in different people. Since natural growth generally produces structural patterns which follow some type of symmetry, this is what we usually expect. While sluggish motion and radial symmetry often are associated, usually animals which dart about or are quick in action have evolved along lines of bilateral symmetry, as have fishes and crabs. Any deviation from recognized actions and structural patterns is certain to attract one's attention. In contrast to a fish and other bilaterally symmetrical animals, including most crustaceans, the crab darts sideways, not along its axis of symmetry. In this study we have been attracted to deviations from symmetry in the external structure of crab claws.

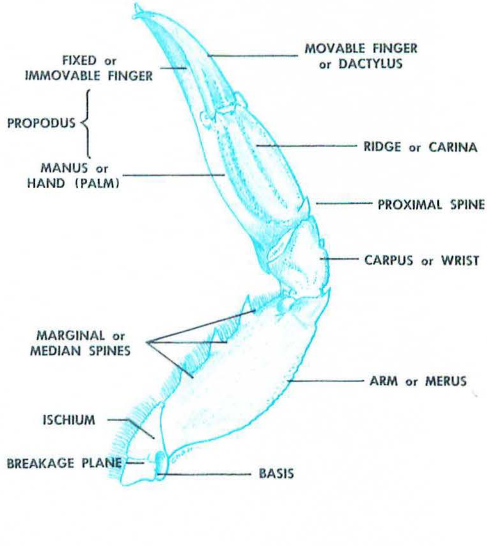
Structure of Normal Chelipeds

The huge pincer-bearing chelipeds of the Blue Crab are homologous to the first pair of walking legs in the more primitive crustaceans. These modified legs no longer serve primarily for locomotion but are flexed in front of the crab and are capable of quick forward extension or a diagonally upward motion to either fend off enemies or grasp food. These legs have the same segments and joints characteristic of other similar crustaceans, as lobsters, crayfish, and other crabs. The parts are variously named as shown in the accompanying illustration.

Normal Regeneration of Appendages

Blue Crabs, as do other crabs, have the ability to shed injured legs and claws. This ability, which enables them to

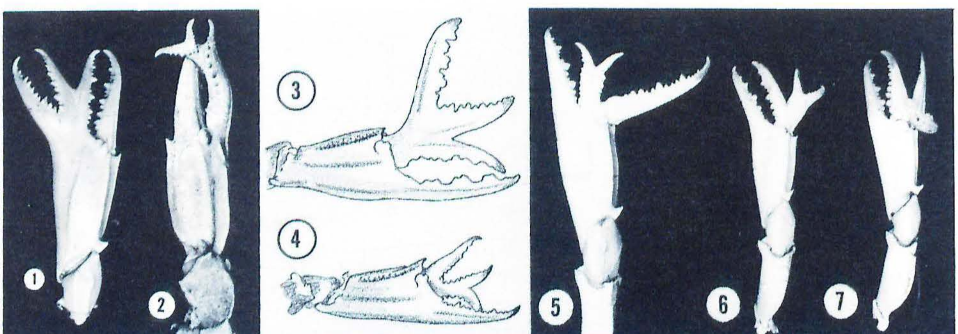
UPPER SURFACE OF RIGHT CHELIPED



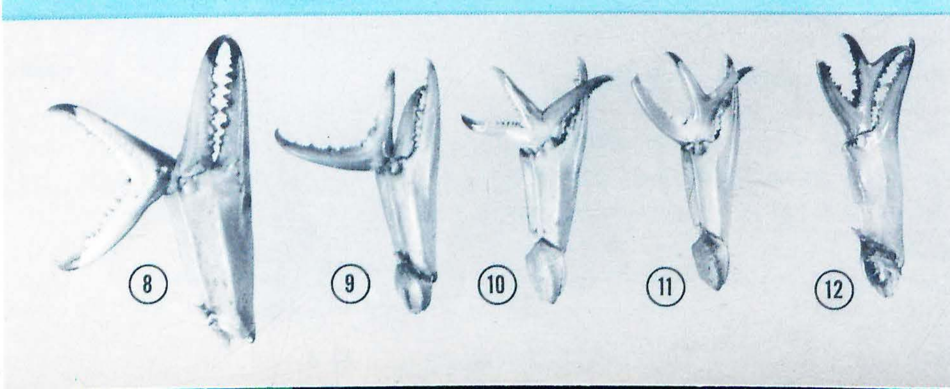
escape when trapped or held by one or more of their appendages is called autotomy. Severance of the appendage occurs at a preformed fracture plane and is initiated by a reflex in the crab's nervous system. The reflex may be stimulated by chemical or physical shock, from the force of a pull, or by the crab itself. If a leg is held firmly near its base, restricting the mobility of the crab, the crab is less able to drop the leg than if it can move freely. Extreme bending of the leg and continued contraction of muscles causes breakage at the performed breakage area. After autotomy a membrane quickly closes the wound and becomes the capsule of the limb bud in which the new appendage is doubled up within a protective covering during regeneration. It is known that regeneration is more rapid at the fracture plane than elsewhere on the limb, which may be due to the negligible loss of blood from wounds at the fracture plane. The ability to regenerate appendages varies among species of crustaceans and is controlled by the nervous system and by external environmental factors, as light and temperature.

Claw Deformities

Because deformities of Blue Crab claws are often so bizarre, and because so many crabs are handled commercially, abnormalities usually are noticed and preserved for display. Over the years we have observed or have been shown a number of these crab claw deformities. This has resulted in what is possibly the largest collection ever made of these deformities of the Blue Crab. Several of these unusual growths are shown here. Interpretations of their origins, as well as suggestions for experimentally induced deformities, are presented here also.



This series shows many variations in deformity involving the movable finger. Only the claw numbered (1) shows involvement of the fixed finger.

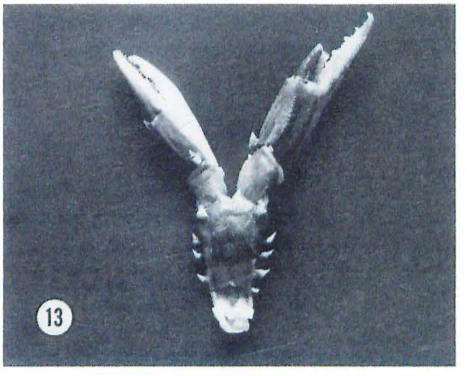


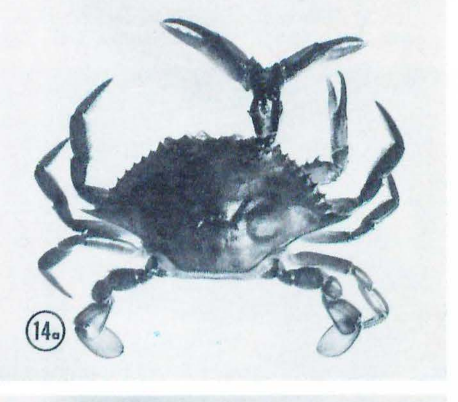
Types of Deformities

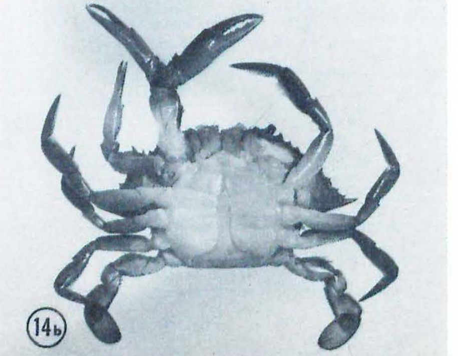
Most prominent among structural deformities are those involving duplication of parts and malformations which occur during molting. We have seen many cases involving a simple duplication of the fingers. These duplications usually produce a two-branched form of abnormality with the additional structures developing in the same plane as the normal fingers or at right angles to them. Thus, these deformities are vertical (same plane) or horizontal (at right angles) to the original pincers. Most of the deformities involve the movable finger, as shown here (as specimens 2 through 12), fewer involve the fixed finger (specimens 1, 21, and 29), and cases of double involvement are the least frequent of all (as specimens 13-14, and possibly 17).

Theoretical Considerations

Practically all of the Blue Crab claw deformities which we have seen, or that have been described elsewhere, show a high degree of conformity to a symmetrical pattern. In most instances this is a simple duplication of parts. It has been recognized for some time that deformities of the crustacean exoskeleton occur most frequently on, or are confined to, the large pincer-tipped appendages or chelipeds. Previous writers have reasoned that this is logical since the large claws, as the chief "weapons" of defense and offense, are more likely to be damaged than other parts of the body. We wish to add another observation, which to us is also fundamental — the deformities usually occur on those parts of the body, as the chelipeds, which have the greatest capacity for regeneration. Not only are both observations valid, but they probably are also complementary. Thus, we believe that whenever an injury occurs — and it probably occurs most often to the cheli-

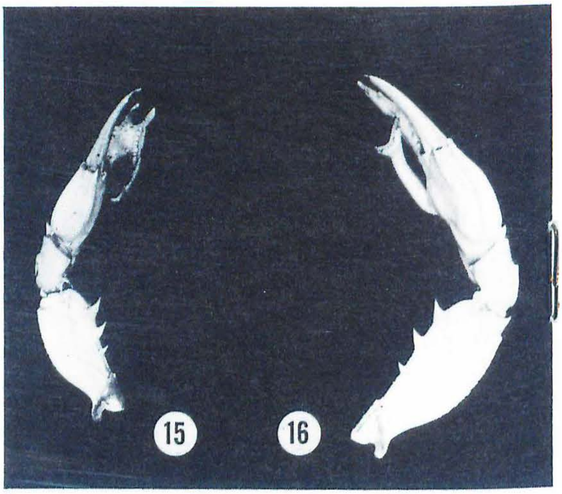






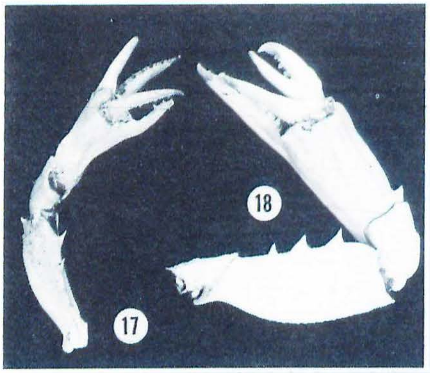
Formation of two complete hands supported by one arm is less common than the other types of deformities we have seen. On claw (13) two wrists are fully formed and the arm is partially doubled; the doubling has formed two sets of marginal spines. Specimen (14) has three functional claws on its right side; this is best seen in the ventral view (b).

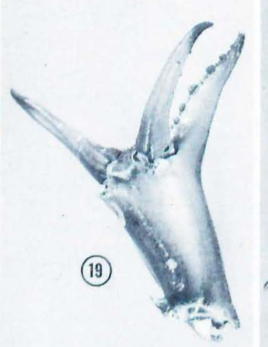
These lateral duplications involved the fixed finger (15) and the inner surface of the hand (16).

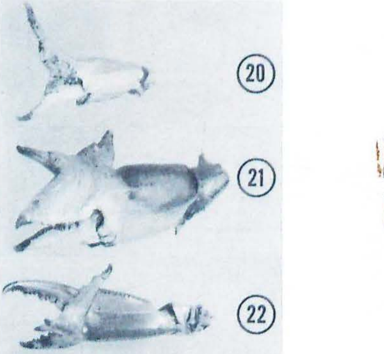


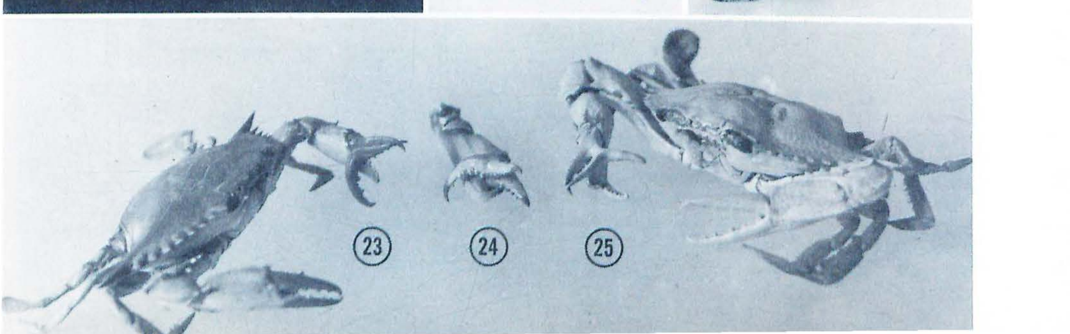
peds — the ability of the cells in that region of the body to regenerate injured or lost tissue may be associated or linked to the genetic mechanism for spine production. It appears that the crab claw has evolved from an ancestral appendage similar to the walking legs, and that the movable finger is homologous with their terminal portion, while the fixed finger of the cheliped is an addition — a greatly enlarged and specialized spine. If we assume it was the evolution of the genetic mechanism governing development of the legs that resulted in claw formation, injury to the claw could create a tendency for the development mechanism to produce a compensatory claw or claw part. If the damaged part has not been lost by autotomy, new growth at the injury site then appears as a duplication. In contrast, a similar injury to any other appendage could result merely in the production of a spine. In any case, the deformities are largely additions to normal claw structure of parts similar to the usual structure.

Some of the more bizarre deformities are shown in this series. In most of these specimens the additional parts are at right angles, that is horizontal, to the original pincers.



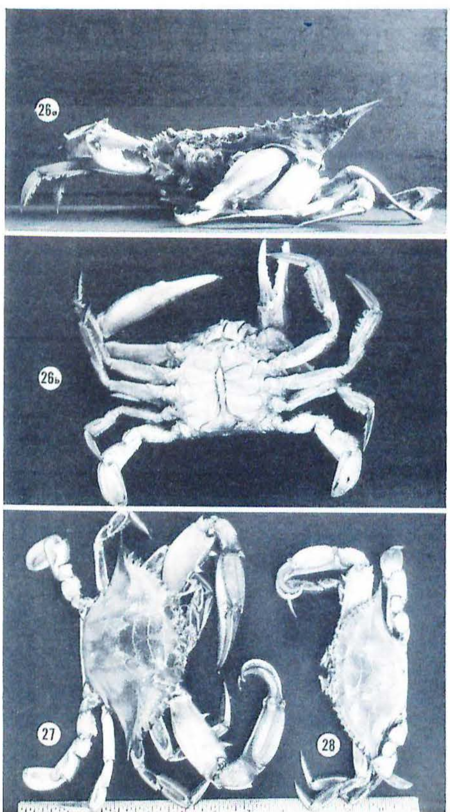






Ability of the Blue Crab and other species to shed an appendage and to replace it later may be a capacity which is linked somhow with the processes that produce deformities. If an injury is inflicted upon a crab while it is in the soft-shell stage immediately after molting, the crab does not, or can not, cast off an appendage. Then, during the healing process duplicate parts are formed. It has been reported that the formation of triple fingers instead of one is due to a special type of injury which produces two wound surfaces and therefore three fragments — the old structure plus two regenerates. This may be so, but it seems more plausible that only one injury site is sufficient to produce the observed duplicated parts. It is also reported that the actual site of injury near the fingers, as well as the depth of the injury, determines what kind of abnormality will develop.

The extent of tissue damage is reflected in a corresponding change in the chemical composition of the tissues and urine. In addition, the rate at which a lost limb is regenerated depends upon the stage of the crab in its intermolt cycle and the number of limbs lost. For these reasons and those discussed earlier, it seems reasonable to theorize that when an injury is confined to the terminal portion of the claw, healing or regeneration of the damaged tissue would be stimulated, *but* the "controlling" mechanism might not be as complete as in other sites on the body, as at the base of the legs for example. This mechanism, which is certainly chemical, involving hormones, could be a function of either secretion or circulation, or possibly both. Then the capacity for production of terminal parts, by dilution or otherwise, would be less well-regulated than for the reproduction of an entire limb, and regenerative processes on a claw tip would tend to produce additional parts and spines. It could be theorized that the impeded mechanism of regeneration that produces extra parts is at the same time related to the growth of both the movable and immovable fingers, a regenerative process that could have been developed during the process of evolution. It is probable that if injury is the usual cause of deformities, especially those manifest as duplicated parts or pseudo-parts, the injury must occur while the exoskeleton is soft.



Deformity of the claws may also occur during molting. In specimen (26) the left cheliped was apparently forced up and backward into the gill chamber when the crab was in the soft shell stage. Crabs (27) and (28) show the curved fingers which we believe result when withdrawal of the cheliped from the cast is not completed until after the new exoskeleton begins to harden.

Some Ideas on Experimentation

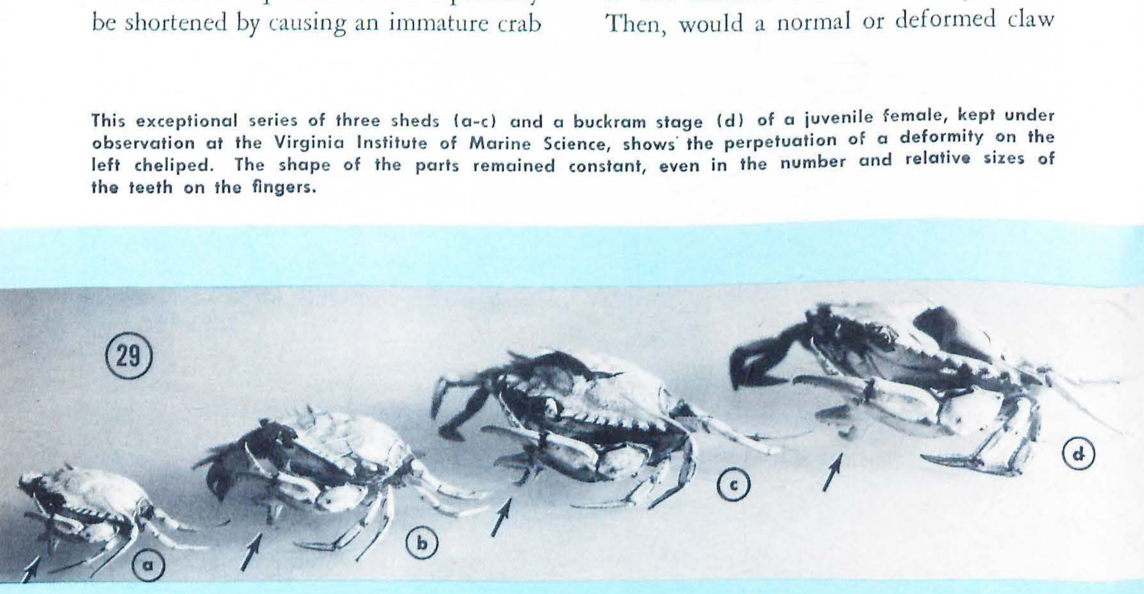
Depending upon the level of the experimenter's training and the quality and use of available equipment, seeking the cause of the claw abnormalities could be the basis for a Science Fair project or a doctoral dissertation. It would make an ideal summer-time project for students who live along the coast.

Experimentation should be done on immature crabs. We suggest using specimens 3 to 6 centimeters wide (about 1¼ to 2½ inches wide) since the time interval between growth stages or instars is shorter in the younger animals. Animals in the immediate premolt or actual molting process should be put into aquaria. Then, while they are in the soft shell stage, one of several kinds of mechanical injury should be made to see if malformation can be induced. Pressure over a broad area, pinching, abrasion, laceration, and injection of the claws are some of the ways to achieve this. Then a crab must be kept alive and fed until it molts again. Of course this procedure could probably be shortened by causing an immature crab to drop one of its chelipeds. When regeneration of the cheliped occurs, a mechanical injury could be inflicted upon the soft, developing appendage.

Well-aerated seawater of about the same salt concentration as that from which the crabs are taken is sufficient. The temperature should be kept below 25 degrees Centigrade (77 degrees Fahrenheit), and the water continuously filtered. Crabs are carnivorous and can be cannibalistic, so it is best to keep them in solitary confinement. Uneaten food should be removed from the aquaria to prevent fouling of the water.

Although the claw malformations could be due solely to genetic causes, it appears most sensible to first check upon the effect of mechanical injuries. If our hunch proves to be correct, some of the experimentally injured specimens will have the deformities which form under natural conditions. It would be of interest to learn if an experimentally-induced deformity would continue beyond a single growth stage, since abnormalities persist if the afflicted crab successfully sheds. Then, would a normal or deformed claw

This exceptional series of three sheds (a-c) and a buckram stage (d) of a juvenile female, kept under observation at the Virginia Institute of Marine Science, shows the perpetuation of a deformity on the left cheliped. The shape of the parts remained constant, even in the number and relative sizes of the teeth on the fingers.



be regenerated if a crab in which an abnormality persisted for several growth stages autotomized its deformed appendage? Perhaps the percentage of successful molting of malformed specimens may be less than normal, particularly if the abnormal part prevents the crab from withdrawing from its old shell, Thus, the whole subject poses challenges; who will be the first to successfully demonstrate the cause or causes of such malformations as described in this article? The discovery may confirm our theory or it may require a different explanation. In either case, it is certain we shall know more about the regeneration process as well as crab claw abnormalities!

Notes on the Specimens

Specimens 5-7, 13, 15-18, and 26-28 in the foregoing article were assembled and arranged by one of the authors, Dr. David H. B. Ulmer, Jr. They are owned by him and Mr. Norris Tawes who also photographed them.

The crabs and claws number 8-12, 14, 19-25, and 29 were donated to the Virginia Institute of Marine Science, Gloucester Point, Virginia, by numerous Virginia watermen, and are part of a collection of crustaceans maintained by Willard A. Van Engel. Photographs of these specimens were made by Robert S. Bailey of the Virginia Institute of Marine Science.

Unless otherwise noted all measurements give the carapace width of the crabs, between the tips of the large lateral spines. Information on each of the specimens figured is given below, according to the number given on the illustrations.

(1) Part of left cheliped from a crab probably slightly over 6" in width. Specimen presented by Colonel Vincent J. Esposito to Mr. Robert Shevock, science teacher and biologist at Milford High School, Delaware. Recipient of a National Science Foundation Teacher Research Participation Fellowship during the summer of 1961, Mr. Shevock was a member of the University of Delaware Marine Laboratories staff during the summer of 1962.

(2) Right cheliped from a specimen probably over 6¾" wide; from Chesapeake Bay, presented by Mr. Vickers to the U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries Biological Laboratory, Oxford, Maryland, (courtesy of Mr. James B. Engle, Director).

(3) Left chela from a large crab caught in Kingston Harbour, Jamaica, March 1953. (redrawn from A. Fontaine. 1953. A monstrous crab claw. *Natural History Notes, Natural History Society of Jamaica,* No. 59:187).

(4) Left chela from a Chesapeake Bay crab (redrawn from W. Faxon. 1881. On some crustacean deformities. *Bulletin, Museum of Comparative Zoology, Harvard,* Vol. 8, No. 13, Pages 257-274, 2 plates).

(5) Doubling which is equilateral but slightly reduced at the base of the inner surface of the hinged dactylopodite. Left claw from a male crab approximately 7 inches; taken from Tangier Sound, near Crisfield, Maryland. Owned by Mr. Tawes.

(6) A much reduced, non-functional claw which formed on the upper surface of the hinged dactylopodite, near its base. Left claw from a female crab approximately 6 inches; taken from the Gulf of Mexico near mouth of Suwannee River — presented to Dr. Ulmer by Roy Tebo of Cedar Key Seafood, Florida.

(7) A truly equilateral but distorted and non-functional chela on the upper surface right at the hinged base. Left claw from a female crab approximately 6 inches; taken from Tangier Sound — presented to Dr. Ulmer by Charles Howard of the Milbourne Oyster Company, Crisfield.

(8-12) Five specimens showing symmetrical, non-functional variations in the movable finger. Specimen 12 is from a left cheliped, the others from right chelipeds.

(13) This is a rare specimen showing nearly complete doubling, with two functional claws. The dactylus, propodus, and carpus are all duplicated as is the merus, although the latter is fused throughout its length. Note the three spines which normally occur only on the forward edge of the meropodite are duplicated on the rear edge. The claw to the right in the photograph was in the normal position while that to the left which is slightly smaller is a mirror image and faced the walking legs. This came from a soft crab. It is the left claw from a male crab of about 6 inches; caught in the vicinity of Crisfield, presented to Mr. Tawes by Stanley Sterling, a seafood packer.

(14) These are dorsal (a) and ventral (b) views of a soft crab showing an exceptionally unusual symmetrical duplication of functional chelae. The crab has three functional pincer-claws on the right side of the body. The first, proximal segment of this structure is a fused pair of coxae. A normally-shaped cheliped originates from the right side of this fused pair. Originating from the other member of the pair of coxae is another pair of chelipeds, mirror-image twins fused from bases through carpi, and then separating into two chelae.

(15) Lateral budding of reflexed dummy dactyli (pincers) on the inner surface of the functional propodite finger. Left claw from a female crab approximately 6 inches; taken from Tangier Sound — presented by a waterman to Mr. Tawes.

(16) Lateral budding of a non-functional miniature dummy claw, from about midway along the inner surface of the propodite. Right claw of a male crab approximately 6½ inches; taken from Tangier Sound near Crisfield — presented to Dr. Ulmer by Charles Howard of the Milbourne Oyster Company, Crisfield.

(17) Doubling of the entire proximal end of the propodite, including, although distorted, 2 propodite fingers and 2 functional (movable) dactylopodites (dactyli). Left claw from a male crab approximately 6½ inches; taken from Tangier Sound near Crisfield — presented by waterman to Mr. Tawes.

(18) Horizontal doubling from the dactylopodite only. A complete but non-functional unit has developed laterally outward from the hinged base. All three fingers are distorted and slightly reduced. Right claw from a very large male crab, over 8 inches; taken from the Indian River, Florida — presented to Dr. Ulmer by Mr. Herbert Sockwell of Vero Beach, Florida.

(19) This specimen shows symmetrical duplication of a functional movable finger and is unusual on that account and in not having an extra fixed finger.

(20-22) These three specimens show deformities of the fixed finger. Specimens 20 and 21 are unusual in having asymmetrical distortions, suggesting an uncommon type of injury or method of regeneration. The movable finger of the specimen 22 has a similar deformity. Extra parts on the specimen at the left are at right angles to the normal plane of the chela.

(23-25) Distortion of the movable finger, at right angles to the normal plane.

(26) Three-quarters and ventral views of a 7-inch male crab which has the left cheliped doubled up upon itself and thrust up under the carapace into the gill chamber. This distorted the left side of the carapace which is bent upward sharply forming a crease on the back surface. This crab was a male buckram (a crab recently hardened after shedding). It was very much alive when presented to Dr. Ulmer by Mr. Charles Howard of the Milbourne Oyster Company, Crisfield. Specimen came from Tangier Sound.

(27-28) Crabs with curved fingers on the right cheliped believed to have resulted from hardening of the exoskeletons before the crabs were able to fully remove their chelipeds from their casts: (27) A 7-inch male. (28) A 6-inch male crab.

(29) Sheds of a juvenile female with a pair of non-functional fingers arising from the base of the fixed finger of the left cheliped. The crab was kept alive in the laboratory and shed

three times (a-c) but died a juvenile in the buckram state (d), after the third shedding. The shape of the non-functional parts remained unchanged, even in the number and relative sizes of the teeth in each shed. Sizes of the crab are 2-1/2 inches (63 mm), 3-1/4 inches (82 mm), 4-1/8 inches (105 mm), and 4-7/8 inches (124 mm).

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Editor's Note

Dr. Carl N. Shuster, Jr., formerly director of the University of Delaware Marine Laboratories, recently was appointed director of the Northeast Shellfish Sanitation Research Center, Public Health Service, Kingston, Rhode Island.

Dr. David H. B. Ulmer, Jr. is a Research Associate Professor at the Seafood Processing Laboratory, Crisfield, Maryland, a unit of the University of Maryland's Natural Resources Institute. He received both the Baccalaureate and the Doctor of Philosophy degree from Duke University. A student of marine organisms and their ecology, he is also a specialist in microbiological and physical aspects of seafood processing, particularly of shellfish.

Mr. Norris "Scorchy" Tawes is a lifetime resident of Crisfield. For several years he operated a well-known restaurant bearing his name. It was there he exhibited all sorts of bizarre and unusual marine objects, including the deformed crab claws. He is now manager of Somers Cove Marina, at Crisfield, one of the most modern and attractive marinas on the Eastern Shore.

Mr. Willard A. Van Engel is a Senior Marine Scientist at the Virginia Institute of Marine Science, Gloucester Point, Virginia, where he is head of the Department of Crustaceology. His chief interest is in the life histories of Chesapeake Bay crustaceans and he is considered the leading authority on the ecology and dynamics of populations of the Blue Crab.

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