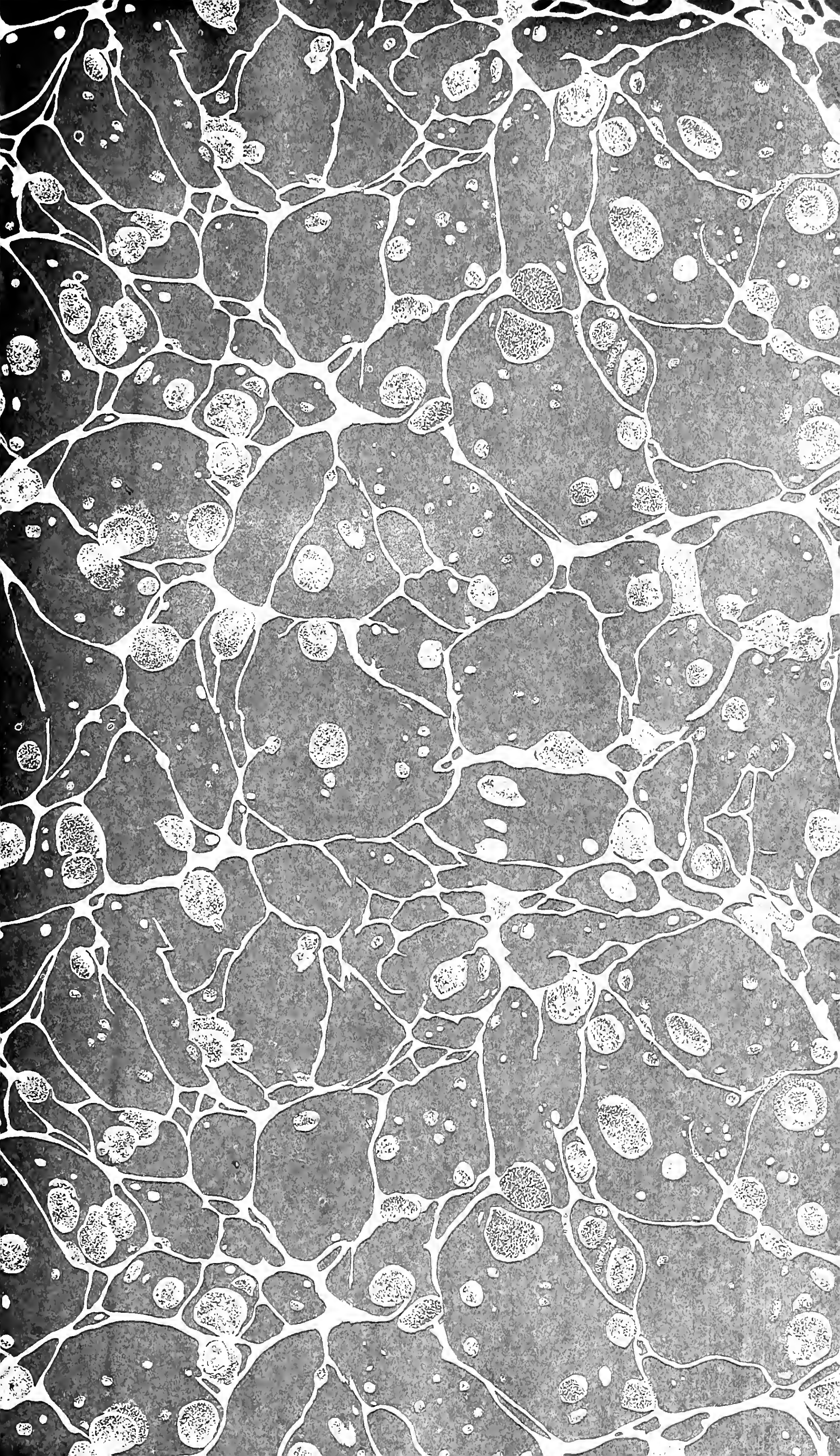


4

SMITHSONIAN

MISCELLANEOUS COLLECTIONS

VOL. 92

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

(PUBLICATION 3332)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1935

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

ADVERTISEMENT

The present series, entitled "Smithsonian Miscellaneous Collections," is intended to embrace all the octavo publications of the Institution, except the Annual Report. Its scope is not limited, and the volumes thus far issued relate to nearly every branch of science. Among these various subjects zoology, bibliography, geology, mineralogy, anthropology, and astrophysics have predominated.

The Institution also publishes a quarto series entitled "Smithsonian Contributions to Knowledge." It consists of memoirs based on extended original investigations, which have resulted in important additions to knowledge.

C. G. ABBOT,
Secretary of the Smithsonian Institution.

CONTENTS

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 1

THE HYPOTROCHANTERIC FOSSA OF THE FEMUR

(WITH 14 PLATES)

BY
ALEŠ HRDLIČKA
Curator, Division of Physical Anthropology,
U.S. National Museum

(PUBLICATION 3250)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 4, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE HYPOTROCHANTERIC FOSSA OF THE FEMUR

By ALEŠ HRDLIČKA

Curator, Division of Physical Anthropology, U.S. National Museum

(With 14 Plates)

CONTENTS

EARLIER DATA ON THE FOSSA

Under the name of "la fosse hypotrochantérienne", Emile Houzé[1] in 1883 described a hollow located in the superior posterior and ex-

[1] Houzé, E., Sur la présence du troisième trochanter chez l'homme. Bull. Soc. Anthrop. Bruxelles, vol. 2, pp. 21-52, 1883-84.

ternal part of the femoral diaphysis and running parallel to the long axis of the same.[2] The borders of this hollow, as well as the rough surface of its floor, served, he thought, for the attachment of the terminal fibers of the great gluteal muscle.[3] The fossa, he said further, may exist alone or be associated with a third trochanter. He found it to be "a constant character" of the femora of the upper paleolithic of Furfooz, Belgium, and frequent in those of similar age of France; but it was less frequent in the neolithic age, and "positively rare in pronounced form in modern man."[4] The data of Houzé (imperfectly summed up later by Pearson and Bell[5]), were as follows:

	Femora examined (341)	With hypotrochanteric fossa Percent
Early man: Furfooz	20	*100.–*
Grenelle	21	*57.–*
Cro-Magnon	2	(100)
Madeleine	1	(100)
Neolithic of Belgium and France	110	*44.–*
Merovingian	30	*23.–*
Modern, Bruxelles	67	*10.5*
Modern, Bruxelles: 10 male	10	......
10 female	10	......
Canary Islanders	16	*18.7*
Asiatic, miscellaneous	11	(*18.–*)
African Negro	18	*6.–*
South American Indian	5	......
Oceanians and Australian	5	(*20.–*)

From this evidence Houzé concluded that the fossa was materially more frequent in earlier man and diminished in frequency of occurrence toward the present; and he was further of the opinion that "the fossa enlarged considerably the transverse diameter of the diaphysis, and that the enlargement was realized at the expense of the antero-posterior diameter"—in other words, that it increased the

[2] "Une cavité creusée dans le sens de l'axe diaphysaire et située à la partie supérieure, postérieure et externe de la diaphyse, ..."

[3] "Les bords de la fosse hypotrochantérienne servent, ainsi que la surface rugueuse de son fond, aux fibres terminales du grand fessier." (P. 41.)

[4] "La fosse hypotrochantérienne est un caractère constant de tous les fémurs de l'âge du Rene en Belgique; ce caractère relie les Troglodytes de Furfooz aux homme de Grenelle, qui leur sont déjà apparentés par le crâne, la taille et la perforation olécranienne. . . . .

"La fosse hypotrochantérienne très accusée, mais moins fréquente à l'âge de la pierre polie, devient positivement rare à l'époque moderne." (P. 43.)

[5] Pearson, K., and Bell, J., A study of the long bones of the English skeleton. Part 1, The femur. Drapers' Co. Research Mem., biometric ser., vol. 10, p. 68. London, 1919.

flattening, or, as it was called later, the platymery, of the proximal portion of the shaft.

In 1886 Von Török, in a study devoted more especially to the third trochanter, reported that he had found a hypotrochanteric fossa in 23 of 76 (30.2 percent) male femora of Hungary ranging from bronze-age to recent, but in only 2 of 32 (6.2 percent) female bones of the same derivation. He regarded the fossa as one of the three structural variants—the other two being the gluteal ridge and the third trochanter—serving for the attachment of the gluteus maximus;[6] and he believed it would show, as did the third trochanter, considerable differences in different human groups.

In 1889[7] Testut reports the presence of the hypotrochanteric fossa in the Chancelade femur and recalls that the fossa existed also in one of the Cro-Magnon femora and in one of Madeleine. There is no discussion, but the following quotation shows that in Testut's opinion the fossa in the Chancelade femur served for the insertion of a powerful gluteus maximus: " véritable *fosse hypotrochantérienne* (Houzé) dont le fond, hérissé de rugosités, donnait insertion à un grand fessier certainement plus développé que dans nos races modernes."

In 1890 the hypotrochanteric fossa received further consideration by the Italian author Costa.[8] He regarded the fossa together with the third trochanter and the gluteal ridge, as abnormalities of regressive or atavistic nature, as signs of inferiority,[9] and as features that might throw light on human phylogeny.

[6] " Das sind nun die drei Ansatzformen des grossen Gesässmuskels." Anat. Anz. Centralbl., Jahrg. 1, no. 6, p. 177, Aug. 15, 1886.

[7] Testut, L., Recherches anthropologiques sur le squelette quaternaire de Chancelade (Dordogne). Bull. Soc. Anthrop. Lyon, vol. 8, pp. 202-203, 1889.

[8] Costa, Pietro, Il terzo trocantere, la fossa ipotrocanterica, la cresta ipotrocanterica nel femore dell'Uomo. Arch. Antrop. Etnol., Firenze, vol. 20, pp. 269-304. 1890.

[9] " Evidentemente dunque il terzo trocantere e con lui la fossa ipotrocanterica e la cresta, sono caratteri di inferiorità, e il trovarli nel femore dell'uomo moderno non è altro che un indizio di regresso, di ritorno all' antico." (P. 297.)

" Questi i resultati, che c'indicano come assuma il terzo trocantere nei criminali talora proporzioni esagerate: e questo fatto mi sembra sia sempre più in appoggio sul considerare il terzo trocantere e naturalmente con lui la fossa e la cresta che spesso vi s'associano, come segni di regresso, di inferiorità, come signi di atavismo." (P. 299.)

" Dunque il terzo trocantere, la fossa ipotrocanterica e la cresta sottotrocanterica sono disposizioni anormali del femore, e desse perciò come tutte le disposizioni anormali che appaiono sporadicamente come ricordi del passato, sono (dice Duchenne) altrettanti materiali che possono essere utilizzati per servire a stabilire le origini antiche del gruppo umano." (P. 300.)

Costa's observations on the frequency of the fossa were as follows:

	Femora examined	With hypotrochanteric fossa	Percent
Europeans	102	30	29.4
Asiatics	6	4	66.7
Africans	12	6	50.0
Australians	2	1	....
Americans (probably Indians)....	14	11	78.6
Fuegians	37	37	100.–

A year after (1891) Bertaux,[10] in his thesis on the humerus and the femur, gives also attention to the hypotrochanteric fossa. By this name, he says (p. 159). is designated "an elliptic hollow that occasionally appears on the human femur and is located on the superior posterior and external part of the diaphysis. This fossa gives insertion to the gluteus maximus. . . . . The frequency of this skeletal feature is very variable".[11] He finds it once only in 47 "determined" French femora; in 38 percent of the Guanches; in the same proportion in the Orrouy femora; in 3 out of 34 (8.8 percent) femora of divers Negroes; twice in four Californians; and in 23 percent of the anthropoids examined. Bertaux is the first to observe the fossa in the anthropoid apes. He suggests that it may present racial differences, but his data on the anthropoid as well as on the human material, owing to lack of clearness as to just what the proportions apply to (femora or skeletons), are unsatisfactory.

The same year (1891) Hyades and Deniker[12] report having found the fossa, alone or in association with a third trochanter, in 13 out of 29 Fuegian femora (44.8 percent). In general, the fossa was less marked than the tuberosity. They illustrate both the fossa and the third trochanter on the femur of a Fuegian girl of eight. They do not discuss the meaning of the fossa.

Manouvrier[13] and Ludewig, in their studies on the femur, both touched more or less on the subtrochanteric fossa but added no

[10] Bertaux, A., L'humérus et le fémur considérés dans les espèces, dans les races humaines, selon le sexe et selon l'age, Paris, Lille, 1891.

[11] "Sous le nom de fosse hypotrochantérienne, on désigne une fossette elliptique qui se présente exceptionellement sur le fémur de l'homme et siège à la partie supérieure, postérieure et externe de la diaphyse. Cette fosse donne insertion au muscle grand fessier. . . . .

"La fréquence de ce caractère squelettique est très variable." (P. 159.)

[12] Hyades, P., and Deniker, J., Mission scientifique du Cap Horn, 1882-1883, vol. 7. Anthropologie, Ethnographie, Paris, 1891.

[13] Manouvrier, L., La platymérie. 10th Sess. Cong. Intern. Anthrop. and Archéol. préhist., [1889] pp. 363-81, 1891; Etude sur les variations morpho-

original data. Ludewig,[14] who failed to find it on the femora of his own preparations, uses the term " subtrochanteric " for hypotrochanteric, which for the sake of euphony would seem preferable.

In 1893 Rudolf Martin[15] reported the presence of the hypotrochanteric fossa in all his five Alakalauf (Fuegian) femora and expresses, doubtless after Houzé, the opinion that the hollow stands in a causative relation to the lateral protrusion and the flattening of the upper part of the shaft.

In 1894 appeared a noteworthy study of the femur by Evangeli-Tramond.[16] He reported finding the hypotrochanteric fossa " in nearly all the neolithic femora of the Crois des Cosaques, Nanteuil-le-Harduin and Copierres-sur-Ept ". He was the first to report the feature according to its grades. In 120 modern French bones of known sex it was represented thus:

	60 male femora, percent	60 female femora, percent
Fossa: very plain	(2) 3.3	(1) 1.7
fairly plain	(6) 10.–	(7) 11.7
trace	(21) 35.–	(14) 23.3
All	(29) 48.3	(22) 36.7

Evangeli-Tramond was also the first to observe that the fossa " is better defined in femora, the epiphyses of which are formed but not yet attached, than in those of adults ". This statement was quoted in subsequent editions of Testut's " Traité d'Anatomie " and was noticed also by Klaatsch (q. v.), but undeservedly has received no further attention. The original observation on this point reads thus (pp. 55-56):

To the present we have noted the existence of the hypotrochanteric fossa in only the femora of the adults. However, since our examination of the prehistoric femora we have been struck by the fact that the fossa appeared more or less clearly according to the age of the subjects. Sufficiently well marked and relatively frequent on young femora with their epiphyses still cartilaginous, it became the more accentuated the nearer the bones approached the age of adolescence, when the epiphyses were already formed but not yet attached, while it became scarcer and above all less well defined in aged femora.

This evolution appeared interesting to me and I wished to compare it with that of modern femora. Having at my disposition a large number of skeletons

logiques du corps du fémur dans l'espèce humaine. Bull. Soc. Anthrop. Paris, vol. 4, pp. 111-114, 1893.

[14] Ludewig, W., Monographie des menschlichen Oberschenkelbeins. Inaug.-Diss., pp. 17, 18. Berlin, 1893.

[15] Martin, R., Zur physischen Anthropologie der Feuerländer. Arch. Anthrop., vol. 22, p. 195, 1894.

[16] Evangeli-Tramond, A., Quelques particularités sur le fémur. Paris, 1894.

of all ages, I divided them into three groups, considering in the first the skeletons of fetuses, in the second infants, in the third adolescents. I encountered it [the fossa] only exceptionally in the first two groups, while in the third group, comprising 18 femurs with epiphyses not attached, but well formed, I found it 12 times perfectly clear, deep, well defined, and 4 times less well marked. In two femora there were only traces of the fossa. I cannot state here the percentages, as the number of femora examined is too small, but this frequency is very significant and permits the consideration of this fossa as best developed about the ages of 18 to 20 years.

Evangeli-Tramond made further interesting original observations on the fossa, which also remained unknown to, or have been forgotten by, subsequent authors. He described its different forms at different ages. A mere finely grained although quite distinct impression in infancy, it deepens and assumes elliptical form as age advances. In adolescence, when fully developed, it may reach 4 to 5 centimeters in length, 1 centimeter in breadth, and several millimeters in depth. Later on, after the epiphyses have become attached, in some of the femora he saw developed within the fossa bony tubercles, which eventually would occupy the internal half of the depression; but sometimes the fossa disappeared entirely as a result of invasion by these rugosities.

Curious as to how the fossa was formed, Evangeli-Tramond dissected six subjects. In three of these (the remainder were without the fossa) he was able to ascertain that the gluteus maximus inserted only in the gluteal ridge, and that the external border of the fossa with the adjoining smooth part of the bone gave insertion to fleshy fibers of the vastus externus—the fossa being found between the two. Where the gluteus is not voluminous the fossa remains well defined; when the gluteus is large, however, its insertion will encroach on the fossa and may even invade this entirely, so that between the tendon of this muscle and the fibers of the vastus there will no longer be any space or any depression.[17]

---

[17] "Comment se forme cette fossette? J'ai disséqué six sujets afin de voir quels rapports avaient entre elles les parties charnues et les surfaces osseuses. Trois de ces sujets ne m'ont rien révélé, car aucun d'eux ne présentait trace de gouttière. Sur les trois autres cependant j'ai constaté que sur la ligne des rugosités, et seulement sur elle, s'insérait le gros tendon du muscle grand fessier, que sur la partie moyenne lisse, et la lèvre qui constitue le bord externe de la fosse, s'inséraient des fibres charnues allant au vaste externe.

"C'est entre ces deux chefs d'insertion tendineux et charnus que se trouve la fossette hypotrochantérienne. Si le tendon du muscle grand fessier est peu volumineux, et si la lèvre externe est très saillante, la dépression restera très nette. Si le muscle grand fessier est surmené, son insertion empiètera sur le territoire de la fossette et pourra même l'envahir tout entier, si bien qu'entre

This led Evangeli-Tramond to the conclusion that the fossa was probably due to an excess of muscular activity at that locality.

This talented worker also gave attention to the possible connection of the fossa with platymery and arrived at the conclusion that even if the two characters "are in no way dependent, at least the more or less accentuated platymery permits the hypotrochanteric fossa to become developed proportionately".

In 1895 Lehmann-Nitsche, in his well-known work on the long bones from the row-graves of Bavaria,[18] although not occupying himself especially with the fossa, found it in frequent (80 to 88.2 percent) association with the subtrochanteric lip and was inclined to regard it as standing in a causative relation to the lateral protrusion and the flattening of the subtrochanteric region. Of 62 femora of his Swabians and Alemans the fossa was present in 23 (37.1 percent). In accordance with the views of previous authors he regarded the fossa, the third trochanter, and the gluteal ridge as merely "die einzelnen Formen des Insertionsstelle" of the gluteus maximus (p. 41).

Another study on the human and also the anthropoid femur, in which the hypotrochanteric fossa is considered, was published in 1899 by Bumüller.[19] Of 407 modern and presumably German femora, he found the fossa alone or in combination with the gluteal ridge or third trochanter, in 200, or 49.1 percent.

Bumüller, however, no longer regarded the fossa as merely one of the bony variants formed by or for the insertion of the gluteus maximus; it "was unjustly attributed hitherto to the gluteus" (p. 54). The action of this muscle is not conducive to the formation of such a hollow. It cannot be assumed that the same muscle, on the same bone, would possess two such wholly different forms of bony formation for its insertion as the ridge and the fossa. With such an assumption, moreover, it would be hard to understand why the

---

les fibres charnues du vaste externe et le tendon du grand fessier il n'y aura plus d'intervalle, partant plus de fossette." (Pp. 57, 58.)

I may state, in this connection, that as Evangeli-Tramond's thesis was not found in libraries in Washington, it did not become accessible to me until after the present work and even the manuscript were completed; so that all the results to be found in this memoir were arrived at independently.

[18] Lehmann-Nitsche, R., Beiträge zur physischen Anthropologie der Bajuvaren: III. Untersuchungen über die langen Knochen der südbayerischen Reihengräberbevölkerung. Beitr. Anthrop. Urgesch. Bayerns, München, vol. 11, nos. 3 and 4, 1894-95.

[19] Bumüller, J., Das menschliche Femur nebst Beiträgen zur Kenntnis der Affenfemora. Munich (Inaug.-Diss.), 1899.

fossa is always located laterally to, or at most underneath, the gluteal ridge, but never mesially or superiorly.

Bumüller attributed the fossa to the insertion of the vastus lateralis; and he held, as did Houzé, that there was a direct connection between the fossa and platymery.[20]

An especially interesting study on the femur in which the hypotrochanteric fossa receives attention appeared in 1900 in Paul-Bon-

---

[20] It will be useful, I think, to cite his exact words in these connections.

"Ich habe schon oben gezeigt, dass crista und fossa vielfach mit Platymerie zusammenhängen, indem bei letzterer die laterale Fläche verkleinert wird. Dieselbe Bedeutung wie diese Verkleinerung hat eine relativ sehr mächtige Muskelentwickelung. In beiden Fällen muss die zu geringe Ansatzfläche vergrössert werden. Dies geschieht durch fossa und crista, besonders ausgiebig durch eine Kombination von fossa und crista. . . . . Hiedurch kann fast eine doppelte Vergrösserung der lateralen Fläche eintreten. Dabei ist aber meines Erachtens nicht nur der M. glutaeus maximum, sondern auch der M. vastus lateralis beteiligt und zwar in folgender Weise. Der Glutaeus zieht so zu sagen die crista aus der Diaphyse heraus und kann so eine mächtige Ansatzstelle erzielen. Der M. vastus lateralis macht sich entweder die durch den Glutaeus geschaffene Vergrösserung zu Nutzen, er partizipiert an der crista oder er ruft neben der crista eine rauhe, mit Höckerchen besetzte, gewöhnlich teilweise etwas vertiefte Ansatzstelle hervor oder er gräbt sich endlich neben der crista in die Diaphyse ein (fossa). Diese fossa wurde wohl mit Unrecht bisher auf den Glutaeus bezogen. Allein es ist doch nicht anzunehmen, dass eine und derselbe Muskel an demselben femur und an derselben Stelle zwei ganz verschiedene Ansatzweisen besitzt. Es wäre bei dieser Annahme auch schwer verständlich, warum die fossa immer auf der lateralen Seite der crista oder höchstens unterhalb der crista sich befindet, niemals aber auf der medialen Seite. Dieses Verhalten entspricht dagegen ganz der Thatsache, dass der Vastus lateralis ausserhalb des Glutaeus inseriert. Manchmal ist die fossa unterhalb der crista und diese selbst nimmt nach oben hin zu. Warum ist, wenn beide Erscheinungen dem Glutaeus ihren Ursprung verdanken, die Aufeinanderfolge nie umgekehrt, die fossa oben und die crista unten? Bei Berücksichtigung des vastus lateralis erklärt sich dieses Verhalten. Infolge grossen Raummangels (oder individueller Variation?) rücken die Ansatzstellen der Muskeln, die neben einander keinen Platz haben, in eine Linie. Der Glutaeus wird seiner Zugrichtung entsprechend etwas nach oben gerückt, der Vastus lateralis, der in entgegengesetzter Weise zur Kniescheibe verläuft, eben dieser Zugrichtung entsprechend nach unten. Deshalb kann niemals die fossa oben, die crista unten sein. Endlich erscheint es geradezu unmöglich, dass der Glutaeus eine fossa hervorbringt. Seine Hauptwirkung auf das femur besteht darin, dass er das gebeugte Bein in die senkrechte Stellung zurückzubringen hat. Dabei hat er die Tendenz, die Diaphyse nach hinten herauszuziehen. Die fossa aber wäre eine dieser Tendenz gerade entgegengesetzter Effekt und deshalb unerklärlich." (P. 54.)

cour's "Skeletal Modifications Following Hemiplegia".[21] The fossa is more frequent on the affected side, and when bilateral, is both larger and deeper in the affected bone (p. 50). The fossa stands in close relation to the different forms of platymery. Its greater frequency and development on the diseased side are due to lesser development of the crural muscle and to structural differences in the affected bone. "It is consequently possible to suppose that at a given time a subject may possess a fossa, that is to say a free space between the gluteal ridge and the external border of the surface of insertion of the [crural] muscle; and that through the enlargement of the latter, caused by conditions of life or activity, this surface [the fossa] diminishes or disappears" (p. 51). And further (p. 57): "The significance of the hypotrochanteric fossa varies according to the form of platymery which it accompanies. In certain cases it denotes accentuated platymery, while in others it is in relation to a smaller muscular development. Its diminution and its disappearance in certain femora would indicate, therefore, a proportionate increase in muscular activity." [22]

Shortly afterward (1900-1), Klaatsch published a valuable paper on "The Most Important Variations of the Skeletal Parts of the Lower Limbs",[23] in which he also deals briefly with the hypotrochanteric fossa (pp. 633-635). There are no new statistical data and no original study of the fossa, but the author has observed the hollow, well developed, in the femora of Neanderthal and Spy, which (together with Boncour's and Evangeli-Tramond's observations) "opens the possibility of conceiving the feature as an old character which ontogenetically or, better, during the growth period of recent man, can still transitionally make its appearance". And Klaatsch is further of the opinion that the location of the fossa in the Neanderthal and Spy femora is such that a genetic connection of the same with

[21] Paul-Boncour, G., Étude des modifications squelettiques consécutives à l'hémiplégie. I. Le Fémur. Bull. Soc. Anthrop. Paris, ser. 5, vol. 1, 1900.

[22] "La signification de la *fossette hypotrochantérienne* varie suivant la forme de platymérie qu'elle accompagne. Dans certains cas elle dénote une platymérie accentuée, dans d'autres au contraire elle est en relation avec un moindre développement musculaire. Sa diminution et sa disparition sur certains fémurs indiqueraient donc un accroissement proportionnel de l'activité musculaire." (P. 57.)

[23] Klaatsch, H., Die wichtigsten Variationen am Skelet der freien unteren Extremität. Ergebnisse Anat. u. Entwickelungsgeschichte, vol. 10, pp. 599-719, 1900-1.

the subtrochanteric lateral expansion of the shaft cannot be mistaken (p. 633).

For nearly [illegible] years after the appearance of Klaatsch's paper the subject of the subtrochanteric fossa received no new contributions of importance, but in [illegible] appeared the extensive work of Pearson and Bell on the long bones of the English skeleton,[1] and this presents for the first time some ample statistics on the fossa, together with considerable new light on its associations.

Pearson and Bell thought they had seen a well-marked hypotrochanteric fossa in a [illegible]; they had not recognized it in the gorillas they examined, but "had noticed indications of it in the gibbon, the orang, and the chimpanzee" (p. [illegible]). In human femora they found the following conditions:

[illegible]

	[illegible]	[illegible]	[illegible]	[illegible]
Femora	[illegible]	[illegible]	[illegible]	[illegible]
Femora with fossa	[illegible]	[illegible]	[illegible]	[illegible]
Percent with fossa	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

	[illegible]	[illegible]
Femora	[illegible]	[illegible]
Femora with fossa	[illegible]	[illegible]
Percent with fossa	[illegible]	[illegible]

[illegible]

[1] [illegible]

the "well marked", II, "distinctly present in definite form", and III, "some trace, slight trough or fossa". The data follow:

Hypotrochanteric Fossa in the Naqada Femora

Femora	Grade I	Grade II	Grade III	I–III
				Per cent
Definite male (388)	(13) 3.35	(36) 9.28	(63) 16.24	28.87
Definite female (422)	(11) 2.61	(24) 5.69	(66) 15.64	23.93
Sex doubtful (385)	(18) 4.68	(32) 8.31	(67) 17.40	30.39
Total (1,195)	(42) 3.51	(92) 7.70	(196) 16.40	27.62

Pearson and Bell gave also a resumé of the available information on the presence of the fossa in early man (p. 153):

The *fossa hypotrochanterica* is well marked in Neanderthal R., and is quite definite in Neanderthal L. and in Spy I and Spy II. According to Boule it is not found in the La Chapelle-aux-Saints femur, but appears in La Ferrassie I. La Ferrassie II is defective at this point. Galley Hill has a slight hypotrochanteric fossa on the mesial side of the ridge preceding the third trochanter. The *fossa* also appears in all Verneau's femora whether of Cromagnon or Negroid Type. *Homo mousteriensis* (Hauser) is defective at this point. We may conclude that the *fossa hypotrochanterica* is usual in all types of Primogenial Man.

Pearson and Bell recognized that the three "anomalies", i.e., the fossa, the third trochanter, and the gluteal ridge, "can exist independently", or that "we may have in the same individual a *fossa hypotrochanterica* surmounted by a *crista trochanterica* [gluteal ridge] which concludes with a well-marked *trochanter tertius*" (p. 66). There is "no significant association between the presence of the fossa and the third trochanter" (p. 75). The fossa "is markedly less prevalent in the female than in the male bones", and in both sexes "the left bone presents the anomaly more frequently than the right" (p. 74).

There "is a small but just sensible correlation between platymery and the presence of the fossa" (p. 70).

No attempt was made at an explanation of the ontogenesis of the fossa, and there is nothing on its age differences. As to its significance the authors express themselves thus (p. 503):

Such a character as the hypotrochanteric fossa in Recent Man exhibits all the signs of a disappearing phenomenon becoming less and less frequent since palaeolithic times. It is more reasonable to suppose it as a vestige of what was once a generic character—even as the lateral protrusion of the anterior face in modern man is a vestige of a lemuroid generic character—than to suggest its independent development in two or even more simio-human lines proceeding from a gibbon-like origin.

As to the relation of the fossa, and the third trochanter, with the gluteus muscle, Pearson and Bell speak as follows (p. 68):

> It is hard to understand how, if they were due to the development of the *gluteus maximus* in man, they should remain anomalous in his case, and the rule in numerous lower types, while their frequent appearance in infants, in women, and in bones of small muscular development at least precludes the theory that their appearance is *solely* due to use development.

Since Pearson and Bell's contribution to the subject there has appeared but one noteworthy study of the fossa, that of A. B. Appleton, "On the Hypotrochanteric Fossa and Accessory Adductor Groove of the Primate Femur".[25]

Basing his findings on dissections made by himself, Appleton points out the presence of certain fossae in primate femora that cannot be identified with the *fossa hypotrochanterica* of man, since they are of a totally different nature. In particular, he says, "a fossa is present on the femur of the gorilla, chimpanzee and orang-outan, named in this paper the 'accessory adductor groove', which superficially resembles the *fossa hypotrochanterica* of man. The homologue of the latter, however, is found in these apes in another situation, viz. on the outer aspect of the shaft well below the level of the lesser trochanter." In addition he has noted another hollow, located near the middle of the posterior surface of the subtrochanteric region of the shaft, which he calls the "pectineal groove". Pearson and Bell, he points out, have confused the hypotrochanteric fossa and the accessory adductor groove in the chimpanzee and orang (footnote 2 on p. 66 of their memoir).

Appleton assumes that "the identity of the *fossa hypotrochanterica* is defined for us by Houzé as the site of insertion of *M. gluteus maximus* and in this sense later writers have dealt with it (Von Török, Costa and Pearson)", and adds the following in this connection (pp. 296-297):

> ATTACHMENT OF *M. GLUTEUS MAXIMUS* TO FEMUR
>
> Man: gluteal ridge, 3rd trochanter or *fossa hypotrochanterica.*
>
> Gorilla, Chimpanzee and Orang-outan: a spiral fossa on the *lateral* aspect of the femoral shaft; this is the *fossa hypotrochanterica* of these animals. It is the largest and most distally placed in the Gorilla . . .

[25] Appleton, A. B., Journ. Anat., vol. 56, pp. 296-306, 1922.

Cercopithecidae: gluteal ridge, replaced or accompanied occasionally by a *fossa hypotrochanterica* . . .

He adds that, in a *Cercopithecus sab.* and a *Papio ham.* the fossa takes the form of a groove in these two named specimens. A mere flattening is present in *Nasalis larv.*, a slight groove in *Nas. larv. juv.* It sometimes takes the form of a faint pit, with prominent medial lip.

No fossa was met with in American monkeys and in Prosimiae. In his concluding remarks Appleton accentuates the fact that:

in this paper no attempt is made at discussing the significance of ridges and of fossae at the site of muscular attachments. Facts established in this paper, however, suggest caution in the employment of the *fossa hypotrochanterica* for the natural classification of Primates. . . . . The distribution of fossa and of the alternative gluteal ridge (when large, known as a third trochanter) is an argument against this assumption. . . . . Until more is known of a possible functional significance for the appearance of a fossa at the site of insertion of *M. gluteus maximus*, it must be precarious to argue as to the nature of that insertion, whether fossa or ridge, in the common ancestor of *Hylobates*, the other Simiidae and Man.

The name *fossa hypotrochanterica* is conveniently reserved for a fossa, groove or pit at the site of insertion of *M. gluteus maximus* on the femur.

Among Primates the hypotrochanteric fossa presents considerable variety of situation; an extreme condition is presented by the large Simiidae.

Barring a few incidental mentions of the hypotrochanteric fossa, the above is apparently about all that has been said about it. The textbooks of anatomy generally allude to it but go into no details or explanations. How little regard is paid to it may be seen from the following quotation taken from the most recent treatise on osteology: [26]

Examine and compare the gluteal ridge in different bones: in some it is a prominent crest, in others only a broad rough area, and in others again it is represented by a rough fossa (*fossa hypotrochanterica*), or these different aspects may be more or less combined in one specimen.

SUMMARY OF OBSERVATIONS FROM THE LITERATURE

The hypotrochanteric fossa was first noted and named in 1883, by Houzé.

It is, in man, a slight to pronounced, nearly vertical, oblong hollow, situated in the lateral portion of the posterior aspect of the upper part of the femoral diaphysis. It differs in man, more or less, both in location and shape, from that in other primates. It exists in close relation with the gluteal ridge and the third trochanter.

---

[26] Frazer, J. E., The anatomy of the human skeleton, 3rd ed., pp. 147-148. London, 1933.

The true significance and function of the fossa have never been definitely determined. Most of those who have dealt with it regard it as a mere structural variant for the insertion of the gluteus maximus muscle. Houzé was of the opinion that the muscle inserted in its borders as well as in its base, but the statement is of a rather general nature and is not supported by any exact determinations. Bumüller attributed the fossa to the vastus lateralis; for Evangeli-Tramond, and probably after him Paul-Boncour, it represented the free space between the insertions of the gluteus and the cruralis; Pearson and Bell doubted its dependence on the gluteus. There is no report in any of the contributions to the subject, save that of Evangeli-Tramond, of any observation on the actual contents of the fossa in the cadaver.

Houzé, with probably Testut and others, believed the fossa to have been more frequent in earlier than in recent man. This assumption has not yet been sufficiently corroborated. Houzé was evidently misled, as far as his Furfooz material was concerned, by the large proportion of juvenile femora in the collection.

Costa, Klaatsch, and Pearson and Bell came to regard the fossa as an atavistic feature. Von Török and Bertaux expressed the belief that its frequency would show race differences. In Houzé's and Bertaux', but not in Costa's material, it appeared to be scarce in the Negro.

Von Török, Evangeli-Tramond, and Pearson and Bell found the fossa more frequent in the males than in the females; Pearson and Bell encountered it more commonly on the left than on the right femur in modern Londoners, but the reverse in the Naquada.

Houzé encountered the fossa in the bones of fetuses and newborn (Furfooz); Hyades and Deniker saw it in a Fuegian girl of eight; Evangeli-Tramond was the first to recognize that it was better defined in adolescent than in adult femora. Boncour, in hemiplegic cases, saw the hollow more frequently and more marked on the affected than on the sound side.

In the opinion of Houzé, Bumüller, Martin, Lehmann-Nitsche, Boncour, and Klaatsch, the fossa stood in close or even genetic association with the subtrochanteric flattening of the shaft and its lateral lipping at that level—in other words, with platymery; but such association was not acknowledged by Manouvrier or by Evangeli-Tramond, and was found to be but slight by Pearson and Bell.

Pearson and Bell could detect no significant association between the fossa and the third trochanter; and they failed to recognize it in the gorilla.

Appleton, finally, called attention to additional fossae of muscular origin on the shaft of the primate femur.

The more noteworthy statistical data as to the frequency of the fossa in different racial groups may be tabulated as follows:

People	Author	No. of femora	Sexes	Ages	Sides	Fossa marked	Fossa less marked	Trace	All with fossa
						Percent	Percent	Percent	Percent
Neolithic of Belgium and France	Houzé	110	both	all	both	....	....	....	44.
Merovingian	"	30	"	"	"	....	....	....	23
Modern Belgian...	"	67	"	"	"	....	....	....	10.5
Bronze Age, Hungary.......	Von Török	76	male	adult	"	....	....	....	30.2
Bronze Age, Hungary.......	"	32	female	"	"	....	....	....	6.2
Modern Europeans	Costa	102	both	....	"	....	....	....	29.4
Africans.........	"	12	"	....	"	....	....	....	50 –
Fuegians..	"	37	"	most young	"	....	....	....	100 –
Diverse Negroes..	Bertaux	34	....	....	"	....	....	....	8.8
Guanches........	"	?	....	....	"	....	....	....	38.–
Fuegians.........	Hyades and Deniker	29	both	all	"	.	....	....	44.8
Modern Frenchmen	Evangeli-Tramond	60	male	adult	"	3.3	10.–	35.–	48.3
Modern Frenchmen	"	60	female	"	"	1.7	11.7	23.3	36.7
Swabians and Alemans	Lehmann-Nitsche	62	....	....	"	....	....	....	37.1
Modern Germans.	Bumüller	407	both	....	"	....	....	....	49.1
Naquada (predynastic) Egyptians	Pearson and Bell	388	male	....	"	3.35	9.28	16.24	28.9
		422	female	....	"	2.61	5.69	15.64	23.9
		of which paired							
		304	both	....	right	....	....	....	31.6
		304	"	....	left	....	....	....	21.7
		385	?	....	both	4.68	8.31	17.4	30.4
Modern Londoners	"	225	male	adult	right	....	....	....	37.3
		236	"	"	left	....	....	....	42.4
		170	female	"	right	....	....	....	22.4
		179	"	"	left	....	....	....	29.0
Mean of neolithic to modern Europeans of both sexes and both sides.........	....	1,816	both	all	both	....	....	....	*30.7*
				(mean	of th	e averag	es.....	......	*31.9*)

The value of the above data is vitiated by the uncertainty in many cases as to the sex and age of the specimens, and by the complete lack of information as to what was included in their reports by most of the authors.

All three reports in which the bones were separated as to sex (Von Török, Evangeli-Tramond, Pearson and Bell) indicate that the fossa is more common in the males than in the females.

As to side, the only two reports, both of Pearson and Bell, are contradictory.

NEW OBSERVATIONS ON THE FOSSA

My own interest in the hypotrochanteric fossa was not fully aroused until I examined a series of adolescent human femora. The fossa in these appeared, oddly enough, not only more common and better developed than in the femora of adults, but in some of the specimens it amounted to a truly major feature, all of which called for further study. Fortunately I could draw on the now unrivaled collections of bones, both adult and juvenile, in my own division and was able to supplement these later, thanks to the kindness of Gerrit S. Miller, Jr., and Prof. T. Wingate Todd and his associates, by the invaluable anthropoid collections in the division of mammals, United States National Museum, and in the department of anatomy, Western Reserve University, in Cleveland. The number of specimens examined was as follows:

Material Examined in the Present Study

	No. of femora
Lemurs:	
Juvenile	2
Adult	14
New World monkeys:	
Juvenile	11
Adult	42
Old World monkeys:	
Juvenile	26
Adult	47

	No. of femora Juvenile	No. of femora Adult
Anthropoids:		
Gorillas	66	77
Chimpanzees	50	60
Orangs	3[illegible]	42
Gibbons	2	35

	No. of femora
Human: Fetal to infant	
U. S. Whites (miscellaneous)	161
U. S. Negroes (miscellaneous)	202
Child adolescent-subadult:	
U. S. Whites (miscellaneous)	26
U. S. Negroes (miscellaneous)	106
Old Egyptians (XII Dynasty)	135
Old Peruvians (Pachacamac and Chicama)	114
N. A. Indians (miscellaneous)	626
Eskimos (Alaskan)	224

Human: Adult:	No. of femora
U. S. Whites (miscellaneous)	1,000
U. S. Negroes (miscellaneous)	100
Old Egyptians (XII Dynasty)	200
Old Peruvians (Pachacamac and Chicama)	868
N. A. Indians (miscellaneous)	3,890
Eskimos (Alaskan)	718
Aleuts	137
Kodiak Islanders (pre-Aleut)	154
Chinese (Canton)	152

THE FOSSA IN LEMURS

Hypotrochanteric Fossa in Lemurs

	No. of femora	Fossa in
Hapalemurs, adult	4	..
Lepidolemurs, adult	6	..
Lemurs (various), adolescent	2	..
adult	4	..
Total	16	..

All these specimens present a more or less marked marginal gluteal ridge (forming a part of the lateral border), and rising from the proximal part of this, a well-developed to pronounced process, the "third trochanter"; but there is not a trace in any of these specimens of the hypotrochanteric fossa.

THE FOSSA IN NEW WORLD MONKEYS

Hypotrochanteric Fossa in New World Monkeys

	No. of femora	Fossa in
Alouattas (Howlers),[a] adult	34	..
Ateles,[a] adolescent	8	2 (a pair)
adult	5	..
Cebus, young	3	..
adult	2	..
Callicebus, adult	1	..
Total	53	2

[a] Several varieties.

In all these American monkeys the gluteal ridge, generally rather distinct, is marginal or nearly so; and in the Alouattas and the Ateles there is frequently on the upper part of the ridge a trace to fair development of a third trochanter, but not of the lemuroid form —

more of an anthropoid nature. In none, however, barring one adolescent Ateles, is there any trace of the hypotrochanteric fossa.

The exceptional specimen (skeleton no. 984, U.S.N.M.) is, according to Gerrit S. Miller, Jr., a true Ateles, and from Brazil, and the only specimen from that region in the Museum collections. Both its femora, and particularly the right, show the hypotrochanteric fossa well developed, unmistakable, and very similar to that in human subjects. The gluteal ridge is plainly discernible, and there is no third trochanter. The proximal fourth of the shaft is stout and approaches the quadrilateral. The fossa on the right femur measures 11 by 2.5, on the left 10 by 2.5, millimeters. It is situated on the posterior part of what here is the lateral surface and is as usual directly adjacent to the gluteal ridge. Except for the conformation of the shaft at this level the fossa is exactly in location, form, and character as in a human femur. It is strange that this should be the only specimen with the fossa among all the Ateles and the other American monkeys examined, but such is the case.

THE FOSSA IN OLD WORLD MONKEYS

Hypotrochanteric Fossa in Old World Monkeys

	No. of femora	Fossa in
Baboons, young	2	..
adult	12	..
Theropitheci, adolescent	2	..
adult	2	..
Nasalis, adult	2	..
Cynopitheci, adolescent	2	..
adult	4	..
Erythrocebi, subadult	2	..
adult	4	..
Presbytis, adolescent	4	..
adult	10	..
Macaques,[a] young	6	..
adolescent	8	..
adult	13	..
Total	73	..

[a] Several varieties.

Gluteal ridge none to marked, generally marginal; third trochanter absent in over 90 percent; hypotrochanteric fossa, no trace.

THE FOSSA IN ANTHROPOID APES

Conditions as to the hypotrochanteric fossa in the anthropoid apes, aside from the gibbons and siamangs, are widely different from those of the lower apes; but the forms differ also considerably *inter se,* as well as from humans, but in other respects. The gibbons approach the monkeys, as they do in so many other characters.

The results of the observations will be seen in the table on page 20.

The gibbon femora, it is seen, have not even a trace of the hypotrochanteric fossa in nearly 86 percent of those examined, and in but two among the five bones with the fossa is it at all fairly developed. However, where the fossa is present, it approaches the human type, though it is more marginal; and in the bone in which it is best developed it presents a new feature—it is a groove without lower (distal) boundary, and not a circumscribed fossa. This is a feature that has not hitherto been reported, but one with which we shall meet again in these reports.

The gluteal ridge in these gibbons is either absent or ranges in development up to fairly well pronounced. There is no third trochanter.[27]

Among the three large anthropoid apes, the hypotrochanteric fossa is most frequent in the orang and least so in the chimpanzee, but in all three genera its presence is relatively common. This is so striking in contrast with the lower apes that the fossa, as far as the order of the primates is concerned, may henceforth justly be regarded as essentially a higher-anthropoid, and, as will be seen later, also human, character.

In the orangs the fossa is almost universal, though not often very pronounced. It is as a rule more or less marginal, i.e., partly or wholly in the lateral border. In two pairs of the femora, one from Borneo and one from Sumatra, the fossa is displaced entirely to the lateral part of the anterior surface, and in one other Sumatra orang femur there is a partial displacement of such a nature. This complete or partial displacement of the hypotrochanteric fossa is another feature that has not been reported before, but its reality is unquestionable. (See pl. 4.)

The differences in the incidence and character of the fossa between the juvenile and adult femora in the orangs is obscured by the insufficiency of the number of specimens for such a comparison; nevertheless, the adults show clearly a larger proportion of the submedium

[27] Observations on these formations were recorded in every case and will be dealt with more in detail in a separate article.

Hypotrochanteric Fossa in Anthropoid Apes (U.S.N.M. and W.R.U.)

No. of femora	Absent	Trace	Small but distinct	Moderate	Medium	Above medium	Pro-nounced	Double	Of which a fossa-groove
Gibbons and siamangs:									
Children (2)	....	....	....	....	...	....	....	....	....
Adult (35)	(30) 85.7	(3) 8.6	....	(1) 2.9	(1) 2.9	....	....	....	(1) (2.9)
Orangs:									
Juvenile (32)	(1) 3.1	(3) 9.4	(5) 15.6	(5) 15.6	(15) 46.9	(3) 9.4	....	....	....
Adult (42)	(1) 2.4	(4) 9.5	(5) 11.9	(14) 33.3	(12) 28.6	(4) 9.5	(2) 4.8	....	....
Gorilla:									
Children (21)	(3) 14.3	(4) 19.0	(6) 28.6	(4) 19.0	(3) 14.3	(1) 4.8	....	....	....
Adolescent (45)	(7) 15.5	(6) 13.3	(13) 28.9	(10) 22.2	(2) 4.4	(4) 8.9	(2) 4.4	(1) 2.2	....
Adult (77)	(7) 9.1	(12) 15.6	(15) 19.5	(19) 24.7	(13) 16.9	(5) 6.5	(6) 7.8	....	(4) (5.2)
Chimpanzees:									
Children (28)	(13) 46.4	(4) 14.3	(3) 10.7	(6) 21.4	(1) 3.6	(1) 3.6	....	....	....
Adolescent (31)	(8) 25.8	(4) 12.9	(2) 6.4	(10) 32.3	(5) 16.1	(2) 6.4	....	....	....
Adult (96)	(14) 14.6	(8) 8.3	(18) 18.8	(25) 26.–	(15) 15.6	(11) 11.5	(5) 5.2	....	....

(moderate), the juveniles a larger proportion of the medium forms, which means that on the whole the fossa is better represented before than in the adult stage. Some interesting conditions bearing on this point will appear later in this paper.

We find in the gorillas the hypotrochanteric fossa differing considerably from that in the other anthropoid apes and especially from that in man. It is generally spacious, oblique, at least partly marginal (in the lateral border), situated low on the shaft—reaching in some instances nearly to the middle—often shallow, and very decidedly rougher than in man. There was found no marked extension of the fossa over the lateral border onto the anterior surface. In four of the pronounced cases the " fossa " was a marked groove.

The frequency of the occurrence of the fossa in the older gorillas is nearly the same as in the chimpanzees, but is less than in the orangs.

The age differences are not so marked as they are in the orangs. There is a mild diminution during the growth period of the " absents " and " traces ", and but a slight increase in the more pronounced forms of the fossa from adolescents to adults. On the whole, it may be said that the fossa in the lowland gorilla increases moderately in frequency as well as in development from childhood to adult life.

In one adolescent left gorilla femur the hypotrochanteric fossa consists of two superimposed hollows, the upper of medium, the lower of submedium dimensions. There is no mistaking the second hollow for Appleton's pectineal fossa or accessory adductor groove.

The hypotrochanteric fossa in the gorilla, according to all the indications of its large rugose surface, gives attachment to a powerful muscle—doubtless the gluteus maximus; and the same must be true, it would seem, of at least the more pronounced fossae in the orang and the chimpanzee. In none of these forms is the gluteal ridge, even when most distinct, of the human character and development. Furthermore, neither in the gorillas nor in the orangs have I seen any trace of a third trochanter; in the chimpanzees, though this feature occurs in roughly 9 percent of the femora, it is never as markedly developed as in some humans. It would seem to follow from all this that the fossa plays a more important functional part in these apes than it does in man; in man, on the other hand, the gluteal ridge and tuberosity (third trochanter) play the greater rôle. All this will be considered further under the human materials.

In the chimpanzees, the frequency of the fossa in children is much less, in older subjects slightly less, than in the orang, and its characteristics are slightly more like those in the human femur. None of the fossae in this genus was of the nature of a groove. In location they were in general more or less marginal and not infrequently rather low. In the two femora of one adult, each with a pronounced oblique fossa, the latter, after hollowing markedly the lateral border, extends on the right bone largely, on the left partly, onto the anterior surface of the shaft.

The age differences in the incidence and development of the fossa in the chimpanzees are very noticeable. There is a steady and marked decrease from childhood to adult life in the "absent" and "trace" records, which indicates that the fossa continues to originate and develop during the growth period. Its greatest frequency as well as its optimum development are evidently not reached in this genus until within the adult period. The fossa occurs with strikingly less frequency in the children than in the adults.

SUMMARY OF OBSERVATIONS ON ANTHROPOID APES

The gibbons and siamangs, so far as the hypotrochanteric fossa is concerned, show conditions more like those of the lower apes than those of the larger anthropoids. A distinct form is rare, occurring in roughly 5 percent of the femora.

In the three large anthropoid apes the fossa is frequent—as a distinct to pronounced depression—in the adolescent and adult femora, being present in 73.8 percent of the gorillas, 75.8 percent of the chimpanzees, and 80.4 percent of the orangs.

In most gorillas, and not infrequently in the chimpanzees, the fossa is situated low on the shaft—decidedly lower than in humans; in the orangs the level of the hollow is nearly the same as that in man.

In all the orangs and generally in the gorillas and chimpanzees the fossa is partly to wholly marginal, involving the lateral border of the shaft. Occasionally, the fossa will encroach on the anterior surface, and in four orang femora it was completely displaced to this surface.

In one gibbon and four gorilla femora, instead of a circumscribed fossa, there was a marked groove without any lower (distal) boundary.

In many of the gorillas, less commonly in the chimpanzees, and occasionally in the orang, the fossa is spacious and rough and has plainly served for the attachment of a powerful muscle, doubtless the gluteus maximus.

THE FOSSA IN EARLY MAN

The hypotrochanteric fossa, according to Boule ("L'homme fossile", p. 248, 1913), is present in a rudimentary form in the casts of the femora of Neanderthal and Spy, and clearly in the two femora of La Ferrassie I; but it is wanting in those of La Chapelle, and in La Ferrassie II the bones are too damaged to permit of the determination.

Pearson and Bell, who also doubtless examined only casts, make some erroneous assertions. We may repeat here what they say (p. 453):

> The *fossa hypotrochanterica* is well marked in Neanderthal R., and is quite definite in Neanderthal L. and in Spy I and Spy II. . . . . Galley Hill has a slight hypotrochanteric fossa on the mesial side of the ridge preceding the third trochanter. The *fossa* also appears in all Verneau's femora whether of Cromagnon or Negroid type. *Homo mousteriensis* (Hauseri) is defective at this point. We may conclude that the *fossa hypotrochanterica* is usual in all types of Primogenial Man.

The writer, who has examined all the originals and has, moreover, first-hand casts at his disposal, finds the following conditions:

Pithecanthropus femur	Fossa existed, now almost filled with secondary deposits of the bone, so that only a trace remains.
Neanderthal, right femur	Moderate fossa.
left "	No definite trace.
Spy, 2 male femora	Moderate fossa present on each.
Krapina, male, left	Traces of a fossa.
La Quina, adult, left	No fossa.

The Galley Hill femur does not belong in this company; and the hypotrochanteric fossa is never located mesially to the gluteal ridge.

The above conditions of the fossa in the adults of early man do not differ substantially from those in man of today.

THE FOSSA IN LATER AND MODERN MAN

As already mentioned in connection with the anthropoid apes, the whole of what may be called the gluteal region on the posterior aspect of the proximal part of the shaft of the femur differs in man in important ways from that in the anthropoid and lower apes. Adult man, in general, has a more pronounced and especially more rugged gluteal ridge; this ridge is only exceptionally, and then usually but partly, marginal; the gluteal tuberosity (third trochanter) is much more common and more developed; the hypotrochanteric fossa is as a rule relatively high on the shaft and is hollowed in the lateral part of the posterior surface, rarely approaching, and never embedded in, the lateral border of the bone. And there are other differences, which will be brought out in our detailed studies. All of this implies that there must exist, between man and the rest of the primates, important differences in muscular attachments and in other soft parts of the region in question. In comparing the features of this region in man with those of the other primates, we are comparing, therefore, what basically are homologous formations, but formations that in their ultimate development in man and the other genera are no longer necessarily fully equivalent morphologically or functionally. The hypotrochanteric fossa, which is here more especially considered, although present and even frequent in man, may thus be in him an "emerited" survival, a still frequent but no longer functionally important memento of his past, rather than a still fully active cog of his mechanism.

It may be useful to bear these reflections in mind when confronted with some of the curious results of this study.

THE FOSSA BEFORE AND ABOUT TIME OF BIRTH

Material Examined

	Femora
U. S. Whites (miscellaneous)	161
U. S. Negroes (fullblood and mixed-blood)	262

The first traces of the fossa may be discerned occasionally as early as the fifth month of the intrauterine life; their detection is made easier by the use of a magnifying glass of medium power. Its first plain representation is a well-dêmarked, not depressed, evenly reticulated roughness. As the age of the bones advances, this area assumes slowly the character of a hollow, and the reticulation of its floor diminishes until, in a fully formed fossa, the floor is generally fairly smooth and uniform.

The formation of the first distinct stages of the fossa is mostly associated with the appearance on its mesial border of the first traces of the gluteal ridge, but the fossa may antedate the ridge, or it may begin to develop later. We shall return to this discussion.

The data on the fossa in fetal life and infancy follow:

Hypotrochanteric Fossa in Fetal and Infantile Femora of U. S. Whites

Oblique length of femur (with cartilages)[a]	None	Trace	Slight but distinct	Moderate	Medium	Above medium	Pronounced
cm	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1.1 to 2.95 (11 femora).....	90.9	9.1[b]	....	....	....	...	..
3 to 3.95 (15 femora).......	53.3	20.–	26.7		....	..	....
4 to 4.95 (19 femora).......	57.9	21.1	21.1	...	...	....	...
5 to 5.95 (14 femora).......	35.7	28.6	28.6	7.1	....	....	....
6 to 6.95 (30 femora).......	30.–	33.3	30.–	6.7	....	....	....
7 to 7.95 (38 femora).......	18.4	34.2	31.6	10.5	2.6	2.6	....
8 to 8.95 (28 femora).......	17.9	42.9	21.4	14.3	3.6	....	..
9.4 to 10.3 (6 femora)......	(In	sufficie	nt)	....	....	....	....

[a] As extracted from the body; all measurements by the writer.
[b] In a femur of 2.2 cm.

Hypotrochanteric Fossa in Fetal and Infantile Femora of U. S. Negroes

Oblique length of femur (with cartilages)[a]	None	Trace	Slight but distinct	Moderate	Medium	Above medium	Pronounced
cm	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1.7 to 2.95 (9 femora)......	88.9	....	11.1[b]	....	....	....	....
3 to 3.95 (13 femora).......	69.2	15.4	15.4	....	....	....	....
4 to 4.95 (20 femora).......	50.–	40.–	10.–	....	....	....	....
5 to 5.95 (42 femora).......	47.6	26.2	26.2	....	....	....	....
6 to 6.95 (40 femora).......	27.5	32.5	32.5	7.5	....	....	....
7 to 7.95 (70 femora).......	30.–	35.7	25.7	7.1	1.4	....	....
8 to 8.95 (51 femora).......	21.6	29.4	33.3	9.8	4.–	2.–	....
9 to 10.75 (17 femora)......	11.8	29.4	29.4	23.5	5.9	....	....

[a] As extracted from the body; all measurements by the writer.
[b] In a femur of 2.95.

The American Negro series, regrettably, includes admixture of white blood and cannot therefore be fully representative. At it is, the two racial groups show no great differences, and some of those that do appear are doubtless due largely to insufficiency in number. Shortly before term (femur length 6 to 6.95 cm), when the numbers of specimens become more adequate, the conditions in the two groups are seen to be closely alike. About and for a brief time after birth (femur length 7 to 8.95 cm) the relations are as follows:

Comparison of the Fossa in Fetal and Infantile Femora of U. S. Whites and Negroes

Oblique length of femur (with cartilages)	None or but a trace	Slight but distinct	Moderate	Medium	Above medium
7 to 8.95 cm	Percent	Percent	Percent	Percent	Percent
U. S. Whites (66 femora)	56.1	27.3	12.1	3.–	1.5
U. S. Negroes (121 femora)....	59.4	28.9	8.3	2.5	0.8

The differences are still small but apparently significant. In the white femora the fossa shows throughout a slight advantage. At and shortly after birth the fossa may therefore be said to tend to be slightly more frequent and more commonly slightly better developed in the U. S. White than it is in the U. S. Negro.

The main point, however, shown by the above records is the gradual appearance and growth of the fossa during those early stages. As the age of the fetus and later that of the infant advances, the fossa becomes steadily more frequent and more substantial. In view of these data it is evident that the formation of the hypotrochanteric fossa, initiated in rare instances as early as the fifth month of intrauterine life, begins in different femora at different periods before and even after birth.

THE FOSSA IN CHILDREN, ADOLESCENTS, AND SUBADULTS

The available juvenile femora, although collectively considerable in number, when divided into the more obvious ontogenetic periods are still not always sufficient for our purposes. The inadequacy applies particularly to the bones of the children and adolescents of Whites, which are scarce in all our collections. On the other hand, however, there are excellent series from racial groups that were not represented in the fetal material, and altogether there is enough to bring out the most salient facts about the feature under scrutiny.

The subdivisions to be used are: 1, The earlier childhood (up to approximately 6 years of age); 2, later childhood (approximately 7 to 13 years) and earlier adolescence (both upper and lower epiphyses still detached); 3, later adolescence (lower epiphyses alone detached); and 4, subadult (approximately 19 to 21 years; all epiphyses attached but lower still imperfectly so or but recently).

In view of the inequalities of the series it will be best to give each racial group a brief separate consideration.

U. S. WHITES

Hypotrochanteric Fossa in U. S. Whites, Children, Adolescents, and Subadults

No. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
About term and shortly after (66)[a].	18.2	37.9	27.3	12.1	3.–	1.5	....	....
Adolescents and subadults (26)....	15.4	15.4	15.4	34.6	11.5	3.8	3.8	....

[a] From data given in preceding section.

Though the number of specimens in the adolescent and subadult class is small, they nevertheless show that remarkable changes in the fossa have been effected during the growth period. The proportion of the "absent", "trace", and "small" have markedly diminished, and the proportions of the "moderate" to "pronounced" cases have correspondingly increased. The fossa plainly has continued to develop, and in a few instances has probably even originated, during the adolescent period.

U. S. NEGROES

Hypotrochanteric Fossa in U. S. Negroes, Children, Adolescents, and Subadults

No. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
About term and shortly after (121).	26.4	33.–	28.9	8.3	2.5	0.8	....	....
Children (6)........	(Insu	fficient	for co	mparis	on)			
Adolescent and subadult (100)....	31.–	16.–	7.–	16.–[a]	19.–[a]	7.–[a]	4.–[a]	(4.–)

[a] One a groove.

The "absents" in these series have probably remained much the same and would seem to indicate that in this racial group no new fossae have originated after infancy. For the rest there are seen the same phenomena as in the Whites, but still more pronounced: the "traces" and the "small" fossae have diminished, the "moderate" to "pronounced" have very markedly increased. The fossa has kept on growing during the adolescent to subadult period.

XII DYNASTY EGYPTIANS

This material is from the deep rock shafts just to the south of the pyramid of Lisht and is identified as of about 2000 B. C. It includes 135 juvenile femora, which, as to the hypotrochanteric fossa, show the following conditions:

Hypotrochanteric Fossa in XII Dynasty Egyptians, Children and Adolescents

No. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Younger children (up to about 6 years) (55).......	23.6	36.4	29.1	9.1	1.8	....	....	....
Older children (approx. 7 to 13 years) (45).......	8.9	11.1	28.9	22.2	24.4	2.2	2.2	....
Adolescents (all) (35).............	2.9	....	14.3	14.3	28.6	22.9	17.1	(17.1)

The above data show the same progressive appearance and development of the fossa as did the U. S. Whites and Negroes, but still more strikingly. In the adolescents the fossa is nearly universal, and in 40 percent of the femora of this stage of life it is markedly developed.

In 6 (17.1 percent) of the adolescent bones the fossa is a marked groove. This feature evidently is also one of later development, for it is absent in the earlier stages of the growth period.

PREHISTORIC PERUVIANS

There are 114 pre-Columbian juvenile femora from Pachacamac and Chicama, on the coast of Peru. They register thus:

Hypotrochanteric Fossa in Prehistoric Peruvians, Children and Adolescents

No. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Children (all, mostly older) (35).......	28.6	11.4	11.4	20.–	22.9	2.9	2.9	(2.9)
Younger adolescents (48).............	8.3	4.2	8.3	10.4	31.3	20.8	16.7	(6.2)
Older adolescents (31).............	3.2	....	9.7	12.9	35.5	22.6	16.1	(6.5)

In the main the conditions are much like those in the previous groups, the only exception being that one of the rather pronounced fossae in an older child is a groove. There is also a sensible proportion of fossa-grooves in both the adolescent groups. In the older adolescents, it may be noted, the fossa is again almost universal, and in nearly 40 percent—practically the same as in the Egyptians—it is above medium to pronounced in development.

NORTH AMERICAN INDIANS

This group includes tribes from many parts of the continent, and the bones range from pre-Columbian (the majority) to fairly recent but probably free from white admixture. The number of juvenile femora in this group is very respectable, reaching a total of 626 specimens, and ranging from preterm to subadult. There were no indications of any material tribal or regional differences, and so all the data may be dealt with as a unit. The conditions it shows are as follows:

Hypotrochanteric Fossa in North American Indians, Children and Adolescents

No. of femora	None	Trace	Small but distinct	Moderate	Medium	Above medium	Pronounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Younger children (to approx. 6 years) (283)......	34.6	24.7	23.7	10.3	6.4	0.4	....	(0.7)
Older children (approx. 7 to 13 years) (64).......	15.6	7.8	21.9	26.6	25.–	3.1	....	(4.7)
Younger adolescents (117)............	3.4	4.3	12.–	18.8	29.1	22.2	10.3	(3.4)
Older adolescents (162)............	2.5	1.2	1.9	16.7	40.7	27.2	9.9	(11.1)

The above results conform with those seen in the other groups of femora. As age advances, during the growth period, the "none", with the "trace" and "small" grades of the fossa, diminish, the "medium" to "pronounced" increase. From birth to later adolescence there is a steady and marked increase in the incidence of the fossa, with a progressive marked diminution in its "trace" and "small" grades, together with an equally progressive and marked increase in large fossae. The "above-medium" to "pronounced" grades reach in the older adolescents nearly 40 percent, which is strikingly similar to what has been shown by the femora of preceding racial groups.

The fossa-groove, one example of which occurs in this group in one of the older subjects among the younger children, progresses also to reach its maximum frequency in the older adolescents. This form also, therefore, appears more frequently as age advances.

THE ESKIMO

The last racial group from which there is a fair representation of juvenile femora, is that of the Alaskan Eskimo. The material consists of 224 specimens, probably all fullblood. They furnish the following data:

Hypotrochanteric Fossa in Eskimo, Children and Adolescents

No. of femora	None	Trace	Small but distinct	Moderate	Medium	Above medium	Pronounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Younger children (up to about 6 years) (70)......	51.4	12.9	24.9	1.4	....	....	....	....
Older children (about 7 to 13 years) (55)......	9.1	25.4	36.4	20.–	7.3	1.8	....	....
Adolescents (all) (99)..........	3.–	3.–	10.1	18.2	35.4	20.2	10.1	(5.1)

Once more, though somewhat less regularly (owing probably to insufficient numbers), there is seen the gradual increase with age in frequency as well as in the size of the fossa. On the whole, however, this group shows somewhat less tendency toward the formation of the hollow, and also of the fossa-groove, than did the preceding ones.

It will now be possible to make some brief and necessarily rough comparisons of the conditions shown by the juvenile bones of the several racial groups; comparisons that must suffer more or less not only from the unequal and in instances insufficient numbers, but also from the unequal age distribution within the different series. For the purpose of these comparisons it will be of advantage to combine the seven grades of the fossa into four larger subdivisions:

Hypotrochanteric Fossa in the Young

Younger Children (about term to 6 years)

Group and no. of femora	None	Trace to small	Submedium to medium	Above medium to pronounced
	Percent	Percent	Percent	Percent
Old Egyptians (55)	23.6	65.5	10.9	....
N. A. Indians (283)	34.6	48.4	16.7	0.4
Eskimo (70)	51.4	37.8	1.4	....

Older Children (approximately 7 to 13 years)

Group and no. of femora	None	Trace to small	Submedium to medium	Above medium to pronounced
Old Egyptians (45)	8.9	40.–	46.6	4.4
N. A. Indians (64)	15.6	29.7	51.6	3.1
Eskimo (55)	9.1	61.8	27.3	1.8

Adolescents (approximately 14 to 21 years)

Group and no. of femora	None	Trace to small	Submedium to medium	Above medium to pronounced
U. S. Whites (26)	15.4	30.8	46.1	7.6
U. S. Negroes (100)	31.–	23.–	35.–	11.–
Old Egyptians (35)	2.9	14.3	42.9	40.–
Old Peruvians (79)	6.3	11.4	44.3	38.–
N. A. Indians (279)	2.9	8.6	53.4	35.1
Eskimo (99)	3.–	13.1	53.5	30.3

The main facts brought out by the above figures are obvious.

There are marked racial differences from early childhood onward.

The Whites and the Negroes among the adolescents, and the Eskimos during childhood, show the least incidence and development of the fossa, the Old Egyptians from later childhood on and the North American Indians throughout, the most.

In adolescents, outside of those of the U. S. Whites and Negroes, conditions show remarkable similarity. The fossa is very common, and in from 30 to 40 percent of the femora it is at this stage a very marked feature of the proximal third of the shaft of the femur. This showing, it will be seen later, is of exceptional interest in the generic history of the fossa.

SEX AND SIDE IN JUVENILE BONES

Differences during the growth period in the incidence and development of the hypotrochanteric fossa in the two sexes may exist, but our body-sexed material is very inadequate, and reliable sexing of juvenile bones themselves, except in the later stages of adolescence, is impossible.

As to the right and left bones, some differences in the fossa appear, but not with sufficient preponderance to have any definite significance. The most suitable group for showing the conditions is that of the North American Indians. In condensed form, the group shows the following:

Hypotrochanteric Fossa on the Two Sides in Juvenile North American Indians

Age group and no. of femora	None	Trace to small	Moderate to medium	Above medium to pronounced
	Percent	Percent	Percent	Percent
Younger children:[a]				
Right (145)	33.1	50.3	15.9	0.7
Left (138)	36.2	46.4	17.4	....
Older children:				
Right (31)	16.1	32.3	45.2	6.5
Left (33)	15.2	27.3	57.6	....
Younger adolescents:				
Right (60)	3.3	20.–	48.3	28.3
Left (57)	3.5	12.3	47.4	36.8
Older adolescents:				
Right (81)	2.5	1.2	56.8	39.5
Left (81)	2.5	4.9	58.–	34.6

[a] In all the series here the bones are largely pairs.

There are, it is seen, differences, but they are so irregular that it is hard to recognize any definite tendencies. Elimination of the unpaired bones does not materially change the picture.

THE FOSSA IN ADULTS

To learn the full life history of the fossa, in view of what has been seen hitherto it would be desirable to segregate the adult material into at least three categories, namely, the young adults, the middle-aged, and the old; but such a division with most of our series would be impossible. It will be feasible, however, to subdivide adults of each racial group on the basis of sex and side.

To render the data as intelligible as possible, the total number of specimens in each group will first be dealt with as a unit. The results follow:

Hypotrochanteric Fossa and Race, Both Sexes and Both Sides, Adults

Group and no. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
U. S. Whites (1,000)	32.–	18.2	20.–	15.8	11.2	2.6	0.2	(1.8)
U. S. Negroes (100)	31.–	16.–	23.–	11.–	17.–	2.–	....	(3.–)
Old Egyptians (200)	20.5	12.5	25.–	18.–	17.–	3.–	4.–	(5.–)
Old Peruvians (868)	24.4	13.7	36.5	16.6	7.6	0.9	0.2	(0.1)
N. A. Indians (3,890)	12.2	19.5	32.2	20.7	13.3	1.5	0.6	(2.1)
Kodiaks, pre-Aleut (154)	15.6	29.2	21.4	21.4	7.8	3.2	1.3	(0.6)
Aleuts (137)	11.7	15.3	16.1	27.–	27.–	1.5	1.5	....
Eskimos (718)	10.4	18.7	24.1	22.3	19.5	3.3	1.2	(3.2)
Chinese (Canton) (152)	38.8	21.1	17.1	13.8	7.9	1.3	....	(3.9)

There are, it is seen, numerous and in some cases marked differences both in the frequency and the development of the fossa. To render these still more obvious, the data may be condensed, as has been done for adolescents, and arranged on the basis of the combined weight of the last two columns:

Hypotrochanteric Fossa and Race, Both Sexes, Both Sides, Adults (Condensed)

Group and no. of femora	None	Trace to small	Moderate to medium	Above medium to pronounced
	Percent	Percent	Percent	Percent
Chinese (152)	38.8	38.2	21.7	1.3
Old Peruvians (868)	24.4	50.2	24.2	1.1
U. S. Whites (1,000)	32.–	38.2	27.–	2.8
U. S. Negroes (100)	31.–	39.–	28.–	2.–
Kodiaks, pre-Aleut (154)	15.6	50.6	29.2	4.5
N. A. Indians (3,890)	12.2	51.7	34.–	2.1
Old Egyptians (200)	20.5	37.5	35.–	7.–
Eskimos (718)	10.4	42.8	41.8	4.5
Aleuts (137)	11.7	31.4	54.–	3.–

The group differences may now be seen very plainly. The lowest incidence as well as the lowest development of the fossa is shown by the Cantonese Chinese, and the next lowest by the Old Peruvians; the highest occurs in the Eskimos, Aleuts, and the Old Egyptians. The U. S. Whites and Negroes—the latter, as far as the adult bones are concerned, all fullblood or very nearly so—are as remarkably close in the adults as they were in the young, and in both the well-marked fossa is rather infrequent. The North American Indians and the pre-Aleut Kodiak Islanders, much alike, occupy a medium position.

It is evident that matters in some of the instances do, in others do not, follow racial affinities. There is a close similarity in conditions in the racially widely apart Whites and Negroes, and a dissimilarity between the fundamentally related Whites and the Old Egyptians. The Old Peruvians differ, as they do in other respects, from the combined contingents of the same race in North America, but are near the Chinese, with whom the racial affinity is considerably less. The frequency and prevalent development of the fossa are plainly, therefore, manifestations of no great value as racial criteria.

In groping for other possible causes of the above differences it is soon appreciated that the subject, as is usual with biological problems, is not simple. There are doubtless involved old chance segregations and consequently differing hereditary influences, and there may be ontogenetic factors. One of the latter that would seem to deserve especial consideration is the general development of the bone. Looking at the above data from this point of view we detect some concordance —but also some disharmonies. The Canton Chinese have on the average relatively short and weak femora, and so have the old Peruvians—and these two groups stand together at the lowest incidence of the fossa; on the other hand, very strong, though not the largest, femora are common to the Eskimos and the Aleuts, while strong as well as large bones are shown by the Egyptians, and these three groups stand at or near the maximum end of our series. But the pre-Aleut Kodiaks have also relatively short and weak, the North American Indians prevalently large and strong, bones, yet the two stand side by side in the middle of the groups; and both the U. S. Whites and Negroes have relatively large and often powerful femora, yet they stand in the scale of frequency and development of the fossa next to the weak Peruvians. Thus here too, although some probability of a correlation between the fossa and the mass of the femur cannot be denied, the conditions are not definite and regular enough for any clear deductions.

Another feature that since Houzé's initial report has been believed by many to stand in correlation with the fossa is platymery, and the concomitant lipping of the lateral border, of the subtrochanteric part of the femur. Pearson and Bell, who tested the matter mathematically, found (p. 79) that there was only " a small but just sensible correlation between platymery and the presence of the fossa ". How small the correlation is may be seen from the two columns below:

THE FOSSA AND PLATYMERY

Our nine racial groups arranged on a basis of platymery, from its maximum (lowest index) to its minimum (highest index):	Same nine racial groups arranged on the basis of incidence and development of hypotrochanteric fossa, from highest to lowest:
Old Peruvians	Aleuts
Aleuts	Eskimos
N. A. Indians	Old Egyptians
Pre-Aleut Kodiaks	N. A. Indians
Eskimos	Pre-Aleut Kodiaks
Old Egyptians	U. S. Negroes
Chinese	U. S. Whites
U. S. Whites	Old Peruvians
U. S. Negroes	Chinese

The first column is probably not absolutely stable. Larger numbers of specimens in such groups as the Aleuts, Kodiaks, Chinese, and Negroes, or the addition of a sufficient number of females to the latter two groups, which include males only, might change the exact position in the row of some or even all of them, but such changes would in all likelihood be small. They would not substantially alter the obvious fact that there can at best be but little correlation between the two features in question.

Nor are these the only facts that speak against such an interdependence of the fossa and platymery, and also between the fossa and the lip of the lateral border. There are highly platymeric and lipped femora with but moderate or small fossae, and there are large fossae with but moderate platymery lipping. And the conditions in the anthropoid apes, so far as they apply to the question, do certainly not testify for any clear correlation.

In view of all this, in the rare cases where a pronounced fossa coexists with marked platymery and lipping, it seems legitimate to doubt their causal connection. These considerations, however, connect directly with the subject of the etiology of the fossa, a detailed discussion of which will be left for another paper.

ADOLESCENTS COMPARED WITH ADULTS

We shall at this point present facts which are of the utmost interest, and to which thus far there are no close parallels in anatomy and anthropology.

In dealing with the fetal and juvenile femora it was seen that the hypotrochanteric fossa began to form in some bones as early as the fifth month of the fetal life and that thenceforth it gradually increased, both in incidence and development, throughout the growth period. The long stretch of time during which it continued to originate, as well as to enlarge, is in itself a phenomenon of no small interest.

By the latter part of adolescence, in all the groups whose bones were available for the study, traces of the fossa to a pronounced hollow, were seen to have become almost universal. We now pass to the adult material, where we encounter a distinct surprise. The records of the frequency and spaciousness of the fossa in the adults show radical differences from those in the preadult life. These differences, moreover, are found in all the groups, and they cannot possibly be due either to chance or error. They are shown in the next table:

Hypotrochanteric Fossa in Adolescents and in Adults Compared (Both Sexes, Both Sides)

Group and no. of femora	None	Trace	Small but distinct	Moderate	Medium	Above medium	Pronounced
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
U. S. Whites:							
Adolescent (26)	15.4	15.4	15.4	34.6	11.5	3.8	3.8
Adult (1,000)	32.–	18.2	20.–	15.8	11.2	2.6	0.2
U. S. Negroes:[a]							
Adolescent (100)	31.–	16.–	7.–	16.–	19.–	7.–	4.–
Adult (100)	31.–	16.–	23.–	11.–	17.–	2.–	....
Old Egyptians:							
Adolescent (35)	2.9	....	14.3	14.3	28.6	22.9	17.1
Adult (200)	20.5	12.5	25.–	18.–	17.–	3.–	4.–
Old Peruvians:							
Adolescent (79)	6.3	2.5	8.9	11.4	32.9	21.5	16.5
Adult (868)	24.4	13.7	36.5	16.6	7.6	0.9	0.2
N. A. Indians:							
Adolescent (279)	2.9	2.5	6.1	17.6	35.8	25.1	10.1
Adult (3,890)	12.2	19.5	32.2	20.7	13.3	1.5	0.6
Eskimos:							
Adolescent (99)	3.–	3.–	10.1	18.2	35.4	20.2	10.1
Adult (718)	10.4	18.7	24.1	22.3	19.5	3.3	1.7

[a] Series least satisfactory: among adolescents a very large proportion of subadults (19–21 years) and a good many mixed-bloods; adults practically all full-blood.

The above data are striking enough, but they will be even more so if we condense them thus:

Hypotrochanteric Fossa in Adolescents and in Adults Compared, Both Sexes, Both Sides (Condensed)

Group	None	Trace to small	Submedium to medium	Above medium to pronounced
	Percent	Percent	Percent	Percent
U. S. Whites:				
Adolescent	15.4	30.8	46.1	7.6
Adult......	32.–	38.2	27.–	2.8
U. S. Negroes:				
Adolescent	(31.–)	23.–	35.–	11.–
Adult..........	31.–	39.–	28.–	2.–
Old Egyptians:				
Adolescent....	2.9	14.3	42.9	40.–
Adult........	20.5	37.5	35.–	7.–
Old Peruvians:				
Adolescent	6.3	11.4	44.3	38.–
Adult........	24.4	50.2	24.2	1.1
N. A. Indians:				
Adolescent...	2.9	8.6	53.4	35.1
Adult.......	12.2	51.7	34.–	2.1
Eskimos:				
Adolescent...	3.–	13.1	53.5	30.3
Adult...	10.4	42.8	41.8	5.–
General approximate means:				
Adolescent[a]............	6.1[b]	16.9	45.9	27.–
Adult....................	21.7	43.2	31.7	3.3

[a] Omitting the Negroes.
[b] With the Negroes—10.2.

The above figures mean that in advancing through the adult life the human femur loses a large proportion of the more marked grades of the hypotrochanteric fossa, gains largely in the "trace" to "small" grades, and to a considerable degree loses the fossa entirely.

This is a highly interesting and, in its definiteness, so far a unique phenomenon in anatomy and anthropology. It is known, of course, though only very generally, that structural changes proceed in probably all parts of the body as age advances, but there is as yet no parallel to such a peculiar and clear-cut range of manifestations as offered by the hypotrochanteric fossa. Here is a formation of some note which, it has been seen, advances steadily in both its incidence and its development during a very large part of the growing period but which, once the adult life is reached, enters upon a retrogressive path tending toward its disappearance.

The strange phenomenon presents two problems. The first of these is, what causes the long sustained development of the fossa during the growth period; and the second, what causes its regression during adult life.

The first question cannot be fully solved until we know precisely what the fossa in man serves for. A portion of the development of the fossa in size is possibly conditioned simply by the general growth of the bone, though with a feature of this nature such a process may not be as simple as it would seem at first thought. A more plausible and appealing theory is that the fossa, during the growth period and especially in adolescence, is functional but that it loses its value in this respect during adult life. No definite conclusions on these points are now possible; they can be reached only by extended observations on suitable dissecting-room materials which thus far, notwithstanding my efforts in this direction, could not be realized.

The second problem, or what causes the curious regression of the fossa during adult life, is also an involved one. There is the weakening functional cause, of which very little can now be said; and there is the actual process of diminution-to-disappearance of the fossa in many cases, which ought to be subject to observation.

As a matter of fact, all the stages of a gradual occlusion of the fossa may be witnessed in human femora, and in some cases such an occlusion starts far ahead of the adult life. Occasionally as early as the later childhood a more or less noticeable "deposit" of bone may be observed in the upper part of the fossa. The process begins as a rule in this upper part of the hollow and often in the form of one or two isolated narrow vertical patches. Where it is larger, such a "deposit" looks not osteophytic, but like a flow of some originally viscid substance, or as if made by the pastry-makers' cone. As age progresses, such "deposits" in the hypotrochanteric fossa become slowly more frequent and more pronounced, and some of them may clearly be seen to connect with and augment the gluteal ridge, whereas in other cases they come to represent a gluteal tuberosity or third trochanter. As the process is followed into the adult life, it is possible to note all stages of obliteration of the fossa by these secondary bony deposits, until in many instances only a small groove or mere trace remains of the once well-marked hollow, and not infrequently the hollow disappears altogether, being traceable only by the new bone formation. The fossa is thus encroached upon and more or less assimilated by the progressive development of the gluteal ridge and the need for a larger basis for the gluteal insertion.

Before this peculiar encroachment and assimilation begin, the fossa in the human femur is in general free from excrescences or irregularities that would denote the attachment of a powerful muscle. It is fusiform, symmetrical, and fairly smooth, with few exceptions in each of these characters. If any part of the gluteus maximus inserts within the fossa before the secondary bone deposits begin, it can only be the weaker fibers or the muscle sheath. But later the fossa is certainly invaded by powerful strands of the muscle, or the weak original strands develop in power.

The same processes here described occur in all the races and may readily be studied from their inception. But nothing of this nature is found in the anthropoid apes, where, in general, the fossa from the start is seen to serve for a strong muscular insertion and is plainly formed by this insertion. It appears that the conditions in these apes, where the fossa is often of primary, the adjacent gluteal ridge of secondary importance, and the gluteal tuberosity (third trochanter) is absent or moderate, have become reversed in man, where the gluteal ridge and tuberosity have assumed the primary position, and the fossa, though it persists, seems to be a sort of left-over, of only secondary significance. These observations would not hold good, however, if the human fossa during the growth period should be found to exercise some special function. It is tantalizing that, with all these fine skeletal series now at our command, the last point cannot be settled for the want of suitable dissection materials.

A few additional observations may be recorded.

In examining the adult femora it seemed in some bones that the fossa may have regressed, both in depth and size, even without any discernible secondary bone formation. This would imply interstitial growth of bone underneath and about the fossa.

The oblong or rounded gluteal tuberosity (third trochanter) was seen in some bones to be located completely above and well separated from the fossa, not affecting this in any way; or to involve its upper end; or to be lying sometimes completely within the hollow. In one femur the tuberosity was situated as low down as the middle of the fossa; in none was it below the middle. In not a few adult specimens a large tuberosity (third trochanter) alone so filled the fossa that only a bare trace of it, perhaps only a part of its old outline, remained perceptible. The tuberosity, when it is in the fossa, may be said to have an even greater effect on the regression or disappearance of the hollow than the gluteal ridge; but as the tuberosity in many cases is a constituent part of the ridge, exact statements are difficult in this connection.

The matter of the relation of the gluteal ridge to the gluteal tuberosity and the fossa will be dealt with further in another paper. The main points that may succinctly be repeated are that in man, from later childhood onward, the fossa in increasing numbers of cases suffers through more or less extensive deposits of new bone in its lumen; that this new bone becomes assimilated by the gluteal ridge, or forms a gluteal tuberosity (third trochanter), or both; and that the diminution in the fossa progresses from above downward and from the gluteal ridge outward until but a lateral or lateral-inferior remnant of the hollow is left, or all traces of it are lost; but that in some cases the fossa appears to diminish also by interstitial growth of the bone underlying and surrounding it.

DIFFERENCES IN ADULTS IN THE TWO SEXES

Owing to the availability of good series of material, it is possible to give here reliable data as to the sex differences in the hypotrochanteric fossa. The White and Negro bones were sexed from the bodies; in a large proportion of the other specimens the sexing was supported by the rest of the skeleton (with occasionally significant articles found in the grave), and the rest were sexed simply on the basis of ample experience. The data will best be given together:

Hypotrochanteric Fossa and Sex, in Adult Femora

Group and no. of femora	None	Trace	Small but distinct	Moderate	Medium	Above medium	Pronounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
U. S. Whites:								
Male (600).....	32.3	16.3	19.7	16.7	11.5	3.3	0.2	(1.8)
Female (400)...	31.5	21.–	20.5	14.5	10.7	1.5	0.3	(1.7)
U. S. Negro:								
Male (64)......	23.4	17.2	21.9	15.6	18.8	3.1	....	(3.1)
Female (36)....	(44.4)	13.9	25.–	2.8	13.9	....	....	(2.8)
Old Egyptians:								
Male (120).....	20.8	11.7	24.2	16.7	18.3	2.5	5.8	(6.7)
Female (80)....	20.–	13.8	26.3	20.–	15.–	3.7	1.2	(2.5)
Old Peruvians:								
Male (268).....	30.3	17.1	36.9	10.5	4.5	0.8	....	....
Female (600)...	21.8	12.2	36.3	19.3	9.–	1.–	0.3	(0.1)
N. A. Indians:								
Male (1,749)...	13.8	20.–	31.3	20.–	12.9	1.4	0.6	(1.–)
Female (2,141)..	10.9	19.2	32.9	21.3	13.5	1.6	0.6	(3.–)
Eskimos:								
Male (369).....	10.–	18.2	26.6	21.9	17.6	3.3	2.4	(4.6)
Female (349)...	10.9	19.2	21.5	22.6	21.5	3.4	0.9	(1.7)
Condensed and rough means of all:								
Male (3,170)...	21.8	43.5		30.8		3.9		(2.9)
Female (3,606)..	24.9	43.6		30.7		2.4		(2.–)

The sex differences in the incidence and development of the hypotrochanteric fossa on the whole are, it is seen, rather insignificant. The males have a slight excess of the large fossae and also of the fossa-grooves, but in the American Indians, both North American and of old Peru, it is the females that predominate slightly in this respect, as they do also in the total frequency of the fossa.

More in detail, the Indians, both North American and those of Peru, stand somewhat apart in this respect from the rest of the groups. They show a larger proportion of the " absent " and " trace " in the males, with a slightly larger proportion of the " pronounced " forms and of the fossa-groove in the females. The females here in this respect, as in so many others, show more juvenile character. In the rest of the groups, except the Negroes, where the numbers are insufficient, the " absent " are nearly alike in the two sexes, the " trace " to " above medium " grades differ moderately and irregularly, and the " pronounced " forms of the fossa and the fossa-grooves, equal in the two sexes in the Whites, predominate in the males in the Egyptians and the Eskimos.

The conclusion of Von Török, Evangeli-Tramond, and Pearson and Bell, that the fossa was more frequent in the males, is thus subject to corrections. The important age factor, it may be said, is presumably much alike in the two Indian and the Eskimo series, but differs in the rest, which doubtless has had some effect on the records.

DIFFERENCES IN ADULTS AS TO SIDE

The large adult series of human femora at our disposal make it possible to learn something definite on the differences in the incidence and development of the hypotrochanteric fossa on the two sides of the body. Pearson and Bell's results on this point were, it will be recalled, contradictory, and nothing decisive was observed in this respect on our North American Indian juveniles. The data, to start with, may most conveniently be presented without regard to sex. A very large proportion of the femora involved in the study are paired.

Some appreciable side differences evidently exist, but they are not large. On the whole, the rights show more " absent " and " trace "—meaning probably more obliteration; somewhat less of " small " to " medium "; about the same of the " pronounced "; and rather notably more of the fossa-grooves. Group differences are small except in the old Egyptians, where the right bones show decidedly more on one hand of the " absent " and " trace " and on the other of the " above medium " and " pronounced," as well as a much larger proportion of the fossa-grooves.

Hypotrochanteric Fossa and Side in Adult Femora

Group and no. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
U. S. Whites:								
Right (500).....	35.–	18.4	20.–	14.6	9.–	2.4	....	(1.6)
Left (500)......	28.4	18.–	20.–	17.–	13.4	2.8	0.4	(2.–)
U. S. Negroes:								
Right (51)......	35.3	17.6	15.7	7.8	21.6	2.–	....	(5.9)
Left (49).......	26.5	14.3	30.6	14.3	12.2	2.–	....	....
Old Egyptians:								
Right (95)......	24.2	17.9	22.1	12.6	14.7	4.2	4.2	(9.5)
Left (105)......	17.1	7.6	27.6	22.9	19.–	1.9	3.8	(1.–)
Old Peruvians:								
Right (457).....	24.5	13.8	37.2	15.5	8.3	0.7	....	....
Left (411)......	24.3	13.7	35.8	17.8	6.8	1.2	0.5	(0.2)
N. A. Indians:								
Right (1,944)...	13.7	20.–	31.9	18.7	13.5	1.7	0.6	(2.5)
Left (1,946) ...	10.7	19.1	32.5	22.7	13.1	1.3	0.6	(1.7)
Eskimos:								
Right (367) ...	10.9	20.7	27.5	21.–	15.5	2.7	1.6	(3.8)
Left (351)......	10.–	16.5	20.5	23.6	23.6	4.–	1.7	(2.6)
Rough means of all:								
Right (3,414)...	23.9	18.1	25.7	15.–	13.8	2.3	1.3	(3.9)
Left (3,362)....	19.5	14.9	27.8	19.7	14.7	2.2	1.4	(1.3)

That, however, side differences of distinct nature may occur in some racial groups will be seen in the following records obtained on the femora of male Canton Chinese:

Hypotrochanteric Fossa and Side in Chinese Femora

Side and no. of femora	None	Trace	Small but distinct	Mod-erate	Medium	Above medium	Pro-nounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Right (77).........	36.4	19.5	16.9	15.6	10.4	1.3	....	(6.5)
Left (75)...........	41.3	22.7	17.3	12.–	5.3	1.3	....	(1.3)

Conditions here in the first five grades ("none" to "medium") are the reverse of those in all the preceding series, but the "above medium" and "fossa-groove" hold true to the general tendencies. Differences such as these are, however, probably due less to race than to localized group peculiarities.

The exceptional showing of the Cantonese, who were all males, raises the question as to possible differences in the relations of the fossa on the two sides in the two sexes. This query may best be answered by our two largest and racially well distinct groups, the U. S. Whites and the North American Indians:

Hypotrochanteric Fossa According to Side in the Two Sexes

Group and no. of femora	None	Trace	Small but distinct	Moderate	Medium	Above medium	Pronounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
U. S. Whites:								
Male:								
Right (300)..	35.3	16.7	20.3	14.7	10.3	2.7	...	(1.3)
Left (300)....	29.3	16.–	19.–	18.7	12.7	4.–	0.3	(2.3)
Female:								
Right (200)..	36.–	21.–	19.5	14.5	7.–	2.–	...	(2.–)
Left (200)....	27.–	21.–	21.5	14.5	14.5	1.–	0.5	(1.5)
N. A. Indians:								
Male:								
Right (857)..	15.3	20.1	31.7	17.4	13.7	1.4	0.5	(1.1)
Left (892)....	12.3	19.8	30.9	22.6	12.2	1.3	0.7	(0.9)
Female:								
Right (1,087).	12.4	19.9	32.–	19.8	13.3	1.9	0.6	(3.6)
Left (1,054)..	9.3	18.5	33.9	22.8	13.8	1.3	0.5	(2.5)

The data, it is plain, do not indicate any material influence of the sexes on the incidence or development of the fossa on the two sides of the body, and the exceptional showing of the Chinese cannot therefore be attributed to sex alone.

The only moderate general influence of sex and side on the hypotrochanteric fossa in man can only mean, it seems, that the feature in the human species is a well ingrained old character.

THE FOSSA IN THE AGED

The extensive collection of the skeletal remains of known Whites now in the United States National Museum permits of an inquiry as to the effects of advancing age on the hypotrochanteric fossa. The material selected for this test consisted of the paired femora of 100 males of 60 years and over. The results are instructive. There is found a greater mean development of the gluteal ridge in these senile bones than in the adults of lower ages, and a decidedly greater retrogression of the fossa. The latter will be clearly seen in the next table.

Although the above general series includes many elderly individuals, nevertheless the differences between it and the aged group is very notable. The " absent " in the aged are over one third more numerous, *Hypotrochanteric Fossa in the Aged*

No. of femora (all paired)	None	Trace	Small but distinct	Moderate	Medium	Above medium	Pronounced	Of which a fossa-groove
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Old Males:								
Right (100)	53.–	19.–	17.–	7.–	4.–	....	....	....
Left (100)	48.–	16.–	18.–	11.–	7.–	....	....	....
All (200)	50.5	17.5	17.5	9.–	5.5	....	....	....
All white adult males (600)[a]	32.3	16.3	19.7	16.7	11.5	3.3	0.2	(1.8)

[a] The majority from elderly subjects.

the "moderate" to "medium" have markedly diminished, and the "pronounced" forms are now wholly absent. The representation of the fossa in the aged, in comparison to the general adult quantum, is decidedly lessened. The regression of the hollow has therefore continued throughout adult life, and that in favor of the gluteal ridge, which kept on developing. Thus by the time senility is reached, the hypotrochanteric fossa has been largely, and in many cases entirely, assimilated or replaced by the gluteal ridge.

SIZE OF THE FOSSA

Evangeli-Tramond, it was seen, reported fossae up to 4 to 5 centimeters in length, 1 centimeter in breadth, and several millimeters in depth. Measurements of 20 of the largest fossae I encountered gave the following values:

Femora	Length (max.)	Breadth (max.)	Depth (max.)
	cm	mm	mm
Adolescent, Peru	5.6	12	1.5
" "	5.6	10	2.–
" "	5.6	12.5	1.5
" "	5.7	11	2.–
" "	5.8	9	1.5
Child, "	5.8	9	2.5
Adolescent, "	6.–	11	3.–
" "	6.2	11	4.–
" S. Dak.	6.5	11	3.–
" " "	7.–	12	3.–
Subadult, Aleut	7.–	12	3.–
Adult, Peru	7.1	10	4.–
" Egypt	7.4	10	4.–
Adolescent, Peru	7.5	10	3.–
" Ohio	7.7	10	3.–
" Egypt	7.9	12	2.–
Subadult, Eskimo	8.2	10	4.–
Adult, Louisiana	8.6	10	3.–
" "	8.8	9.5	2.–
" Egypt	9.4	9	2.–

It is obvious that in some femora the hypotrochanteric fossa is no negligible feature.

LIFE HISTORY OF THE FOSSA

Thanks to the data it has been possible to present here, it is practicable, for the first time, it seems, in anatomy and anthropology, to view—grossly at least—the whole ontogeny, the full life history, of a definite feature of human morphology.

The life history of the hypotrochanteric fossa could be presented graphically in the form of a curve of long but steady ascension, a mildly rounded or flat summit, and then a prolonged descent to about or even below one half of the height of the earlier rise. In other words, we see first a gradual long rise of the fossa on a phylogenetic basis toward the condition of a fullfledged character, and then its slow, irresistible assimilation by a vigorous neighboring feature.

And there are indications—in some instances, or to some degree, definite proofs—that every single separate organ or part of the human body, and every human function, too, has its own extensive and highly interesting life history, a history connected in its origins with human derivations and antiquity, and ending in advancing regression and apparent preparation for disappearance; or in seeming tranquility, stability; or in some degree of progressiveness toward a greater representation. The realization of these conditions opens a vast and intensely attractive field for coming researches. The studies of human variation and those of the life histories—or perhaps they should be called existence histories—of the innumerable components of human structure and functions are the most alluring realms of human anatomy, physiology, and anthropology of the future.

THE FOSSA IN LOWER MAMMALS

Thanks to the aid of the division of mammals of the United States National Museum, I have been able to examine for the fossa a series of femora representing the principal mammalian forms, with the following results:

Carnivores:

Lion	No hypotrochanteric fossa
Tiger	" " "
Puma	" " "
Wolf	" " "
Fox	" " "
Bear	" " "

Insectivores:	
Galeopithecus	No hypotrochanteric fossa
Erinaceus	" " "
Cetaceans:	
Merounga	" " "
Rodents:	
Hydrochoerus	" " "
Beaver	" " "
Rabbit	" " "
Ungulates:	
Camel	" " "
Bison (*B. urus*)	" " "
Horse	" " "
Deer	" " "
Antelope	" " "
Marsupials, Edentates, Monotremata, Chiroptera:	
Macropus	" " "
Anteater	" " "
Dasypus	" " "
Duckbill	" " "
Pteropus	" " "

None of the above mammals below the primates, it is seen, shows the hollow under consideration, though a fossa or groove mesially to the generally marginal gluteal ridge, serving possibly to the adductor muscle, is not uncommon. However, the bones of but one individual of each kind were examined, and many forms are not represented at all. Yet the uniformity of the showing, together with the fact that the gluteal ridge, usually sharp and mostly inconspicuous, forms in these mammals a portion of the lateral border and thus leaves no room for the fossa, speak for the probability that the hypotrochanteric fossa is essentially or even entirely a primate character. Furthermore, it has been shown previously in this paper that among the primates the hollow belongs almost exclusively to the anthropoid apes, particularly the three large genera, and to man. There is surely something of interest in this distribution.

SUMMARY

The present study has thrown light on many details of the feature under consideration, some of which are quite new; but, as usually happens, while clearing some problems, the inquiry has raised others which call for further research, particularly that on the musculature and other soft parts of the region in question.

The points of paramount interest that issue from the work are in brief these:

The hypotrochanteric fossa in man is a well-established phyletic feature passed on from the common ancestry of man and of the larger anthropoid apes. It is a feature the old function of which, apparently, was that of a place for the attachment of the gluteus maximus; but in man this function has it seems become largely, if not entirely, obsolete, and in part perhaps changed.

Ontogenetically, the fossa begins to appear from the fifth month of the intrauterine life; but because of its lost importance, in all probability, there is much retardation, so that the period during which it may originate is greatly prolonged, extending over practically the entire growth period.

Doubtless for the same reason, i.e., the obsolescence of the fossa in the human femur, there are cases in which the hollow does not appear at all, and there are many in which it develops only in a more or less rudimentary form.

And from the same cause, basically, the fossa is not permanent. On the whole, it reaches its optimum dimensions during adolescence, but in individual instances even in childhood, it begins to show already signs of obliteration. This obliteration is due to secondary bone deposits or growths beginning in and extending from the upper part of the fossa. It is a slowly progressive osteoblastic process that finally involves and occludes most or all of the fossa and thus leads to its partial or total disappearance. This regressive course, although it may begin early, is essentially a phenomenon of the subadult and adult periods and proceeds to old age.

The active cause of this regression or obliteration is the gluteal insertion adjacent to the fossa. This insertion in man has become confined mainly or entirely to the gluteal ridge; and in active individuals, as the need for a greater insertion grows, new bone that eventually becomes assimilated into the enlarging gluteal ridge is deposited, and this deposit is always realized in and at the expense of the hypotrochanteric fossa. Thus the gluteal ridge during subadult and adult life may be said to more or less assimilate the fossa.

The hypotrochanteric fossa possesses some interesting physical characteristics. From the start, when it is a mere imprint on the bone rather than a hollow, it presents a well-demarked fusiform outline, with the long axis vertical and always longer than the transverse. The floor of the fossa, reticulated at first, becomes in general symmetrical and fairly smooth later on. In a small proportion of femora the lower boundary of the fossa is wanting, and the hollow then forms a marked smooth groove, which descends parallel with the crista aspera and which in instances may be traced to near the middle of the shaft; the meaning of this condition is not as yet understood.

The mesial border of the fossa constitutes invariably the gluteal ridge or a part of it, and the lateral border is never conspicuous. The size of the fossa may reach very considerable proportions; it has little, if any, relation to the size of the bone. In location the fossa in man is generally postero-lateral, but in some femora it may be displaced close to, or rarely even into, the lateral border, as is common in the larger anthropoids. It has no basic or causative relation to the subtrochanteric flattening of the femur. It is a formation *sui generis,* not a by-product of any of its neighboring structures. It is allied to other fossae or grooves that serve for muscular insertions and which can be seen to advantage in other—especially the anthropoid—femora; but the hypotrochanteric fossa in man, as seen at its optimum in the adolescents, has much more of definiteness and individuality, is much more of a well evolved and differentiated character, than any of the other hollows.

Precisely what the fossa in man contains or serves for before its "glutealization" is still uncertain, an appeal to several of the dissecting rooms having thus far proved unsuccessful owing to the dearth of adolescent cadavers.

As further points of interest, there may be mentioned the following: The fossa in a distinguishable form may appear before or after the first stages of the gluteal ridge; it may remain completely absent while the ridge develops; and it may persist throughout life without any marked gluteal ridge or with any degree of this ridge, though the more developed the ridge, the more likely is its encroachment upon the fossa. Finally, the hollow is earlier than, as well as wholly independent of, the third trochanter, though this may extend over, or even develop within, the upper-to-middle reaches of the hollow and diminish its lumen accordingly. Notwithstanding the seeming—and probably largely real—independence of the fossa and the gluteal ridge, a certain amount of reciprocity appears to exist during life, between the fossa and the ridge: where the fossa is absent, the ridge in general will be found to be more distinct than where the fossa exists.

The incidence of the hypotrochanteric fossa differs in various human races and other groups, but these differences are neither great nor always conformable to general racial affinities. Moreover, the ordinary comparative data, it is now plain, are not pure enough, embracing as they do adults of all ages and not presenting in all the groups the same age distribution. They are biased, in other words, by irremediable differences in the important age factor.

The incidence and development of the fossa shows also some sex and side differences, but these are neither very marked nor of great importance.

The future of the hypotrochanteric fossa in man probably will be, in general, a gradual further diminution in both its incidence and development.

HYPOTROCHANTERIC FOSSA, LARGE, ROUGH, MARGINAL

Femora of two gorillas, U.S.N.M. nos. 239,883 and 174,723.

HYPOTROCHANTERIC FOSSA, DEEP MARGINAL

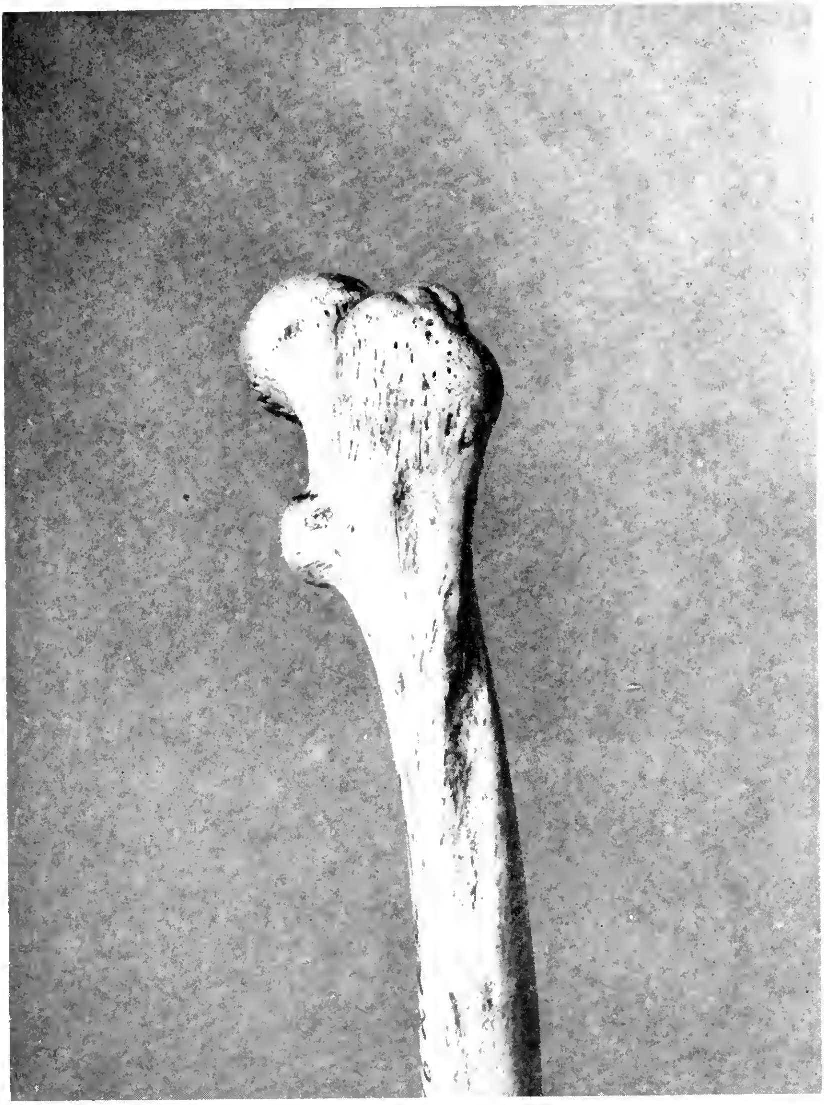
Orang, male, U.S.N.M. no. 49,859.

MARKED HYPOTROCHANTERIC FOSSA, PARTLY MARGINAL, PARTLY (THE LEFT LARGELY) DISPLACED TO THE ANTERIOR SURFACE

Chimpanzee, U.S.N.M. no. 220,327.

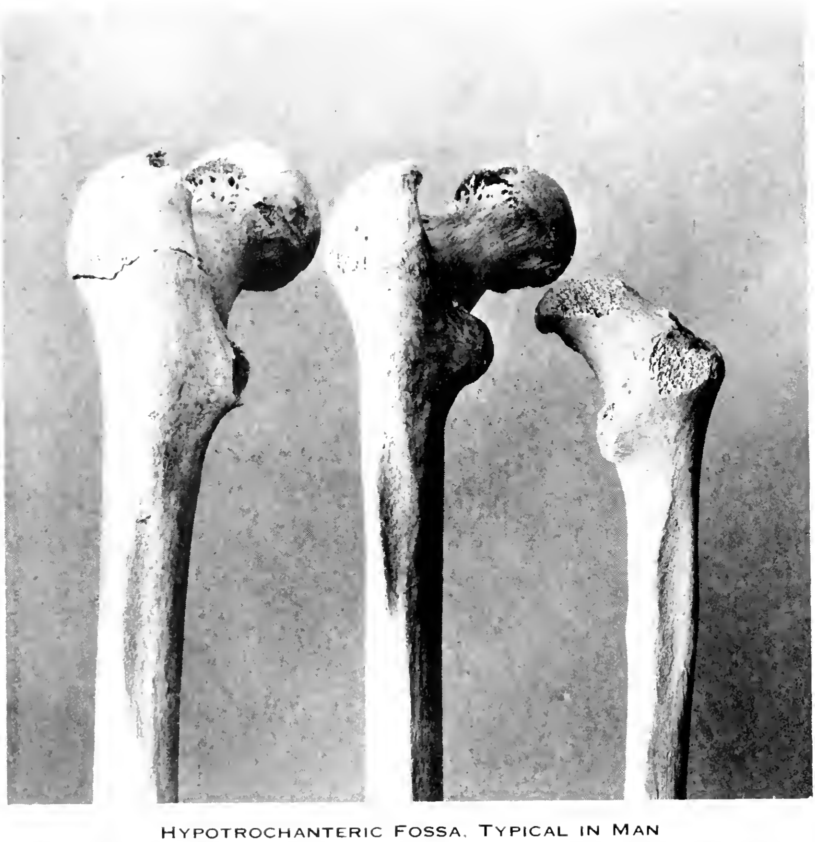
HYPOTROCHANTERIC FOSSA, DISPLACED ENTIRELY TO THE ANTERIOR SURFACE (BILATERALLY)

Orang, male, U.S.N.M. no. 49,860.



MARKED HYPOTROCHANTERIC FOSSA, MARGINAL

Marked acc. adductor fossa (ant.-sup.). Mild pectineal fossa (indistinct on photograph).
Chimpanzee, U.S.N.M. no. 176,226.



HYPOTROCHANTERIC FOSSA, TYPICAL IN MAN

Left to right: Male, Egypt, older adolescent; U.S.N.M. no. 268,356—2218, Pachacamac, older adolescent; Lisht, young adolescent.

HYPOTROCHANTERIC FOSSA, LARGE

Left to right: Male, Pavik, U.S.N.M. no. 363,568; male, Louisiana, U.S.N.M. no. 341,225; male, Ohio, U.S.N.M. no. 320,061.

HYPOTROCHANTERIC FOSSA-GROOVES

Left to right: Female, Illinois, U.S.N.M. no. 227,336; female, Point Barrow, U.S.N.M. no. 365,892; male, Lisht.

HYPOTROCHANTERIC FOSSA-GROOVES, PRONOUNCED

Left to right: Male, Egypt, Lisht; male, Eskimo, Yukon, U.S.N.M. no. 345,736; male, Lisht.

BEGINNINGS OF GLUTEAL TUBEROSITY (THIRD TROCHANTER) IN FEMORA OF CHILDREN

Left to right: Pair, U.S.N.M. no. 329,121, Ohio, right, 18.2 max. length, U.S.N.M. no. 268,350—2212, Pachacamac, right, 17.8 max. length.

SECONDARY DEPOSITS OF BONE IN HYPOTROCHANTERIC FOSSA AND A FOSSA-GROOVE (MIDDLE)

Left to right: Male, older adolescent, Pachacamac, U.S.N.M. no. 268,356 2257; female, young adult, Kentucky, U.S.N.M no. 290,033; younger adolescent, Pachacamac, U.S.N.M. no. 268,356 2242.

SECONDARY DEPOSITS OF BONE IN HYPOTROCHANTERIC FOSSA

Left to right: Midadolescent, Pachacamac, U.S.N.M. no. 268,356-2203; male, midadolescent, Chicama, U.S.N.M. no. 265,331; male, older adolescent, Pachacamac, U.S.N.M. no. 268,356-2239.

SECONDARY DEPOSITS OF BONE IN HYPOTROCHANTERIC FOSSA; FROM LEFT TO RIGHT—TRACES, MODERATE, PRONOUNCED DEPOSITS

Left to right: Young adolescent, Pachacamac, U.S.N.M. no. 268,356; older adolescent, Pachacamac, U.S.N.M. no. 268,356; young adolescent, Pachacamac, U.S.N.M. no. 268,356 2230.

MARGINAL FOSSA

Left to right: Orang, male, U.S.N.M. no. 49,850; midadolescent, Eskimo, Nunivak, U.S.N.M. no. 339,235.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 2

NEW FRESH-WATER MOLLUSKS FROM NORTHERN ASIA

(With One Plate)

BY
ALAN MOZLEY
Walter Rathbone Bacon Scholar, Smithsonian Institution

(Publication 3253)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 8, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NEW FRESH-WATER MOLLUSKS FROM NORTHERN ASIA

By ALAN MOZLEY

Walter Rathbone Bacon Scholar, Smithsonian Institution

(WITH ONE PLATE)

During the years 1932 and 1933 a journey was made through certain parts of Siberia and northern Kazakstan, under the grant of the Walter Rathbone Bacon Scholarship [1] of the Smithsonian Institution. The object of this expedition was to investigate the molluscan fauna of the region, and in the course of working up the material collected, several forms have been discovered which appear to be undescribed. A report on the fauna as a whole will appear at a later date, but in the meantime it appears to be desirable to place on record a brief description of the new forms, which is given below.

VALVATA ANTIQUILINA, n. sp.

Plate 1, fig. 4

Shell of moderate size for members of this genus, length 6.4 mm, broadly conical; surface smooth, with minute crowded lines of growth; whorls four and seven-eighths, convex, very slightly flattened; aperture subcircular, very slightly angulated along the superior margin, lip continuous, attached to the preceding whorl for about 0.6 mm. The dimensions of the type are as follows: Length 6.4 mm, greater diameter 5.9 mm, lesser diameter 5.2 mm, aperture length 3.1 mm, aperture width 2.5 mm.

Type.—U.S.N.M. no. 469212, collected at Lake Khomotenoye, Aj-Bulat drainage basin, Siberia. This is approximately 370 kilometers southeast of Omsk.

This species has some resemblance to both *V. piscinalis* (Müller), and *V. antiqua* Morris, and in many respects is intermediate between these two species. It differs from most forms of *V. piscinalis* in having

[1] Created through a bequest to the Institution by Mrs. Virginia Purdy Bacon "to be used in establishing a traveling scholarship, to be called the Walter Rathbone Bacon scholarship for the study of the fauna of countries other than the United States of America."

the shell as a whole more solidly built, the spire more bluntly conical, and the whorls less broadly rounded, those in the new species being a little flattened, and turning sharply into the suture. *V. antiquilina* differs from *V. antiqua* Morris (pl. 1, fig. 5) in the proportions of the shell (see measurements below), the new form being slightly more broadly built, in having the suture a little deeper, and in the whorls being regularly rounded and slightly flattened, rather than rounded and projecting downward as in *V. antiqua*.

No living specimens were found, all the shells being empty and bleached. Apparently this species lived in Lake Khomotenoye at some former time when the water level stood considerably higher than at present.

Measurements of the Shells of Valvata antiquilina, n. sp., from the Shore of Lake Khomotenoye, Siberia

No. of whorls	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
4 3/4	6.4	6.0	5.5	2.7	2.5
4 3/4	6.0	5.1	4.7	2.8	2.4
4 5/8	5.7	4.8	4.6	2.3	2.1
4 5/8	5.5	4.9	4.7	2.4	2.4
4 1/2	5.6	5.4	4.8	2.5	2.4
4 1/2	5.4	4.9	4.7	2.5	2.3
4 1/2	5.3	4.8	4.5	2.7	2.1
4 1/4	5.3	4.8	4.5	2.6	1.9
4 1/4	4.7	4.5	4.1	1.9	1.8
4 1/8	4.9	5.1	4.6	2.7	2.2

Measurements of the Shells of Valvata antiqua Morris from Grays, Essex (Type Locality)

No. of whorls	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
4 7/8	7.3	6.1	5.3	2.8	2.6
4 7/8	6.4	5.2	4.5	2.8	2.3
4 3/4	6.3	5.5	5.0	2.8	2.3
4 5/8	6.4	6.0	5.6	3.2	2.9
4 5/8	6.3	5.2	4.9	2.4	2.3

LYMNAEA (GALBA) PALUSTRIS SARIDALENSIS, n. subsp.

Plate 1, fig. 1

Shell of moderate size, length 23.9 mm, elongate, and much narrower in proportion to the length than in the usual forms of *palustris*; light horn-colored, thin, surface smooth, minutely wrinkled, lines of growth not prominent, crossed by impressed spiral lines; whorls seven and one-half, regularly convex; spire long and narrow, more than half the length of the shell; suture moderately deep; aperture elongate-elliptical; outer lip gently rounded, periphery sharp and thin; columella somewhat twisted; umbilical chink a minute elongated slit.

Type.—U.S.N.M. no. 469734. It comes from a small, somewhat saline lake on the Steppe Sari Dala, 15 kilometers southwest of Pavlodar, northern Kazakstan.

This species is known only from the type locality, which is about 400 kilometers southeast of Omsk, and 600 kilometers north of Lake Balkhash. Some idea of the geographical position may be given by stating that Pavlodar is situated approximately midway between Delhi, British India, and the Arctic Ocean.

Measurements of the Shells of Lymnaea palustris saridalensis, n. subsp., from the Steppe Sari Dala 15 Kilometers Southwest of Pavlodar, Kazakstan

Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
25.7	9.5	9.0	10.7	5.4
25.0	9.6	8.7	10.4	5.0
24.9	9.9	9.1	10.8	5.9
24.8	8.9	8.2	9.5	4.8
24.7	9.4	8.6	10.3	5.5
24.5	9.5	8.4	9.9	4.9
24.2	9.5	8.8	10.0	5.6
24.1	9.8	9.2	11.0	5.9
23.9	9.7	8.8	10.4	5.8
23.9	9.5	8.9	10.4	5.3
23.9	9.5	8.8	10.2	5.5
22.3	8.5	7.7	9.5	5.0
21.0	7.9	7.4	8.7	5.1
19.0	7.4	7.2	7.7	4.6
18.0	7.7	7.1	8.0	4.7

LYMNAEA (GALBA) PALUSTRIS KAZAKENSIS, n. subsp.

Plate 1, fig. 7

This resembles *L. palustris saridalensis* but has eight whorls, which are somewhat shouldered; the suture is very deeply impressed, the lower side of the whorls slopes into the suture in a plane not far from the vertical, the superior margin of each whorl, however, while at first gently curved, finally turns abruptly into the suture; the spire is very long, forming nearly three-fifths of the length of the shell as a whole, and has a somewhat turreted appearance.

Type.—U.S.N.M. no. 470457, from a small dry lake bottom near the village of Novo Troetskaya, northern Kazakstan.

Measurements of the Shells of Lymnaea palustris kazakensis, n. subsp., from near Novo Troetskaya, Kazakstan

	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
Type	30.0	11.7	10.9	12.3	7.4
	26.5	10.9	10.4	11.3	6.3
	25.7	10.7	9.9	11.0	6.5
	25.1	9.9	10.0	11.3	6.6
	24.9	10.5	9.8	10.8	6.3
	24.8	10.2	9.5	10.5	5.7
	24.6	10.2	9.6	10.4	6.1
	23.8	9.9	9.0	10.4	5.9
	23.4	10.0	9.2	9.8	6.3
	21.2	8.9	8.5	8.9	5.3
	20.4	8.5	7.8	7.8	4.8

LYMNAEA (GALBA) PALUSTRIS DRAVERTI, n. subsp.

Plate 1, fig. 9

Shell somewhat resembling that of *L. palustris kazakensis* but having a more broadly conical spire; whorls seven and a half, convex, gently rounded, turning gradually into the suture, which is deep; aperture small and subovate, oval by comparison with that of *kazakensis*, columella not twisted, umbilical chink of large size.

Type.—U.S.N.M. no. 469681, from the River Om, near Omsk, Siberia.

This species is known only from the type locality. Collected by Prof. Pierre Dravert, after whom it is named.

Measurements of the Shells of Lymnaea palustris draverti, n. subsp., from the River Om, near Omsk, Siberia

	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
Type	19.6	8.8	8.2	7.7	4.8
	19.2	9.1	8.7	8.9	5.4
	18.5	8.4	7.6	7.7	4.6
	17.9	9.2	8.1	8.3	5.5
	17.7	8.3	7.6	7.8	4.8
	16.3	7.9	7.1	7.3	4.4
	16.0	8.2	7.4	7.5	4.7
	15.8	7.8	7.2	7.2	4.7
	15.2	7.4	6.8	7.0	4.4
	14.1	7.0	6.4	6.2	3.7
	13.4	7.0	6.3	6.0	3.5

LYMNAEA (GALBA) PALUSTRIS BOLOTENSIS, n. subsp.

Plate 1, fig. 3

Shell somewhat smaller than in all the subspecies here described (length 22.7 mm) but of greater thickness; the general appearance somewhat barrel-shaped in comparison with *kazakensis* and the others, as a result of the shallowness of the suture, and the relatively large size of the last three whorls; the aperture is small and roundly auriform, the columella thin and only slightly twisted, and the outer lip thin, sharp and without any tendency toward flaring.

Type.—U.S.N.M. no. 469821, from flooded area between the Rivers Chaganak and Chederti, Djarla-Uli drainage basin, northern Kazakstan.

Measurements of the Shells of Lymnaea palustris bolotensis, n. subsp., from several localities in Kazakstan

	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm	Locality
Type	22.7	8.9	8.5	8.1	5.4	Flooded area between the Rivers Chederti and Chaganak.
	21.4	9.1	8.7	9.3	6.8	Same.
	21.4	8.4	7.9	9.5	5.4	River Chaganak.
	21.3	8.9	8.1	8.7	5.7	Small lake (No. 6) near Novo Troetskaya.
	21.1	8.5	8.3	8.4	5.3	Same.
	20.8	9.0	8.1	8.7	5.9	River Chaganak.
	20.7	8.1	7.8	8.8	4.8	Lake No. 6, as above.
	20.4	8.1	7.8	7.6	5.1	Same.
	20.4	8.1	7.5	8.6	5.3	Chederti-Chaganak, as above.
	20.1	8.4	7.7	8.7	5.6	River Chaganak.
	20.1	8.3	7.9	8.1	5.3	Same.
	19.5	8.0	7.4	8.2	5.3	Same.
	18.5	8.5	7.9	8.8	5.2	Same.
	17.6	7.6	7.1	8.7	4.8	Chederti-Chaganak, as above.
	13.6	6.9	6.5	7.0	4.1	Same.

The four subspecies of *Lymnaea palustris* here described are all closely similar, but in any moderately large series it is possible to distinguish the different forms without difficulty. *Lymnaea palustris saridalensis* is characterized by the tall spire, slightly convex whorls, and moderately impressed suture; *kazakensis* is distinguished by even higher spire, slightly convex whorls turning sharply into a deep suture; *dravcrti* by its shorter and broader, though still acute, spire, more convex whorls, and smaller subovate aperture and very gently curved columella; while *bolotensis* has a shorter spire with fat whorls, and shallower suture.

LYMNAEA (RADIX) ZAZURNENSIS, n. sp.

Plate 1, fig. 2

Shell of fairly large size, length 18.5 mm, broad relative to the length, horn-colored; surface bright, glossy, crossed by many regularly spaced lines of growth which give the shell a slightly ribbed appearance, and by many microscopic spiral impressed lines; whorls five, convex, protruding and well rounded in all cases; the body whorl nearly semicircular in outline on the left side; having a slightly shouldered appearance at the junction with the preceding whorl, but actually having a small V-shaped depression intervening and continuing around the shell for at least one whorl above the aperture; aperture ovate-ellipsoidal; outer lip thin, sharp; inner lip gradually curving, columella nearly flat, not twisted, spreading out to some extent over the umbilical region, which is seen from the side and below to be fairly wide open.

Type.—U.S.N.M. no. 470709, collected at Lake Zazurnia, in the mountain range known as Khamar Daban, eastern shore of Lake Baikal. The species is known only from the type locality.

Measurements of the Shells of Lymnaea zazurnensis from Lake Zazurnia, Khamar Daban, Siberia

	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
Type	18.9	12.5	11.0	11.9	7.9
	18.8	13.3	11.2	11.7	7.8
	18.5	12.8	10.9	12.4	7.8
	18.2	12.4	11.1	12.2	7.7
	18.2	12.4	10.1	12.0	7.8
	17.2	12.1	10.3	11.1	7.7
	16.6	11.8	8.9	11.2	7.9
	15.9	11.1	9.9	11.7	7.9
	15.2	10.0	8.8	10.1	6.3

PLANORBIS (SPIRALINA) JOHANSENI, n. sp.

Plate 1, fig. 8

Shell of moderate size, greater diameter 7.5 mm, discoidal, very thin (height 1.2 mm) slightly concave above and below, closely resembling *P. compressus;* surface bright and shining, with many fine but distinct lines of growth; whorls five and a quarter, gradually increasing in size, carinate on the upper side; the upper side of the carina of all or nearly all the whorls being visible on the dorsal side of the shell; aperture inclined and oblique, ellipsoidal; lip sharp and thin.

Type.—U.S.N.M. no. 470515, collected at Kotur Kulb near Borovoye, Kazakstan.

The dimensions of the type are as follows: Height 1.2 mm, greater diameter 7.4 mm, lesser diameter 6.6 mm, aperture height 1.0 mm, aperture width 1.8 mm.

Named after Mr. Bodo Johansen, of Tomsk, who has made a study of the fresh water mollusks of that neighborhood.

PHYSA SARTLANDINENSIS, n. sp.

Plate 1, fig. 6

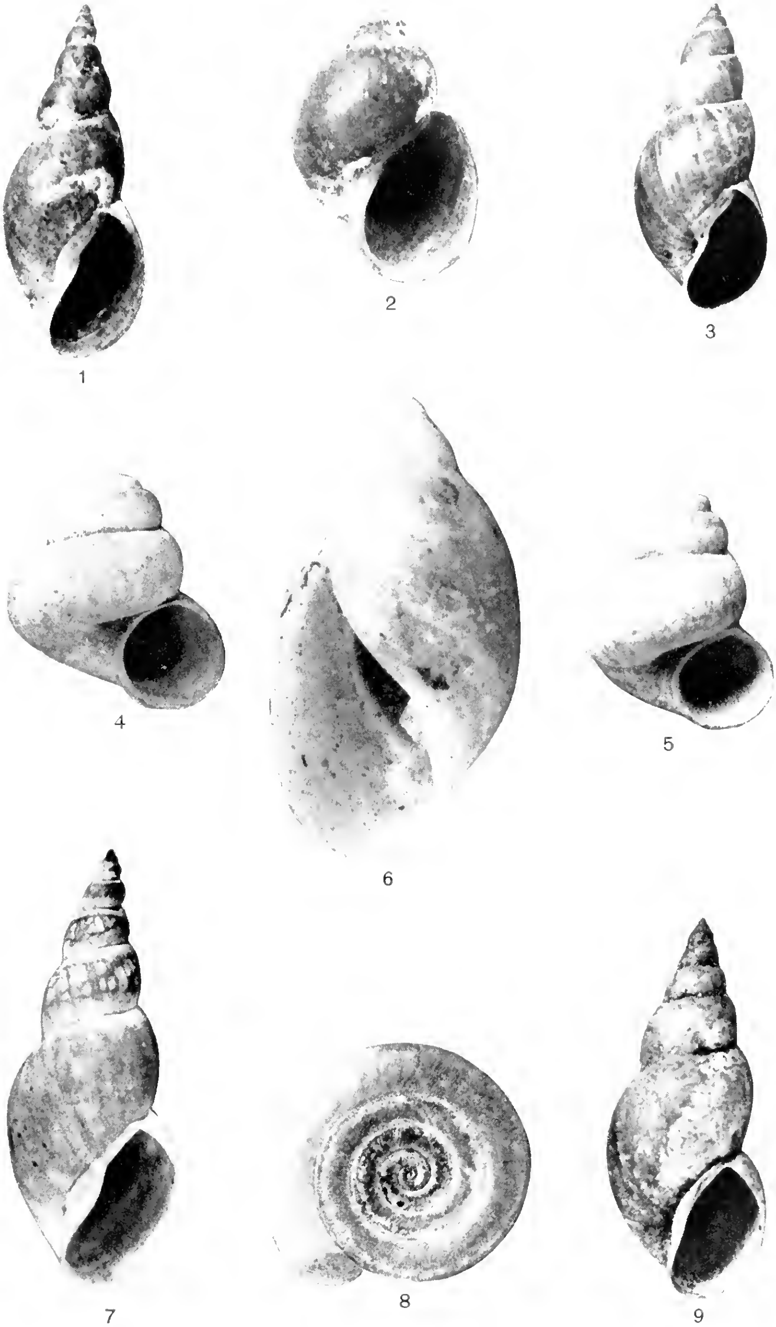
Shell resembling that of *Physa fontinalis* but of larger size, length 12.6 mm; the aperture shorter than in that species and the spire much higher and more conspicuous; the suture more deeply impressed; whorls four and three-quarters, surface smooth, lines of growth microscopic, crossed by larger, regular, impressed spiral lines.

Type.—U.S.N.M. no. 469613, collected in Lake Sartlan, Barabinsk Steppe, Siberia. It is known only from the type locality.

In this new species the length of the aperture is approximately two-thirds of the length of the entire shell, while in *P. fontinalis* it is three-quarters of the shell length.

Measurements of the Shells of Physa sartlandinensis from Lake Sartlan, Siberia

	Length mm	Greater diameter mm	Lesser diameter mm	Aperture length mm	Aperture width mm
Type	12.6	7.1	5.7	8.7	4.1
	11.4	6.2	5.2	8.0	3.4
	10.6	6.0	4.8	7.4	3.1
	10.3	5.4	4.6	6.4	2.9
	10.2	5.3	4.6	6.6	3.2
	9.7	5.3	4.6	6.4	3.0
	9.5	4.9	4.1	5.6	2.3
	9.3	5.4	5.7	5.9	2.8
	9.2	5.7	4.4	6.0	3.2
	9.1	5.3	4.0	6.1	3.0



New Fresh-Water Mollusks from Northern Asia

1. *Lymnaea (Galba) palustris saridalensis.*
2. *Lymnaea (Radix) zazurnensis.*
3. *Lymnaea (Galba) palustris bolotensis.*
4. *Valvata antiquilina.*
5. *Valvata antiqua Morris.*
6. *Physa sartlandinensis.*
7. *Lymnaea (Galba) palustris kazakensis.*
8. *Planorbis (Spiralina) johanseni.*
9. *Lymnaea (Galba) palustris draverti.*

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 3

Arthur Fund

LETHAL RESPONSE OF THE ALGA CHLORELLA VULGARIS TO ULTRAVIOLET RAYS

(WITH THREE PLATES)

BY
FLORENCE E. MEIER
Division of Radiation and Organisms, Smithsonian Institution

(PUBLICATION 3254)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 6, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

Arthur Fund

LETHAL RESPONSE OF THE ALGA CHLORELLA VULGARIS TO ULTRAVIOLET RAYS[1]

By FLORENCE E. MEIER

Division of Radiation and Organisms, Smithsonian Institution

(With Three Plates)

INTRODUCTION

In a previous paper Meier (1932) reported a quantitative study of the lethal effect of the wave lengths 3022, 2967, 2894, 2804, 2753, 2699, 2652, and 2536 A on the unicellular green alga *Chlorella vulgaris*. Wave lengths longer than 3022 A, which is the approximate short-wave limit of ultraviolet irradiation in nature—that is, the wave lengths 3130, 3341, and 3650 A—had no lethal effect on the green cells, although two of them, 3130 and 3650 A, were of greater intensity than the shorter lethal ones.

The present paper gives the results of further study on the lethal response of the alga *Chlorella vulgaris* to the same ultraviolet wave lengths with special reference to the radiotoxic spectral sensitivity and the radiotoxic virulence.

This work was done with the cooperation of Dr. E. D. McAlister, of the Division of Radiation and Organisms, who carried out the spectroscopic manipulations and physical measurements.

I wish to express my appreciation to Dr. C. G. Abbot, Secretary of the Smithsonian Institution, for his assistance in the interpretation of the results of these experiments and for suggesting the new terms here used. I am also grateful to Dr. E. S. Johnston, Assistant Director of the Division of Radiation and Organisms, for his help in the accomplishment of this piece of research.

RECENT INVESTIGATIONS

Striking work requiring nice technique on the lethal action of ultraviolet irradiation on certain living Protozoa has been done recently by the Cancer Research Laboratory at the University of Pennsylvania.

[1] This paper reports investigations made under a grant from the National Research Council to the author as National Research Fellow in the Biological Sciences.

The micro-moving-pictures and microphotographs made by Franklin, Allen, and McDonald (1933) show how ultraviolet irradiation below 2900 A causes immediate cessation of all motion of the unicellular organisms followed by marked internal changes and in some cases a complete breakdown of the cellular structure. Swann and del Rosario (1932) noted that the death rate of the cells was not related to the intensity of the light nor to the number of the cells present, but to the length of exposure. Furthermore, cells continued to die even after the light was removed. In the work here reported it was similarly observed with algae that certain ultraviolet rays injured the cells but that death followed some time later. Swann and del Rosario found that the total number of *Euglena* cells that died subsequently as the result of irradiation was proportional to the total quantity of radiant energy in question, within the limits of intensity and concentration investigated.

The algal cells did not begin to die as soon after irradiation as did the *Euglena* cells. This may be due to a difference in the irradiation intensity. Tanner and Ryder (1923) found in their irradiation experiments that pigmented yeasts are more resistant than white yeasts and also that yeasts live a little longer than bacteria, a fact that they explain as due to the difference in size.

The work of Beauverie and Cornet (1929) on the leaf and bud of *Elodea canadensis* shows that the chloroplastids in the cell withstood continued irradiation much better than did the cytoplasm, mitochondries, and chondriocontes.

Noethling and Rochlin (1931) also irradiated *Elodea* with ultraviolet rays less than 3000 A in wave length and found a cessation of plasma streaming, also the appearance of oxalate crystals, and necrosis.

Gibbs (1926) noted that a latent period occurred before death in irradiated filaments of *Spirogyra nitida affinis*. The limits of the toxic action were the wave lengths 3126 and 2378 A. The chloroplasts were observed to clump characteristically, owing to the great difference in intensity of radiation reaching the " near " and " far " sides of the filament. The behavior of the filaments was variable. Some died while apparently perfectly normal in appearance. Coagulation of the protoplasm was noted, also a brown precipitate that exhibited Brownian movement.

Martin and Westbrook (1930) reported browning of the cells of the leaves of *Voandzeia*, *Pelargonium*, and other plants by ultraviolet irradiation. The browning was compared to the reddening or erythema and subsequent browning induced by ultraviolet in the human skin. Generally there is a latent period from 3 to 24 hours' duration before erythema makes itself evident. Martin and Westbrook define as the latent period the time elapsing between the irradiation and the visible culmination in browning. The term "latent period" is in a sense comparable with its application to the appearance during development of the latent image on a photographic plate.

EXPERIMENTAL PROCEDURE

The technique, methods, and apparatus used in this work are similar to those described for the exposure of the second plate of *Chlorella vulgaris* by Meier (1932) and by Brackett and McAlister (1932).

In August 1932 three separate portions of each of 10 plates covered with Detmer $\frac{1}{3}$-agar 1.5 percent about 4 to 5 mm thick, the entire surfaces of which were uniformly green with cells of *Chlorella vulgaris*, were irradiated in the quartz spectrograph using a quartz mercury lamp as the source. Data regarding their inoculation and irradiation dates together with the exposure times are listed in table 1. In April 1933 nine additional plates (plates 14 to 17 and 19 to 23) that had been prepared in a similar fashion were also irradiated as noted in table 2. The intensity data are given in table 3.

EFFECT OF ULTRAVIOLET RAYS ON AGAR PLATES

Two blank agar plates (plates 18 and 24) that had been made at the same time as plates 14 to 17 and 19 to 23 and left under similar conditions but not inoculated with algae were also irradiated in April 1933. Separate portions of plate 18 were irradiated for 64, 16, and 32 minutes, and separate portions of plate 24 were irradiated for 16, 4, and 8 minutes. When the plates were finally examined 2 months after inoculation, there was no evidence of any differentiated regions.

On June 24 a freshly inoculated Detmer $\frac{1}{3}$ solution of *Chlorella vulgaris* was poured over plate 18, and after a short interval the excess was removed. The plate was then placed in a north window. Within 3 weeks' time the plate was covered with a uniform green growth of the algal cells.

This experiment seems to indicate that the wave lengths which prove lethal to the green cells of the algae do not affect the culture medium which covers the glass plate in any way that will accelerate or retard the subsequent growth of the algae.

TABLE 1.—*Results of First Experiment*

Plate	Inoculation date 1932	Irradiation date 1932	Irradiation time min.	Irradiation time sec.	Total radio-toxic regions Nov. 30, 1932	Initial appearance of radiotoxic regions in angstroms (1932): Aug. 29	Aug. 31	Sept. 2	Sept. 6	Sept. 17	Sept. 27	Oct. 1
1	May 19	Aug. 24	60	0	8	....	2652, 2699, 2753, 2804	2894	2967	2925, 3022		
			1	40	0							
			10	0	5	....	....	2652, 2804	2699, 2753	....	....	2894
2	May 5	Aug. 24	60	0	8	....	2652, 2699, 2753, 2804	2894	2967	2925, 3022		
			1	40	0							
			10	0	5	....	....	2652, 2804	2699, 2753	....	....	2894
3	Apr. 19	Aug. 24	60	0	8	....	2652, 2699, 2753, 2804	2894	2967	2925, 3022		
			1	40	0							
			10	0	5	....	....	2652, 2804	2699, 2753	....	....	2894
4	June 18	Aug. 25	10	0	5	....	2652, 2699, 2753, 2804	....	....	....	....	2894
			0	16	0							
			1	40	0							
5	Apr. 19	Aug. 25	10	0	5	....	2652, 2699, 2753, 2804	....	....	....	....	2894
			0	10	0							
			1	40	0							
6	May 12	Aug. 25	10	0	Infected							
			0	16								
			1	40								
7	May 5	Aug. 25	1	40	0							
			0	3	0							
			0	16	0							
8	May 12	Aug. 25	1	40	0							
			0	3	0							
			0	16	0							
9	Apr. 19	Aug. 25	1	40	0							
			0	3	0							
			0	16	0							
13	Apr. 19	Aug. 26	360	0	11	2652, 2804	2699, 2753	2894, 2967	2536, 2576, 2602, 2925, 3022			
			10	0	5	....	....	2652, 2804	2699, 2753	. .. .	2894	

TABLE 2.—*Irradiation Data for Second Experiment*

Plate	Inoculation date	Irradiation date	Irradiation time, minutes
14	January 10, 1933	April 17, 1933	8
			2
			4
15	December 3, 1932	April 17, 1933	16
			4
			8
16	January 10, 1933	April 18, 1933	32
			8
			16
17	January 10, 1933	April 18, 1933	64
			16
			32
18	Uninoculated	April 18, 1933	64
			16
			32
19	January 10, 1933	April 18, 1933	8
			2
			4
20	December 3, 1932	April 18, 1933	16
			4
			8
21	November 3, 1932	April 19, 1933	64
			2
			32
22	January 10, 1933	April 19, 1933	32
			8
			16
23	January 10, 1933	April 19, 1933	72
			2
			4
24	Uninoculated	April 19, 1933	16
			4
			8

TABLE 3.—*Intensity Data*

A	August 23, 1932 Plates 1-13, intensity: ergs/sec. cm^2	April 17, 1933 Plates 14-24, intensity: ergs/sec. cm^2
2536	less than 100	150
2652	2,000	1,960
2699	680	640
2753	570	540
2804	1,930	1,840
2894	930	930
2925	450	440
2967	2,740	2,450
3022	5,700	5,300
3130	12,500	11,800
3340	1,940	1,720
3650	28,500	25,000

RESULTS

The results of irradiating the 10 plates of the first series with ultraviolet rays are shown in table 1. The regions of decolorized cells that appeared in the green plates where the wave lengths of ultraviolet proved to be lethal or radiotoxic are tabulated with the initial dates of their appearances. The experiment was brought to an end October 30, an arbitrary date, 2 months after the irradiation date, but the plates remained in good condition until November 30 and showed no further marked differences in appearance. The total number of radiotoxic regions for each exposure was listed at this time. See plates 2 and 3.

The results of the second experiment, in which 11 plates including the uninoculated agar plates were irradiated, are given in table 4. The radiotoxicity as shown by the colorless algal regions which were present on the plates June 24, 1933, 2 months after the irradiation date, is indicated here with the exposure times. (See pl. 1.)

As indicated in tables 1 and 2, the inoculations were made from 2 to 5 months previous to the dates of irradiation. This difference in the age of the cultures had no apparent effect on the response of the algae to the ultraviolet irradiation.

THE LETHAL RADIOTOXIC THRESHOLD

A study of tables 1 and 4 shows that the lethal radiotoxic threshold, or minimum amount of radiotoxicity required to produce lethal effect, for wave lengths 2652 and 2804 A lies between 100 and 120 seconds and probably midway between 105 and 120 seconds (the 100-second exposure being with light of greater intensity) for intensities 1,960 and 1,840 ergs/sec. cm^2 respectively. If it is assumed that the radiotoxic effect is proportional to the intensity and the duration of irradiation, then for 1,000 ergs/sec. cm^2 the exposures required for 2652 and 2804 A may be set as $1.96 \times 112 = 220$ seconds and $1.84 \times 112 = 206$ seconds respectively. For 2699 and 2753 A, 8 minutes or 480 seconds did not always suffice for killing the cells but usually did, so it is near the threshold. Then for 1,000 ergs/sec. cm^2, the required time would be $0.64 \times 480 = 307$ seconds and $0.54 \times 480 = 259$ seconds. Also, 2894 and 2967 A occur once or twice at 480 seconds. Hence for 1,000 ergs/sec. cm^2, the required time would be $0.93 \times 480 = 446$ seconds and $2.45 \times 480 = 1,176$ seconds. Also, injury at 2925 and 3022 A first appears at 1,920 seconds and then not always, therefore similarly we find required times of $0.44 \times 1,920 = 845$ seconds and

TABLE 4.—*Wave Lengths of Radiotoxic Regions Two Months after Irradiation* [a]

Exposure time in minutes (equivalent time in seconds given in parentheses)

Plate	2 (120)	4 (240)	8 (480)	16 (960)	32 (1920)	64 (3840)	74 (4440)
14	2652, 2804	*2652, 2804*	2699, 2753,				
	....	....	*2652, 2804*				
19	no effect	no effect	2699, 2753,				
	....	....	*2652, 2804*				
23	2652, 2804	2652, 2804	....	....	....	....	2925, 3022,
	....	....	....	....	....	....	*2652, 2699,*
	....	....	....	....	....	....	*2753, 2804,*
	....	....	....	....	....	....	*2894, 2967*
21	2652, 2804	....	....	....	2925, 3022,	2925, 3022,	
	....	....	....	....	*2652, 2699,*	*2652, 2699,*	
	....	....	....	....	*2753, 2804,*	*2753, 2804,*	
	....	....	....	....	*2894, 2967,*	*2894, 2967*	
15	....	2652, 2804	*2652, 2804*	*2652, 2699,*			
	....	....	....	*2753, 2804,*			
	....	....	....	*2804*			
20	....	2652, 2804	2699, 2753,	*2652, 2699,*			
	....	....	*2652, 2804*	*2753, 2804,*			
	....	....	....	*2894*			
24 [b]	....	no effect	no effect	no effect			
16	....	....	2699, 2753,	2967, *2652,*	*2652, 2699,*		
	....	....	2894, *2652,*	*2699, 2753,*	*2753, 2804,*		
	....	....	*2804*	*2804, 2894*	*2894, 2967*		
22	....	....	2894, 2967,	*2652, 2699,*	*2652, 2699,*		
	....	....	*2652, 2699,*	*2753, 2804,*	*2753, 2804,*		
	....	....	*2753, 2804*	*2894, 2967*	*2894, 2967*		
17	....	....	....	*2652, 2699,*	2925, 3022,	2925, 3022,	
	....	....	....	*2753, 2804,*	*2652, 2699,*	*2652, 2699,*	
	....	....	....	*2894, 2967*	*2753, 2804,*	*2753, 2804,*	
	....	....	....	....	*2894, 2967*	*2894, 2967*	
18 [b]	....	....	....	no effect	no effect	no effect	

[a] The regions where the radiotoxic effect was less marked precede the more marked radiotoxic regions, which are in *italic*.
[b] Uninoculated plates.

$5.3 \times 1{,}920 = 10{,}176$ seconds. From the above rough determinations and the computation of the lethal factors for each wave length as compared with 3022 A, table 5 has been compiled and the smooth curve in figure 1 has been drawn.

TABLE 5.—*Lethal Radiotoxic Threshold and Radiotoxic Spectral Sensitivity (Based on Table 4)*

A	Intensity ergs/sec. cm²	Lethal radiotoxic threshold For given intensity sec.	For 1000 ergs/sec. cm² sec.	Radiotoxic spectral sensitivity	Smooth curve
2652	1960	112	220	46.3	45
2699	640	480	307	33.1	43
2753	540	480	259	39.3	38
2804	1840	112	206	48.9	34
2894	930	480	446	22.8	22
2925	440	1920	845	12.0	16
2967	2450	480	1176	8.7	9
3022	5300	1920	10176	1.	1

RADIOTOXIC SPECTRAL SENSITIVITY AND RADIOTOXIC VIRULENCE

The lethal response of the algae to the ultraviolet rays may be considered from two points of view, as to the radiotoxic spectral sensitivity and the radiotoxic virulence. The term " radiotoxic spectral sensitivity " relates to the certainty of the lethal action, while the term " radiotoxic virulence " may be used to describe the quickness of the attack. To make the matter clearer by analogy, let the behavior of algae with respect to three different ultraviolet rays be compared to the behavior of a human being toward three poisons, namely, radium in watch-face paint, cyanide of potassium, and rattlesnake venom.

With respect to sensitivity, each one of the three poisons is fatal if administered in a sufficient dose. Probably in order of minimum lethal dosage or sensitivity, they would rank: radium, cyanide, snake venom. But in order of toxic virulence, or the time required for lethal effect, they would rank very differently, probably: cyanide, snake venom, radium.

Applying this analogy to the selected ultraviolet rays, the determination of the radiotoxic spectral sensitivity, that is, the relative radiotoxicity of rays of different wave lengths when applied with equal intensity and duration, has been measured as described in the preceding section. The determinations for each of the eight ultraviolet rays when plotted against wave lengths gives a curve of radiotoxic spectral sensitivity. (See table 5 and fig. 1.)

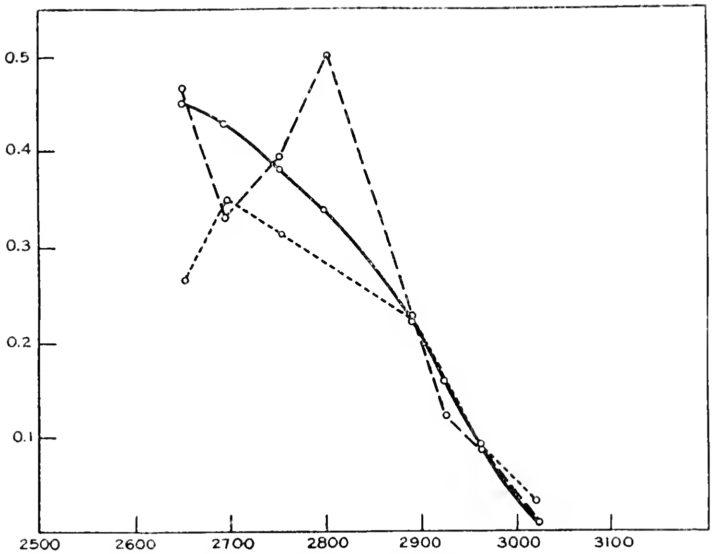


FIG. 1.—Radiotoxic spectral sensitivity of *Chlorella vulgaris* to ultraviolet rays. The abscissae are wave lengths in angstroms. The ordinates are relative lethal effectiveness in arbitrary units. Black line, smooth curve; dash line, actual values; dot line, curve obtained by Meier (1932).

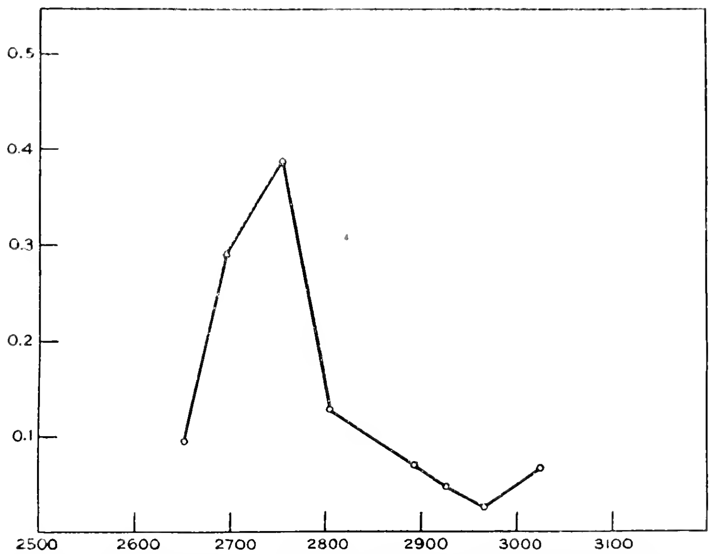


FIG. 2.—Radiotoxic virulence determined from *Chlorella vulgaris*. The abscissae are wave lengths in angstroms. The ordinates are radiotoxic virulence in arbitrary units.

Applying the analogy to the consideration of radiotoxic virulence, the determination of the speed with which the toxic doses of the several rays produce lethal effects has been made by computing the brevity of time required to produce lethal effect for a standard radiotoxic quotum exceeding the lethal radiotoxic threshold.

The radiotoxic quotum is the amount of radiotoxicity applied, and it is apparently proportional (1) to the time during which the algae are exposed to it, (2) to the intensity of the ray, and (3) to the radiotoxic spectral sensitivity. The radiotoxic virulence is evidently inversely proportional (1) to the radiotoxic quotum applied and (2) to the time required to produce a toxic effect. The determination has been made for eight ultraviolet rays, and as plotted against wave length gives a curve of radiotoxic virulence (the reciprocal of the product of the radiotoxic quotum for each ray by the time of response). (See table 6 and fig. 2.)

DISCUSSION

The curve in figure 1 does not disagree beyond reasonable error with the one shown in figure 1 of Meier (1932), although the earlier curve was determined by a different method. It is questionable whether the wave length for the maximum radiotoxic effect has yet been determined, since effects at 2600 A and shorter wave lengths have not been sufficiently studied in these experiments. Experiments including regions 2300 to 2700 A should be made for the purpose of finding further information on this subject. Additional experiments should also be performed to check the assumption made that the radiotoxic effect is proportional to the intensity of irradiation and to the time of irradiation jointly. It is also possible that weaker irradiations would produce a stimulation of growth which is not apparent in these plates because of the luxuriant green growth covering the entire surface of each culture before irradiation. Further experiments are being planned to investigate this point.

SUMMARY

The radiotoxic spectral sensitivity has been determined for eight wave lengths in the ultraviolet ranging from 2652 to 3022 A as applied to a unicellular green alga, *Chlorella vulgaris*. Although all the rays from 2652 to 3022 A killed the algae eventually, death ensued much more quickly in some of the regions than in others. The radiotoxic virulence or speed of effectiveness of each lethal ray in killing the algal cells for a radiotoxic quotum at eight wave lengths ranging from 2652 to 3022 A has been calculated.

TABLE 6.—*Radiotoxic Virulence (Based on Tables 1 and 5)*

A	Exposure time min. ×	Intensity ×	Radiotoxic spectral sensitivity =	Radiotoxic quotum ×	Days =	Product / 100	Reciprocals	Virulence[b] = Reciprocals / 2
2652	360	2.	45	32400.	3	972.		
	60	2.	45	5400.	7	378.		
	10	2.	45	900.	7	63.		
				900.	9	81.		
				900.	6	54.[a]	1.85	.93
2699	360	.68	43	10526.4	5	526.32		
	60	.68	43	1754.4	7	122.80		
	10	.68	43	292.4	11	32.16		
				292.4	13	38.01		
				292.4	6	17.54[a]	5.70	2.85
2753	360	.57	38	7797.6	5	389.88		
	60	.57	38	1299.6	7	90.97		
	10	.57	38	216.6	13	28.16		
				216.6	6	13.00[a]	7.69	3.85
				216.6	11	23.83		
2804	360	1.93	34	23623.2	3	708.69		
	60	1.93	34	3937.2	7	275.60		
	10	1.93	34	656.2	9	59.05		
				656.2	6	39.37[a]	2.54	1.27
				656.2	7	45.93		
2894	360	.93	22	7365.2	7	515.59		
	60	.93	22	1227.6	9	110.48		
	10	.93	22	204.6	38	79.75		
				204.6	37	75.70		
				204.6	34	69.56[a]	1.44	.72
2925	360	.45	16	2592.	11	285.12		
	60	.45	16	432.	24	103.68[a]	.96	.48
2967	360	2.74	9	8877.6	7	621.43		
	60	2.74	9	1479.6	13	192.34[a]	.52	.26
3022	360	5.7	1	2052.0	11	225.72		
	60	5.7	1	342.0	24	82.08[a]	1.22	.61

[a] Smallest product. [b] Halved for convenient scale.

LITERATURE CITED

Beauverie, J., and Cornet, P.

1929. Action des rayons ultra-violets sur la structure cellulaire dans la feuille et le bourgeon d'*Elodea canadensis*. C. R. Soc. Biol., Tome 102, pp. 775-777.

Brackett, F. S., and McAlister, E. D.

1932. A spectrophotometric development for biological and photochemical investigations. Smithsonian Misc. Coll., vol. 87, no. 12, pp. 1-7.

Franklin, Rachel, Allen, A. J., and McDonald, Ellice.

1933. Some micro-moving-pictures showing the lethal effects of ultra-violet radiation on certain living Protozoa. Bull. Amer. Phys. Soc., vol. 8, no. 2, p. 5.

Gibbs, R. D.

1926. The action of ultra-violet light on Spirogyra. Proc. and Trans. Roy. Soc. Canada, vol. 20, pp. 419-425.

Martin, M. T., and Westbrook, M. A.

1930. Influence of ultra-violet radiation upon some plant cells. Journ. Exper. Biol., vol. 7, pp. 293-307.

Meier, Florence E.

1932. Lethal action of ultra-violet light on a unicellular green alga. Smithsonian Misc. Coll., vol. 87, no. 10, pp. 1-11.

Noethling, W., and Rochlin, E.

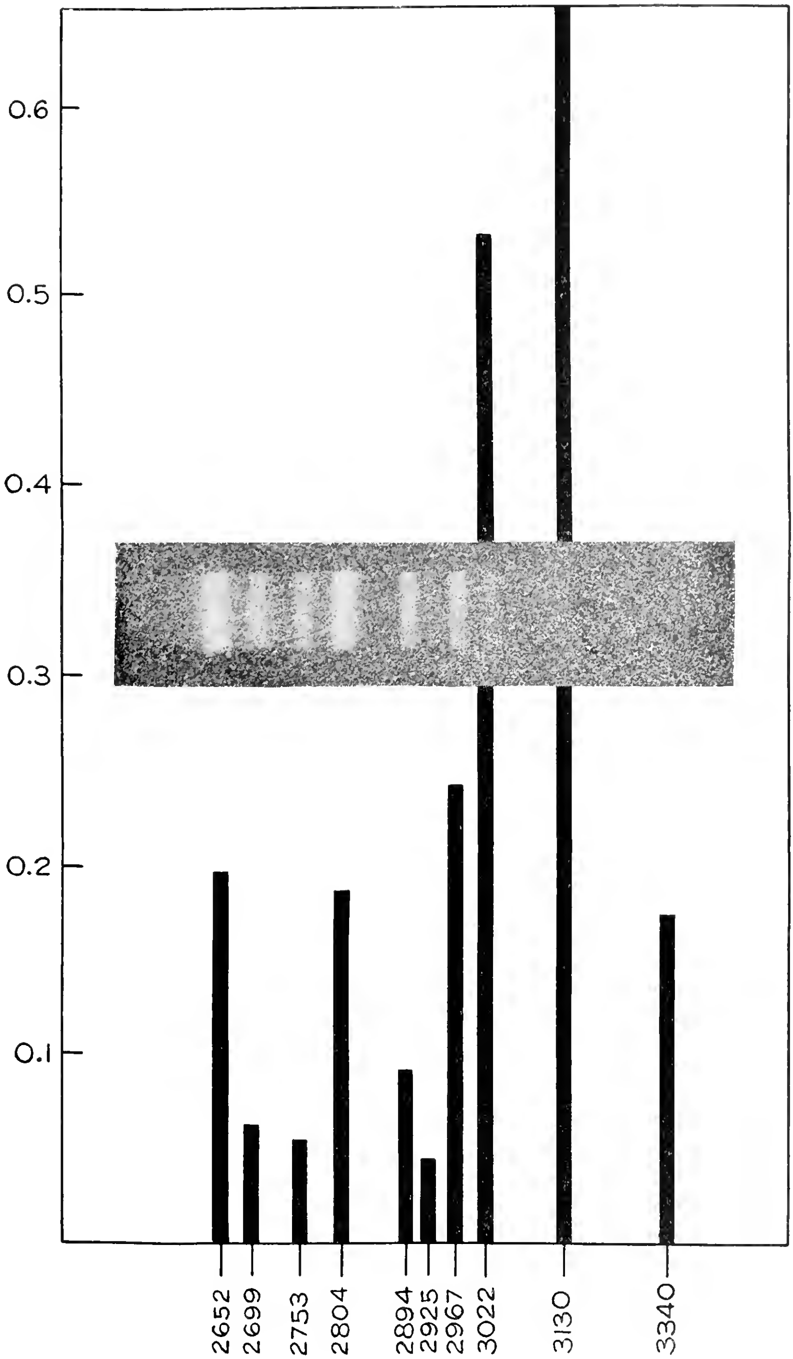
1931. Über Photodinese im Kurzwelligen Ultraviolett. Planta, vol. 14, pp. 112-131.

Swann, W. F. G., and del Rosario, C.

1932. The effect of certain monochromatic ultra-violet radiation on *Euglena* cells. Journ. Franklin Inst., vol. 213, pp. 549-560.

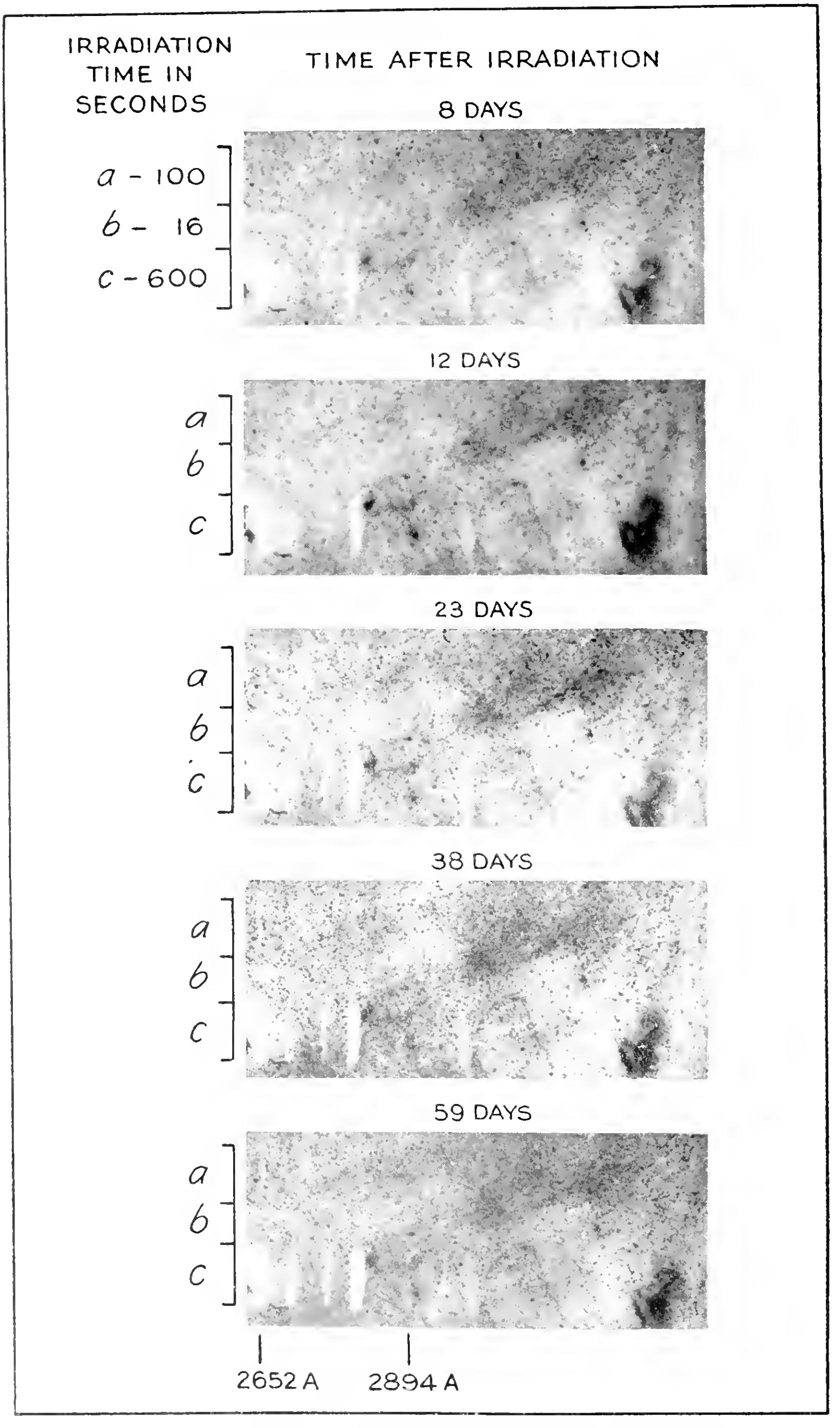
Tanner, Fred W., and Ryder, Earl.

1923. Action of ultraviolet light on yeast-like fungi. II. Bot. Gaz., vol. 75, pp. 309-317.



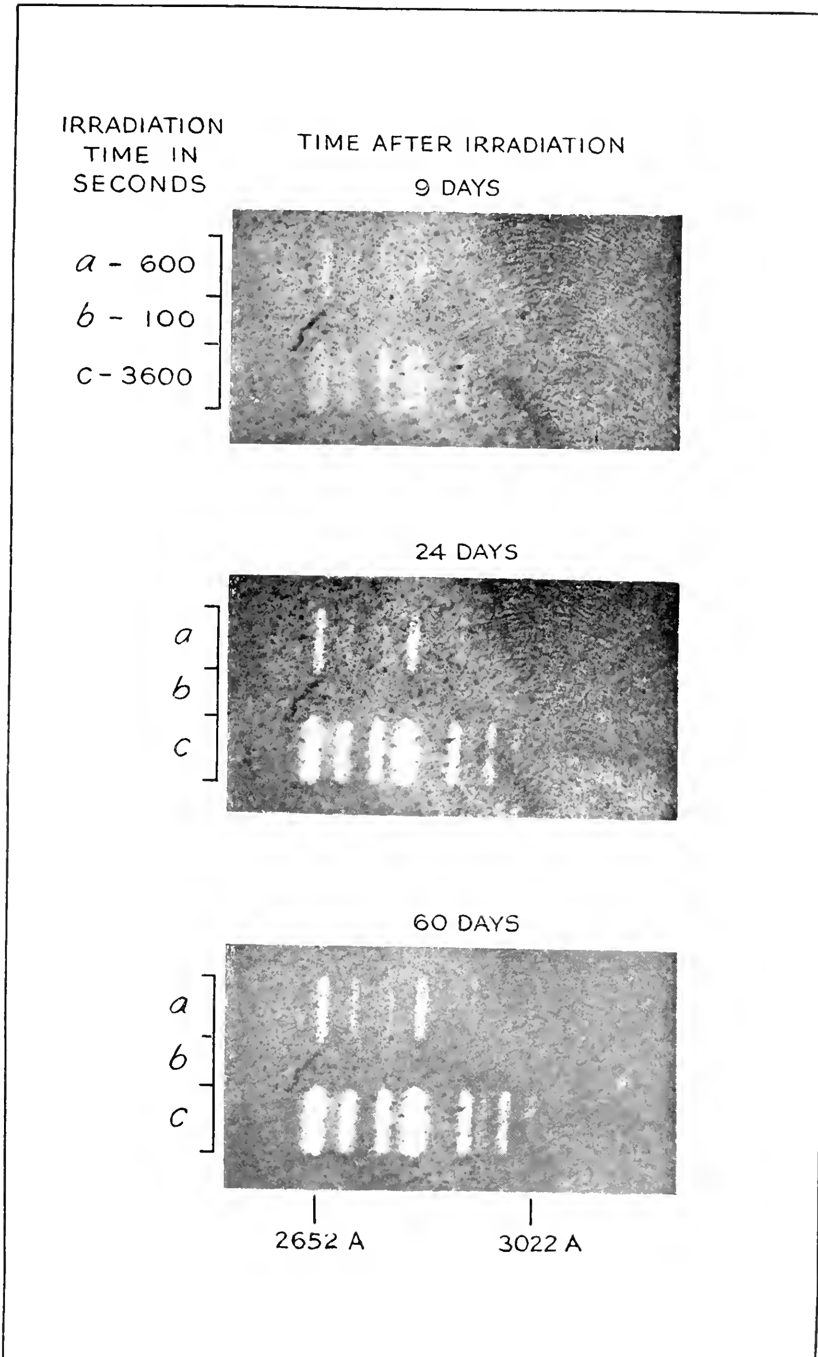
AN ALGAL SPECTROGRAM. OBTAINED BY EXPOSING PLATE 23 OF CHLORELLA VULGARIS TO ULTRAVIOLET RAYS FOR 4440 SECONDS, SUPERIMPOSED ON A DIAGRAM OF THE INTENSITIES OF THE WAVE LENGTHS.

The abscissae are wave lengths in angstroms. The ordinates are intensities in ergs/sec.cm^2.



GRADUAL APPEARANCE OF RADIOTOXIC REGIONS IN PLATE 5 OF CHLORELLA VULGARIS AFTER EXPOSURE OF 600 SECONDS TO ULTRAVIOLET RAYS.

No radiotoxic effect was noted for exposures of 100 seconds and 16 seconds.



Radiotoxic Regions in Plate 1 of Chlorella vulgaris After Exposures of 600 Seconds and 3600 Seconds to Ultraviolet Rays.

No radiotoxicity was noted for the exposure of 100 seconds.

+

Viva Jesus

1

Relacion historica de la creencia usos costumbres y extravagancias de los Indios de esta Mision de S. Juan Capistrano llamada la nacion Acagchemem.

Introduccion.

El haverme determinado á escrivir esta historia fabulosa en si, ó en lo que contiene, pero verdadera respecto de estos Indios ha sido primeramente para poder dar en algo cumplimiento á mis obligaciones de Misionero Apostolico, teniendolo siempre presente, y la mano, como tambien dejar á mis venideros instruccion y luces para que puedan governarse sin tanto trabajo como á mi me ha costado, procurando por todos modos, empleando todos los medios posibles para adquirir el conocimiento de la creencia, usos, y costumbres, que tenian estos naturales en su gentilidad, y por la misericordia de Dios

de 1812 con trabajo y maña en el espacio de mas de diez años, he podido averiguar

hta 1822 con una moral certidumbre, todo quanto en el presente escrito se refiere.

Y estar persuadido de que ignorando la creencia que tienen los Indios, en sus usos, y costumbres, es muy dificil sacarlos del error en que viven, y darles a entender la verdadera Religion, y enseñarles el verdadero camino para su salvacion. Confieso que es dificil poder penetrar sus secretos porque el significado de sus usos y costumbres no lo saben todos, esto es solo para los Capitanes y algunos Sacerdotes, que hacian el oficio de Sacerdotes y pregoneros, y quando estos lo enseñavan á sus hijos (y esto solo a los que los havian de suceder) era siempre con la advertencia que no lo manifestaran á nadie, porque si lo decian o manifestavan tendrian muchas desgracias, y que se moririan Dicc infundiendoles mucho temor y miedo y por tanto se sabe tanpoco de sus cosas, porque los pocos que lo saben y entienden lo tienen reservado para si.

REPRODUCTION OF PAGE 1 OF THE NEWLY DISCOVERED MANUSCRIPT

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 4

A NEW ORIGINAL VERSION OF BOSCANA'S HISTORICAL ACCOUNT OF THE SAN JUAN CAPISTRANO INDIANS OF SOUTHERN CALIFORNIA

(WITH TWO PLATES)

BY
JOHN P. HARRINGTON
Ethnologist, Bureau of American Ethnology

(PUBLICATION 3255)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JUNE 27, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

A NEW ORIGINAL VERSION OF BOSCANA'S HISTORICAL ACCOUNT OF THE SAN JUAN CAPISTRANO INDIANS OF SOUTHERN CALIFORNIA

By JOHN P. HARRINGTON,
Ethnologist, Bureau of American Ethnology

(WITH TWO PLATES)

When I first started to study the California Indians, I looked about to see what had been recorded concerning them in early times, that is, during the period of Spanish occupation. I found that only one account of California Indians, or indeed of Indians of the Southwest, worthy of being called an ethnological treatise had survived from that period, namely Father Jerónimo Boscana's "Chinigchinich", which tells in several penetrating but all too short chapters of the life of the Indians of the San Juan Capistrano Mission on the coast of southern California. There was comparatively rich Spanish archival material to be found, consisting of chronicles of voyages and land expeditions, church records, etc., but no other good description of a tribe and its customs, although certain writings on Lower California Indians constituted the nearest second to the Boscana. And the Boscana treatise was accessible only in a rather inadequate English translation published by Alfred Robinson as an appendix to his Life in California.[1] Persistent attempts made in this country and abroad toward locating the all-important Spanish original all resulted in failure. It was therefore a gala day in my life, unparalleled by any other, when I recently discovered the long lost Boscana original.

The manuscript proves to be even more valuable than was expected, since it is an 1822 variant version of the Historical Account that Robinson translated, each version containing certain important data that the other omits. It consists of 58 octavo pages written in a rather neat

[1] Chinigchinich: a historical account of the origin, customs, and traditions of the Indians at the missionary establishment of St. Juan Capistrano, Alta California; called the Acagchemem nation . . . , by the Reverend Father Friar Geronimo Boscana . . . New York, 1846. For a reprint of this work see Boscana, Gerónimo, 1776-1831, Chinigchinich (Chi-ñi'ch-ñich), a revised and annotated version of Alfred Robinson's translation of Father Gerónimo Boscana's historical account, edited by Phil Townsend Hanna, annotations by John P. Harrington, foreword by Frederick Webb Hodge, Santa Ana, Calif., 1933.

hand, the hand already familiar to me through working with the church records at San Juan Capistrano. An introduction, written in very fervent tone, is followed by 15 chapters devoted respectively to the subjects of origin, creation tradition, history of the traditional leaders Ouiot and Chinigchinix, instruction of children, marriage, general manner of life, chieftainship, description of the native temples, feasts and dances, calendar, extravagancies, burials and funerals, beliefs of immortality, origin of the inhabitants of San Juan Capistrano Mission, and list with etymologies of 15 rancherias inhabited by these Indians. A halftone reproduction of page 1 of the manuscript is shown in plate 1 (frontispiece).

Boscana was born May 23, 1776, at the country town of Llumayor on the island of Mallorca off the coast of eastern Spain. His native tongue was, of course, the Catalonian language, very different from Spanish. He was ordained at a Franciscan college at Palma, capital of the island, and was sent as a missionary to Mexico, and thence to Alta California, now the California of Americans. He was missionary at San Juan Capistrano from 1812 to 1826, a period of 14 years, and died, still a middle-aged man, at the nearby mission of San Gabriel, Calif., in 1831. The only picture of Father Boscana known to be extant is the reproduction of what was evidently a pencil drawing published in Robinson's book, here republished as plate 2. It shows the father in the latter years of his life, probably when he was stationed at San Gabriel.

The San Juan Capistrano Indians which the Historical Account describes are a northwestern subdivision of the so-called Payomkawish or San Luiseño Indians of San Luis Rey Mission, who occupy the San Luis Rey River drainage in northern San Diego County, Calif., and adjacent regions. The dialect which they speak belongs to the great Aztecan family of languages.

The religion of the Indians described by Boscana centers about the revelations of a prophet named Chinigchinix, as it is spelled in this version, the x being pronounced as in Catalonian, that is, equal to English sh. The prophet was known by three sacred names: Saor, meaning common person, noninitiate; Tobet, medicine man, initiate; and Quoar, a name too sacred to pronounce aloud. These three names apply to three successive periods in the prophet's revelatory life. The prophet was born at the rancheria of Pubu in Los Angeles County, Calif., only a couple of miles inland from Alamitos Bay, there accomplished his principal teaching, and when he died, was from there merely translated to the heaven of the stars, leaving no earthly bodily remains. From above and everywhere he watches our deeds and

ONLY EXTANT PICTURE OF REV. JERONIMO BOSCANA, REPRODUCED FROM LITHOGRAPH FRONTISPIECE IN ALFRED ROBINSON, LIFE IN CALIFORNIA, NEW YORK, 1846

thoughts, and sends poisonous medicine animals, known as Chinigchinix animals, also calamities and death, to punish those who mock his dances and disobey his commandments. So much does this deity prophet command our central attention throughout the essay that Robinson calls his translation outright: Chinigchinich.

A very literal and careful translation of the newly found manuscript, following all the minutiae of its style, is here presented. Exhaustive notes have been prepared and will constitute a separate publication.

+

VIVA JESUS.

A historical account of the belief, usages, customs, and extravagancies of the Indians of this Mission of San Juan Capistrano, called the Acágchemem tribe.

INTRODUCTION

My having resolved to write this history, fabulous in itself, or in its subject matter, but true as far as these Indians are concerned, has been primarily with the aim of being able to fulfill to some degree my duties as Apostolic Missionary, having their fulfillment ever present and near at hand, as well as also of leaving to those who come after me instruction and lights in order that they may be guided without such labor as it has cost me, trying in every way, using all possible means, to gain knowledge of the belief, usages, and customs which these natives had in their gentile state. And by the mercy of God, through labor and cunning during a period of more than ten years [marginal annotation: from 1812 to 1822], I have been able to investigate to a moral certainty everything that is related in the present book.

Since I am of the persuasion that if we are ignorant of the belief held by the Indians, of their usages and customs, it is very difficult to take them out of the error in which they live and to give them to understand the true religion, and to teach them the true way to their salvation. I confess that it is difficult to be able to penetrate their secrets, because the signification of their usages and customs is not known to all of them. This [signification] is only for the chiefs and certain satraps, who performed the work of priests, and [certain] criers, and when these taught it to their sons (and that only to those who were to succeed them), it was always with the admonition that they should not divulge it to anyone, for if they told or divulged it, they would have many misfortunes, and would die, etc., instilling into them much dread and fear; and for that reason so little is known about their affairs, since those few who know and understand keep it to themselves.

Since these Indians did not use writings, letters, or any characters, nor do they use them, all their knowledge is by tradition, which they preserve in songs for the dances which they held at their great feasts. But since these songs have their form or are in a language distinct from that which is spoken at the present time, no one, except those mentioned above, understands the meaning of the song and dance; the others sing and dance but without knowing either what they are saying or what they are doing. I imagine that such songs are in a primitive language, and they preserve them in their feasts, and these songs and dances contain all their religion, usages and customs, and for this reason these songs are not used or sung except in their feasts.

They also have common songs and dances in their own language, which latter are sung and danced daily, and are understood by all, but these are nothing more than for the purpose of amusing themselves and idling about with one another.

What I have said above seems to me sufficient for understanding the purpose which has led me to write this little work about the belief, usages and customs of these Indians, and if it may seem to some that my bravery has been great, attributing it to arrogance and presumption, since I am a pigmy beside my brethren, they being more illustrious and of greater experience, let it be borne in mind that I have not written it to show myself to be anything more than what I am, but that my purpose is that I may free from delusion those who have confided to me their errors, as well as that certain ones may be incited to make public the secrets of the Indians which they have encountered, with the result that with information on record as regards their belief, usages and customs, they can be told what they may follow and what they should put aside; and for this reason I hope that he who reads this composition may be pleased to see such information, and if he should find anything which may disagree with the truth which I have proposed to set forth, or any defect to correct, I shall give boundless thanks to him who may show it to me, so that the error may be perceived and corrected. And withal I am beseeching God that he grant us his holy grace and benediction. Amen.

Chapter 1

FROM WHAT RACE OF PEOPLE MAY THESE INDIANS COME?

[1.] Since no information is found as to where these people of California may have come from, neither the natives of this Mission nor of the rest of the country being able to give an account of their origin or race, not even having it by tradition, it is necessary [for us] to walk blindly, traveling to and fro with closed eyes after the truth, and perchance not knocking at her door for a long interval, or perhaps departing further from the truth—inasmuch as this chapter is all by way of conjecture, if I err in this undertaking, it is not through will and caprice, but because of not being able to discover the light in a place so dark, going along groping blindly.

2. Without pausing over what the authors relate as to whether they are descended from Jews, as some think, or from Carthaginians or Phenicians, as others think, I for my part, without involving myself in times so remote, shall give attention to the kinds of people who came to settle the Mexican kingdom.

3. The kinds of people who settled the Mexican kingdom, according to what Fr. Torquemada tells us in his Monarquia Indiana [marginal annotation: book 1, chapter 14], were four, he says, namely: Tultecas, Chichimecas, Aculnas, and Mexicans. Among these above mentioned different kinds of people, it is my feeling that the Indians of California here are of the Chichimeca race, because they are similar [to them] in every respect, according to what the above mentioned Torquemada relates to us [marginal annotation: same book, chapter 15], when he says: that toward the regions of the north (away from the City of Mexico, and at a great distance) there were certain provinces, the principal city of which was called Amaqueme, and the inhabitants Chichimecas, people naked of clothes, fierce of appearance, and great warriors, their arms bows and arrows, their ordinary subsistence is game and wild fruits, and their habitation in cavernous places or straw huts, for since the principal exercise of their life was hunting, they did not amuse themselves with building palaces.

4. Although the said Chichimecas lived in towns or rancherias, they had very few police, for they did not recognize any king or lord, but let themselves be governed by a chief, though not by one greater, as we

shall see in the proper place, or by one more esteemed, than any other man of those of the rancheria, with the result that in treatment and life all were equal.

5. This name Chichimeca means sucker or one who nurses, and since the principal and usual food of these was animals which they hunted, the meat of which they ate raw, and since they first sucked the blood of the animal, from this they got the name Chichimeca. Perhaps among themselves they may have had another distinct name which I do not know. These Chichimeca people did not live stationary at a single place, but from time to time moved from one place to another. They were ignorant of medicine for curing their diseases, and they did not bury the dead, but burned them. They did not use many idolatries, or venerate many Gods, and for this reason they did not have sacrifices.

6. Comparing then these Indians of California with the above mentioned Chichimecas, we find them absolutely similar: For their life was the same, because although they lived in towns and rancherias having a chief, which these [Indians] called *Not,* he was without police or laws, and to him they held very little obedience, as we shall see. Their dress was the natural one, which is to go about in their bare skins; their subsistence animals and wild seeds; their medicines almost none; and they also burned the dead. And in a word I find them similar in every way; I speak of those whom I have [here] treated and whom I have observed, who are the people of this Mission and its environs. And I think that through all the Province they are the same; I only find a difference in the Canaleños, who in many things differed from these Indians [here], for one perceives in them greater industry, a different bearing, and they buried the dead and did not burn them.

7. Only the diversity of languages which we find in the Province causes me much difficulty for assuming that the entire Province comes from that Chichimeca race, for each tribe appears to be of a distinct language. For we should suppose that the Chichimeca tribe would speak a single language, although from place to place there would be certain different [terms], such as provincialisms, but in general it would be the same [language] and all would have understood each other; but we find it so different that the Dieguino language and that of this Mission neither in terms nor accents resemble each other, nor can a single word be understood mutually. And I say the same of the Canaleño language and the others of the north. If I am told that certain tribes may have corrupted the primitive language, I say that it may well be, but that there would always be a connection,

such as we see between Old Castilian and that which is spoken at present.

8. [The matter set forth in] this paragraph above is what confuses me without being able to discern what may be the cause; if anyone of my brethren or others who may see this could make it clear, I would be boundlessly grateful to him, it being a matter useful to all and especially to us. Let what has been said be sufficient, and may others enlarge upon the above chapter.

Chapter 2

ABOUT THE CREATION OF THE WORLD.

Do not let the reader think that I wish to give here an account of that which Moses relates in the first chapter of Genesis. I do not intend any such thing, but to set forth the belief which these Indians had in their gentile state about the beginning of the world. And although one encounters in the narration many contradictions, we should not be surprised that certain crude Indians, without knowledge of the true God, without faith, without law or king, governed so long by the Father of Lies, without writings or characters, but having everything by mere tradition—we should not be surprised, I repeat, at their extravagancies and the little discernment in their acts, for since they were so ignorant, without being able to distinguish the true from the false, they did not know the path of light, and continually walked in darkness.

The belief which these Indians had concerning the origin of the world was thus: they relate that formerly there was nothing, only one above and another below; these two were brother and sister, man and woman, the one above, a man, which is properly the Heaven, and the one below, a woman, which is the Earth, but it was not the Heaven and the Earth as they are seen now, but of another nature which they do not know how to explain, and it was continually very dark night, without sun, moon, or stars. The brother came to the sister, and brought the light, which is the sun, telling her that he wanted to do many things with her; it meant that he wanted to cohabit with her. But the sister resisted declaring to him that they were brother and sister, and that therefore it was impossible to consent to what he desired, and that for that reason he should go back and leave her in peace.

Note: And the Indians of these parts pay such faithful observance to the first degree of consanguinity that I have never heard that brothers with sisters, or fathers with daughters, or sons with mothers, have been seen at all, nor even with first cousins, for being first cousins they are treated the same as brothers; but not so with the relatives by affinity, for there were many married to two sisters, as they also had the custom that if a woman died and she had a sister, the latter entered as a wife in place of the deceased woman. Here is seen the Mosaic law.

But at last in spite of all the resistance that she made, the sister became pregnant, and what she brought forth was earth and sand, but a small quantity, after the shape and manner of a little plot of ground; this was the first childbirth. She again found herself pregnant, and in this second childbirth she brought forth rocks of all kinds, sorts and sizes, and principally flint for the arrows. She again found herself pregnant, and in this third childbirth, she brought forth trees, and shrubs or chamize. In a word, after having given birth to all the things which are seen on the earth, such as plants, herbs, and the rest, she brought forth as her last childbirth one whom they call *Oüiot*. This was an animate being, but different from the rational kind, and irrational. But the father and mother of the said Ouiot were not people, but something else, and they do not know how to explain or to give to understand how they imagined them.

The above mentioned Oiot had children, and was the king or great chief of all that family. This Oiot and his children constituted, according to what I have understood, a species of animals distinct from those of the present day. Asking them how Chief Oiot had sons, or who was his wife and what she was called, they do not know how to answer this question, but say that he had many children, but how they do not know, nor whether all were males or whether there were females, they do not know this either, but conjecture that there were both, because women give birth that way. The discussion of the above I leave to philosophers, for my intention is nothing more than to make a succinct account.

Chapter 3

THE LIFE OF CHIEF OUIOT AND THE ORIGIN OF THESE INDIANS.

While Chief Ouiot was with his people, as they say, which he kept procreating, that first ground, which his mother had given birth to, kept increasing and widening, always from the north to the south (it is to be noted that all these Indians believe that they come from the region of the north), and as they kept on increasing, the earth kept growing all the time. Oiot already being very old, the eldest of his vassals, whether it may have been because of envy or because of the desire of governing, determined to kill their chief, alleging that he was not governing them well, and that he already was too old to govern; they held their conference as to what manner of death they should put him to, and the decision was rendered that he should be herbed or poisoned. They made the mixture, and giving him to drink that beverage which they had prepared for the purpose of killing him, immediately he felt sick, and finding this to be his fate he descended from the hills or mountains where he was making his home, and he came to where the beach now is (for at that time there was no sea yet). His mother knowing the danger in which her son, Oiot, found himself, prepared a remedy for curing him, which was in this manner: she urinated in a large abalone shell, placed in the urine some worms and certain herbs, put it in the sun, but while she had it fermenting, the Coyote came along, gave the shell a kick, and spilled all the medicinal preparation, and by this accident were frustrated all the desires and hopes of the mother of Chief Oiot.

Note: These Indians were of the belief that from this urine which the Coyote spilled, the sea was formed, that from the worms which were in the shell the fish were created, and that from the herbs were born the Giant Kelp and other plants which there are in the sea, and for this reason, they say, that the water of the sea has the taste or flavor of urine, because it is salty and bitter.

At last Chief Oiot died, and although before he died he had told them that in a short time he would return to live with them, from that time on they never saw him more. It is to be noted, that at that time there were no seeds or game, their food was earth, (which according as they explained and as I understand) is a kind of white clay or fine argil, with which they plaster their heads. Finding themselves thus situated after the death of Oiot, they discussed the matter of giving him burial. It was deliberated whether he should be buried or burned, and all the votes were that he should be burned. They prepared the hearth with wood and with the dead Oiot on top of it, and fearing that the Coyote might eat him, they sent him away to hunt for fire. And what the said Coyote did was to withdraw to a short distance and hide, spying on what they were doing, and on one occasion when he was some distance off they lighted the pyre, and the Coyote seeing it, behold he comes back at full speed, and although they did not allow him to approach, he saying that he wanted to burn himself up and die with his chief, he jumps over them into the flames, and seized a piece of the shoulderblade and shoulder of Oüiot, ate it up, and he did not get any more because the rest had been consumed by the flames. This Coyote was called *Eyacqüe,* which is the same as second chief, and at that time they changed the name Eyacque to the name of Enó, which means thief and eater of people, and thus they call coyotes at the present time: *Enó.*

After concluding the functions and ceremonies of the burial of their Chief Oiot, that is, after having burned him, they all assembled for a great council, at which they discussed in what way they could have wild seeds to eat, such as acorns, Wild Amaranth, chia, etc., and also game such as deer, cottontail rabbits, jackrabbits, quails, groundsquirrels, rats, etc. While all were at the above mentioned meeting, they saw on various days and many times one like a phantom, different from themselves, who kept appearing to them and disappearing, sometimes in one direction, sometimes in another, and finding themselves in suspense and fear at what they were seeing, they decided to call him to them. They called him, he came to them and they asked him if he was their Chief Ouiot. " I am not Chief Oiot," he answered them, " but a greater chief, and I am called *Chinigchinix.*" They asked him where he lived, and he answered: " My habitation is above." He asked them what matter they were discussing at the meeting and why they were all gathered there. They answered him that it being that their Chief Oiot had died, they were disussing how they could support themselves with wild seeds and game, and not have to subsist any longer on the clay that they were eating.

In consideration of these motives Chinigchinix answered them and told them: " I make all things, and I shall create people for you people, distinct from yourselves, whom you soon shall see. And now, from this moment on I give unto you power and faculty, to each one of you, that one shall make it rain, that another shall make the weather clear up, that another shall produce acorns, that another shall produce chia, that another shall produce Wild Amaranth, etc.; likewise that another shall produce cottontail rabbits, that another shall produce ducks, that another shall produce geese, that another shall produce deer, etc. To each one he gave the power, now to produce seeds, now animals, of the kind that they eat. And still at the present time, those who pretend to be their descendants, claim to have this power, and the [other] Indians consult them, asking that they produce many seeds, that they make the ducks tame, and they pay them well, so that they will be pleased, for they believe that if they do not pay them, there will be no seeds, nor will they get game.

After Chinigchinix had given the power, as we have said, to the descendants of Oiot, which must have been the time of *dixit et factum est*, he created the people that he had told them about, and Chinigchinix made these people from a little mud of the shore of a lake, and these are the Indians that now exist, and he did not make merely one but a number of men and women, and he told them: "He who obeys me not or believes not in what I teach him, him shall I punish, to him shall I send bears to bite, rattlesnakes to sting, and other misfortunes." And he taught them the law which they should observe henceforth with its rites and ceremonies.

The first commandment which he gave them was that they should build him a temple in which they were to worship him, offer him sacrifices, veneration, and cult, this same Chinigchinix furnishing the design or model of how the temple was to be built. This Chinigchinix, whom from that time on they considered as God, the Indians say had no father or mother, and all are ignorant of his origin. I have not been able to obtain the etymology of the name Chinigchinix, nor do the Indians know what it means or its significance, as is also the case with the name Ouiot. It is true that they are proper names, and for that reason must have and should have their origin, but so far I am ignorant of it.

They believed that the God Chinigchinix was everywhere present, that he saw everything, though it were dark night, but that no one could see him; that he was a friend of the good and punished the wicked much. This God Chinigchinix has three distinct names, namely: *Saor, Quoar,* and *Tobet.* Each name has its own meaning, for *Saor* signifies or means the time when the said Chinigchinix did not yet know how to dance. *Quoar* when he already knew how to dance. And *Tobet* when he danced wearing a little skirt or apron of feathers, adorned with feathers like a crown on his head, and painted up. And they say that this Chinigchinix went away dancing to Heaven. And this kind of dress their God Chinigchinix commanded them to use in their feasts, and they use it in the special dances of their great feasts.

This is the belief which these Indians had about the creation of the world and their origin; and in the narration of this fable alone we see included and comprised all the usages, customs and ceremonies of the Indians of this Mission and vicinity with slight variation.

I consider that the reader is in suspense after reading the above account and that he is desirous of learning what became of the children and descendants of Ouiot, after Chinigchinix created the Indians from the mud of the lake, since we have made no further mention of them. According as some relate, the God Chinigchinix after making the Indians, transformed them[the race of Ouiot]into people or Indians like themselves, and to this account I adhere as being the one more reasonable and congruous, because of what we have said above about the power and faculty which Chinigchinix gave them [the race of Ouiot] of producing seeds and game, and about those who hold themselves to be their descendants claiming to have that power yet. Others tell that when they [the race of Ouiot] saw the Indians which Chinigchinix had made, they [the race of Ouiot] departed to another region, and it is not known where, and that they have not been seen more. Others tell other things which I am not taking time to write, considering them the forgings of their crude brains.

Chapter 4

ABOUT THE TEACHING OR INSTRUCTION WHICH THEY GAVE TO THEIR CHILDREN.

One of the matters in which the Ancients experienced the greatest difficulty and which gave them considerable care was the bringing up of the children, because on this being good or bad depends the goodness or badness of the child. Since these Indians did not know either the mechanic arts, or the liberal ones, or did they need them because of the manner of life which they led, but only those necessary for their own preservation, they therefore were not able to teach their children anything useful to rid them of their idleness. They merely instructed them in the handling of the bow and arrow, and this in order that they might learn to hunt for food and defend themselves from their enemies.

Although these Indians were ignorant of the true path, and the beginning of wisdom is the fear of the true God, and this fear the beginning of the instruction of children, nevertheless the instructions which the parents gave their children had their moral virtues, for the parents and grandparents took care very earnestly that their children be well brought up and good [children], because if one of them turned out perverse, although they quickly removed him from their midst, they were disgraced. And for this reason from the time they were small they admonished them (and this by showing them beforehand many misfortunes and punishments, if they did not follow carefully what was being taught them), telling them that they should not be thieves, or liars, that they should not injure people, should not fight with one another, and should not use bad words, and above all that they should not make fun of the old people, but should respect and fear them; and that if they did not give heed to these instructions which their parents gave them, even though they might kill him [the perverse child], the God Chinigchinix would punish him much. And this was the daily harangue. These Indians did not punish the faults of their children, they merely gave them certain admonishments to correct them, but in reality very few offences were committed and the reason was the much fear and great dread which they felt.

When the males were at the age of about 6 or 7 years, they gave them a kind of God as a protector, and it was the animal in which they should put all their faith in times of need, and it would defend them in all dangers, especially in the wars against their enemies; and it was never the principal [God], for they knew that he was hidden, and that if at any time he appeared to them and spoke to them, it was always in the form of animals, and of these the most abominable, ugly, and hideous. Indeed, in order that the boy might know which one the God Chinigchinix destined for him, and in which he was to place confidence, they gave him a drink, which is prepared from a kind of tobacco (I do not know the [Spanish] name of this herb) which they call *Pibat* (they apply this term to all tobacco which is smoked), this they prepare by grinding it up, and when it is pulverized they make a cake, mixed with other ingredients, which according to what they have told me are lime and urine.

To others they gave another [kind of a] drink [prepared] from a plant which is called *Toluáche,* and which they call *Mani,* and drunkenness is produced by one of these as much as by the other, in drinking which they shortly lose their senses, and finding themselves deprived of their senses by their drunkenness, they were made to fast 3 or 4 days or more (and it is to be noted that their fasts were natural ones, they being given nothing to eat or drink during the entire time that the fast lasted). During this period they continually had by their heads some old men or old women who were preaching to them without letting them rest either day or night, telling them that he [the boy] should take good notice and be watchful, and therefore should not go to sleep, that he might see if the bear, the coyote, the raven, the rattlesnake, etc., were to come, naming over a great many; if they were to come gentle or angry; and that from the first animal whom he might see he should ask for what he wanted. The poor unfortunate, in his drunkenness, and without having eaten or drunk for many days, had a thousand visions and deliriums and when he said that he saw this or that one and explained what he had manifested to him, that is, what he was to do for him, he was then given something to eat, so that he would come to himself, and when he was somewhat stronger they began a great dance feast, according to their custom, exhorting him to be very careful not to make angry the one who had appeared to him, and to carry out exactly what he had commanded.

There were others who did not drink these drinks, and what was done with them was that first they feathered them and painted them well with a kind of soot between black and red color, and adorned in this manner, they carried them to the temple called *Vanquex,* with many ceremonies. On reaching there, the satraps put him [the boy] at one side of Chinigchinix and in front of him on the ground they painted a figure, the most ridiculous which can be imagined, for it consisted of nothing more than streaks or lines, horizontal and transverse, circular and semicircular, all poorly made without order or arrangement. There they left the boy, forbidding him to leave there until the penance of fasting was concluded (which was wont to last 3 entire days), telling him that should he feel hunger or thirst he must have patience and bear it, for if he ate or drank, though it were alone at night in secret, the evil figure which was painted in front of him would make it known, and that Chinigchinix was looking at him and would punish him, sending diseases upon him so that he would die, and other similar nonsense. And these poor boys believed it all infallibly, and observed it to the very letter.

I was told of a case that had happened in the time of their gentile condition, and it was that a boy being in the Vanquex during the penance of fasting, on the second day found himself with considerable hunger and thirst, and he went in secret to a nearby house at which there were no people home at this time, found something to eat, ate and drank, and immediately returned to his place, without anyone having seen him. And after the period of penance was finished, finding himself one day with his companions, he told them of what he had done at the time of his penance in that he had eaten and drunk, and having found that the evil figure said nothing, and that nothing happened to him, he stated that everything which the *Puplem*, that is, the wizards or soothsayers, told was lies and deceit, for having eaten and drunk and even rubbed out part of the figure with his feet, nothing had happened to him, for which reason one should not believe the Puplem. But his companions, instead of opening their eyes and perceiving the error and the deceit, so great was their resentment and fury which they felt against him, because of the disrespect which he had shown the old men, that when the matter was divulged he was shot to death with arrows.

Note: The drinks *Pibat* and *Toluáche*, of which we have spoken above, outside their use for the boys, were also employed by the men, and still are, for the purpose of winning in their games, for obtaining the women whom they covet, and for procuring any evil thing that they may think of. It is to be noted that at the time of their drunkenness they also have to observe a fast, for at least some 3 days, and that when this is over they are said to be cured, and that when they are cured in this manner, they believe, and this without having the slightest doubt enter their minds, that they will be able to attain any evil thing which they crave; but if they are not successful and their luck is reversed, as frequently happens, they attribute it to being poorly cured, that is, that they did not drink sufficient medicine, or did not keep the fast well; or to other similar causes.

After the boys had been put through everything that we have related, they put on them their mark, which is properly speaking a brand—for it is obvious that the Devil, entering into the use of reason, wished to have them marked like slaves, which was accomplished in this manner: They took a species of herb or grass, this they pounded and crushed until it became like tinder, and put it on the place where they were to be branded (which was on their arms and thighs) in the figure which he [the boy] was to have, lighted it, and let it burn until it was consumed. We must consider that the burn soon raised a blister and made a sore. This they left until it healed, without putting any remedy on, and the place remained scarred permanently. Others instead of the grass used dry tule, and others the dung or manure of jackrabbits or cottontail rabbits.

The cause or reason which they allege for branding themselves thus was that they believed that with this mark they have more strength in the arm and better pulse for handling the bow, and that Chinigchinix wished it thus and so commanded, in order that they might conquer their enemies, and that he who was not branded with this sign, which they called *potcusc*, would always be unfortunate and beaten, like a despicable man and one having little strength.

The boys, in addition to what has been mentioned, had to suffer still other martyrdoms in order to become men and be able to present themselves among the rest. It was their custom, after the mark had been put on them, when they were bigger boys, to whip them with nettles and to put ants on them, and this was done in order to make them more robust and stronger, and it was done as follows: In the summer time at about the months of July and August when the nettles are in season and the fiercest they took some bunches of them and with these began to whip the boys on their legs, thighs, butts, shoulders and arms. After this sacrifice, having been well lashed with nettles, they placed the patient on a nest of fierce ants, and another one was stirring them up to make them still fiercer, and since the patient had no more clothes on than what he brought from the belly of his mother, we can imagine in what condition he must have been, after having been thoroughly lashed with nettles, as a result of those fierce ants, which even cause fever. And so great was their patience, that they seemed like dead, without a groan or movement. These were the ones called cured. There were some who suffered this torture several times over, and many went through it alone or with some companion, for they believed that when thus cured, they were from that time on more agile, and that the arrows of their enemies could not harm them.

They also deprived the youths from getting close to the fire, in order that they might learn to suffer and to harden themselves to the inclemency of the weather, and also from eating certain foods, such as acorns, Islay, Chia, etc., as well as the meat of certain animals, such as deer, cottontail rabbit, jackrabbit, etc., in a word, all the best foods that they had, telling them that these foods were for the old people only, and that until they had 2 or 3 children they could not eat of them, and that if they ate of them before that time in secret, the *Toux,* which is the Devil, would make it known and would punish them, causing them many injuries, such as: stumbling over rocks, tripping over burrows, that mountain lions, bears, rattlesnakes, etc., would bite them, and that their Chinigchinix would be very angry and that they would die. And they had such faith and belief in these fabulous stories, and so great was their dread and fear, that they would sooner perish than transgress to the slightest extent.

In the instructions that they gave to the girls, in addition to the general admonishments which they gave to the boys, they added that they should not be run-abouts, but remain in retirement, nor should they be sleepy-heads or lazy, but always ready and obedient, so that when they were grown up they would know how to work at their chores, which are the hunting and cleaning of seeds, the preparation of acorn mush and pinole, these being the foods which they use. And for this reason from the time they were little girls they would make a traybasket for them suitable to their size, and would teach them to do this work, as well as to grind or to pound up the seeds, telling them that knowing how to work and not being lazy, they would have, when they grew up, many men who would seek them, and that they would be very much liked.

In this region, toward the south, the custom prevailed of tattooing the women, and from the time they were little girls they began to tattoo them, commencing in the case of some between the eyebrows, in that of others on the chin, extending it as they kept growing over almost the entire face, breasts, and arms, which tattoo was generally lattice pattern, [but] there were other women who had lines and other figures. This tattooing was done as follows: With some thorns from an Opuntia Cactus thicket they pricked the place until it bled. Then they rubbed it with a kind of charcoal, and that place remained with a blue color which never disappears. The principal reason why they tattooed women, according to what I have been able to investigate, is because they say that when tattoed thus they are prettier and better liked and will have many suitors. But I fancy and believe another thing, and it is that just as the Devil put the burn on the men as a brand, in the case of the women it must be the tattoo, and thus he had both men and women marked.

What these Indians had rare and special was that the fathers and mothers advised their daughters when they were grown up, telling them that if while gathering seeds for pinole or traveling to some other place they met with one of the eaters of human flesh or one of the wizards, and these wanted to use them, they should not resist, but should agreeably comply with their desires, and this though they might be going along with their own mothers, or if married they might be going along with their husbands, for these latter at the first insinuation yielded their right. And this was because they told the women that if they resisted and did not willingly comply, they would poison them with herbs and make their bodies rot, along with other similar nonsense, and the poor wretched women believed it infallibly, and full of fear they submitted to everything, although it was against their wishes.

At the first menstruation, or at the time of the first monthly, as they say, they used to hold some big feasts with many ceremonies, which began in the following manner: They made, and still do make, a hole about a half yard in depth, not round but long, after the fashion of a grave, they fill it with fire with some rocks in it, and when it is good and hot they clean the hot coals out of it, leaving in it the rocks, good and hot, they lay on top of them a bedding, as it were, of California Mugwort (which is a species of Wormwood), called *Pacsil.* On top of the California Mugwort the girl lies, covered up well, without being given anything to eat or drink for 2 or 3 days, or at least very little, and thus they keep her until she has become clean. In there, the girl patient, in her hot pit, is bedecked all about the pit with the feathers of various birds, shell beads, and many things which they have, and with some old women, who have that task, singing without letting her rest either day or night, a song so tiresome that one does not know if they are crying or laughing, a black glue or bitumen on their faces so that they look like devils. I have not been able to determine what they say in their song, because I can never understand them [the old women], and when I asked others about it, they all answered that they did not understand them, while unmarried women dance around the girl patient at certain designated hours during every day of the roasting. Since these days were feast days, many people, men and women, went there, some to dance and others to watch the dancing and to get something of what was being distributed, be it pinole, shell beads, or whatever it was. The above described was the general method, with exception of some poor [girls] who got fixed up with their mothers and grandmothers alone, without so much witchcraft. In their present status of being Christians they use the same procedure, with the witchcraft removed, which they used in their gentility, of feathers, dances and songs.

The most peculiar custom which these Indians had was that there were a few [girls] although very few, daughters of chiefs, and among these principally the first born, in the case of whom, after the catamenia had come to an end and the girls had come forth from the roasting, an old man, one of the wizards, designated for the purpose, made with a flint a little cut in the girl's private parts, and after the operation started preaching before all the people, saying that that girl was already a woman, that she was good, that she would have many children, and other similar nonsense.

Chapter 5

ABOUT THEIR MARRIAGES.

One of the things necessary for the conservation of the life of man was company, for which reason God ordained that man should have woman, with whose company he should pursue two ends, one, the intercourse, of which he was capable, and the other, that from the union of the two would be born children who would follow in the propagation and increase of the race. Although it has been an ancient custom among all nations to give the women to their husbands, it has not been everywhere in the same manner or with the same ceremonies, and for that reason I shall set forth those which these Indians employed.

The general custom which they employed for seeking a woman for the purpose of marriage was that the man who wanted to be married went for several days to and fro about the house of the woman that he desired, but without entering it, waiting for an occasion to speak to her, and when he found her all alone he told her: *I want to marry you,* or *We should get married.* There were others who sent a third [party] to talk to her in private, and if the girl said yes, she notified her parents, and if they agreed, the bridegroom was notified that he could come into the house and talk with them and with the girl. There were also certain ones whose marriage was fixed up by the old people, and it was that after the parents of the girl had been notified these same old people notified her telling her: You have to marry such a one, and you will live well, and you will have many things, for he knows how to kill deer, cottontail rabbits—and [telling her] other similar things.

The first time that the bridegroom entered the house of the bride he brought his little present, now a deer skin, otter skin or seeds, or shell beads, in fact, whatever he could, and from that day on he was considered bridegroom of the house, tending to the bringing of something to eat, for he ate and in most cases also slept there, but without cohabiting with the bride, or having the least indecency with her either in words or actions, and they were very scrupulous about this.

During this period, which we may call the period of betrothal, the obligations of the bridegroom were to bring wood to the house every day, and to hunt cottontail rabbits, groundsquirrels, mice, etc., to eat. And the girl had the obligation of working at the chores and duties of the house. The first thing that she did was that at the first streak of dawn she arose, went to the water and bathed herself, brought water for the house, sprinkled it, swept it, and this with much promptness and care; then she prepared the food of various kinds of mush, pinoles or of whatever they had, and [did] the other chores of the house, and she had to do all of it alone, without the help of anybody. Sometimes also the parents of the bridegroom went to eat [there].

Note: Having the bride perform all the tasks of the house was in order that the bridegroom might observe whether the girl was lazy, and whether she knew how to prepare food and to do the other necessary work of the house, and whether she would serve him well, and for this reason he lived in the house of the bride.

When they determined the day of the wedding, after having spent some 15 days, in some cases a longer and in some a shorter time, during which the above mentioned manner of living lasted, they notified the relatives and friends, or we might better say the whole rancheria, of the wedding feast, which lasted from 3 to 4 days. When the day arrived, certain old men called Puplem (who are those of the Sanhedrim) took the girl and in public took off of her all the jewels and adornments which she was wearing (these were a kind of earrings [made] of shells and long bones) in her ears, and on her throat and arms, they decorated her head with feathers, but not like the crown of the dancers, but with the feathers spread out—her hair, arms and bosom, and decked thus with feathers they presented her to all the people, and then seated her beside the bridegroom on a tule mat, certain old men dancing in front of them and singing to them, and with the other people also dancing and eating all the time that the feast lasted.

The instructions which the parents gave to their daughter before they parted were very good ones, for they told her that she should always remember that she was the daughter of some good parents, and that therefore she should not disgrace them, that she should serve her husband well whom Chinigchinix had given to her, that she should not be with another man, for even though she were executed they would remain disgraced, and other similar things, and at the end they added: and if your husband does not treat you well, let us know, and you shall return to our house.

There were others who went themselves straight to ask the parents for the girl, and if they yielded her, gave them a present of shell beads or of something else (which I consider to be like a promise or pledge). These notified their daughter telling her: Daughter, you are to marry such a one, for we have already given you to him. And the poor girl, whether it were her pleasure or against her will, or however it might be, had to marry the man who had asked for her.

There were also certain ones who were given in marriage from the time they were small [children], and it was in this way: The children being of tender age, the fathers and mothers on both sides being together, either with a feast or without one, would say: These 2 little children are to be married, and without further ceremony they were already married, and from that time on the 2 little children played together, ate, and slept together, and the 2 houses were one and the same for both of them; until on reaching competent age they gave their feast as we described above, and they cohabited together. The marriages celebrated thus were mostly those of relatives by affinity, for among them relationship by affinity was not held to be an impediment. In the year 1821 at this Mission I married in the face of the church a couple whose marriage had been contracted since the time they were children, for the girl must have been about 6 months old, and the boy about 2 years when their parents already married them.

There were also among these Indians marriages by rape, and it was that when a captain or his son fell in love with a certain girl of another rancheria, what he did was to send to that rancheria 3 or 4 or more Indians, well armed. On reaching that rancheria, they went directly to the house of the girl and laid before her father and mother the commission which they had brought from their chief, that therefore they should give their daughter to be taken to the chief, and that otherwise they would kill them. The poor wretches, full of fear and dread from the threats that were made them, delivered their daughter, though it might be against their will, and she was taken and led to their lord, and they were already married without performing the ceremonies which we have described above.

What we should search out is whether these marriages of the Indians were true marriage contracts or not. There is no doubt that according to what we have seen they were apparently true marriage contracts (except the rapes, and the unwilling ones, which were null and void), but the rest it seems were true matrimonial contracts, and should therefore be perpetual ones. Yet among these Indians in many cases they were not so, or better stated, it was their belief that they could get divorced whenever it pleased them and they felt inclined, and it was a custom current among them, for if after being married they did not suit each other, be it for whatever reason it might be and after whatever period of time might have elapsed, if they did not suit each other, as I said, they got divorced at once and each one took his [own] road, and they got married again to others.

My way of thinking is, and I believe I am right, that their marriage contracts were not absolute, but conditional ones, that although at the time of getting married this was not explained verbally, tacitly it was understood, for the reason that it was their custom. This is my way of feeling, *Salvo meliori*, it is obvious to us through experience, and it is confirmed by the exhortation which the parents gave to their daughter when she departed with her husband: *That if the husband did not treat her well, she should return to her home*. Therefore they were not true marriage contracts, for *conjugium* is to unite two together, under a perpetual yoke.

They had the custom that the first time that the woman found herself pregnant, all the people of the rancheria held a feast, eating and dancing, and this for one night only. This feast was held with the rejoicing that another one was coming to them, and in the song of the dance they asked their God Chinigchinix to guard for them that child, the mother being a good woman, since she was about to give them children, for they considered a sterile woman to be a bad omen. When the time of childbirth arrived, they did not do anything special, but after she had brought forth and the baby had been cleaned off, they showed it to the people, and if it was a male the grandfathers named it saying: N., thus this child will be called, and if it was a female the grandmothers named it; and it was always the name of themselves [the grandfathers or grandmothers], of their parents, or of their ancestors, unless at the time of the birth something rare and peculiar might have happened, from the significance of which they gave the name.

The oddest custom of these Indians (although the Ancients [the ancient Mediterranean peoples] also had it) was that at every childbirth, from the time the woman brought forth, the husband had to go on diet like the woman herself, and this consists mainly in his not being able to leave the house except to bring wood and water, [and] in not eating meat or fish or other foods forbidden by them. This diet usually lasted for some 15 days, although in many cases it lasted during the entire period of the lochia of the mother, in the case of others a shorter time, according to the love which they had for the child, and now that they are Christians they still observe it, for they are of the belief that if they break or do not observe this diet, chiefly by eating meat or fish, the baby will die, and it is to be noted that in order for the child to die the father had to be at home; if at the time of the childbirth he is away from home, though he knows about it and does observe the diet, there is no danger.

And in confirmation of the above I shall relate a case which happened in the year 1819 at the Mission of N. [marginal annotation: San Diego]. The wife of an Indian who was cook for the priests at the said mission, gave birth before the proper time to a baby, very weak and sickly. The husband after it was born began his diet, and on the second day, the priest seeing that the Indian ate nothing more than a little bread asked him the reason why he did not eat meat and other things as usual. The Indian answered him that he was not eating meat because he did not want to kill his child. The priest began to exhort him telling him that he should abandon these gentile ideas that his child would not die though he [the father] ate meat. The Indian was reluctant, but seeing the persistence of the priest (and he was doing it in order to disimpress him of those ideas), he ate like the rest, and in the evening the child died. Of course it is to be reflected that the death of the child did not come from the eating of meat, but from the child's sickness and weakness and premature birth, but all the Indians and he himself attributed it to the eating of meat.

Entre las barbaridades, que pueden contarse de estos Indios, (aunque el P. Torquemada [marginal annotation: lib. 13. c. 9.] ya habla de unos semejantes, y quizas serán de una misma rasa) una es y no poco pesima, sino de las mas abominables, el casarse hombres con hombres, estos son unos hombres, que aunque sean varones desde chiquitos les enseñan todos los oficios y trabajos de mugeres, y su modo de vestir es el de las mugeres, hasta en sus brutalidades usan de ellos como de mugeres: Estos tales servian, tanto en su Rancheria como en otras que fueran, como publicas rameras, y este mal trato sodomitico, les era permitido, entregandose á aquel que queria usar de ellos. De estos havia algunos Capitanes, ù otros que se casavan con ellos, y estos los tenian que á mas de usar de ellos en sus brutalidades, para hacerles sus comidas, y servicio de la casa, que como hombres siempre tenian mas fuerza.

Estas especies de hombres todos tenian un mismo nombre que era generico: en las Rancherias de este contorno los llamavan *Cuút,* y un poco mas tierra adentro *Uluqui,* y por la canal *Coyas.* Estos de esta Provincia, no eran como los que refiere Torquemada, pues dice: que aquellos eran unos hombres mariones impotentes, corpulentos, y membrudos. Los que Yo he visto, son hombres usuales como los demas, y no padecen tal impotencia, pues conosi á uno casado con muger de Christiano y tenia dos hijos. Lo mas particular que havia entre estos dichos era: que como ellos, servian de mugeres á los que los querian, tenian estos la facultad y licencia de cohabitar con la muger que les quadrava, si ellas consentian, y los maridos no decian nada por ello, porque como ellos decian era *hombre muger,* podia jugar y divertirse con las mugeres, pues con ellas iva á pinolear, y hacer todos sus trabajos, y nunca usava de arco y flecha, advirtiendo que eran la gente mas despreciable de los demas.

Chapter 6

ABOUT THE MANNER OF LIFE WHICH THESE INDIANS LED.

The mode of living or of life which these Indians had is not of great moment, for they led an idle and lazy life, more like that of brutes than that of rational beings, and being ignorant of the arts, they had no employment and profit with which to busy themselves for using up their time, for they did not cultivate the ground or sow any kind of seed, inasmuch as they subsisted on the wild seeds of various plants which the earth produces, and on the fruits of trees, and on game; and therefore their tasks and labors were confined to the making of bows and arrows (nor did all of them do this, for the youths did not wish to work at anything, but the old men and the poor men), the hunting of deer, cottontail rabbits, groundsquirrels, rats, etc., in order to eat and dress, if going about in their bare skins, as they used to go, can be called dress. For the clothing of the men consisted generally of nothing but their naked skins, but some of them put a deer skin or coyote skin over their shoulders, after the fashion of a cape. The women prepared from the skins of cottontails and jackrabbits a kind of cloak after the fashion of a choir-cope; this they made as follows: they kept twisting the skins, making a cord or string of them, long, and about an inch thick; this cord they sewed together turn on turn making the cape, as I said. In front of their private parts they [the women] wore certain little nets, or a kind of fringe made of grass which reached nearly to their knees; and nothing else except the decorations of shells and bones in their ears and on their necks.

Their way of spending their time was in playing games, taking trips about, sleeping and dancing. The whole life of the men was confined to this, except the old men and the poor men, who also busied themselves in making certain household utensils; or again instruments for working the bows and arrows, such as little saws, punches or awls, and other similar things (the little saws they made from the shoulder-blades of deer; and the borers or punches from their shin bones, as well as from the bones of fish); in making nets for various uses: now for fishing; or again those which they use for carrying their utensils, the women the babies; for catching quails; and for other uses.

Among the women the mode of life followed was very different, for they in addition to making the household utensils had to seek all the things necessary for a livelihood, which are the wild seeds of the country; after gathering them [they had] to clean them, to grind them or toast them for making their pinoles and various kinds of mush, which were the foods on which they subsisted. It was pitiful and caused compassion to see a poor woman with the baby on her shoulders about the country, suffering cold, and again heat, hunting certain herbs or seeds; [to see her] arrive home without finding either fire or water, and most times not even wood; [to see her] clean them, grind them and cook them, and after they were prepared [to behold] her idler coming now from the game or dance, or getting up from sleep, [to watch him] consume [the fruits of] the toil and fatigue of the poor woman, while if he ate everything up, she had to go without food, not being able to say a word. The women in their gentile condition were worse off than slaves, for one cannot realize the subjection in which they found themselves; it was sufficient [reason] if her husband became angry with her either because she answered harshly or because she did not have what he wanted, for him to leave her, or to slay her, and most times the quarrels came from the husband gambling away the utensils of the poor woman. But thank God, since the light of the faith entered these lands, since the holy gospel has been preached, the women have gained the Christian liberty which Jesus Christ won for us through his passion and death.

The woman could not be idle at her home, for after the food had been sought and prepared and all the chores of the house had been done, she had to make all the utensils needed for her work: such as large and small baskets, which serve as plates and cups for eating, and for other uses; traybaskets for cleaning and toasting seeds; and other similar things.

What is wonderful and for which we should bless God, as regards these women, was the facility and happiness which they had in the bringing forth of children; it can be stated that they scarcely felt at all the pains of childbirth, which did not last half an hour, and many times the woman was alone, and she herself after having given birth cleaned the baby, and after passing the afterbirth washed herself of all the mess of the childbirth, and we are to note that they did not give birth to children inside the house, but outdoors, and this though they might be in the house, for upon feeling [that they were about to give birth] they would go outside, turn the face in the direction that the wind was coming from—and shortly afterwards would set themselves to working at whatever was necessary to be done about the house, that was, if there was no one else to do it. In their present state of being Christians, the Creole women of the Mission no longer have this facility, which they had in their gentile condition; I attribute it to the exercise which they used to have when they were gentiles, since many of them now have more idleness, for finding herself pregnant, she no longer works at anything unless it be something short and easy.

Chapter 7

ABOUT THEIR OBEDIENCE AND SUBJECTION TO THEIR CHIEFS.

Before speaking of the obedience which these Indians had for their chiefs, we shall set forth the method and ceremonies which they employed in their election or proclamation. When the chief was already old or because of some incapacity desired to retire from governing, he prepared a great feast, and invited the neighboring chiefs and friends. On the arrival of these, all being together, he declared to them that his purpose in inviting them to that great feast was to elect his son as chief, since he already found himself quite old, and afflicted (this amounts to a sort of acknowledgment). On the following day in the morning the crier came forth shouting through all the rancheria, declaring that the chief was making his son a chief, and that they should come to the feast of the new chief. Everything necessary having been arranged for the function, the new chief put on himself the imperial insignia or robes, which consisted of his hair being tied around his head by means of its cord, and a slender stick about half a yard long, shaped like the blade of a knife, stuck in his hair, the little skirt of feathers, and the crown, [he being] well painted up and reddened, and dressed in this manner, he began to dance alone for a while, and then the other chiefs came out and putting him in the middle danced together with the new chief, and it is to be noted that they also were dressed with all the insignia of chiefs.

This feast lasted for at least 3 days including the nights. The old chief saw to it that there were many kinds of food in the line of pinole and meat for the invited ones and for all the people of his town, and without further ceremonies than the ones above mentioned he was already recognized as chief; but it is to be noted that he did not take up the reins of government immediately, but when his father determined, or upon the death of the latter, and then they did not do anything special, but from that time on he already performed the functions of chief.

In the succession of these chieftainships, women also entered, when males were lacking. She could marry whoever she pleased, though he were not of the race or lineage of chiefs; but the husband, be who he might, though he were the son of another chief, was never recognized as such nor did he have command, but they only recognized the woman. But she did not govern or perform the functions of chief, but the government was exercised by another, an uncle or a grandfather, the nearest of blood. But the first male whom she bore, immediately was declared chief, and from that time on all of them already recognized him as such, although the other one was ruling during the entire period of his minority, which was up to such time as he could perform alone the functions of chief. On the day when the command was delivered to him, they invited the neighboring chiefs and friends, the crier called together the town, and they made their great feast as we have mentioned above.

It is to be noted that whenever a feast was held all those invited brought their present for the chief who was inviting them, but he had the obligation to return it when they invited him, and in the same kind which they had given him.

As regards the obedience and subjection which these Indians had to their chiefs, what I have been able to investigate is that in as far as his mode of living was concerned, they did not recognize him at all; nor did he mix [that is, interfere] with his people, as they say: they [the people] had a free life, without subjection or subordination to anyone, without laws of government, or police, without punishments for wicked doers, as also without rewards for the well deserving; and in a word everyone lived as he pleased without anyone interfering with him, do what he might. Since the knowledge of the true God was lacking among these Indians, they lived without faith, without law or king, and therefore a life more that of brutes than of rational beings. What causes wonder is how these towns could keep in peace and quiet without laws of government or police. And indeed in the gentile period there were very few fights and quarrels between them, for since all the rancherias were composed of a single relationship, I believe that it was for that reason that all lived in peace, the parents continually exhorting their children to be good; for if someone committed some crime, if the offended person was able to revenge himself, the revenge, which was almost invariably death, was the punishment for the crime, but the chief did not intervene in the matter at all.

Although the chief did not exercise any authority so to speak in the administration of justice, nevertheless they had for him great respect and veneration, and especially so the youths on account of the great fear and dread with which they were imbued from the time they were small, and likewise for the elders, this being the daily harangue as we have said above. And because of the fear and dread which had been impressed on them, they did not dare to commit any incivility, for if some bold [youth] presumed to maltreat or to injure them either by deeds or words, at once they ordered him slain, and it was in the following manner: an old man, one of those who had been appointed for the purpose, began to shout through the rancheria weeping bitterly, saying that such a one had done or said this or that to the chief, and because of this crime the God Chinigchinix is very angry with us, and wants to send a great sickness upon us; and therefore, young men, arm yourselves for killing such a one, that by presenting him dead to Chinigchinix, he may lay aside his wrath and not kill all of us. Since the Indians believed these deceivers like infallible truths, immediately the men went forth armed with bow and arrow, and wherever they found him, there they killed him, and together with the arrows that they had shot at him they presented him to Chinigchinix. Afterwards the relatives of the dead man took him and carried him to the pyre to burn him. The authority which the chief exercised in his rancheria was: that he was the one who had to tend to and handle all matters which came up with other rancherias; to call together for war, defensive as well as offensive, and also for [making] peace; to announce the day of all the feasts which they celebrated, which were many; to set the general days for hunting and seed gathering, for the old women and the women also went privately whenever they wanted to and needed them [the seeds] for their subsistence without the permission of the chief or of anyone. These general expeditions were for the purpose of [obtaining food for] celebrating their feasts, and in them all those of the rancheria, men and women, participated. The men killed the game, such as ducks, geese, cottontail rabbits, rats, etc., and the women gathered and carried them; having returned to their rancheria they all of them delivered the greater part of what they brought, both of the animals which they had killed as well as of the seeds of all kinds which they had gathered to the chief, (and that night a great feast was begun). But do not imagine that these seeds and animals which they delivered to the chief were a kind of tribute, that as such they owed it to him. Not so, for these seeds which they delivered to the chief were for the purpose of celebrating the feasts, and the chief had to keep them like a deposit, being deprived of eating or using the least part of them, not having any more of them than what was left over in the feasts.

And if any chief ate the said seeds or sold them, or gave them out squandering them, what they did was to kill him, alleging that he was a bad chief and did not take good care of his people. It was the old men, wizards, or soothsayers who proposed the death of their chief to the youths, the latter armed themselves for killing their chief, and not hastily and guardedly, but with a day designated for the execution. The same fate befell the first chief, Oiot, as we have stated above.

The chief, if he wanted anything to eat, had to seek it the same as the rest, although there were some who made him their little gifts; this was not because of obligation, but through good will; and for this reason I believe, and they have assured me, many of them had 2 or 3 wives for the purpose of hunting seeds and having them in abundance, so that those who came to visit could be invited to eat. Of the wives which he had, one was the principal one, and the others were like concubines, and the children of the latter did not come into the right of the crown, unless legitimate children were lacking. These princedoms or chieftainships were by succession and not by election.

Chapter 8

DESCRIPTION OF THE TEMPLE CALLED *VANQUEX* AND ABOUT ITS IMMUNITY.

The temple which these Indians had, called *Vanquex,* ordained by their God Chinigchinix at the time of its formation, was built at all the rancherias near the house of the chief, which house was always the biggest and tallest one. Although the town or rancheria was built without order or symmetry, since everyone placed his house where was most convenient for him, nevertheless the house of the chief got to be located at about the middle of the town, and adjacent to the house they built the Vanquex in the following shape: they made a circle about 3 or 4 yards in diameter, not round but oval. Of this they took half of the circle, and in this half circle they built a fence or stakework of brush or tule mats about 2 yards or more high. At the other half circle they built another little stakework of small sticks, which did not project from the ground but 2 or 3 fingerwidths: inside this oval circle they had the figure of their God Chinigchinix, on top of a framework, which consisted of a bundle, in a coyote skin, of feathers, deer horns, mountain lion's claws, and other small things of this sort; the beaks and claws of the hawk were not lacking there, especially those of a kind called *Pames*, with the feathers of which they dressed the Chinigchinix [figure] and made the little skirt for dancing, but this [little skirt] could not be worn by all, but only the chiefs and satraps or wizards called Puplem.

When the chief gave notice by means of the crier of the general expeditions for going to hunt game or for gathering seeds, the *Puplem,* which means soothsayer, or he who knows all things, and for this reason they are called wizards (Note: I consider them as priests, since all the functions in which the people had to assemble at the temple were directed by them; and the chief and crier were of their number and were the principal ones), the said *Puplem* painted a figure on the ground inside the Vanquex, very ridiculous and odd, like the one which we mentioned in connection with the penance of the boys, and before leaving the rancheria the crier announced to all the people that they should venerate it, and all should go to worship it.

Their manner of worshipping this evil painting was that when all the people were assembled, all the men being armed with their quiver, bow, and arrows, and well painted up, the chief and the Puplem being dressed in their vestments, which were the little skirt of feathers and the crown on the head, and with the rest of the body painted with a dye of hematite and black, and the rest of them being in their natural dress, which was in their bare skins, but well sooted up so that they resembled devils more than men, all went one behind another, commencing with the chief and following in order, running, and as each one arrived in front of the Vanquex, before the Chinigchinix [figure] and the figure which was on the ground, he gave a jump with a half turn, like a kind of a skip, and a loud cry, raising his bow and arrow as if shooting in the air, and in this manner all of them passed by, performing the same ceremony. The most amazing thing about it was that when they gave the half turn they turned their backs to the Chinigchinix [figure], or better said their butts, surely a ridiculous thing, and the subject which they venerated merited nothing less. The women after the men had passed by also went one behind another, but slowly, and on arriving [at the place] each of them made an obeisance like a half bow with her body, showing the traybasket or tools which she was carrying. And this ceremony they performed in order that that horrible painting might preserve them from all ill, notably from stumbling over rocks, tripping over burrows, so that the limbs of trees would not fall upon them, and from other similar accidents.

Great was the veneration and respect which these Indians had for their temple, for rather than have the slightest irreverence be committed in it, no one save the chiefs and Puplem, or elders, entered within it (that is, on the feast days); the other people remained outside of the stakework, and the boys and girls did not even approach it. They did not speak inside it, except what was very necessary and that in a low voice, and also those who were outside observed silence. Inside the temple there was dancing, but only by the chief and some other one of the Puplem, and this in the dress of Chinigchinix, making in front of him a thousand odd and ridiculous maneuvers. The position which they assumed when before the Chinigchinix [figure] inside the Vanquex was sitting on the ground with their buttocks on or to one side of their heels (this position has always caused me much wonder—for the Devil, who wishes to be honored and venerated like the true God, taught them the ugliest, most indecent and ridiculous way of worshipping him which can be imagined—to be in a squatting position some Indians whose dress was to go naked), and in this fashion they remained without moving for 2, 3 or more hours until the function was concluded.

The immunity which these temples or Vanquex possessed was so great that whatever the crime, be it what it might be, homicide, adultery, theft, etc., if the delinquent had the fortune to be able to take refuge at the temple before his opponents encountered him, and those whom he had aggrieved knew that he had taken asylum, he was already free and could go where he pleased without ever being molested or the least mention being made of what had happened; they merely told him if they met him: You went to the God Chinigchinix, and had you not gone we would have slain you, but he will punish you because you are wicked. They believed that Chinigchinix was a friend of the good, and punished the wicked, as we have said above, and they also believed that Chinigchinix did not wish when once refuge had been taken with him in the Vanquex that they should take vengeance or justice with their own hands, and for this reason they let him [the delinquent] go free. It is to be noted that although the delinquent remained free, the crime did not remain exempt from punishment, for although the evil doer might not be molested in any way, either his children or grandchildren or relatives came to pay for it, which happened when the grievance was the occasion for vengeance, and this hatred or grudge with desires for revenge ran on, being handed down from parents to children until they were able to fulfill their desires.

In this same way the chief could save his life and escape from death when they accused him of squandering the seeds which he had on deposit, if he had the fortune to be able to take refuge at the temple, and when they went to look for him for the purpose of slaying him to be found there; indeed no one entered or dared to shoot an arrow, for if anyone had dared the least profanation and irreverence they would immediately have taken his life. And from that time on the chief could go about during his entire lifetime free, as a private and not public man, without anyone daring to make to him the slightest mention of what had happened; but he lost forever the diadem of chief, and immediately they elected one of his sons, to whom it fell by right, admonishing the new chief that he should behold the example of his father, that if he was not a good chief they would do the same with him.

Chapter 9

ABOUT CERTAIN OF THEIR PRINCIPAL FEASTS AND DANCES.

Since the feasts of these Indians all consisted of dances, I shall therefore treat certain ceremonies of their feasts, and especially certain dances on account of the rarities and oddities which they contain. Although they enumerate many different dances, most of them amount to being of the same kind, merely differing in the words of the song, while the song and manner of dancing is the same. And so great is the affection which they have for their dances that they will spend days, nights and whole weeks dancing, and it can be said that all their passion is given to dancing, for few days pass that they do not have a dance, without becoming tired of a thing that is continually of the same sort, the most insipid that one can imagine.

Note: That these Indians are so fond of the dance is in memory of their God Chinigchinix who as we have said above went away dancing to Heaven, and they were of the belief that those who did not dance (that is, of the dancers, who are only the chiefs, and Puplem or wizards), and those who did not attend the dances, were to be punished and hated by their God Chinigchinix.

The manner of fix-up or dress for their dances we already mentioned in treating the proclaiming of the [new] chief, it being a feather ornament made like a crown from various feathers of birds, placed on the head; and the little skirt or apron, also of feathers, made in the form of fringe which reaches half way down the thigh, which skirt they call *Páelt;* and the rest of the body painted black and red, and some of them with some white, and fixed up in this way they dance their dances. The women do not paint more than their faces, arms, and breasts, with a kind of varnish between black and red color, very shiny and sticky. It is to be noted that they never dance men and women mixed, but the men alone, and the women alone, though they all dance together, the men always apart and separate from the women, but indeed all sing in the same tempo and the same song.

Many of their dances are very decent and for a time entertaining on account of the many maneuvers which they perform in them. There are certain men and also women who are the singers, appointed for leading in the song, who have some little shells of small turtles, a couple of them stuck together, and with some little stones inside, called *Páail.* This is the instrument which they used and still employ in their dances. Since this instrument is made of some shells of small turtles with some little stones inside, they call it *Páail,* because the turtle is called thus. It was made like the following figure [drawing of two-shell turtle rattle follows this word and another with grasping hand is given in left margin]; they also used, when the páail was lacking, some reeds open down the middle, and the singers sound them and sing, and when the couplet is finished it is repeated by the men and women who are dancing. Many of their dances do not contain anything more than a mocking of certain animals.

Among all the feasts which they celebrated every year, among the principal and most solemn ones was one which they called the feast of the *Pames,* which means the feast of the bird, for they gave a kind of worship and veneration to a bird which has the same form and size as a kite, although somewhat larger. It is a kind of carnivorous hawk, but very sluggish and stupid. The day set for the great feast of the Pames, which feast consisted of many extravagancies, was spent as follows. The night before, the crier, crying throughout the town, invited all to the great feast which began the following morning. First they made outside the town or rancheria a kind of temple. To this temple, which was not used for anything more than for that function, the elders or Puplem carried the said Pames or bird in silence.

Note: The construction of this temple consisted in cleaning off a piece of ground from 1½ to 2 yards in diameter, of round shape, and around the edge they set some brush of willow, cottonwood, or other brush, and sometimes they did not set anything, but very clear of any litter.

The Pames having arrived at the said temple, immediately the unmarried girls, and the married ones, but young, who had not yet given birth to a child, began to run like crazy women, some in one direction, some in another, without order or arrangement, whose running lasted for about an hour, more or less. While they were running all the rest of the people were looking at them, and with the old men or elders daubed up with black, uglier than the very Devil, dancing around the bird. When all that we have mentioned above was concluded, they took the Pames and with all the people in procession they carried it to the principal temple, the Puplem dancing and singing in front of the bird all the way. Arriving at the Vanquex, they killed it, without drawing blood, they stripped off and dried the skin with the feathers on, which latter they kept as a relic, for from these feathers they made the little skirt or *páelt,* as they call it, for dressing the Chinigchinix [figure], and for dancing. Then they buried it [the body of the Pames] in a hole which they had made inside the *Vanquex,* the old women immediately rushing to the spot crying and well stained up with black gum, throwing to it [to the Pames] seeds, pinole and whatever food they had, saying a thousand foolish things to it, such as: *Why did you run away? Were you not better off among us? If you had not run away, you would not have turned into a bird,* and other expressions of this sort. When the whole function was over, the dance began, which lasted at least 3 days including the nights, in which they committed a thousand brutal actions.

I have not been able to learn what was the meaning of so great a ceremony, neither have I been able to determine what may have been the particular signification of the running of the single and married girls at the beginning of the feast of the Pames while all the people, men and women, watched them run, for it must contain its peculiar mystery. What I conjecture in it is that as the Pames according to their way of thinking was a girl who ran away from them, these [girls], imitating her, run as if fleeing away, and therefore they run without order, and watching them run must be for the purpose of perceiving the girls who run swiftest and with least embarrassment—that they may spend with them the days of the feast, for as they say, on these days all intercourse was free.

The Indians relate that the said Pames or bird was a girl who ran away from a rancheria and went to the mountains, and that the God Chinigchinix made her into Pames, or turned her into a bird, and this is their belief; and that every year although they kill her, she is born again, and the nonsense does not stop here, but they believe that she multiplies herself, for every year 3 or 4 or more birds were seen, for all the chiefs gave the feast of the Pames, and since it was only one girl who fled away from them, they believe that all these birds are the same girl. This feast of the Pames or bird which they celebrated every year was ordained by their God Chinigchinix.

These Indians had in their gentility a dance for the commencing of which they lighted first a great fire of chamize or of straw, and when it was well lighted the men began to jump upon it and into the middle of it until they put it out, while the women remained at some distance crying, and when this bonfire was entirely extinguished the crying of the women ceased and the dance began, and if it happened that it was not thoroughly extinguished or that some sparks appeared, they remained sad for a considerable time, for they held it to be a bad omen and feared some mishappening. These dances were always at night. If this dance was executed on the day of some great feast to which they invited the neighboring rancherias, in addition to what has been related they added [the following]: Before they began they sent someone to bring water from a designated place, and it was always somewhat distant. This water they put in its little well or hole, which they had already made inside the Vanquex, all the chiefs and Puplem in their proper order went over to blow to it and to make certain imprecations to it, which was like blessing it, although one might better say cursing it, and after all the ceremonies were concluded all the men went, beginning with the chief, in their proper order, to sprinkle their faces with that water, and when this ceremony was finished the putting out of the fire followed, and after that the dance, as we have said.

They had another kind of dance in which after the men had danced for a time they formed themselves in a file, and a woman would come out alone with her hands under her breasts as if to hold them up, dancing in front of the file of men for 3 or 4 turns (dressed according to their custom which was: the little strings in front for covering up her private parts, and a skin of a coyote, wild cat, or some other animal for covering her butt, and nothing else), and would then retire. The men resumed their dance the same as before, and the woman followed again, they continuing in this way until the dance was concluded. The woman did not sing, but only the men, without there being in this dance the customary singers, but they had the Páail instrument.

There was another dance which they called *Aputs,* which signifies naked or in one's bare skin. This dance was danced by one woman alone, and it was in this manner: just one woman stripped herself naked (although she had very little to take off), and this had to be a girl, and the other people all around in a circle, men and women, big and little, and she in the middle, her hands placed underneath her breasts as if holding them up, dancing in the middle of that circle, and all watching her dance and observing her movements and actions. She herself sang, but her song was confined to naming her private parts and those of the men, an infamous thing and a diabolical invention.

They had another dance similar as it were to the one above described which they executed when some son of a chief or of the Puplem was to dance for the first time in public, and this day was one of great festivity, and it was in this manner: When the little boy was about 2 or 3 years of age, or a little more or less, he who was to be a dancing man, danced for the first time in public, they dressed the boy with the little skirt of Chinigchinix made of the feathers of the Pames, they placed the crown of feathers on his head, the rest of his body painted black and red, and in this way he danced alone for a while, the musicians and singers playing the rattle and singing, nothing being lacking on this occasion, until he became tired, and if the child was no longer able to dance alone, one of the Puplem, dressed in the same vestments, carried him on top of his shoulders and danced with him, and with all the rest of the people watching them. When this dance was concluded, a sister or aunt or some other one of his closest female relatives, single or married as long as she was a young woman, got up, stripped herself naked before all those assembled, who were always many, without exceptions of persons, and naked thus with her hands underneath her breasts she began to dance, giving turns back and forth in front of all, offering herself to anyone that desired her. She alone sang, and her song was confined to saying, that she was well, healthy, that she was already a woman, and many brutal things. This dance was danced inside the Vanquex, but the preceding one was danced outside in another place. They had other dances and similar songs. But through the mercy of God since they have become Christians they are already abandoning them, or at least they do not execute them in public as they were accustomed to in time of their gentility.

Chapter 10

ABOUT THE CALENDAR OF THESE INDIANS.

It can not be doubted but that the calendar is one of the most curious and useful of things and even to some extent necessary to man in order to distinguish him from the brutes and enable him to divide times and ages, and know past happenings, the time which has elapsed since they occurred.

The calendar of these Indians, if it can be called a calendar, differs very little or not at all from the natural instinct of brutes. These latter know the times, with their seasons, for their food and procreation, we see many animals at the prescribed time move to another place or even to another climate because of inclemency of weather and lack of food, and when the season arrives return to the same place. These Indians had this same way of doing that the animals had or something very similar, for they had nothing more than the name of the months, which denoted the time or season for gathering the various seeds for their maintenance and the preservation of life. And this matter of the names of the months, all of them did not know, [but] only certain ones of them and these were few.

What causes wonderment, compassion, and pity is to see creatures endowed like the rest with spiritual souls, created in the image and likeness of God, so rude and so slow that all their activities appear to be mere natural instinct like the brutes, for all their activities are those of cunning for the purpose of deceit, theft, fornication, and other wicked things, but they fall short of attaining to the cunning of the cat, female fox, and female monkey, etc.

These Indians lacked in the first place a chronology and starting point whereby they could reckon the dates of past years, nor did they have this either in figures or in signs, and therefore their calendar was confined to the months of the year from tropic to tropic, or to the return of the sun, and since their months followed the course of the moon or were counted by the lunations, all their years were lunar, and since lunar years are different from solar years, all the years had vacant days, some years [having] more and others fewer, for when the moon of December was finished, they waited for the return of the sun from the tropic of Capricorn, and began another new year, without remembering what had passed by, and for this reason they did not know (and this [included] those best instructed in their antiquities) how much time had elapsed since this or that thing had happenel, etc., and therefore they did not know anything more than the present time, putting their reason to use [only] with natural instinct, as it were, like so many animals.

Names of months according to the natives.

Aaxcomil	December and January.
Peret	February.
Yamar	March.
Alasoguil	April.
Tocoboaix	May.
Siütecar	June and July.
Cucuat	August.
Lalavaix	September.
Aguitscomil	October.
Auquit	November.

In order to comprehend the method or manner in which these Indians counted the months of the year, it must be understood that their year always began the 21st of December, and thus those days which elapsed between the last conjunction and the 21st were vacant [days], and according to their way of expressing it they said: *there are no days,* and on the 21st, whatever number of days old the moon might be, they began to reckon the month of Aaxcomil, which lasted during all of the following moon, and the new year began; therefore this month alone comprised 2 moons, that of December, though only in part, yet some years in its entirety, which happened when the conjunction passed the 21st, and that of January. The same thing happened in the month of Siutecar, which corresponds to the month of June, with the only difference that if the 21st of June fell in the full of the moon, the days before the full of the moon were not vacant [days], but were added to the preceding month, Tocoboaix, and on the 21st the other month started, but if it fell before the full of the moon, the month began the day of the full of the moon, and the other ensuing month followed. All the other months began with the conjunctions of the moon; for that reason they never or scarcely ever agreed with ours.

What is described above is all that these Indians had in their calendar, which served them for gathering their seeds, as we have said, and for celebrating their feasts. They were ignorant of the number of days of which the months were composed, and much more so the years, and were only governed by the phases of the moon; this latter indicated to them the days on which they were to celebrate their feasts and also for the anniversaries of their dead, though these latter did not fall on the same day on which the person had died in any year. With this end in view the Puplem when the deceased died observed the aspect of the moon, and in what month it was, and the next year, the month having arrived and the aspect of the moon being the same as when he died, they then celebrated the anniversary. And we are to understand that the same method applied for the celebrating of their feasts.

Chapter II

SOME OF THEIR MANY EXTRAVAGANCIES.

Many were the rare, extravagant, and ridiculous practices which these Indians had, and therefore in addition to those mentioned in the proper place, I shall relate some of these which appear especially ridiculous and singular, everything being derived from the stories and fables with which they are imbued from the time they are small children, so that they are brought up full of fear, and for this reason anything whatsoever fills them with dread, and since they were so rude with such sluggish understanding, they were not able to distinguish or deduce that which is true from that which is false, but continually adhered to that which the old people told them, and for this reason are seen so many extravagant and ridiculous things among them.

They had the notion when buzzards were flying about, if the shadow of the buzzard passed close by, of immediately covering themselves, and they still cover their heads, chiefly the young women do, for they believe that if the shadow of the buzzard would touch their heads, sores would come out on them, such as scalled-head and other similar [sores].

There was another rare and singular practice among these Indians, and it was that the deer hunters or hunters of deer could not eat of the deer which they killed, for they were of the belief that if they ate of the game which they themselves killed, they would not kill any more, and the fishermen had this same idea and never ate of the fish which they themselves caught. But the most singular practice was that in the case of the youths, when they went to hunt cottontail rabbits, groundsquirrels, or deer, one of them could not go alone, and therefore at least 2 of them went [together], for he who killed the game could not eat of it, but this was not for the above mentioned reason [that the eater will not be able to kill any more game], but for another reason [that the eater will sicken], which was that if one of the unmarried men were to get a cottontail rabbit or some other animal and were to eat it by himself hiddenly, in a few days he would start feeling pains in his body and start wasting away, getting thin like a hectic person, and for this reason they always went in company, and what one killed the other one ate, swapping their game; but it is to be noted that in order that this effect be produced, the eating has to be in secret, for if it was in public on the general [expeditions] when all the people went along, though they ate of the same game that they had killed, there was no such sickness. They had for this sickness their healers, who with 2 incantations of blowings and feathers, made them well in short order. Nowadays since they are Christians nothing of what we have mentioned happens to them, nor do I believe that it would happen to them in their gentility, and that if any boy at any time was seen to be sick, it must have come from other causes, or else from mere imagination, for this was also a daily harangue which they gave them. And it was for the purpose that if they found cottontail rabbits, jackrabbits, or others in the country they should bring them to the house and should not eat them.

When they discover any eclipse of the sun or of the moon they start great shouts, cries, and bitter weeping, and this all of them, big and little, throwing dirt into the air, beating on skins, [and] tule mats with great noise. And this they do because they are of the belief that a hideous animal eats the sun or the moon, and they make such exertions in order to scare it away, and they think that if that animal would eat up all the sun or the moon, that is, if it would be a total eclipse, they would all have to die and the world would have to come to an end. I believe that at the time of the eclipse when they make such a noise, they are making their supplications to the God Chinigchinix, because I saw (at one which there was in the year 1813 and at another in 1822), of the sun, that when the eclipse was over the old men began their dance like giving him thanks for having delivered them from that animal.

They also had the custom at the time of the new moon, the first day that the new moon appeared, [that] some old men began to shout, saying: boys, start your moon running! And immediately the youths began to run like crazy men without order or arrangement, and the old men to dance as a sign of joy, saying in their song that even as the moon died and lived again, even so, though they also were to die, they were to live again (this very clearly manifests the resurrection of the flesh), but how they understood it I have not been able to determine.

The rarest thing that I have found among these Indians is that there were certain ones who claimed to be descendants of the Coyote, and these ate human flesh, but not like the Caribs, Mexicans and others, but in another manner, the dirtiest thing that can be imagined, and it was in this way: when the chief or another of the satraps died (for the function was performed for all of these), they summoned the Eno, Tacue, for thus he was called, and after the death of the person, with a flint, the said Enó cut a little piece of meat from the shoulder near the neck of the deceased, and before all the people who were present there, he ate it raw. (This was in imitation of what the

Coyote did to his Chief, Oiot, as we have related above.) And for the above mentioned function they paid him well, and all the people gave him of what they had. The people were in great fear and dread of these [Tacue], because they held them to be poisoners and wizards, and therefore they used great caution as regards them.

These Indians had also an account of the universal flood. I do not know, nor can I understand, from where such an account comes to them. And this I have learned from certain songs which I heard sung on a certain occasion, it being a little story which I shall give later. These Indians believe and say that at a remote time the sea began to fill up so that it came in over the valleys, and the water rose over the mountains, and all the people and animals died, except some who went to a very high mountain, and the water did not reach there. The account that they give extends only thus far, but the [little] story which I heard, gives it more clearly and extensively, and is as follows. It is to be noted first of all that the Indian is very rancorous and nurses hatred to the third or fourth generation, and grievance being handed down from parents to children as we have mentioned, and when they were not able to take revenge, they contented themselves with singing the following little story, which is as follows: They were of the belief that one of the descendants of Oiot, whom they poisoned, begged of Chinigchinix the avenging of Chief Oiot. Chinigchinix answered him: You are the one who makes rain, therefore you can make so much water rain down that you will drown everyone, and thus you will be revenged. And indeed it began to rain and the sea [began] to get rough and to fill up, and with the water that was raining down it came in over the valleys and canyadas, the water continued rising over the hills and mountains, and rose to such an extent that it covered all of them, all the people and animals dying with exception of a few who went with the one who was making it rain to a very high mountain, the top of which the water did not reach, and these alone saved themselves. Thus one who I believe must have been removed from Oiot further than the 6th generation took his revenge. And this is what they ask of Chinigchinix: that he drown their enemies and save themselves.

If their adversaries heard or learned that they were singing this ballad against them, they answered with another one which amounts to saying: *We now have no fear because Chinigchinix does not wish it, nor will there be another flood.* There is no doubt but that all the above account has some correlation to the universal deluge, and the promise which God made to us that there would not be another one.

Chapter 12

ABOUT THEIR BURIALS AND FUNERALS.

Before I deal with the method that they employed in their burials, it will be convenient to treat first the remedies which they used in their diseases. These Indians did not lack the use of certain crude remedies in their diseases or the knowledge of certain herbs, that is, for external diseases, for in the case of internal ones, such as fevers, no matter what kind they might be, I have not known them to use any remedy at all; just bathing with cold water was all the remedy they had, and therefore when they felt a headache at once the first remedy was to wash the head with cold water.

In external diseases, such as tumors, swellings, sores, and vagrant pains they used certain herbs such as sage, California Sagebrush, and others, putting them on pounded up, as a poultice; and if they felt a bellyache, they inhaled the smoke of the above mentioned herbs through the mouth; but the most frequent and commonest practice, especially when in pain, was to whip the place where the pain was with nettles, and to put them right on the place of the pain, and likewise ants, and these latter especially on sores, and in this manner they cured themselves.

In internal diseases such as fevers, pains in the side, burning fevers, I do not know if they may have used special remedies other than bathing; what they did was to lie down naked on top of a pile of sand or ashes, the little fire in front of them being in whatever condition it might be, and a basket or pot of water at the head of the person; they were also accustomed to set for the person a little basket of acorn mush, but the sick person, if he wanted to eat, ate, and if not, he left it, and without anyone importuning him to take food, and it is to be noted that he always had someone or other at his side day and night, and thus he remained until either nature conquered or the disease conquered.

When they felt themselves attacked with some kind of fever immediately they called their healers, who are the Puplem, of whom we have spoken above, and (into their profession not all entered, but those to whom it fell by succession). These on seeing the sick person gave a great discourse, mentioning to them many kinds of diseases, but in the case of all of these, that they came from foreign substances which they had in their bodies, such as the hairs of certain animals, sticks, little stones, thorns, etc., and that these foreign bodies were the disease, and these imposters for the purpose of effecting a cure made ready with many ceremonies, putting feathers on them, and other things, blowing in the 4 directions, saying certain words without anybody or anyone understanding them; and then sucking the place where the pain was they pretended that they were extracting the bodies such as they had mentioned—but in reality after their sucking they extracted from their [own] mouths some of these bodies, such as little stones, sticks, thorns, similar to or the same as those which they had told them previously that they had; and these bodies they showed to those standing about, and all believed it without having the slightest doubt, and the sick person [being] very well satisfied whether he got well or died. They told some that the disease had been sent to them by their God Chinigchinix as a penalty or punishment for some delinquency which had been committed.

There are many of these charlatans and deceivers everywhere, who after they have been well paid and have filled their bellies laugh at and make fun of the poor innocents, or better said, of their credulity.

After the deceit of the wizards, they having used all their diabolic art, if the sick person died they tended to giving him burial, that is, to burning him, (in these regions they burned them). After the sick person died they allowed the interval of 10 or 12 hours to pass, watching if he would come to life again, as they said. In the meantime they prepared the pyre, and having seen that he was really dead, they summoned the cremator (it is to be noted that in these regions there were certain ones assigned to this work, and it went according to family succession). Everything being ready, they carried the corpse to the pyre, leaving it there. All the people withdrew to a little distance, the cremator alone remaining. He lighted the pyre, and he could not stir from the place until the dead person was entirely consumed. And when it was over they gave him something to eat, and paid him well, and after that he retired to his lodging place.

All the things and utensils which the dead person had used, such as bow, arrows, feathers, and the rest, were all burned with him, serving as food for the pyre. They did not have special ceremonies at the time of burning him, but after he was entirely consumed, they retired to a little distance from the rancheria to cry over the death of the deceased.

Chapter 13

ABOUT THE IMMORTALITY OF THE SOUL.

In this chapter it seems that we have a somewhat difficult one, since it deals with a substance imperceptible to the bodily senses, because it is incorporeal and spiritual, nevertheless it has been possible to set forth with concise words and briefly the belief which these Indians held concerning the rational soul and how they imagined it, for the purpose of observing something about its immortality; but since there are arguments pro and con, I shall expand somewhat more than I have been accustomed to in the other chapters, in order that the reader may be acquainted with the validity of both sides [of the argument], and may be able to choose that which seems to him best, presenting first my way of feeling and my opinion, according as I have been able to understand and grasp, following their explanation.

These Indians were materialists, for they imagined the soul to be the spirit of life, which is taken in through the air that we breathe, without their knowing or believing that within ourselves there is supposed to be another substance distinct from the material body; that is, that we are no more than bones, flesh and blood, which constitute what composes the body, which they call *Petácau*. A name for distinguishing the soul from the body they do not have; they merely use the name *pusún,* which is the generic term that means thing which is inside, and this name they apply to the heart, since it is the principal place in man. Since these Indians do not penetrate further than what they perceive or can perceive with their senses, they do not attain to understand the spirituality of our soul, but merely the materiality of our body, and therefore are materialists, for they say that dead and with body burned, nothing remained and everything was already ended. Also, as we have mentioned in the preceding chapters the punishments which they feared from their God Chinigchinix, were all bodily, such as stumbling over rocks, falling down on the ground, being bitten by rattlesnakes, [and] bears, and diseases, all of them ills of the body, and lastly death, which was their final end—without ever talking or thinking of penalties, punishments or glory after they were dead. What has been said seems to me sufficient for perceiving that they were materialists. But since they tell a thousand little stories, originating indeed in dreams and deliriums, which manifest the immortality of the soul, and I promised to relate everything that I have acquired on the matter which we are treating, I shall set forth ingenuously all their accounts.

Since it has been proven therefore that they are materialists by the arguments given above, not to add others which are also convincing, the great insensibility which they manifest at the hour of death, their little affection for and little inclination toward divine things, their having all their desire set in brutal things, and other congruent arguments which I could adduce, show very clearly the little or no perception which they had of the rationality of the soul, and therefore of their immortality. Nevertheless there appears to be validity of argument, in what we have mentioned in chapter 11 in connection with their moon running, at which they mentioned in their song that *even as the moon died and lived again, so also though they were to die, they were to live again.* But as I said, I have not been able to comprehend how they understood this, if it was that as the moon shows itself the same, they were to resurrect the same, which is what the Catholic faith teaches us, or if they understood transmigration. I think that they did not believe either one way or the other, for what they say is that thus the ancients did, and that they they are doing the same as they learned from their ancestors, without giving further notice or account of what has been given above.

Let us examine their little anecdotes which deal with the immortality of the soul, which though they all of them are nothing more than mere fables, framed from dreams and deliriums both of men and women, will serve at least in their narration to amuse the reader.

Some of them narrate that all the Indians when they die go to Heaven to their God Chinigchinix (this Heaven they imagine as a terrestrial paradise), that they have much to eat there, and to wear, that they dance much and play many games, that they do not work, that no one is sad, but that all are happy and glad, and everyone does what he wants to, and they have all the women that they please. Let the reader compare this paragraph with [their belief as regards] the immortality of the soul. This account has been invented by Christians, for the old people have no such idea, and in confirmation of this I shall recount a little tale which was related to me by a woman.

At the Mission of N. [marginal annotation; San Juan Capistrano] in the year of 1817 a woman who was convalescing from a burning fever related to me the following: When she was in the most violent part of the fever she had a great paroxysm, and she told me that she had died and that certain Indian relatives of hers had taken her to the God Chinigchinix. Before entering the rancheria (which was very large and beautiful, and we are to note that the houses were not of the form and figure such as they use, but of another form, she being unable to give the design), she beheld there a great number of people, men and women (but all of them Indians), some of them playing games, others dancing, the same games and dances that they have, and others bathing in a great arroyo of very crystalline water. They arrived at the house or palace of Chinigchinix, but he did not permit them to enter, telling them that the woman could not live with them yet, that they would give her something to eat and that she should return to her country. They gave her to eat a very savory and good acorn mush such as she had never tasted, and much of it, and after she had eaten well, she returned to her rancheria, without having seen Chinigchinix. This is her account. It is at once seen to be nothing more than a mere delirium.

Note: I went to visit this woman when she was in her paroxysm and in the most violent part of her fever, and seeing that she was shaking and gnashing her teeth very much, and with her mouth very dry, I gave her with my own hand a glass of warm water with sugar, and she drank it all up. This water perhaps may have been the acorn mush that was so good, which they gave her at the house of Chinigchinix. She began to perspire and came to herself, the fever letting loose of her, from which she recovered in a short time. The other accounts that they relate are about the same as what has been related above.

Others relate, and this is handed down from antiquity, that when the Indians died, although they burned them after death, the heart did not burn, that is, the spirit or soul (for the heart of flesh of course had to be consumed like the rest of the body), and that this spirit or soul went to stay at another place, where Chinigchinix destined it, but it is to be noted that if it was a chief or satrap, they went to Heaven, and were placed among the stars, and therefore they say that especially the planets and those large stars which are very brilliant, are the souls of chiefs or Puplem. Note: The reason that they give why only these latter should go to Heaven and become stars is that Enó, who was the eater of [human] flesh, before they were cremated ate his piece [of flesh] from them, but if it happened that the Enó did not eat of their flesh, as in case by drowning or [of death] at the hands of their enemies, etc., he [the chief or satrap] did not then go to Heaven, but to another place where Chinigchinix destined him.

Others Chinigchinix stationed along the ocean shore or through the hills, ranges, valleys or mountains, and there they remained without the period of time being designated, but such time as Chinigchinix desired, but what they became later, if they returned to their bodies or went to another place, this they do not know. And if the Indians, when going from one place to another, see or imagine [they see] something extraordinary, they say that that is the soul of some dead person, and they hold it a bad omen, fearing some misfortune, for they are of the belief that if a dead person shows himself to someone, it is to do injury to him, and particularly to the women, and there are some imposters who pass themselves off as these ghosts, in order thus to attain their desires. And this has happened many times, not only when they were gentiles but even since they have become Christians.

And lastly others, and these the most pitiable and unhappy of all, remained near their homes and those of their relatives, filling them with dread and doing them certain injuries, and these are the ones for whom their relatives did not lay on the pyre many feathers and other things of the kind that they were accustomed to lay. And as confirmation of this last point I shall relate a case which I myself witnessed in part, and it was as follows: In the year of 1813, at the Mission of N. [marginal annotation: San Luís Rey], there died a Christian Indian, and the Indians said that another Indian, also a Christian of the same Mission, had poisoned or bewitched him, whose death all believed came from witchery. That dead man used to make every year his little garden patch of corn, pumpkins, and watermelons. This same garden patch he left to one of his relatives; and at the time when the plants were in blossom, the said garden patch all got spoiled and dried up without being able to harvest even a single fruit or grain, while it is to be noted that when the plants were tender they were very luxuriant like the neighboring ones and [those of] all the vicinity, but upon blooming the plants died, and the Indians said (this they learned from an old woman who had also told me about it), that the dead man was walking all about through the plot and that he was killing all of it little by little, which was whatever he touched. With this news I went to see the prodigy and saw certain dead plants, but many of them very luxuriant and fresh. The next day I returned to assure myself of the truth, and I found 7 plants, some of them corn, some pumpkin, some watermelon, dry and burnt to the roots, and it is to be noted that I had myself pointed these out as being the most luxuriant ones. And in this manner all of them dried up without harvesting a grain. There is no doubt but that this is a little fable, but thus it happened.

The dead man had died of dysentery which had come from syphilis, and therefore through the path of tuberculosis, without suffering any bewitching or poisoning such as they said. That the dead man should be walking through the plot killing the plants we see to be the story of an old woman, because nobody saw him except the old woman. What causes me confusion and difficulty is how such a catastrophe may have originated, for it was not through lack of care, nor through an epidemic of certain animals such as worms, gophers, etc., for in addition to the fact that such were not seen, if the plant had been cut, it would have been withered, and not dry as if burned. The above, I believe, will cause the reader astonishment. I exercised all possible diligence, believing that I could discover the cause, but I could not discover it through natural means. Therefore I believe that it was performed by the Devil, lest many escape from his hands. Concerning the above let everyone deduce what seems to him best.

With what we have related it is easily recognized that their reports on the immortality of the soul are nothing more than fabulous stories and lies for deceiving the simple, causing them to believe that which does not exist, and how slight must be their belief in the spiritual substance with which we are adorned, and this not only on the part of the rudest and most ignorant ones of them, but on the part of those most versed and best instructed in our holy religion. And lest anyone doubt what has been said above and attribute it to my odd ideas, I shall relate 2 cases which happened in my time and at the very places where I was residing.

In the year of 1808, if I am not mistaken, finding myself a missionary at the Mission of N. [marginal annotation: La Purísima], a youth about 23 years of age, raised with the priests from the time he was a child, very well instructed in matters of religion, and a good speaker of Spanish (for he served as interpreter for the priests), finding himself in a grave sickness, did not wish to subject to taking any medicament or to receiving any of the advice which the priest gave him, but the first thing that he did was to call one of their healers, who executed with him all his diabolical art. Seeing that he was becoming continually worse the priests exhorted him daily that he should confess and should prepare himself for dying as a Christian, but the sick man intractably was never willing to do so, arguing exemption from examination [on the grounds] that he was still strong, and finally, that he did not expect to die since he had hope in his healer. The latter, seeing that his lies were bringing no benefit, gave him up telling him that because he had always believed the priests, his God, or better said the Devil, was angry and for that reason was sending death upon him, and that he was not able to cure him. When the poor fellow saw that there was no remedy, he yielded to confess himself, but he did not confess with that satisfaction which the priest desired, and he died shortly afterward.

In the year of 1817 an Indian at the Mission of N. [marginal annotation: San Juan Capistrano], like the preceding a speaker of Spanish and well instructed, fell ill with a serious sickness, of which he died, and though the priests, relatives and friends exhorted him much indeed to confess and receive as a Christian the holy sacraments, he could not be reduced, becoming when this matter was mentioned to him like one frantic and desperate, bursting forth in blasphemies and expressions of despair. A little before he died I went for the purpose that he should confess and beg God's pardon, exhorting him toward His great mercy, in order that he might receive the sacrament of extreme unction, but all was in vain, for he manifested such extreme grief and displeasure, foaming at the mouth, his eyes glittering, that he seemed to be truly condemned to hell, 3 men not being sufficient to hold him in check. I indeed attributed all these extreme actions to the violence of the disease, but when I had remained silent for a time, he became calm, and someone asked him, saying: Why do you not confess? And he answered in a tone of fury: Because I do not want to; having lived deceived, I do not want to die deceived. And in a short time he expired, his body remaining so ugly and horrible that it caused fright. Let the reader imagine my feelings on beholding in my presence that sight in which I observed to the very letter that which David tells us [marginal annotation: Psalm III, last verse]: *Peccator videbit et irascetur dentibus suis fremet et tabecet* [sic], *desiderium peccatorum peribit.*

I reflect that some will probably tell me that in spite of the occurrence of the cases given above, they do not prove little faith and belief on the part of all [the Indians], since everywhere rare and prodigious cases occur which God permits through his inscrutable secrets, and as a warning to others. This I admit and confess, but this I state: that those [believing Indians] who form the exception are very few and cases worthy of note, while in the general run all of them seem to me to be the same, and I believe that anyone who has observed them will agree with me; and the fact is that those [Indians] who appear to us to be more intelligent are the very ones who leave us more deceived, for since they conduct all their activities with malice [against us] while we with simplicity show them trust in every matter, they deceive us at every step. And this needs no proof, because we have all come into contact with it through experience, and I believe that there is not a priest in this Province who will not flatly confess the fact.

Chapter 14

THE ORIGIN OF THE INHABITANTS OF THIS MISSION.

Since all the knowledge of these Indians about their antiquities is entirely fabulous, the present chapter, which deals with the first populators of this Mission and its environs, will not contain less that is fabulous and ridiculous than the preceding ones. I write it merely in order that we may know from what region they came and by what persons they were chieftained, and also because it is a very strange and curious account.

The place from which those who populated this Mission and its environs came was a land or place called *Seját*, at which place or rancheria the inhabitants were called *Pubuiem*, which signifies: people of the land or place *Sejat* (this place Sejat is distant from this Mission about 7 or or 8 leagues, and it is in the valley which they call Los Nietos Ranch). This city or rancheria of Sejat had many inhabitants. The chief, named Oyáison, which means wise, and his wife, named Sirorum, had 3 daughters, named Coronne, Uuinagram, and Uiuiojam. Chief Oyaison after the death of his wife, seeing the multitude of people at his rancheria and that the seeds which that country produced were not sufficient for supporting that multitude, separated from the rest many families of his rancheria, all those [families] which wished to follow him, and with his oldest daughter, Coronne, they took trail in a southerly direction in search of good sites for settling.

They came to a place about a quarter of a league before reaching this Mission (I have not been able to determine, because the Indians do not know, how many days or journeys they spent from the land of Sejat to this place), where there is a spring of water. There they halted and made a camp, since it appeared to them to be a place suitable for living. When all of them had already settled at this place, having built their houses and established their town, Chief Oyaison returned to his country of Sejat, leaving with these new settlers as chieftainess his daughter Coronne. The said Coronne was an unmarried girl, but already grown up, and to this place they gave the name of *Putuidem*, which means navel sticking out, because the said Coronne had a lump at her navel. Note:—The Indians do not know if she had this lump which she had at her navel from the time she was born or if it came out on her while they were staying at this place. It is very likely that the said lump appeared while at this place, for if she had had it since her birth, they would have named her Putuidem and not Coronne. Be the matter as it may, from that time on she was always called Putuidem, and this same place or rancheria they named and now call Putuidem.

Seeing that the land was scant for so many people as were multiplying and that they were having to go quite a distance from their rancheria to hunt their seeds, some families began to remain at the same places where they gathered, some of them building their houses at one place, others at another, and thus were settled all the rancherias which there were in this canyada of San Juan Capistrano. But it is to be noted that all these families separated with the approval of Chieftainess Putuidem.

At all the new settlements the oldest man of the family became chief, and they called him *Nu,* and his second [they called] *Eyacque,* and as regards their wives, the wife of *Nu* they called Coronne, and the wife of the Eyacqüe [they called] Tepi. The name Coronne was in memory of Putuidem. And as regards Tepi, I do not know what ground they may have had for giving her the name Tepi. The names Coronne and Tepi signify those little animals which fly about, called ladybugs, which live in the garden plots and fields. The red ladybugs they call Coronne, and those yellow ones, gilt colored as it were, they call Tepi, and these are the lineages of most noble blood, and they are all of this great descent and race.

The said Putuidem gave a great feast, inviting all the new settlers, it being that they were her people, the feast began with great rejoicing and contentment of all of them dancing, eating and making merry, but since there is no complete pleasure in this world, or true joy, it befell that as the said Putuidem lay down on the ground, as was her custom, on her back, the lump at her navel swelled up and she turned into earth (and at the said place where the rancheria called Putuidem was, amid some willows, there is a pile of earth, and the Indians say that this pile of earth is the body of Putúidem). With this event the feast came to an end, and the new settlers as well as some of the inhabitants of the rancheria of Putuidem itself left for their new settlements, and that night they put up at a place which is about a hundred paces before reaching the Mission, and they called the said [place] *Acagchemem,* the name of which the new settlers of this canyada, or the entire tribe, took as their name. This name Acagchemem signifies heaped up pile of something that moves, such as an ant nest, nest of worms, or of other animals together in a heap. Others apply the name Acágchemem also to inanimate things, but it seems that the proper meaning applies to animate things.

The reason or cause which these Indians may have had for calling themselves, and their entire tribe, *Acagchemem,* I have not been able to determine, for it seems that they ought rather to be called *Pubuiem,* since they came from the land *Sejat,* whose people were called *Pubuiem,* and they also were called thus until they came to settle these lands [here]. The reason that these Indians had for taking the name *Acagchemem* and abandoning that of *Pubuiem* I conjecture may have been, inasmuch as *Acagchemem* signifies heaped up pile of something alive, because they may have slept that night which they spent at the place mentioned above all heaped together, men, women, boys and girls, and the next day when they got up they may have said Acagchemem, as if to say: we have all been together in a heap, and from this their name may have followed: those who were heaped together; this is my way of thinking.

It may also have happened that they found at that place some kind of a pile of animals and called them Acagchemem; but if that had been the case, the place only would have been called Acagchemem, and not the people or tribe. I incline to what I have suggested above, and it seems very probable, because it is the custom of the Indians that when they get together they pile up some on top of the rest.

It is to be noted that before they came to settle this canyada of San Juan Capistrano, they spoke somewhat differently from the language which they now speak. What was spoken at *Sejat* appears to have been the Gabrielino language, and these [people here] have it very much corrupted, but nevertheless it can be recognized as having been the same, for among their common and general terms they use some of the same ones, except for the accent and a few letters more or less. The reason that they speak the language which they use today is that Chief Oyaison when they came to these lands taught them while on the way the language which they at present speak, telling them that since they were changing country they had to change language, and this is the reason why they are different from their relatives of Sejat.

The name Sejat signifies place of wild bees, or jicotes as the California Spanish people call them, for Sejá in the language of the natives is jicote, and seja pepau is the honey of the jicotes, and in these regions there are many of these swarms or hives underground.

Chapter 15

ABOUT THE RANCHERIAS INHABITED BY THESE INDIANS.

Since the preceding chapter deals with the first settlers of this canyada of San Juan Capistrano and its environs, it will be fitting to give the towns or rancherias that were founded by the above mentioned new comers from the territory of Sejat and their descendants, giving in detail the names of the rancherias with their meanings and the name of the first chief of each of them.

1. The first rancheria or town which was founded in this canyada was the one called Putuidem, as we gave in the preceding chapter together with what the name Putuidem signifies. This was founded by Chief Oyaison and his daughter Coronne, or Putuidem. After what happened to the said Putuidem there entered into rule as chief one named Choqual, which means *lift it up!* He was a very near relative of Chief Oyaison.

2. The second was called *Atoum-pumcaxque* [or i for c] (which is the place where the Mission is located). This name signifies a kind of little animals which according to what they have told me are similar to yellowjackets, but small, like big ants, which came out from underneath the ground. I have not seen these animals, nor are they seen at present anywhere around, for they say that from the time the Mission was established at this place they disappeared and they have not been seen any more. The reason that these insects came to an end I attribute to this canyada having been a thick growth of willows, cottonwoods, sycamores, fuchsias, beds of reeds, all of it being a marsh of water, and when after the establishment of the Mission the ground was begun to be cleared off for cultivation, these animals may have found themselves deprived of a breeding place and with the cultivation of the ground they may have come to an end. The chief of this rancheria was the same Choqual, [also chief] of the preceding one.

3. The third was called Ulbe, which signifies California Sagebrush. This is a kind of chamizo similar to rosemary and it has almost the same virtues. The Indians do not fail to use it in certain of their diseases. The chief of this rancheria was called *Temiachocot*, which signifies place or locality where much willow grows.

4. The fourth was called Tébone, which signifies an herb which grows in the seashore lagoon at the mouth of the creek estuary at

the beach at the port of this Mission, and the Indians used it among their foods. Its chief was named Tobaláuc, which means very much wrinkled old man.

5. The fifth was called Eñe. This name signifies a plant which grows in these environs and along the ocean shore, which plant produces on the surface of its leaves a salt which the Indians used with some of their foods, especially with chia. This salt seems to me a very good purgative, since it is milder than sea salt and other purgative salts. The chief of this rancheria was named *Sidoc*, which means a jet of water which issues from a place that is dammed up; and at the said place in a gulch there is a lake of water and at one side there runs out a little jet of water.

6. The sixth was named *Panga*, which signifies canyada. This is the place which since the time of the arrival of the discoverers has been called San Mateo. Its chief was named Seqüilqüix, which means plant which dries up.

7. The seventh was called *Souche*, which signifies little canyada or gulch. This was located near the preceding. Its chief was named Toroc, which means to limp or to sprain one's foot.

8. The eighth was called *Tobe*, which signifies a kind of clay or fine argil, white, similar to white lead, with which the women painted themselves. Its chief was named *Quapchocops*, which means care taker, or watchful.

9. The ninth was called Túmume, which means a flat place, better said, a bench on a hill. Its chief was named *Temex*, which means stumbler.

10. The tenth was called *Tepipche*, which signifies a kind of bush or chamizo (I am not acquainted with it, nor do I know its proper name), which the natives call Tapipche [sic]. Its chief was named Páat, which means mountain sheep.

11. The eleventh was called *Ecjelme*, which signifies a kind of seed, of the plant which is called Wild Amaranth, and it is one of their particular foods. Its chief was named Taclet, which means hump-backed or crook-backed.

12. The twelfth was called *Tajé*, which signifies flint arrowhead. Its chief was named Gualua, which means drag it.

13. The thirteenth was called *Uút*, which signifies the little stick [foreshaft] which they put on their arrows. It is to be noted that it is a special kind of bush. Its chief was named Uchat, which means all unanimous.

14. The fourteenth was called *Alume,* which signifies to raise the head in looking upward. This alludes to this rancheria having been located at the foot of a very high mountain which today is called El Trabuco. Its chief was named *Cusuol,* which means severed, or cut.

15. The fifteenth was called *Uxme,* which signifies rose, and in this country there are many of these roses. They are small, having 5 or 6 petals, very odoriferous, and bear a fruit shaped like a pear, but tiny or small, which also served the Indians as food. Its chief was named Chululeck, which means hair tied up on top of the head, or insignium of a chief.

These are the 15 rancherias or towns which were founded by the first settlers of this Canyada of San Juan Capistrano and its environs. It is to be reflected that they must have been settled not all at a single time, but little by little, some later than others, according as was found more convenient and to the purpose. It also should be noted that since these Indians never lived fixed in a single place, but moved from time to time from one place to another depending on the seeds, there were always some unoccupied rancherias.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 5

Arthur Fund

COLONIAL FORMATION OF UNICELLULAR GREEN ALGAE UNDER VARIOUS LIGHT CONDITIONS

(WITH THREE PLATES)

BY
FLORENCE E. MEIER
Division of Radiation and Organisms, Smithsonian Institution

(PUBLICATION 3256)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 8, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

Arthur Fund

COLONIAL FORMATION OF UNICELLULAR GREEN ALGAE UNDER VARIOUS LIGHT CONDITIONS [1]

By FLORENCE E. MEIER

Division of Radiation and Organisms, Smithsonian Institution

(WITH THREE PLATES)

INTRODUCTION

Light of certain ranges of wave lengths and intensity is generally considered essential for the formation of chlorophyll in green plants. A number of green algae, mosses, and pine seedlings prove to be exceptions to this generalization. For example, *Scenedesmus obtusiusculus* Chodat and *Scenedesmus chlorelloides* Chodat develop and maintain their green chlorophyll better in darkness than in light. Different green algae, however, vary in their reactions to light conditions just as different higher plants vary in their reactions to temperature and other environmental conditions. *Chlorella rubescens* Chodat forms chlorophyll in the dark but not so vigorously as in the light, while the cells of *Scenedesmus quadricauda* are dark green in diffuse light and pale green in direct light.

The ability of these plants to form chlorophyll without the aid of natural or artificial light is generally attributed to the presence of assimilable carbohydrates in the nutrient solution in which they are growing. Chodat (1913) has shown in the case of *Stichococcus bacillaris* that when a carbohydrate is assimilated with difficulty or not assimilated at all by an alga in the dark as demonstrated by its decoloration or complete lack of growth, the growth and development of chlorophyll by the same alga in the light is not prevented in the slightest degree. Chodat carried on a long series of experiments to determine the type of sugar best assimilated by certain algae growing in darkness. For that reason, further discussion of the necessary nutriments will not be treated here.

[1] This paper reports investigations made under a grant from the National Research Council to the author as National Research Fellow in the Biological Sciences from July 1931 to 1933.

The experiment described below is one carried out preliminary to an elaborate piece of research under definitely controlled conditions on the effect of light intensity and wave length on algae. A number of different algae from my collection in pure culture were studied to determine their general reaction to natural and artificial light and to total absence of light.

I wish to express my appreciation to Dr. Earl S. Johnston, Assistant Director of the Division of Radiation and Organisms, Smithsonian Institution, for his aid and suggestions. I am also very grateful to Dr. W. T. Swingle, of the United States Department of Agriculture, for his cooperation in obtaining the excellent color plates of the algal cultures made by Marcel L. F. Foubert, of the Photographic Division of the Department of Agriculture.

DISCUSSION OF LITERATURE

Numerous workers have studied the effect of varying day lengths on higher plants. The recent work by Arthur (1930), Garner and Allard (1925), and Shirley (1929) covers the field very well, and their long lists of literature references are an indication of the work done on this subject from the time of Hervé Mangon (1861), who found that grain planted in darkness turned yellow while that in electric light was green and thriving, up to the present when the beneficial amount of artificial light that should supplement winter daylight has been ascertained for various plants. References to the effect of light and darkness on lower plants are not as abundant.

Klebs (1896) studied the effect of light and darkness on gamete formation in *Chlamydomonas media* Klebs and demonstrated that only vegetative division takes place in darkness. A 2 percent sugar solution aided growth but did not entirely replace the light.

Etard and Bouilhac (1898) recorded the presence of chlorophyll in a *Nostoc* cultivated in the dark in a nutrient solution to which glucose had been added. They extracted the chlorophyll with alcohol and found the resulting yellow-green solution showed a red fluorescence and had the following absorption bands: 6900 to 6500 A, 6310 to 6060 A, 5890 to 5680 A, and 5480 to 5360 A.

Artari (1899, 1900, 1902) studied *Pleurococcus* and *Scenedesmus* in media containing peptone, glucose, maltose, beet sugar, or mannite and found growth in conjunction with chlorophyll formation taking place not only in the light without carbon dioxide but also in absolute darkness. He also reported chlorophyll formation in the dark for

Stichococcus bacillaris, Chlorococcum infusionum, Chlorella vulgaris, Raphidium polymorphum, and the gonidia of certain lichens. He showed that the formation and quantity of chlorophyll was dependent on nitrogenous conditions and carbon sources in the solution. However, different algae vary in this respect.

Radais (1900) grew *Chlorella vulgaris* on steamed potato slices and malt extract in light and darkness between 12° and 38° C. (25° C. optimum). The multiplication of the alga was similar in light and in darkness, and when both sets of cultures were dissolved in alcohol and examined spectroscopically, their absorption spectrum at 1/500 concentration was found to be 6910 to 6450 A, 6280 to 6040 A, and 5920 to 5670 A. A carbon bisulphide solution of the chlorophyll gave the same absorption spectrum but with a shift toward the red and very slight differences in the borders of the bands. Both dark and light cultures gave identical absorption bands. By dilution, the two bands of shorter wave lengths disappeared, but the band 6910 to 6450 A was still visible at a concentration of 1/100000.

Matruchot and Molliard (1902) reported green cells in *Stichococcus bacillaris major* Naegeli growing in darkness.

Grintzesco (1903), experimenting with *Chlorella vulgaris* Beyerinck, found that too much light—that is, direct sunlight—is unfavorable and injures the cell membrane. The algae developed well in electric light, but no intensity data are given. The cultures growing in darkness on agar with an addition of 2 percent glucose were a beautiful green and presented a better growth than those in flasks placed in light. His cultures of *Scenedesmus acutus* Meyen were 3 to 4 times smaller in darkness than in light, but they were green.

Muenscher (1923) grew a *Chlorella* in diffuse light and in total absence of light for 105 and 235 days in a nutrient solution to which nitrogen was supplied either as calcium nitrate or ammonium sulphate. He states that *Chlorella* can synthesize proteins in total darkness when nitrogen is supplied in inorganic combination.

Colla (1930) found that the chloroplasts of *Chlorella* were discolored when grown on flint stone in a petri dish of Detmer solution for 35 days. He does not mention the presence of glucose in his solution. He then irradiated the alga for 2 hours daily, and the chloroplastids became intensely green the third day. He repeated the experiment with *Elodea canadensis* which had become etiolated after growing for 1 month in darkness on dampened cotton. After 2 days of irradiation of 7 hours daily the chlorophyll reappeared in the cells of the plant. He found very little variation in the chlorophyll absorption bands of the normal and the irradiated plants.

Meier (1929) proved that light is not necessary for the formation of chlorophyll and carotin in the cells of *Chlorella rubescens* Chodat, *Scenedesmus obtusiusculus* Chodat, and *Scenedesmus chlorelloides* Chodat when an abundant quantity of nitrate and glucose are present in the medium upon which they are growing.

METHOD

The medium on which the algae were grown for these experiments was Detmer solution made up in the following proportions:

	Grams
Calcium nitrate	1.
Potassium chloride	0.25
Magnesium sulphate	0.25
Potassium acid phosphate	0.25
Distilled water	1000.
Ferric chloride	0.002

The solution was diluted to $\frac{1}{3}$ for this experiment, then 2 percent dextrose and 2 percent difco-bacto agar were added.

Nine series of 18 different algae were inoculated in 125-cc Erlenmeyer flasks each containing 75 cc of the above medium. Three inoculations were made on the surface of the solid medium in each flask by means of a platinum needle. The necessary precautions were taken for strict sterilization. All the algae used were from pure cultures, the majority of which had been isolated by the author.

The following set of nine treatments was given to each alga:

1. Control in intermittent light (daylight) during 2 months.
2. Intermittent light for 1 month, then placed in continuous light (electric light) for 1 month.
3. Intermittent light for 1 month, then placed in continuous darkness for 1 month.
4. Continuous darkness during 2 months.
5. Continuous darkness for 1 month, then placed in intermittent light for 1 month.
6. Continuous darkness for 1 month, then placed in continuous light for 1 month.
7. Continuous light during 2 months.
8. Continuous light for 1 month, then placed in intermittent light for 1 month.
9. Continuous light for 1 month, then placed in continuous darkness for 1 month.

The schematic outline of the treatments is as follows:

	Intermittent light	Continuous darkness	Continuous light
Day 1 (Inoculation)			
Day 2	1 2 3	5 4 6	7 8 9
Day 30	1 5 8	3 4 9	7 2 6
Day 60 (End of experiment)			

The continuous light was supplied by four 300-watt Mazda daylight lamps so placed that there was a distance of 92 centimeters from the filament to the top of the table on which were the flasks containing the algae. The intensity as measured by the thermocouple was 60 microwatts per square millimeter per second, which is about the same as 1/10 of noon sunlight in the summer.

The continuous darkness was provided by placing the flasks of algae in a tightly closed closet in a concrete pier in a basement room that as a rule is kept dark continually, and if lighted is illuminated by a red lamp.

The intermittent light and darkness were natural day and night conditions in March and April in a north window of the flag tower of the Smithsonian Institution.

RESULTS

All the results have been tabulated on pages 9-12 for convenient reference.

CHLOROPHYLL FORMATION

Eleven varieties were equally green in all nine treatments at the end of 30 days. However, in the following cultures a variation in chlorophyll content was indicated by a difference in color: *Oocystis naegelii* and *Chlorella vulgaris* var., in all nine treatments; *Scenedesmus quadricauda*, very evident change in the cultures in continuous darkness, slight differences in color in the cultures in intermittent and continuous light; *Chlorococcum viscosum* in intermittent light and in continuous darkness; *Cystococcus irregularis* in continuous light; *Coccomyxa viridis* in continuous light and in intermittent light; and *Palmellococcus protothecoides* in all cultures except treatment 5.

After 60 days seven algae showed abundant chlorophyll in all nine treatments. This included the following varieties: *Scenedesmus chlorelloides* var., *Heterococcus viridis, Chlorella viscosa, Chlamydomonas intermedia, Oocystis naegelii, Cystococcus cohaerens* var., and *Chlorococcum viscosum*.

Six varieties had very little or no chlorophyll in any of the cultures at the end of 60 days. Among these were *Chlorella vulgaris, Chlorella vulgaris* var., *Palmellococcus variegatus, Scenedesmus flavescens, Palmellococcus protothecoides*, and *Coccomyxa viridis*. But after the 30-day period, the following were still green: *Palmellococcus variegatus* and *Scenedesmus flavescens* in the cultures that had been kept in intermittent light and in continuous darkness, *Palmellococcus proto-*

thecoides in the culture kept in continuous darkness, and *Chlorella vulgaris* in the culture kept in intermittent light.

Two varieties, *Scenedesmus quadricauda* and *Coccomyxa viridis,* were all slightly off-color, being a more or less pale or mottled green. *Cystococcus irregularis* cultures in treatments 2, 6, and 7 were also off-color.

Cystococcus irregularis had green colonies in treatments 1, 5, 8, 3, 4, and 9.

Coccomyxa simplex retained chlorophyll in treatments 1, 5, 8, 3, and 2. At the end of 30 days all the cultures had been equally green.

Haematococcus pluvialis was green only in treatments 1, 5, and 8. At the end of the 30-day period it had also been green in 4, 5, and 6.

Scenedesmus quadricauda formed a green culture in intermittent light.

Stichococcus bacillaris was greenest in 3, 4, and 9 at the end of 60 days; at the end of 30 days the cultures in 4, 5, and 6 were a little greener than those in the other six treatments.

DECOLORATION AT THE END OF 60 DAYS

Decoloration was evident in all the cultures of *Chlorella vulgaris* var.; in *Chlorella vulgaris* in 3, 4, and 9 and in 2, 6, and 7; in *Coccomyxa simplex* in 4, 9, 6; in *Palmellococcus protothecoides;* and in *Cystococcus cohaerens* in 1, 8, 4, 9, 2, 6, and 7. Decoloration (rose color) was beginning to appear in *Palmellococcus variegatus* under conditions 8, 3, 9, 2, 6, and 7; and in *Coccomyxa simplex* in 7.

CAROTIN FORMATION

Five of the 18 algae formed carotin. *Chlorella vulgaris* and *Scenedesmus flavescens* had orange-colored colonies in all the treatments. The greatest amount of carotin was formed for *Chlorella vulgaris* in intermittent light and for *Scenedesmus flavescens* in intermittent light and in continuous light. Beads of carotin were also formed for *Chlorella vulgaris* var. in 1, 8, 3, 4, 2, 6, and 7: for *Palmellococcus variegatus* in 1, 5, 3, 4, and 2; and for *Palmellococcus protothecoides* in 4.

HAEMATOCHROME

Haematochrome was formed in *Haematococcus pluvialis* in 2, 6, 7, 4, and 9. The greatest amount was in treatment 2, the culture kept in intermittent light the first month and in continuous light the second month.

GROWTH AND GENERAL DEVELOPMENT

In the majority of the varieties studied, the growth and development of the colony attained its maximum at the end of 30 days, and with the exception of the algae listed below, the colonies showed no increase in size after the first month. These exceptions are *Chlorella vulgaris* in 5, 1, 2, 7, 8 and 9; *Palmellococcus variegatus* in 5, 2, 3, 7, 8, and 9; *Chlorella vulgaris* var. in all nine treatments; *Chlorococcum viscosum* in all nine treatments; *Scenedesmus quadricauda* in 7, 8, 9; *Oocystis naegelii* in 4 and 6; *Heterococcus viridis* in 2 and 5; *Scenedesmus chlorelloides* var. in 2.

In general, the colonies made the same amount of growth and were approximately the same size in all nine treatments. There were striking exceptions, however, in the following cases as indicated in the table and plates 2 and 3. *Palmellococcus variegatus* in 2 and 5; *Scenedesmus chlorelloides* var. in 2; *Chlamydomonas intermedia* in 4; *Heterococcus viridis* in 5 and 2; *Cystococcus cohaerens* var. in 2 and 3; *Chlorococcum viscosum* in 1, 2, 3, and 9; *Chlorella vulgaris* var. in 2, 4, 5, and 6; and *Chlorella vulgaris* in 1 and 5.

Those cultures that showed remarkably poor growth were *Chlorococcum viscosum* in 6; and *Chlorella vulgaris* in 4, 6, and 3.

There were striking morphological differences in some colonies of the same alga subjected to different conditions. The disks of *Chlorella vulgaris* in 1, 5, 8 were firm and sectored; in 3, 4, 9 they had a moist appearance; and in 2, 6, 7 they appeared to be very dry. *Coccomyxa viridis* had very firm colonies in 1, 5, 8 and in 2, 6, 7, but those in 3, 4, 9 were very fluid. *Cystococcus irregularis* in 1, 3, 2 and 6 were characteristically wrinkled, while those in 7, 8 and 9 were smooth little peaks. For *Scenedesmus quadricauda* in 1, 4, 6 all the three colonies were run together in brilliant liquid masses, in 2 and 7 the colonies were finely nerved; while in 8 and 9 they were mottled and distinct. *Chlorococcum viscosum* in 2, 6 and 7 had dull disks while the other six treatments caused glistening and brilliant colonies. The colonies of *Stichococcus bacillaris* were firm, and rough with tiny excrescences, shining brightly with the exception of those in 3, 4, 9 and 2 which were dull. The cultures of *Oocystis naegelii* were smooth, brilliant, and fluid with the exception of 6 and 7, which were wrinkled, dry, and dull, and 2, which had smooth, dry, and dull colonies. The colonies of *Chlamydomonas intermedia* were brilliant in three treatments but in 2, 6, 7 were dull, while 3, 4, 9 caused a curdled appearance. *Heterococcus viridis* had dry, dull disks in 1, 8, 2, 6, and 7 but brilliant, moist ones in 5, 3, 4, and 9. *Chlorella viscosa* in 2, 6, 7 had wrinkled disks but brilliant, smooth ones in the other six treatments. *Scenedesmus chlorelloides* var. had moist colonies in 1, 5, 8, and dull, dry ones in the other six treatments.

SUMMARY

Of 18 varieties of unicellular green algae, 11 developed chlorophyll while growing for 30 days in continuous light, in natural conditions of intermittent light and dark, and in continuous darkness. The other 7 varieties showed individual reactions to the different treatments; 3 showed poor development in all of the conditions; 2 algae had the best chlorophyll formation in continuous darkness and in intermittent light; 1 grew best in continuous light; and 1 variety developed best in continuous darkness. Seven of the 11 algae still maintained their chlorophyll at the end of 60 days, although the growth and development of each colony had attained its maximum at the end of 30 days. Decoloration was manifested in all the cultures of 1 alga and in some treatments of 6 other algae.

Five of the 18 algae formed carotin, 2 of the 5 in all the treatments, the greatest amount being formed in intermittent light.

Haematochrome was formed in 1 variety to the largest extent in continuous light and least in those cultures exposed to intermittent light during the last 30 days of their development.

The colonies differed greatly in morphological appearance.

TABLE 1.—*Appearance of the Colonies after Two Months*

Symbols: I, intermittent light (daylight) and darkness (night); CD, continuous darkness (dark cupboard); CL, continuous artificial illumination. The arabic numbers in parentheses indicate the relative size of the colonies, l being the largest. b, brilliant; c, curdled appearance; d, dry; du, dull; f, firm; fl, fluid; m, moist; n, finely nerved; p, peaked; s, smooth; se, sectored; w, wrinkled.

Treatment number First month Second month	1 I I	5 CD I	8 CL I	3 I CD	4 CD CD	9 CL CD	2 I CL	6 CD CL	7 CL CL
ALGA *Chlorella vulgaris* var.									
Waxlike with characteristic beading 3 mm high (12 to 20 mm diam.)	. . . . .	Green border with green and white beads on murky green center (3)	White with green beaded border and orange beaded center (3)	Green border and small white center with orange beads (4)	Dirty white with orange beads (1)	Green rim and flesh-colored border and white center (5)	White with orange beads (1)	White with orange beads (2)	White with orange and murky green beads (3)
Palmellococcus variegatus									
Firm, waxlike with slight excrescences and beads (3 to 15 mm diam.)	Brilliant green rim about a pale rose center (4)	Green with orange beads (1)	Rose center with a murky green rim (4)	Orange with a rose center (3)	Green with yellow beads (5)	Apple-green with a rose center (4)	Rose and green with some orange beads (2)	Murky green border with pale rose center (4)	Murky green border with rose center (4)
Chlorella vulgaris (pl. 2)									
Beaded peaks (5 to 20 mm diam.)	Deep orange with green border (1) f se	Red-orange with green border (2) f se	Red-orange with green border (3) f se	Orange with green border (7) m	Orange with green border (8) m	Orange with white beads and green border (7) m	Orange-pink with white beads and green border (4) d	Smoky-pink with white beads and green border (6) d	Orange-pink with white beads and green border (5) d
Scenedesmus flavescens									
Uniform, brilliant mounds, slight green border and striking green roots, 2–3 mm high	Orange	Brilliant orange	Brilliant orange	Green-yellow	Yellow-green	Yellow-orange	Brilliant orange	Brilliant orange	Brilliant orange

TABLE 1.—*Appearance of the Colonies after Two Months* (continued)

Treatment number First month Second month	1 I I	5 CD I	8 CL I	3 I CD	4 CD CD	9 CL CD	2 I CL	6 CD CL	7 CL CL
Haematococcus pluvialis									
Tiny specks in the agar	Dark green (1)	Green (2)	Dark green (2)	....	Red-brown (3)	Olive-green (2)	Deep red (2)	Red (2)	Red (3)
Palmellococcus protothecoides									
Characteristic zonation, conspicuous depressed center, and ruffled rim. Uniform in size, firm, 1 mm high (12 to 16 mm diam.)	Soft green with gray center	Dark green with pale green center	Dark green rim about green with gray center	Slight orange rim about apple-green with pale green center	Green with orange and white beads in center	Olive rim about green with gray center	Olive rim with white center	Olive rim with white center	Brown rim with green spots and white center
Coccomyxa viridis									
Brilliant, all slightly off-color, smooth, slightly raised above surface except fluid ones which cover surface of agar (10 x 15 mm to 15 x 12 mm)	Faded green f	Faded green f	Faded green f	Pale green center surrounded by yellow fluid fl	Pale green center surrounded by yellow fluid fl	Pale green center surrounded by yellow fluid fl	Gray-green center with yellow rim f	Gray-green center with yellow rim f	Gray-green center with yellow rim f
Cystococcus irregularis									
Brilliant, firm (15 to 20 mm diam.)	Green (1) w	....	Apple-green with tiny yellow border (3) p	.... (2) w	....	Apple-green with yellow border (3) p	Gray-green (off-color) (2) w	Yellow-green (off-color) (2) w	Yellow-green (off-color) (3) p
Scenedesmus quadricauda									
All slightly off-color (15 x 10, 20 x 15, 40 x 40 mm)	Green (3) fl	....	Mottled green (2)	....	Pale brown (1) fl	Mottled green (2)	Green with discolored border (2) n	Very pale green (2) fl	.... (2) n

TABLE 1.—*Appearance of the Colonies after Two Months* (continued)

Treatment number First month Second month	1 I I	5 CD I	8 CL I	3 I CD	4 CD CD	9 CL CD	2 I CL	6 CD CL	7 CL CL
Chlorococcum viscosum (pl. 3)									
Uniform, glistening, brilliant (7 x 10 mm)	Dark green center with apple-green rim (1)	Dark green center with apple-green rim (1)	Dark green center with apple-green rim (2)	Dark green center with yellow rim (1)	Green center with apple-green border and yellow-green rim (1)	Yellow-green (2)	Dark green (2) d	Dark green (2) d	Dark green (2) d
Stichococcus bacillaris									
Firm, shining, rough with tiny excrescences (2 x 3 to 15 x 5 mm)	Dark green with trace of decoloration (1)	Dark green with trace of decoloration (1)	Dark green with trace of decoloration (1)	Green (2) d	Green (2) d	Green (2) d	Gray-green (3) d	Tiny gray specks (5)	Brown-gray (4)
Cystococcus cohaerens var. (pl. 1)									
Characteristic dull vermiform masses 1.5 mm high, uniform (10 x 20 mm)	Tendency toward green-yellow	....	Green	Green-yellow	Green-yellow	....	Green	Green	....
Coccomyxa simplex									
Smooth, cone-shaped mounds .5 mm high (7 x 7 to 10 x 10 mm)	Yellow-green c	Dark green with apple-green sectors	....	Yellow-green c	Green with trace of decoloration in center	Green with trace of decoloration in center	Yellow-green c	Green with white center	Flesh-colored center with tiny green border
Oocystis naegelii									
Brilliant, smooth, liquid colonies except 2, 6, 7 which are wrinkled, dry, and dull (25 x 15 to 20 x 20 mm)	Green with light green border s fl b	Green with light green border s fl b	Green with light green border s fl b	Green with light green border s fl b	Green with light green border s fl b	Green with light green border s fl b	Dark green center and light green border with yellow-green dots s d du	Dark green 1 mm high w d du	Dark green 1 mm high w d du

TABLE 1.—*Appearance of the Colonies after Two Months* (concluded)

Treatment number First month Second month	1 I I	5 CD I	8 CL I	3 I CD	4 CD CD	9 CL CD	2 I CL	6 CD CL	7 CL CL
Chlamydomonas intermedia									
Smooth plateaus 1 mm high (3 x 3 to 20 x 4 mm)	Dark green (3) b	Dark green (3) b	Dark green (4) b	Brilliant apple-green (2) b c	Brilliant apple-green (1) b c	Brilliant apple-green (4) b c	Dark green center with green rim (4) du	Dark green center with green rim (4) du	Dark green center with green rim (4) du
Heterococcus viridis									
Finely powdered excrescences, 2 mm high (5 mm diam.)	Dark green d du	Dark green m b	Dark green d du	Green m b	Green m b	Green m b	Dark green d du	Green d du	Dark green d du
Chlorella viscosa									
Fairly uniform (10 to 15 mm diam.)	Dark green with tiny yellow rim b s	Dark green b s	Dark green b s	Dark green with green border and yellow rim b s	Dark green b s	Dark green b s	Dark green w	Dark green w	Dark green w
Scenedesmus chlorelloides, var.									
Small beaded colonies 0.5 mm high (5 x 5 to 10 x 6 mm)	Dark green m	Dark green m	Dark green m	Dark green d	Dark green d	Dark green d	Dark green d	Dark green d	Dark green d

EXPLANATION OF PLATES

Plate 1

Cystococcus cohaerens var. (× approx. 3/4) grown on Detmer 1/3-agar 2 percent-dextrose 2 percent in intermittent light for one month. The algae in plates 2 and 3 were cultured in a similar manner.

Plate 2

Chlorella vulgaris, × approx. 1/2.

Plate 3

Chlorococcum viscosum, × approx. 1/2.

(Figure numbers refer to both plates.)

Fig. 1. Intermittent light for 3 months.
2. Intermittent light for 1 month, continuous light for 2 months.
3. Intermittent light for 1 month, continuous darkness for 2 months.
4. Continuous darkness for 3 months.
5. Continuous darkness for 1 month, intermittent light for 2 months.
6. Continuous darkness for 1 month, continuous light for 2 months.
7. Continuous light for 3 months.
8. Continuous light for 1 month, intermittent light for 2 months.
9. Continuous light for 1 month, continuous darkness for 2 months.
10. Continuous darkness for 3 months.
11. Continuous light for 3 months.

Fig. 1-9. Colonies on Detmer 1/3-agar 2 percent-dextrose 2 percent.
Figs. 10-11. Colonies on Detmer 1/3-agar 2 percent.

LITERATURE CITED

Artari, Alexander
1899. Ueber die Entwicklung der grünen Algen unter Ausschluss der Bedingungen der Kohlensäure-Assimilation. Bull. Soc. Imp. Nat. Moscou, pp. 39-47.
1900. Ueber die Entwicklung der grünen Algen unter Ausschluss der Bedingungen der Kohlensäure-Assimilation. Bull. Soc. Imp. Nat. Moscou, pp. 37-47.
1902. Ueber die Bildung des Chlorophyls durch grüne Algen. Ber. Deutsch. bot. Ges., Bund 20, pp. 201-207.

Arthur, John M.
1930. Light and the green plant. Scientific Monthly, vol. 31, pp. 343-346.

Chodat, R.
1913. Monographies d'algues en culture pure. Matériaux pour la Flore Cryptogamique Suisse, vol. 4, fasc. 2, Berne.

Colla, Silvia
1930. Formazione della clorofilla nelle piante exposte alla luce de Wood. Annali di Botanica, vol. 18, pp. 329-349.

Etard, A., and Bouilhac
1898. Présence des chlorophylles dans un Nostoc cultivé à l'abri de la lumière. C. R. Acad. Sci., tome 127, pp. 119-121.

Garner, W. W., and Allard, H. A.
1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Journ. Agric. Res., vol. 18, pp. 553-606.

Grintzesco, Jean
1903. Contribution à l'étude des Protococcacées. *Chlorella vulgaris*, Beyerinck. Rev. Géné. Bot., tome 15, pp. 5-19, 67-82.

Klebs, Georg
1896. Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen, pp. 431-432, Jena.

Mangon, Hervé
1861. Production de la matière verte des feuilles sous l'influence de la lumière électrique. C. R. Acad. Sci., tome 53, pp. 243-244.

Matruchot, L., and Molliard, M.
1902. Variations de structure d'une algue verte sous l'influence du milieu nutritif. Rèv. Géné. Bot., tome 40, pp. 114-130, 254-268.

Meier, Florence E.
1929. Recherches expérimentales sur la formation de la carotine chez les Algues vertes unicellulaires et sur la production de la gelée chez un *Stichococcus* (*S. mesenteroides*). Bull. Soc. Bot. Genève, vol. 21(1), pp. 161-197.
1933. Cultivating algae for scientific research. Ann. Rep. Smithsonian Inst. for 1932, pp. 373-383.

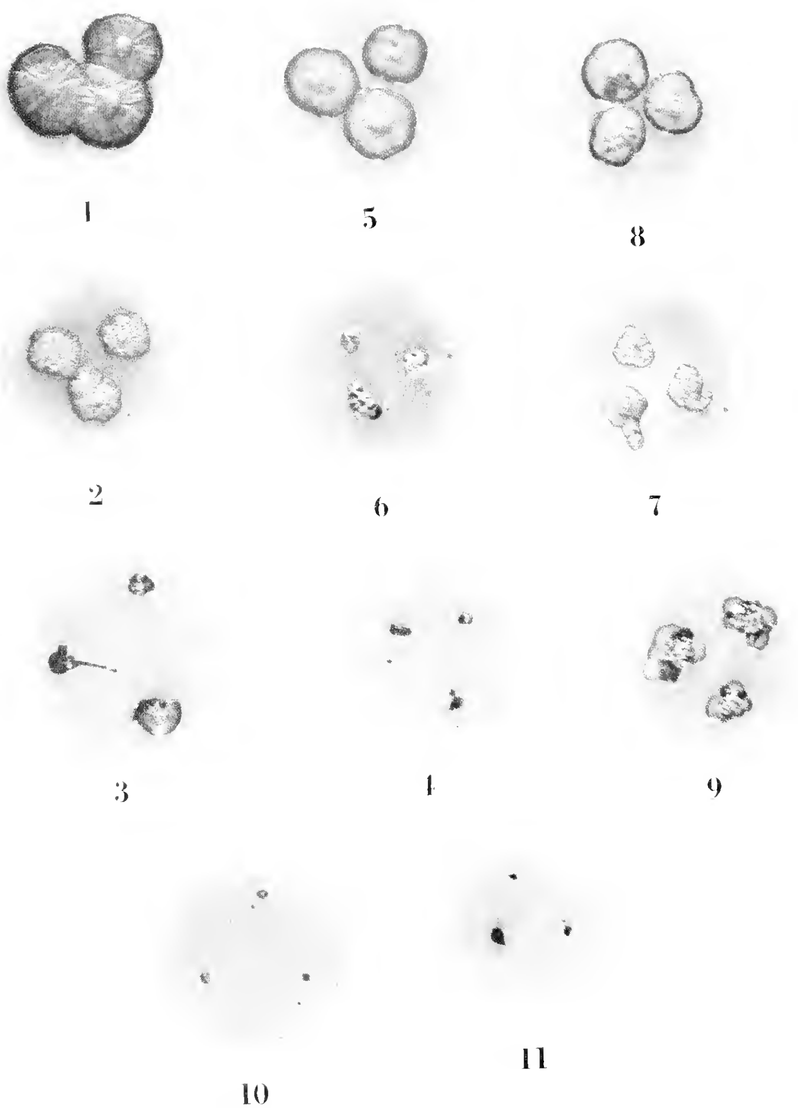
Muenscher, W. C.
1923. Protein synthesis in *Chlorella*. Bot. Gaz., vol. 75, pp. 249-267.

Radais
1900. Sur la culture pure d'une algue verte; formation de chlorophylle à l'obscurité. C. R. Acad. Sci., tome 130, pp. 793-796.

Shirley, H. L.
1929. Influence of light intensity and light quality upon the growth of plants. Contr. Boyce Thompson Inst. Plant Res., Inc., vol. 2, no. 3, pp. 159-194.

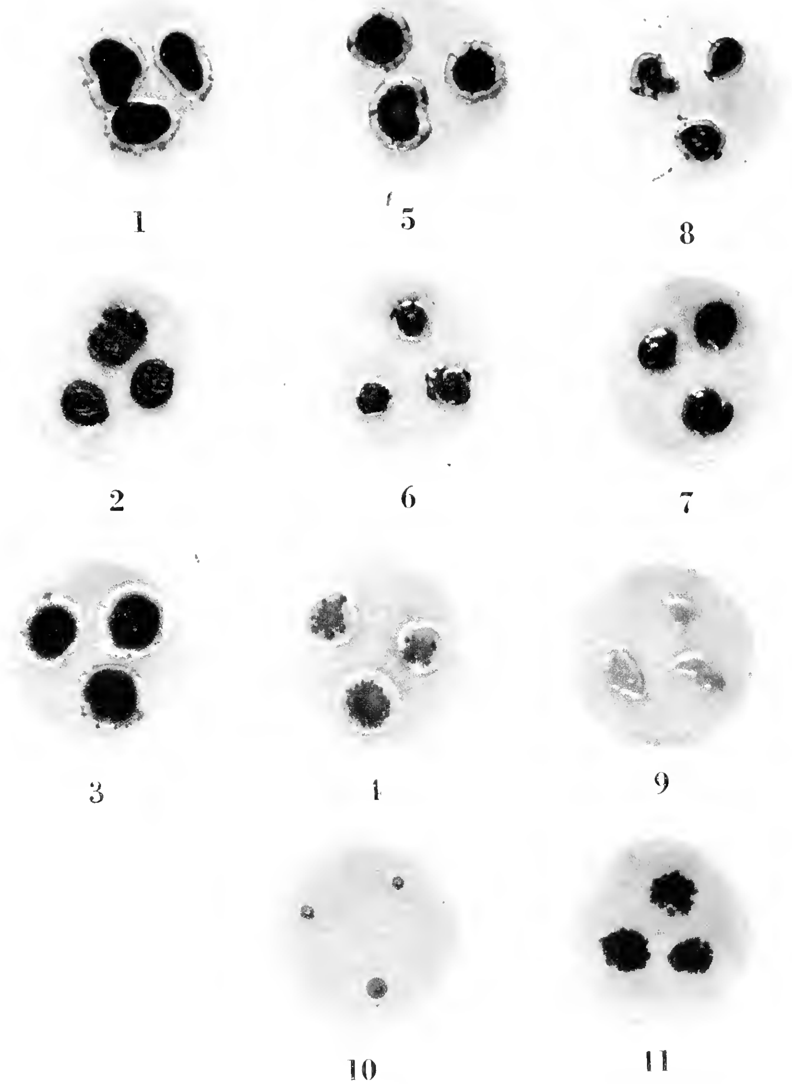
CYSTOCOCCUS COHAERENS VAR., X APPROX. $\frac{3}{4}$

(For explanation, see page 13.)



CHLORELLA VULGARIS, X APPROX. ½

(For explanation, see page 13.)



CHLOROCOCCUM VISCOSUM, X APPROX. ½
(For explanation, see page 13.)

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 6

Arthur Fund

EFFECTS OF INTENSITIES AND WAVE LENGTHS OF LIGHT ON UNICELLULAR GREEN ALGAE

(With Three Plates)

BY
FLORENCE E. MEIER
Division of Radiation and Organisms, Smithsonian Institution

(Publication 3257)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 11, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

Arthur Fund

EFFECTS OF INTENSITIES AND WAVE LENGTHS OF LIGHT ON UNICELLULAR GREEN ALGAE[1]

By FLORENCE E. MEIER

Division of Radiation and Organisms, Smithsonian Institution

(With Three Plates)

INTRODUCTION

Unicellular green algae are admirably adapted to the study of the effectiveness of light intensity and light of different wave lengths on chlorophyll formation and on growth as defined by multiplication of cells. Their chief advantages as subjects of experimentation are: (1) their small size, the mechanism of photosynthesis being complete in the microscopic individual with its green chloroplast; (2) the uniformity of their surfaces, since each cell in those varieties that do not form zoospores may be considered comparable to every other one placed in a symmetrical environment; (3) their mode of growth in nutrient solution; and (4) the comparative ease of controlling the temperature and humidity conditions.

Control of the environment of algae as regards culture medium, temperature, and illumination was made the primary consideration in these experiments conducted in an effort to determine the reaction of algae to light. The importance of controlled conditions especially in matters of light intensity and wave length is easily seen when one reads through the literature. A few results of other investigators are reviewed.

I wish to express my deep appreciation to Dr. C. G. Abbot, Secretary of the Smithsonian Institution, and to Dr. Earl S. Johnston, Assistant Director of the Division of Radiation and Organisms, for their assistance in the completion of this piece of research. I am also very grateful to the other members of the Division of Radiation and Organisms, whose united efforts have made possible these experiments.

[1] This paper reports investigations made under a grant from the National Research Council to the author as National Research Fellow in the Biological Sciences from July 1931 to July 1933.

RESULTS OF PREVIOUS INVESTIGATIONS

As early as 1861 Sachs (1864) originated the well-known method of growing plants in double-walled glass cylinders to determine the effects of colored lights. The cylinders contained respectively solutions of ammoniacal copper oxide for blue light, and potassium dichromate for orange light. No coloring solution was used with the third cylinder. He reported that plants needed from 4 to 6 days more in blue light than in orange light to unfold their leaflike cotyledons which remained smaller in the former so that the lamina in orange light was 2 to 3 times larger than in blue light, but largest of all in white light. Regarding leaf formation, the orange light acted as a lesser, the blue as a higher, degree of darkness. There was no formation of organic substance in the blue light, while a small amount was formed in orange light.

Pfeffer (1871) also working with double-walled cylinders of solutions found the following percentages of growth under the filters: 46.1 percent, yellow; 32.1 percent, red and orange; 15.0 percent, green; and 7.6 percent, blue, violet, and indigo. Later, in 1872, working with a prism he again found the maximum growth in the yellow.

Weber (1875) working with colored glasses as filters obtained similar results but in the following different percentages: 82.6 percent, yellow; 35.5 percent, red; 22.4 percent, blue; and 14.5 percent, violet.

Wiesner (1877) used a filter of potassium dichromate which transmitted the less refrangible half of the spectrum: red, orange, yellow, and a part of green; and also ammoniacal copper oxide which allows the passage of the remainder of the visible rays, the rest of the green and all of the blue and violet. He observed that the plants in weak light became greener sooner under yellow but in strong light sooner under blue. He believed rapid destruction accompanies chlorophyll formation in strong yellow or strong blue light which might not act directly upon the chlorophyll already formed but might have a harmful effect upon some process antecedent to chlorophyll formation.

Zachariewicz (1895), Flammarion (1897), and Strohmer and Stift (1905) agree that the maximum chlorophyll production is in the yellow rays.

Artari (1899) observed that blue-violet light accelerated the development of *Chlamydomonas ehrenbergii*.

Teodoresco (1899) using filters made up of chemical solutions studied the growth of corn in regions of the spectrum corresponding to the general chlorophyll absorption bands. Growth was found to be best in the blue and violet, 5220 to 4260 A; less favorable in the red and a small part of the orange, —— to 6130 A; and poorest in the green, 5680 to 5240 A. Chlorophyll was present in all the regions of the spectrum studied separately.

Thirty years later Teodoresco (1929) reports about 170 experiments in which he investigated two main regions of the visible spectrum, using both colored solutions and glass filters. He measured the energy transmitted through both sets of filters by means of a thermopile and a galvanometer and equalized the intensities. In measuring the light intensity he used a screen of water and copper acetate to eliminate the effect of the infrared radiation. Using a variety of hepatics, vascular cryptogams, and phanerogams, Teodoresco found that in the red-orange, 7750 to 6440 A, the general configuration of the plant was abnormal, while in the blue, 5090 to 3660 A, the general appearance of the plant was normal and similar to plants grown in the shade or in white light. Fern germination was retarded in the blue light.

Nadson (1910) grew *Stichococcus bacillaris* Naegeli under bell jars of colored solutions and found that red-yellow light caused abnormally shaped cells and disorganized chromatophores of a pale yellow-green color. Cultures, 3 to 6 months old, grown in blue light finally attained a stage of development similar to the cultures in white light which were more normal in color and morphology.

Otto Thelen (1910), growing oats, beans, and other plants under light filters, obtained maximum production in the bright yellow and yellow-red light; the bright red light gave more than a third less dry weight, the blue still less, and the red and dark red, the least. The plants grown in white light produced almost as much dry weight as those grown under the yellow-red filter.

Dangeard (1912) immersed a piece of white blotting paper into a culture flask of *Chlorella vulgaris* growing in Knop solution, stretched it on the wall of a culture dish, and radiated it in a quartz spectrograph. The maximum action of the rays as indicated by the differences of vegetation was in the chlorophyll absorption bands. The algae grew best in the region 6700 to 6600 A, less in regions 6800 to 6700 A and 6600 to 6300 A, with a feebler growth in 6300 to 6000 A, and a very feeble growth in the range 6000 to 5700 A. No trace of the alga was visible from 5200 to 4000 A.

Klebs (1916-1917) showed that very striking formative changes can be induced in prothallia placed in different regions of the visible spectrum. He indicated that intensity and duration of light as well as other environmental factors may bring about similar effects. This demonstrates the importance of measuring or recording all these factors in any study of the effect of light on plants.

Schanz (1919) grew higher plants in eight beds covered with various kinds of glass. In the first five beds the range of wave lengths of light transmitted was gradually decreased from the violet end of the spectrum toward the red, thus making possible the study of the effect of light from which greater and greater regions of the spectrum were eliminated in the blue-violet end. Combinations of colored glasses which gave predominating colors of yellow, green, and blue-violet were used in the last three beds. He found that chlorophyll development in beans, soybeans, and potatoes was more rapid the more the short rays were cut off, being most rapid under red light. In lettuce, chlorophyll developed fully under blue-violet rays but not in normal quantity in yellow or green light. Schanz did not measure the light intensity, nor does he give accurate information concerning temperature and other factors that possibly varied under the different types of glass.

Popp (1926) grew a number of higher plants in greenhouses under glasses transmitting only definite regions of the spectrum. The plants receiving no wave lengths shorter than 5290 A or 4720 A had a good development of chlorophyll and were somewhat similar to those grown under reduced light intensity. There was very little difference between plants that received all the rays of the spectrum of daylight and those from which only ultraviolet rays were eliminated. Popp claims that light intensity was not an important factor in his experiment for the following reason: The plants grew normally and vigorously in the full spectrum of daylight at an intensity that was at all times lower than that of the house in which all wave lengths shorter than 4720 A were removed and only slightly greater than that of the house in which wave lengths shorter than 5290 A were eliminated.

Sayre (1928) investigated the development of chlorophyll in seedlings under Corning glass ray filters and found that wave lengths of radiant energy longer than 6800 A are not effective in the formation of chlorophyll in corn, wheat, oats, barley, beans, sunflowers, and radishes, but that all other regions of the remaining visible and ultraviolet spectrum to 3000 A are effective provided the energy value is sufficient. For approximately equal energy values in these regions the red rays are more effective than the green and the green than the blue. The effectiveness of radiant energy seems to increase with the wave length to about 6800 A, where it ends abruptly.

Meier (1929), while working in Professor Chodat's laboratory, conducted a preliminary light experiment in conjunction with an experiment relating to the formation of carotin in green algae. Three series of cultures of *Chlorella rubescens* planted on solid media, Detmer $\frac{1}{3}$ plus glucose 2 percent with agar 1.5 percent, were placed at a north window; one in the modified diffused light, the second in violet light in a Senebier jar containing copper sulphate, and the third in yellow-orange light, in a Senebier jar containing potassium dichromate. Chlorophyll production followed by formation of carotin, and growth of the cells progressed most rapidly in natural light and least rapidly in the violet light. These results agree with those reported by Sachs on higher plants.

Arthur (1930) observed that plants grown under a red glass filter transmitting no blue light resembled those grown in a dark basement except that chlorophyll developed. The plants under a blue glass filter transmitting no red were dwarfed but otherwise normal.

I. EFFECTS OF DIFFERENT INTENSITIES

DESCRIPTION OF APPARATUS

To determine simultaneously the effect of different light intensities on algae under exactly similar conditions of medium and temperature, a large metal table similar to the one pictured in plate 1, figure 1, was constructed with four glass-bottomed water baths, each holding eighteen 300-cc Erlenmeyer flasks. The four water baths are connected to a centrally located thermostated mixing chamber which kept the temperature for these experiments at 21° C. In order to insure uniform dispersion of the algae, a common driving mechanism continuously agitates the Erlenmeyer flasks. The cultures are illuminated from below by artificial light from Mazda daylight lamps.

PRELIMINARY EXPERIMENT

A preliminary experiment was conducted to determine the best growing conditions and the nutrient solution best suited to the algae in this apparatus. The following solutions were prepared:

1. Detmer (Modified Koch Solution)

Calcium nitrate	1.	gram
Potassium chloride	0.25	"
Magnesium sulphate	0.25	"
Potassium acid phosphate	0.25	"
Iron	0.002	"
Distilled water	1	liter

This solution made up in the above proportions was diluted to one-third.

2. Emerson's (1929) Solution

Magnesium sulphate	0.01	molar
Potassium nitrate	0.0125	"
Potassium acid phosphate.....	0.0090	"
Calcium carbonate	0.0001	"
Iron [a]		

3. Johnston's (1929, 1932) Solution

Calcium nitrate	0.005	volume	molecular	concentration
Magnesium sulphate	0.002	"		"
Potassium acid phosphate.....	0.002	"	"	"
Distilled water made up to 1 liter				
Iron [a]				

4.

Detmer $\frac{1}{3}$ solution in which potassium chloride is replaced by .33 grams of potassium acid carbonate which supplies the same amount of potassium.

5.

Detmer $\frac{1}{3}$ solution in which potassium chloride is replaced by .6 grams of potassium acid carbonate.

6.

Detmer $\frac{1}{3}$ solution in which potassium chloride is replaced by 1.2 grams of potassium acid carbonate.

7.

Detmer $\frac{1}{3}$ solution in which potassium chloride is replaced by 2.4 grams of potassium acid carbonate.

8.

Similar to 1 but with cotton plugs.

9.

Similar to 2 but with cotton plugs.

[a] An equal quantity of iron was added to all the solutions.

Rubber stoppers were used for all the Erlenmeyer flasks except in 8 and 9, duplicate cultures of Detmer $\frac{1}{3}$ and Emerson respectively, which were plugged with cotton. The excess sulphur was removed from the rubber stoppers with petroleum ether before they were sterilized. One hundred cc of nutrient solutions was placed in each 300-cc Erlenmeyer flask and sterilized in an autoclave at 20 pounds pressure for 20 minutes.

Five cultures of each of the above solutions were inoculated with *Stichococcus bacillaris* Naegeli. A similar number of cultures was inoculated with *Chlorella vulgaris* var. Four sets of each alga were placed in the water baths, the fifth in a north window of the Smithsonian flag tower.

For this experiment, a 300-watt Mazda daylight lamp was placed under each of the four water baths. Under baths 1, 2, and 3 the bulb was placed so that the filament was 20 centimeters from the glass bottom of the bath. For bath 4 the distance was 40 centimeters. In bath 1 the cultures were stationary; the cultures in the other three baths were continuously agitated so that the cells were more evenly dispersed in the culture media. Cultures in baths 1, 3, and 4 were lighted continuously throughout the experiment, but those in bath 2 were illuminated for 6 hours daily from 1 a.m. to 7 a.m.

This experiment was of one month's duration from June 19, 1931, to July 17, 1931.

RESULTS

A. As regards growing conditions.—

1. The best development took place in those cultures grown under natural conditions of light and darkness in a north window of the tower.

2. Of the cultures grown under artificial conditions in the baths, the best ones were those grown in intermittent light at about a distance of 20 centimeters from the light.

3. The next best Detmer cultures were those grown in bath 4 at a distance of about 40 centimeters from the light.

4. The cultures in baths 1 and 3 gave the poorest results. There was continuous illumination at a distance of about 20 centimeters in both of these baths and in one set the cultures were stationary and in the other, continually shaking.

B. As regards solutions.—

1. The cultures of Detmer $\frac{1}{3}$ both with rubber stoppers and cotton plugs showed the best growth and most normal cells under all the different conditions.

2. All the other cultures showed poor growth under continuous light at 20 centimeters distance from the light in baths 1 and 3.

3. The cultures in which the potassium chloride of the Detmer solution was replaced by potassium acid carbonate did not give as good results as the Detmer $\frac{1}{3}$ solution.

4. The algae in the Johnston solution were a brighter green than the algae in the Detmer solution in the tower cultures.

5. The most normal algal cells occurred in the Emerson, Johnston, and Detmer solutions in the tower and in intermittent light, bath 2.

6. The cells of the stationary cultures were irregularly shaped and showed abnormally cut plastids.

7. The cells in the cultures 20 centimeters from the light, continuously illuminated, were very tiny.

CONCLUSIONS

1. Intermittent light gives more favorable results than continuous light.

2. In continuous illumination better results were obtained by the weaker light (at a distance of 40 centimeters).

3. Agitation is favorable to a more equal distribution of cells and hence a more uniform lighting condition. It also favors multiplication, as the cells do not collect in large masses.

4. Detmer $\frac{1}{3}$ is a favorable solution for the growth of the algae under the controlled conditions described above.

5. Rubber stoppers serve as well as cotton plugs in 300-cc flasks containing 100 cc of solution for an experimental period of a month.

SECOND EXPERIMENT

A second experiment was carried out with cultures of the following 15 algae: *Coccomyxa simplex*, *Chlorella viscosa*, *Scenedesmus flavescens*, *Chlorella vulgaris*, *Stichococcus bacillaris*, *Palmellococcus protothecoides*, *Oocystis naegelii*, *Cystococcus irregularis*, *Chlamydomonas intermedia*, *Palmelococcus variegatus*, *Chlorococcum viscosum*, *Scenedesmus chlorelloides* var., *Chlorella vulgaris* var., *Cystococcus cohaerens*, and *Heterococcus viridis*. Three sets of the cultures were illuminated each by a 300-watt Mazda daylight lamp at a distance of 40 centimeters from the glass bottom of the bath to the top of the filament of the lamp. The fourth was kept in darkness.

Of the three illuminated culture sets, one received intermittent light for 6 hours. All the cultures were constantly agitated with the exception of one of the two receiving continuous illumination. The experiment was in progress from July 28 to August 18, 1931. Detmer $\frac{1}{3}$ solution was used for each alga.

The cultures that were agitated continuously and lighted intermittently and the cultures that were stationary and lighted continuously produced the most satisfactory results at the end of the experimental period. In the stationary cultures, the algae had formed a film on the bottom of the glass flasks that shielded those in the solution from the intense light. The first seven algae listed above were greenest and in the best condition. The next six listed were less green probably because the light was too intense, while the last two listed, that is, *Cystococcus cohaerens* and *Heterococcus viridis*, were killed by the intense light in all three of the baths.

The cultures which were continually agitated and kept as closely as possible in continuous darkness gave the following results: all the algal suspensions were practically colorless in appearance, but by microscopic examination some green cells mixed with numerous colorless cells were found for the following eight varieties: *Stichococcus bacillaris*, *Chlorella vulgaris*, *Scenedesmus chlorelloides* var., *Oocystis naegelii*, *Chlorella viscosa*, *Scenedesmus flavescens*, *Cystococcus irregularis* and *Palmellococcus variegatus*. All colorless cells were found in the following four varieties: *Palmellococcus protothecoides*, *Coccomyxa simplex*, *Chlorella vulgaris* var., and *Chlamydomonas intermedia*.

THIRD EXPERIMENT

In the third experiment, which was in progress from October 10 to November 9, 1931, all the cultures in the four baths were constantly agitated and lighted continuously. Mazda daylight lamps were used and were so placed that the ratios of intensities in the four baths were 1 : 3 : 9 : 27.

Bath	Wattage	Distance [a]	Intensity [b] microwatts/mm [2]	Ratio
1	60 (frosted)	5.95	3.76	1.00
2	200	36.7	11.5	3.06
3	300	35.9	34.1	9.06
4	300	18.8	102.0	27.0

[a] The distance was measured from the glass bottom of the bath to the top of the filament of the lamp.
[b] As measured with a thermocouple.

In addition to the algae listed in the second experiment, cultures of *Haematococcus pluvialis* and *Palmellococcus miniatus* were used. Microscopic counts were made of each culture at the beginning and at the end of the experiment.

The increase in number of cells was roughly proportional to the increase in light intensity in the cultures of *Oocystis naegelii*, *Palmellococcus protothecoides*, *Chlorella vulgaris*, *Palmellococcus miniatus*, *Chlamydomonas intermedia*, *Scenedesmus chlorelloides* var., *Heterococcus viridis*, *Chlorella viscosa*, *Cystococcus irregularis*, *Cystococcus cohaerens*, *Coccomyxa simplex*, and *Palmellococcus variegatus*. Four algae behaved differently. The most intense light caused the poorest development of *Stichococcus bacillaris* and *Scenedesmus flavescens*, although for the three other intensities the growth was proportional. The growth was inversely proportional to the light intensity in *Chlorella vulgaris* var. *Chlorococcum viscosum* grew very little in all four light intensities. Cells with green chloroplasts were present in all the cultures of the algae listed above. *Hematococcus pluvialis* had a few gray-green cells in the lowest light intensity, more green cells in the next two light intensities, and numerous green cells with red eye spots and a number of completely orange-red cells in the highest light intensity.

II. EFFECTS OF DIFFERENT WAVE LENGTHS

THE PLANT USED

Stichococcus bacillaris Naegeli, the green alga used in this experiment, consists of a single cylindrical cell with rounded ends usually partially filled with the chloroplast. The dimensions of the cell vary from 2 to 2.5 μ in diameter and from 4 to 8 μ in length. Multiplication takes place by transverse division of the protoplast and the formation of cross walls. The nucleus usually lies near the center of the cell. (See pl. 2.) Filaments of cells were rarely observed in my cultures. The alga develops rapidly, soon forming a green deposit in Detmer $\frac{1}{3}$ containing 0.005 percent to 0.02 percent ferric chloride.

The cells multiply very slowly on a solid medium such as Detmer $\frac{1}{3}$ agar, and after two months' time small green buttons about 4 to 7 millimeters in diameter are present on the agar. If dextrose from 1.5 to 2 percent is added to the medium, the flat regular dark green disks may grow to over 1 centimeter in diameter.

This alga does not liquefy gelatine but forms a slight dark green growth on the surface of the culture medium.

My cultures have remained green in the dark for two months on Detmer $\frac{1}{3}$ agar plus 2 percent dextrose. The colonial formations, although greener, are smaller when grown in darkness than corresponding cultures in the light, owing to the less rapid development and exhaustion of the nutrient medium. Artari (1899), Radais (1900), Matruchot and Molliard (1902), and Chodat (1913), have also grown green cultures of *Stichococcus bacillaris* in darkness. Cultures illuminated continuously by electric light for two months were a brownish-gray color and the individual cells were abnormally shaped. Corresponding cultures in sky illumination showed normal cells but were beginning to discolor at the center of each colonial disk.

APPARATUS

A metal table somewhat similar to the one used for experimenting on the effects of light intensity was constructed for experimental work on the effect of light of different wave lengths on one variety of alga. (See pl. 1, fig. 1.)

This table was constructed with four glass-bottomed water baths each holding six 300-cc Erlenmeyer flasks. Each flask is enclosed in a container with a light filter on the bottom. (See pl. 3, fig. 2.) The holders containing the flasks are maintained in continuous agitation. Each filter is one of a duplicate series of 12 short wave length cut-off filters, that is, a set which transmits progressively shorter and shorter

Table 1.—*Short Wave Length Cut-off Filters*[a]

Name of filter	Cut-off A
Heat resisting pyrometer red, 62 percent	6000
Heat resisting red, 130 percent	5900
Heat resisting red, 245 percent	5800
Heat resisting lighthouse red, 100 percent	5600
Heat resisting yellow, red shade	5200
Heat resisting yellow, medium shade	5000
Heat resisting yellow, yellow shade	4800
Heat resisting Noviol	4600
Noviol "C"	4500
Noviol "O"	4000
Nultra	3700

[a] These filters are made by the Corning Glass Company.

wave lengths from one transmitting only deep red to the other extreme where the whole region is included, as shown in table 1. One special filter is included in each set. Each flask containing its inoculated culture of *Stichococcus bacillaris* was placed in the container, which cut out all light except that entering through the glass filter. For the sake of convenience, one set of cultures is indicated north side (N) and the duplicate set, south side (S).

EARLY EXPERIMENTS

Five experiments were conducted in this apparatus. The results of the first two experiments are questionable, since the light intensity measurements taken through the various filters at the close of the experiment were found to vary as much as 50 percent from the original measurements. The experiment was attempted a third time, care being taken to clean the flasks and filters daily and also to observe any change in light intensity with a photoelectric cell and to correct the intensity changes accordingly. After the experiment had run for 10 days, the belt of the motor governing the circulation of water broke during the night. By morning, the temperature of the cultures had risen to 120° F. and as the majority of the algal cells were found to be deformed, colorless, or exuding their chlorophyll, the results of this experiment were also discarded.

FOURTH EXPERIMENT

The apparatus was completely overhauled for the fourth experiment. This time a more trustworthy thermostat was used with a safety device for cutting off the heater and lights in case of accident. An electric clock was connected with the lighting system in such a manner as to indicate any length of time the apparatus was not functioning properly when the observer was absent.

Johnston's (1932) work with tomato plants grown under Mazda lamps indicates that a large proportion of infrared radiation present in this type of illumination is injurious to the plants. Heat-absorbing filters give more normal growth and physiological response, and where the excessive infrared radiation from the lamps is absorbed by a solution of copper sulphate, the plants are more normal. For this reason a solution of copper sulphate (1.007 specific gravity at 80° F.) was used in place of distilled water in the circulating system that controls the temperature of the four baths.

In the third light-intensity experiment on page 9 it was found that *Stichococcus bacillaris* increased in proportion to the increase in light intensity when the intensities measured through water were 3.76, 11.5, and 34.1 microwatts/mm^2. In this experiment, as well as in the fifth one, the intensity measured through the copper sulphate solution was 25 microwatts/mm^2. Since the intensity as measured through the copper sulphate solution is less than the next to the highest light intensity used in the third light-intensity experiment, we know that the light intensity in the filter experiments is favorable to the growth of these algal cells.

The copper sulphate solution entered each separate bath through a flaring glass tube, over the end of which was placed a bag of huck toweling. These bags strained out most of the bubbles caused by the central pump, as well as any dirt or grease present, thus keeping the copper sulphate solution clear in each bath.

Mazda lamps were used under each bath and so arranged at distances from the glass bottom of the bath that the light intensity was the same under each of the duplicate sets of 12 filters as measured by the thermocouple. Frequent readings of the light intensity were made during the experiment to insure the similarity of the intensity under the filters, and when necessary the distances of the lamps from the bottom of the bath were changed or the lamps replaced by new ones. The voltage was read at the same time the intensities were measured, since the voltage fluctuated slightly from day to day thus causing a difference in intensity. The Erlenmeyer flasks, the filters, and the glass bottoms of the water baths were cleaned whenever necessary. While the filters were being cleaned, the culture flasks were kept in a covered dark box.

The temperature of the baths was regulated by a thermostat set at 21° C. throughout the experiment. The experiment was in progress from February 7 to March 24, 1933.

A uniform medium and uniform inoculation were insured for all the cultures by the following method: A 3-liter pyrex glass flask was fitted with a rubber stopper through which was inserted a large glass tube. One end of the tube was plunged in the culture medium, the other fitted in rubber tubing with a stopcock ending in a glass pipette. A second smaller glass tube was inserted through the rubber stopper, then connected to a compressed air tube by rubber tubes and a glass tube with cotton filters to filter out dust. (See pl. 3, fig. 1.) The culture medium Detmer $\frac{1}{3}$, for the 24 individual flasks was made up in this large previously sterilized flask, which was again sterilized in the autoclave at 20 pounds pressure for 20 minutes.

About 100 cc of a dark green suspension of cells of *Stichococcus bacillaris* that had been growing in a north window for one month was used to inoculate the 3-liter flask of Detmer $\frac{1}{3}$ solution. Twenty-four hours later the solution was well shaken and siphoned into each sterilized 300-cc flask to the previously marked 100-cc level.

Three extra cultures were placed in the north, south, and west windows of the tower. Samples of the inoculated medium were measured by the nephelometer, the pH was determined colorimetrically, and microscopic counts were made at the time when the flasks were adjusted in the baths and the experiment started. Microscopic counts, nephelometer measurements, and pH determinations were also made at the close of the experimental period. The results of this experiment are indicated in tables 2 to 9 and will be discussed in connection with those obtained in the fifth experiment.

FIFTH EXPERIMENT

A fifth experiment, a repetition of the fourth experiment with the exception of the duration, was carried on from May 29 to June 13, 1933. The results of this experiment are assembled with those of the fourth experiment in tables 2 to 9.

THE pH OF THE CULTURES

As Kostychev (1931) points out, the change of pH is a factor not to be ignored when stimulation or retardation of enzyme action, electrical discharge of cell colloids, and the permeability of the plasma membrane and other physiological processes are at work in a culture. There is a certain range of pH in which each plant can exist. In the fourth and fifth experiments the pH of the cultures was measured at the beginning and at the end of the experiment with the Hellige comparator, which uses colored glass disks in place of the standard

TABLE 2.—*pH Determinations at End of Experiments*

Filter: short wave length cut-off	Fourth experiment (Original solution, pH 5.4) North	Fifth experiment (Original solution pH 5.6) North	South
A	pH	pH	pH
6000	5.2	5.8	5.2
5900	5.2	5.2	5.6
5800	4.8	5.4	5.4
5600	4.8	5.6	5.2
5200	4.8	5.2	5.6
5000	5.2	5.8	5.6
4800	4.8	5.8	5.6
4600	4.8		5.6
4500	4.8	5.8	5.8
4000	5.4	5.4	5.6
3700	4.8	5.4	5.8

solutions with which the sample of culture solution plus the indicator is compared. Inadvertently, the cultures grown on the south side of the water baths for the fourth experiment were discarded before the pH could be determined. In these experiments, as shown by table 2, the change in acidity of the cultures at the end of the experimental period as compared with the original acidity is negligible, the maxima being 0.6 pH in the fourth experiment and 0.4 pH in the fifth experiment.

THE NEPHELOMETER

A special type of nephelometer was constructed to compare the relative concentrations of the solutions. As shown in plate 1, figure 2, this piece of apparatus consists of two stationary glass cells in each of which is inserted a similar movable cell filled with distilled water enclosing a stationary glass plunger lined with black paper to prevent reflections. A beam of light is thrown on the glass cells from a condensing lens, and the cells are adjusted so that the light beam always passes through the same depth of liquid. Each movable glass cell is attached to a metric scale that gives the depth of the solution and is adjustable so that the depth of the unknown solution placed in the bottom stationary cell may change from zero to the length of the scale. The intensity measurements are made with a photronic cell and galvanometer system.

A zero adjustment was made with the nutrient solution in the four cells so that there is equal intensity on both sides of the apparatus as shown by the deflection of the galvanometer. It was found that this intensity was practically independent of the depth of the nutrient solution. Then the nutrient solution in the bottom cell on one side is replaced by the freshly inoculated solution at a chosen depth, thus causing a deflection of the galvanometer less than that of the nutrient solution in the cells on the other side. The percentage change in the ratio of the two galvanometer deflections represents the absorption of the inoculated solution. After the experimental period the depth of each culture solution was adjusted to give the same ratio with the nutrient solution as did the original inoculated solution.

According to Beer's Law, the concentration of the solution is proportional to the logarithm of the intensity of the light transmitted through the various thicknesses; or if the ratio of the light falling on the cell to the light transmitted remains constant, the concentrations of the solutions are inversely proportional to the depth.

$$I = I_0 e^{-acx} \quad \text{(Beer's Law)}$$

where

I = Intensity of light transmitted by thickness x of nutrient solution plus algae

I_0 = Intensity transmitted by nutrient solution (no algae)

(I and I_0 are measured with the photronic cell)

x = thickness or length of column

c = concentration of algae

a = a constant depending on absorbing medium (we assume a is constant for the algae before and after growth in the experiment)

The procedure was usually to measure the intensity transmitted through the original inoculated solution and to call this I_s for a length x_s. Then after growth, x was adjusted to the same ratio.

$$\frac{I_s}{I_0} = \frac{I}{I_0} = k$$

then

$$\log_e \frac{I_s}{I_0} = \log_e \frac{I}{I_0} = \log_e k = K$$

and

$$\log_e \frac{I}{I_0} = acx = K$$

also

$$\log_e \frac{I_s}{I_0} = ac_s x_s = K$$

or

$$acx = ac_s x_s$$

so

$$\frac{c}{c_s} = \frac{x_s}{x}$$

i.e., the concentrations are inversely proportional to the length (x). Also

$$\frac{c}{c_s} = \text{growth},$$

i.e., if

$$\frac{x_s}{x} = 3$$

then the increase or growth was 3 times.

RESULTS

TOWER CULTURES

The three cultures grown in natural conditions of light and dark in the tower gave the following results:

Window	Galvanometer deflection	Growth factor	Microscopic count	Microscopic growth ratio
North	55.1	.99	106.8	4.9
South	65.5	.83	92.4	4.2
West	52.5	1.04	116.0	5.3

The pH was 5.8 in all three cultures. The cultures in the north and south windows contained bright green cells, while those in the west window were pale green and many of the chloroplasts were shrunken and slightly abnormal. Possibly the afternoon sunlight in the heat of the day is too strong for the cells.

CHLOROPHYLL

Samples of each culture when examined microscopically at the end of the fourth and fifth experiments showed that chlorophyll was present in all the cultures. The chloroplastids in some cultures were in a more healthy condition than in others, as shown by table 3. In

TABLE 3.—*Description of Chloroplasts of Cells at End of Experimental Periods*

Filter: short wave length cut off	Fourth experiment		Fifth experiment	
Å	North side	South side	North side	South side
6000	40% green and pale green 3% with yellow granules 57% colorless	48% green and pale green 48% greenish yellow 4% colorless	68% olive-green and greenish yellow 32% colorless, dark spots in some cells	green and faded blue-green
5900	23% green and pale green 62% with yellow granules 15% colorless	60% green and pale green 20% with yellow granules 20% colorless	84% green with yellow granules 12% very faded 4% colorless	bright green
5800	86% green 14% colorless	74% green and pale green 13% with yellow granules 13% colorless	pale sickly green	sickly green disintegrated
5600	50% green 50% colorless	38% pale green 21% with yellow granules 41% colorless	green with yellow granules	green with yellow granules
5200	15% green and pale green 58% with yellow granules 27% discolored and disintegrated	60% green and pale green 40% with yellow granules	very faded olive green	green
5000	31% green and pale green 59% with yellow granules 10% colorless	80% green and pale green 11% with yellow granules 9% colorless	68% bright green 20% orange 12% colorless	green lumps with yellow granules
4800	73% green 9% with yellow granules 18% colorless	68% green and pale green 20% with yellow granules 12% colorless	grass-green a few yellow-green	green lumps
4600	83% green 17% colorless	83% green and pale green 17% colorless	green and pale green	76% bright green 24% colorless
4500	100% green, most normal culture in this series	68% green 16% with yellow granules 16% colorless	grass-green and dark green	green
4000	67% green and pale green 22% with yellow granules 11% colorless	80% green 7% with yellow granules 13% colorless	very pale green	green, a few discolored
3700	93% green and 7% colorless	98% grass green 2% colorless	normal green	green with yellow granules

studying these tables, it should be borne in mind that the fourth experiment was in progress for a period of 45 days, whereas the fifth experiment was of 16 days' duration. The difference in time probably accounts for the greater number of colorless cells and cells in which carotin had begun to appear in the fourth experiment. It should be noted that cultures growing in light where the wave lengths were cut off at 3700, 4000, 4500, 4600, 4800, and 5000 A were in especially good condition.

The cultures that showed the most disintegration of the chloroplasts were those where the light was cut off at 5200 A in the fourth experiment, 5600, 5800, and 5900 A, with the exception of one culture in the fifth experiment, and 6000 A.

GROWTH AS INDICATED BY MULTIPLICATION OF CELLS

The results show that cell multiplication ranging from twofold to fourfold occurred in all the complex beams of radiation.

The third intensity experiment indicated that within the limits of intensity here employed multiplication is proportional to the intensity of illumination.

If it be assumed that this law holds for each of the complex beams employed, means are found for separating the propagating influences of different wave lengths. For if in the energy curves of two complexes whose included areas are equal a part P is common, then if Q be the total area of either curve and M the growth ratio due to the complex of longer wave lengths, $\frac{Q-P}{Q} M$ would be the growth ratio due to the part of the long-wave complex remaining in the shorter-wave complex. If N be the observed growth ratio of the shorter-wave complex, $N - \frac{Q-P}{Q} M$ will be the growth ratio due to the shorter wave lengths not found in the longer-wave complex.

Working on this plan, growth ratios have been computed for many narrow ranges of wave lengths, and by inspection of the overlapped energy curves, approximate values of their effective wave lengths have been estimated. (See tables 4-9.)

In this way it is found that a wide red and infrared complex of wave lengths from 0.6 to 1.4 microns is moderately effective in promoting multiplication of algae. It is impossible to know from these experiments which of its wave lengths are the most effective. The other ranges of wave lengths show different results. Some appear to inhibit multiplication, while others seem greatly to enhance it.

Inasmuch as the results depend on difference computations as between determinations themselves of considerable probable error, these estimates of the effectiveness of different narrow ranges of wave lengths to promote algal multiplication are very uncertain, but are given for what they may be worth.

Growth experiments made with definite narrow ranges of wave lengths by the aid of Christiansen filters should give more conclusive results.

GENERAL CONCLUSIONS

Multiplication of the unicellular green alga, *Stichococcus bacillaris* Naegeli, is proportional to the intensity of illumination ranging from 3.76 to 34.1 microwatts/mm ^{2}. A higher intensity than 34.1 microwatts/mm ^{2} such as 102.0 microwatts/mm ^{2} checks the growth of this alga.

Complex beams of radiation from 11 short wave length cut-off filters were used to transmit progressively shorter and shorter wave lengths from one transmitting only deep red, 6000 A, to the other extreme, 3700 A, where most of the visible region is included. Chlorophyll was formed under all the filters, but in best condition when the wave lengths of the blue-violet region were included.

A multiplication of algae ranging from twofold to fourfold was obtained in the cultures. By computing growth ratios for many narrow ranges of wave lengths and by estimating approximate values under the energy curves of the effective wave lengths it is found that a wide red and infrared complex of waves from 0.6 to 1.4 microns is moderately effective for the multiplication of the algal cells.

Some ranges of wave lengths appear to inhibit cell multiplication and chlorophyll formation. Some appear to favor them. Only by means of experimentation with isolated narrow ranges of light can the effectiveness of all the wave lengths be determined. A similar experiment with Christiansen filters instead of the glass ones is now in progress and should give more conclusive results.

TABLE 4.—*Microscopic Count of Algal Cells in Cultures at End of Experimental Period*

Filter: short wave length cut off	North side				South side			
	Fourth experiment		Fifth experiment		Fourth experiment		Fifth experiment	
	Final count	Final count ÷ 9 [a] to find N_4 ratio	Final count	Final count ÷ 22 [b] to find N_5 ratio	Final count	Final count ÷ 9 [a] to find S_4 ratio	Final count	Final count ÷ 22 [b] to find S_5 ratio
6000	40	4.4	116	5.3	23	2.5	80	3.6
5900	91	10.1	88	4.0	15	1.7	75	3.4
5800	117	13.	38	1.7	15	1.7	24	1.1
5600	46	5.1	133	6.0	29	3.2	185	8.4
5200	96	10.7	105	4.8	120	13.3	142	6.5
5000	145	16.1	62	2.8	131	14.5	98	4.5
4800	132	14.7	20	0.9	25	2.8	48	2.2
4600	120	13.3	57	2.6	36	4.	64	2.9
4500	100	11.1	45	2.0	57	6.3	48	2.2
4000	72	8.	46	2.1	15	1.7	42	1.9
3700	90	10.	100	4.5	66	7.3	136	6.2

[a] The original culture in the fourth experiment contained 9 cells.

[b] The original culture in the fifth experiment contained 22 cells.

TABLE 5.—*Computation Table Made to Find the Mean Microscopic Counts*

Filter: short wave length cut off A	Ratios of N_4 ÷ ratios of N_5	Ratios of S_4 ÷ ratios of S_5	N_4 ratios ÷ 4.4	N_5 ratios	S_4 ratios ÷ 1.7	S_5 ratios	Sums of relative ratios omitting wild ones	Mean omitting wild ones
6000	(0.8) [a]	0.7	(1.0)	5.3	(1.5)	3.6	8.9	4.45
5900	2.5	(0.5)	2.3	4.0	(1.0)	3.4	9.7	3.23
5800	7.6	1.5	3.0	1.7	1.0	1.1	6.8	1.70
5600	(0.9)	(0.4)	1.2	(6.0)	1.9	(8.4)	3.1	1.55
5200	2.2	2.0	2.4	4.8	(7.8)	6.5	13.7	4.56
5000	5.8	3.2	3.7	2.8	(8.5)	4.5	11.0	3.66
4800	(16.3)	1.3	3.3	0.9	1.6	2.2	8.0	2.00
4600	5.1	1.4	3.0	2.6	2.4	2.9	10.9	2.72
4500	5.6	2.9	2.5	2.0	3.7	2.2	10.4	2.60
4000	3.8	0.9	1.8	2.1	1.0	1.9	6.8	1.70
3700	2.2	1.2	2.3	4.5	4.3	6.2	17.3	4.32
Sum	34.8	15.1						
	$\frac{34.8}{8} = 4.35$	$\frac{15.1}{9} = 1.67$						

N_4 = North side of fourth experiment. N_5 = North side of fifth experiment. S_4 = South side of fourth experiment. S_5 = South side of fifth experiment.

[a] Results enclosed in parentheses are questionable and were omitted.

TABLE 6.—*Nephelometer Data of Algal Cultures at End of Experimental Period*

Filter: short wave length cut off	North side: Fourth experiment[a]		North side: Fifth experiment[b]		South side: Fourth experiment[a]		South side: Fifth experiment[b]	
	Galvanometer deflection mm	Growth factor	Galvanometer deflection mm	Growth factor	Galvanometer deflection mm	Growth factor	Galvanometer deflection mm	Growth factor
A								
6000	38.3	7.5	74.3	.73	22.8	12.5	67.4	.81
5900	38.2	7.5	60.0	.91	17.5	16.3	86.3	.63
5800	26.0	11.0	80.3	.68	33.1	8.6	83.5	.65
5600	30.4	9.4	72.5	.75	15.0	19.0	72.5	.75
5200	26.8	10.6	61.3	.89	31.7	9.0	102.0	.54
5000	28.3	10.1	106.0	.52	30.2	9.5	103.0	.53
4800	33.1	8.6	81.3	.67	39.2	7.3	66.9	.82
4600	25.0	11.4	45.5	1.20	24.4	11.7	104.0	.53
4500	21.8	13.1	66.0	.83	43.1	6.6	105.0	.52
4000	40.5	7.0	51.1	1.07	33.4	8.5	105.0	.52
3700	32.3	8.8	42.2	1.29	53.3	5.4	72.3	.76

[a] Fourth experiment. Galvanometer deflections made at 80 mm depth. The deflection of the original solution was 26.7 mm, that directly after inoculation was 23.83 mm.

[b] Fifth experiment. Galvanometer deflections made at 90 mm depth. The deflection of the original solution was 30.40 mm, that of the inoculated solution, 12.75 mm.

TABLE 7.—*Computation Made to Find the Mean Nephelometric Growth Factors*

Filter: short wave length cut off	Growth factors of N_4 ÷ growth factors of N_5	Growth factors of S_4 ÷ growth factors of S_5	N_4 growth factors ÷ 11.8	N_5 growth factors	S_4 growth factors ÷ 15.6	S_5 growth factors	Sums of relative growth factors omitting wild ones	Mean omitting wild ones
A								
6000	10.27	15.43	.64	.73	.80	.81	2.98	.745
5900	8.24	(25.87) [a]	.64	.91	1.04	.63	3.22	.805
5800	16.17	13.23	.93	.68	.55	.65	2.81	.702
5600	12.53	25.33	.80	.75	1.21	.75	3.51	.877
5200	11.91	16.66	.90	.89	.58	.54	2.91	.727
5000	19.42	17.92	.86	.52	.61	.53	2.52	.630
4800	12.83	8.90	.73	.67	.47	.82	2.69	.672
4600	9.50	22.07	.97	(1.20)	.75	.53	2.25	.750
4500	15.78	12.69	1.11	.83	.42	.52	2.88	.720
4000	6.54	16.34	.59	1.07	.54	.52	2.72	.680
3700	6.82	7.10	.75	1.29	.35	.76	3.15	.787
Sum	130.01	155.67						

$$\frac{130.01}{11} = 11.81 \qquad \frac{155.67}{10} = 15.56$$

[a] Results enclosed in parentheses are questionable and were omitted.

TABLE 8.—*Computation Made to Find the General Mean Algal Multiplication*

Filter: short wave length cut off	Mean microscopic counts ÷ mean nephelometric growth factors	Mean nephelometric growth factors × 4.0 [a]	Mean microscopic counts	Sums of relative means	General mean algal multiplication
A					
6000	5.07	2.98	4.45	7.43	3.71
5900	4.01	3.22	3.23	6.45	3.23
5800	2.42	2.80	1.70	4.50	2.25
5600	1.77	3.51	1.55	5.06	2.53
5200	6.28	2.91	4.56	7.47	3.74
5000	5.81	2.52	3.66	6.18	3.09
4800	2.98	2.69	2.00	4.69	2.34
4600	3.63	3.00	2.72	5.72	2.86
4500	3.61	2.88	2.60	5.48	2.74
4000	2.50	2.72	1.70	4.42	2.21
3700	5.49	3.15	4.32	7.47	3.74
Sum	44.47				

$$\frac{44.47}{11} = 4.04$$

[a] To reduce the mean nephelometric growth factors to the status of mean microscopic counts.

TABLE 9.—*Computation Made Assuming Algal Multiplication Proportional to Intensity*

Filter: short wave length cut off	General mean algal multiplication	Mean area ratio	Computed multiplication of longer waves	Effective multiplication of shorter waves	Divisor equals unity minus mean area ratio	Same for equal energy	Effective mean wave length μ	Wave length with ultraviolet weighting of curves
A								
6000	3.71				1.000	+ 3.7	1.00 ?	1.00 ?
5900	3.23	.940	3.48	− 0.25	0.060	− 4.1	.643	.643
5800	2.25	.917	2.96	− 0.71	0.083	− 8.6	.618	.618
5600	2.53	.972	2.19	+ 0.34	0.028	+ 12.1	.607	.605
5200	3.74	.983	2.49	+ 1.25	0.017	+ 73.5	.598	.590
5000	3.09	.917	3.43	− 0.34	0.083	− 4.1	.574	.562
4800	2.34	.943	2.91	− 0.57	0.057	− 10.0	.554	.540
4600	2.86	.924	2.16	+ 0.70	0.076	+ 9.2	.526	.500
4500	2.74	.972	2.78	− 0.04	0.028	− 1.4	.523	.490
4000	2.21	a	a	a	a	a	a	a
3700	3.74	.975	2.13	+ 1.61	0.025	+ 64.4	.507	.400

[a] Overlapping of absorption curves of filters hindered the completion of this computation.

LITERATURE CITED

Artari, Alexander

1899. Ueber die Entwicklung grünen Algen unter Ausschluss der Bedingungen der Kohlensäure-Assimilation. Bull. Soc. Imp. Nat. Moscou, pp. 39-47.

Arthur, John M., Guthrie, John D., and Newell, John M.

1930. Some effects of artificial climates on the growth and chemical composition of plants. Amer. Journ. Bot., vol. 17, pp. 416-482.

Dangeard, A.

1912. La determination des rayons actifs dans la synthese chlorophylliene. Le Botaniste, vol. 12, pp. 22-26.

Emerson, Robert

1929. Relation between maximum rate of photosynthesis and concentration of chlorophyll. Journ. Gen. Phys., vol. 12, no. 5, pp. 609-622.

Flammarion, von Camille

1897. Ueber die Wirkung der verschiedenen Strahlen des Sonnenspektrums auf die Vegetation. Biedermanns Central-Blatt, vol. 26, pp. 171-173.

Johnston, Earl S., and Dore, W. H.

1929. The influence of boron on the chemical composition and growth of the tomato plant. Plant Phys., vol. 4, pp. 31-62.

1932. The functions of radiation in the physiology of plants. II. Some effects of near infra-red radiation on plants. Smithsonian Misc. Coll., vol. 87, no. 14, pp. 1-15.

Klebs, Georg.

1916. Zur Entwickelungs-Physiologie der Farnprothallien. Sitz. Heidelberger Akad. Wiss., Math.-nat. 4 Abh., pp. 1-82.

1917. Zur Entwickelungs-Physiologie der Farnprothallien, Zweiter Teil. Sitz. Heidelberger Akad. Wiss., Math.-nat. 3 Abh., pp. 1-138.

Kostychev, S.

1931. Kostychev's chemical plant physiology. Translated by Charles J. Lyon. Pp. 55-60. Philadelphia, P. Blakiston's Sons & Co., Inc.

Meier, Florence E.

1929. Recherches expérimentales sur la formation de la carotine chez les Algues vertes unicellulaires et sur la production de la gelée chez un *Stichococcus* (*S. mesenteroides*). Bull. Soc. Bot. Genève, vol. 21 (1), pp. 161-197.

Nadson, G. A.

1910. Über den Einfluss des farbigen Lichtes auf die Entwickelung des *Stichococcus bacillaris* Näg. in Reinkulturen. Bull. Jardin Imp. Bot. St.-Pétersbourg, Tome 10, pp. 137-150.

Pfeffer, W.

1871. Die Wirkung farbigen Lichtes auf die Zersetzung der Kohlensäure in Pflanzen. Arb. Bot. Inst. Würzburg, Band 1, pp. 1-76.

Popp, Henry William
1926. A physiological study of the effect of light of various ranges of wave length on the growth of plants. Amer. Journ. Bot., vol. 13, pp. 706-736.

Sachs, Julius
1864. Wirkungen farbigen Lichts auf Pflanzen. Bot. Zeit., vol. 22, pp. 361-372.

Sayre, J. D.
1928. The development of chlorophyll in seedlings in different ranges of wave lengths of light. Plant Phys., vol. 3, pp. 71-77.

Schanz, F.
1919. Wirkungen des Lichts verschiedener Wellenlänge auf die Pflanzen. Ber. Deutschen bot. Ges., Band 37, pp. 430-442.

Strohmer, Friedr. und Stift, A.
1905. Über den Einfluss der Lichtfarbe auf das Wachstum der Zuckerrübe. Biedermanns Central-Blatt, vol. 34, pp. 229-233.

Teodoresco, E. C.
1899. Influence des diverses radiations lumineuses sur la forme et la structure des plantes. Ann. Sci. Nat. Sér. Bot., 8e série, tome 10, pp. 141-262.
1929. Observations sur la croissance des plantes aux lumieres de diverses longueurs d'onde. Ann. Sci. Nat. Sér. Bot., tome 11, pp. 201-336.

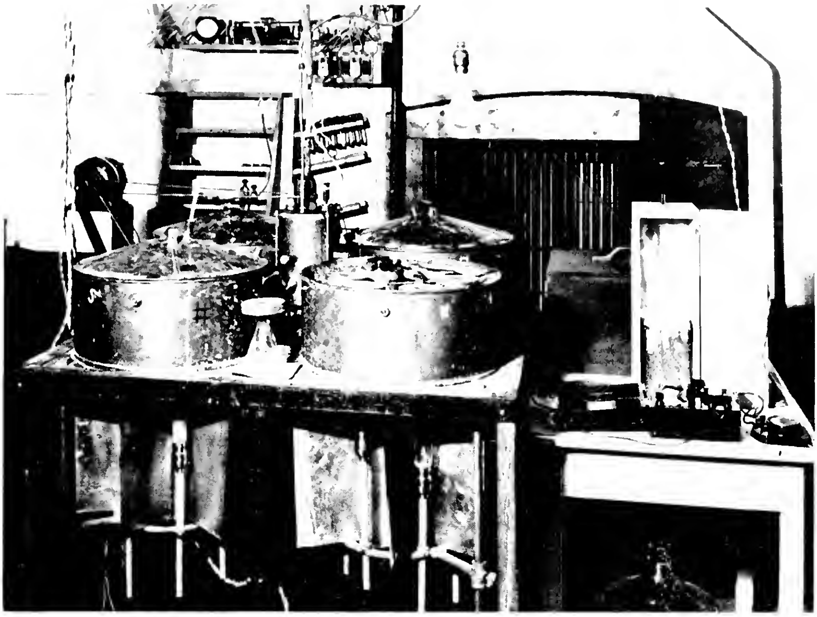
Thelen, Otto
1910. Natürliches künstliches und monochromatisches Licht in seiner Bedeutung für Entwickelung und die Stoffproduktion einiger Kulturpflanzen. Inaugural-Dissertation zur Erlangung der Doktorwürde der hohen philosophischen. Fakultät der Universität Rostock. pp. 1-59.

Weber, Rudolf
1875. Ueber den Einfluss farbigen Lichtes auf die Assimilation und die damit zusammenhängende Vermehrung der Aschenbestandtheile in Erbsen-Keimlingen. Die landwirthschaftlichen Versuchs-Stationen, Band 18, pp. 18-48.

Wiesner, Julius
1874. Untersuchungen über die Beziehungen des Lichtes zum Chlorophyll. Sitz. Math. nat. K. K. Akad. Wiss., Band 69, Abtheilung 1, pp. 327-385.

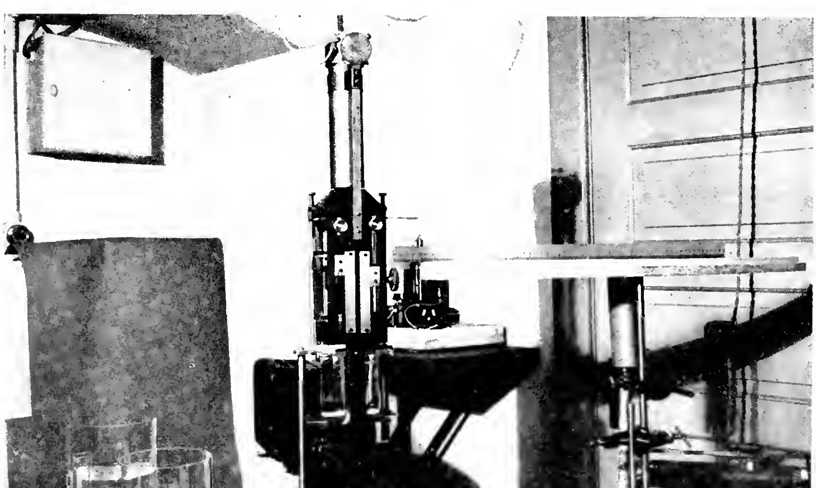
Yoe, John H.
1929. Photometric chemical analysis, vol. 2, pp. 1-66. New York, John Wiley & Sons, Inc.

Zacharewicz, Ed.
1895. Ueber den Einfluss der farbigen Lichtstrahlen auf die Kultur der Erdbeere. Biedermanns Central-Blatt, vol. 24, p. 495.



1. WATER BATHS IN WHICH THE FLASKS OF ALGAE ARE IMMERSED

Each flask of algae is enclosed in a container with a light filter on the bottom. Conditions of light, temperature, and humidity are controlled alike in all four baths.

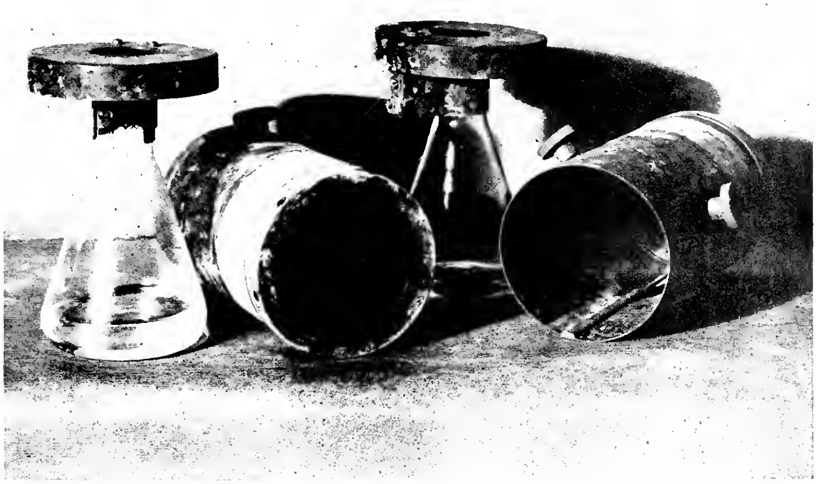


2. NEPHELOMETER EMPLOYED FOR QUANTITATIVE TRANSMISSION MEASUREMENTS TO DETERMINE THE COMPARATIVE AMOUNTS OF GROWTH OF ALGAE

A PHOTOMICROGRAPH OF A TYPICAL DROP FROM A DETMER 1/3 CULTURE OF STICHOCOCCUS BACILLARIS NAEGELI THAT HAS BEEN GROWING IN A NORTH WINDOW FOR ONE MONTH. X 250

1. FLASK IN WHICH THE CULTURE MEDIUM FOR ALL THE CULTURES WAS STERILIZED AND INOCULATED

The sterilized pipette was adjusted to the large container immediately before the culture was poured into the small Erlenmeyer flasks.



2. TWO CULTURE FLASKS READY TO BE INSERTED IN THE METAL CONTAINERS, EACH OF WHICH HAS A DIFFERENT COLOR FILTER ON THE BOTTOM

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 7

HERPETOLOGICAL COLLECTIONS FROM THE WEST INDIES MADE BY DR. PAUL BARTSCH UNDER THE WALTER RATHBONE BACON SCHOLARSHIP, 1928–1930

BY
DORIS M. COCHRAN
Assistant Curator, Division of Reptiles and Batrachians,
U.S. National Museum

(PUBLICATION 3259)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
OCTOBER 15, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

HERPETOLOGICAL COLLECTIONS FROM THE WEST INDIES MADE BY DR. PAUL BARTSCH UNDER THE WALTER RATHBONE BACON SCHOLARSHIP, 1928-1930

By DORIS M. COCHRAN

Assistant Curator, Division of Reptiles and Batrachians, U.S. National Museum

During 3 successive years, from 1928 to 1930, the Walter Rathbone Bacon Scholarship of the Smithsonian Institution was awarded to Dr. Paul Bartsch, of the United States National Museum, primarily for the extension of his studies of West Indian mollusks. In addition to obtaining vast series of mollusks, he was able to make valuable collections in many vertebrate groups, the lizards being of especial interest scientifically, as diagnoses of five new species and subspecies from his collection have already been published, and three other new species are being described in the present report.

In the first excursion Cuba was thoroughly worked for mollusks, and in addition nearly 100 amphibians and reptiles were obtained. On the second trip, in 1929, the party touched at Cuba and Puerto Rico, then continued eastward to the Virgin Islands and down the chain of the Lesser Antilles to Margarita and Orchilla and the Dutch Leeward Islands just north of Venezuela. Over 400 amphibians and reptiles were collected, many of them considerably extending the ranges of known species. The last expedition, in 1930, yielded nearly 600 specimens taken in the Bahamas, Cuba, and the Cayman Islands. Seven of the eight forms new to science came from this collection of 1930.

Class AMPHIBIA

Order SALIENTIA

Suborder LINGUATA

Family HYLIDAE

HYLA SEPTENTRIONALIS Boulenger

Hyla septentrionalis Boulenger, Cat. Batr. Sal., p. 368, 1882.

The only species of amphibian taken in the Bahamas by Dr. Bartsch is *Hyla septentrionalis*. It is exceedingly common in Acklins Island, 79 specimens, now U.S.N.M. nos. 81570-648, having been taken on Pinnacle Hill on July 9, 1930, and two others, nos. 81650-1 from Indian Wells on the same date. From Crooked Island we have two examples, no. 81490 from Land Rail Point, July 14, 1930, and no. 81491 from Pitch Point on the same date.

Pinnacle Point, Acklins Island.—While hunting for mollusks among the huge bromeliads I discovered a small frog. With careful searching of many plants we secured about 50 frogs of this species tucked away in the moist appressed basal portion of the leaves . . . . Our next stop was at Pinnacle Hill, where we made a careful search through the brush but found only a few specimens of a little brown Cerion, ... also two frogs.

Several examples were obtained in Cuba, as follows:

U.S.N.M. nos. 75751-2 from one-half mile south of La Guira Mansion, near San Diego de los Baños, Pinar del Río Province, Cuba, June 16, 1928; nos. 75791-2 from Baños San Vicente, Pinar del Río Province, Cuba, June 26-27, 1928; nos. 75817-24 from one-fourth mile northwest of Vega Alta, Santa Clara Province, Cuba, August 12, 1928; no. 75841 from Jumagua Hills, west of Sagua La Grande, Santa Clara Province, Cuba, August 1, 1928.

Jumagua Hills. At station 2 we caught a huge tree toad nestling in a cavity in a small tree which he completely filled and which he rendered flush, matching beautifully the color scheme.

Family BUFONIDAE

BUFO EMPUSUS (Cope)

Peltaphryne empusa Cope, Proc. Acad. Sci. Philadelphia, 1862, p. 344.

U.S.N.M. no. 75864 from Remedio, Santa Clara Province, Cuba, August 11, 1928.

BUFO MARINUS (Linnaeus)

Rana marina Linnaeus, Syst. Nat., ed. 10, vol. 1, p. 211, 1758.

U.S.N.M. nos. 78995-7 from Monserrat, July 28, 1929; nos. 79032-7 from Grand Terre, Guadeloupe, on July 30-31, 1929; nos. 79198-202 from Mineral Springs, northeast Grenada, August 27, 1929.

Family LEPTODACTYLIDAE

ELEUTHERODACTYLUS JOHNSTONEI Barbour

Eleutherodactylus johnstonei Barbour, Mem. Mus. Comp. Zoöl., vol. 44, no. 2, p. 249, 1914.

U.S.N.M. no. 79192 from the Annandale Estate, Grenada, August 25, 1929.

ELEUTHERODACTYLUS LOCUSTUS Schmidt

Eleutherodactylus locustus Schmidt, Ann. New York Acad. Sci., vol. 28, p. 174, 1920.

U.S.N.M. no. 78925 from El Yunque, Puerto Rico, June 27, 1929, I assign with some hesitation to the above species, the type of which I have not seen. The specimen in hand agrees with Schmidt's description except for the tympanum, which in the type is said to be " scarcely distinct, one-fourth the diameter of the eye ", while in the present specimen it is quite distinct and is over one-third the eye diameter. My specimen measures 21 mm from snout to vent. It is dark brown, with only faint traces of the dark interorbital band and some dark rhombic markings on the labial regions.

ELEUTHERODACTYLUS PORTORICENSIS Schmidt

Eleutherodactylus portoricensis Schmidt, Amer. Mus. Novit., no. 279, p. 2, 1927.

U.S.N.M. nos. 78923-4, an adult female with a number of hatching eggs taken at El Yunque, Puerto Rico, June 27, 1929:

> . . . . The strangest find was a frog—treetoad—with a mass of eggs in a rolled-up palm leaf, which she seemed to guard. The eggs were on the point of hatching and began at once, on being exposed, to vibrate, and yielded their young, which turned out to be not tadpoles but small jumping frogs. I gathered a number of these, as well as the parent.

This observation as to the egg mass being guarded by the female has been made by two collectors—by Gundlach (Peters, Monatsb. Akad. Wiss. Berlin, 1876(1877), p. 709) and by Bello y Espinosa (Martens, Zool. Garten, vol. 12, p. 351, 1871)—and the dates on which they found the developing eggs, May 24 and July 8, are borne out by the date of the present find, June 27.

LEPTODACTYLUS VALIDUS Garman

Leptodactylus validus Garman, Bull. Essex Inst., vol. 19, p. 14, 1887.

U.S.N.M. nos. 79068-75 from Brighton, St. Vincent, August 14, 1929; nos. 79076-7 from Mount St. Andrews, St. Vincent, August 15, 1929.

Family BRACHYCEPHALIDAE

PHYLLOBATES TRINITATIS Garman

Phyllobates trinitatis Garman, Bull. Essex Inst., vol. 19, p. 13, 1887.

U.S.N.M. nos. 79203-4, a half-grown specimen and tadpoles from the summit of a road leading north from Arima, Trinidad, September 1, 1929.

Class REPTILIA
Subclass DIAPSIDA
Order SQUAMATA
Suborder SAURIA
Family GEKKONIDAE

GYMNODACTYLUS ANTILLENSIS Lidth de Jeude

Gymnodactylus antillensis Lidth de Jeude, Notes Leyden Mus., vol. 9, p. 129. 1887.

U.S.N.M. no. 79225 from Bonaire Island, September 12, 1929; no. 79231 from Orchilla Island, September 10, 1929. The latter appears to be the first specimen of this species taken on Orchilla Island.

GONATODES ALBOGULARIS (Duméril and Bibron)

Gymnodactylus albogularis Duméril and Bibron, Erpét. Gén., vol. 3, p. 415, 1836.

U.S.N.M. no. 79952, a very young and somewhat damaged specimen from Otra Banda, near Red Sark, Curaçao, taken on September 17, 1929, shows a body pattern of four narrow white bands edged anteriorly with deep brown. The back of the head bears a broad U-shaped light mark, edged anteriorly and on the sides with brown. A few white dots appear on the upper labials.

PHYLLODACTYLUS PULCHER Gray

Phyllodactylus pulcher Gray, Spic. Zool., p. 3, 1830.

U.S.N.M. nos. 79256-7, two very young specimens from Bonaire Island, September 12, 1929; nos. 79315-6, two adults from Aruba Island, September 17, 1929.

HEMIDACTYLUS MABOUIA (Moreau de Jonnés)

Gecko mabouia Moreau de Jonnés, Bull. Soc. Philom., 1818, p. 138.

U.S.N.M. no. 75843 from Havana, Cuba, July 18, 1928.

THECADACTYLUS RAPICAUDUS (Houttuyn)

Gekko rapicauda Houttuyn, Verhandl. Zeeuwsch. Genoot. Wet. Vlissingen, vol. 9, p. 323, 1782.

U.S.N.M. no. 79132 from Carriacou Island, Grenadines, August 21, 1929.

ARISTELLIGER PRAESIGNIS (Hallowell)

Hemidactylus praesignis Hallowell, Proc. Acad. Nat. Sci. Philadelphia, 1856, p. 222.

Three geckos of this species were taken on Six Hill Cay off South Caicos on August 3, 1930, now U.S.N.M. nos. 81444-6. They do not differ essentially from the 16 Jamaican *praesignis* in the national collection. All the Caicos lizards have eight upper labials and seven lower labials. Their subdigital lamellae are really 20 to 21 in number, although only 13 to 16 of these are enlarged beyond the width of the surrounding granules. The largest specimen measures 72 mm from snout to beginning of tail; the tail itself has been partly reproduced, but now measures 86 mm.

These lizards were found by turning over rocks.

TARENTOLA CUBANA Gundlach and Peters

Tarentola cubana Gundlach and Peters, Monatsb. Akad. Wiss. Berlin, 1864, p. 384.

A young individual, U.S.N.M. no. 81721, was taken on Cachiboca Cay, Doce Leguas, Province of Camagüey, Cuba, on September 8, 1930 and a larger specimen, no. 81826, came from Puerto Portillo in the Province of Oriente, Cuba, on August 29, 1930.

SPHAERODACTYLUS ARGIVUS Garman

Sphaerodactylus argivus Garman, Bull. Essex Inst., vol. 20, p. 3, 1888.

U.S.N.M. nos. 81754-5 from Cayman Brac, September 11, 1930.

SPHAERODACTYLUS BARTSCHI, n. sp.

Diagnosis.—Dorsals keeled, imbricate, no differentiated middorsal zone; about nine dorsals in the standard distance between center of eye and tip of snout; lateral grooves more or less apparent on the rostral; faintly or distinctly spotted on the posterior part of body and on tail; sometimes a light dark-bordered stripe on each flank extending onto the tail; adult size rather small.

Type.—U.S.N.M. no. 81759, an adult male from Little Cayman Island, taken September 12-13, 1930.

Description of the type.—Snout moderately long but not very acutely pointed, its length two and one-half times the diameter of the eye; eye slightly nearer ear than tip of snout; rostral moderate, with a long median cleft behind, with merely a trace of lateral crescentic grooves; nostril between rostral, first supralabial, two postnasals (the upper the smaller) and a large supranasal which is separated from its fellow by a single small scale followed by another of about the same size; superciliary spine moderate in size; three large supralabials to a point below the center of the eye; a very large anterior infralabial, a smaller second and part of a third infralabial to the same point; top of head covered with granules which are relatively large, hexagonal, and very faintly keeled or smooth on the snout, more elongate and heavily keeled between the eyes, and much smaller but still distinctly keeled on the occiput; scales of back keeled, imbricate, nine in the distance between tip of snout and center of eye; no middorsal granular zone; laterals irregular, only slightly larger than dorsals, about seven to seven and a half lateral scales in the standard distance; mental a trifle longer than rostral, followed by two enlarged postmentals; scales of gular region small, slightly tubercular and indistinctly keeled only at the level of the commissure of the jaws, becoming smooth and imbricate on the throat; scales of chest and belly smooth, rounded, imbricate, about seven ventral scales to the standard distance, not perfectly regular in size; scales of limbs anteriorly and below like those of the belly, much smaller and granular posteriorly; 14 smooth lamellae under the fourth toe; scales of tail (reproduced) above keeled, imbricating, below smooth, enlarged transversely into a series of wide, rather irregular plates. A triangular "escutcheon" of differentiated scales about five scales long by nine wide, which projects only for a distance of one or two scales on the femur.

Dimensions.—Head and body, 25 mm; tail (reproduced), 21 mm; width of head, 5 mm; tip of snout to ear, 6.5 mm; foreleg, 7 mm; hind leg, 10 mm.

Coloration in alcohol.—Head drab, upper part of body mouse-gray, tail pale olive-buff; numerous sepia spots one scale in width beginning between the shoulders, indistinct on the anterior half of the back but becoming very apparent on the tail. Lower parts pale olive-buff, with very minute dark punctulations on the belly and on the posterior edges of the transversely enlarged plates beneath the tail. Fore limbs very indistinctly, hind limbs rather distinctly spotted above.

Paratypes.—Five specimens, a female (U.S.N.M. no. 81758), three males (nos. 81757, 81760, 81761) and a very young one (no. 81756) were taken at the same place and time as the type.

Variation.—In size of scales there is little variation, all of the adults having nine dorsals in the standard distance. The keels on the scales of the throat below the corner of the mouth are as distinct in two adults as they are in the type, but are less distinct in the other two examples. The crescentic grooves on the rostral are fairly well developed in two specimens, but are scarcely apparent in the others. In coloration, one male (no. 81760) most nearly resembles the type, although the spots are much less apparent. The other three specimens, including the female, have scarcely a trace of spotting, but there is a distinct dark-bordered light stripe on the flank beginning just anterior to the groin and continuing for some distance onto the tail. The very young specimen, unfortunately too mutilated to be of use in scale comparison, nevertheless shows these posterolateral light lines very plainly, as its body color tends toward sepia, instead of the pale drab or gray characteristic of the adults.

Relationships.—The new species agrees with *argus* and *caicosensis* in general in scalation as well as in having at least the traces of crescentic grooves on the rostral. It differs from *caicosensis* in having the throat scales entirely smooth, and from *argus* in having three instead of four supralabials to a point below the center of the eye, and from both these species in its much reduced pattern. It is interesting to note that the new species is not closely related to *argivus*, the only Sphaerodactyl heretofore known from the Cayman group, and which is apparently confined to Cayman Brac.

SPHAERODACTYLUS CAICOSENSIS, n. sp.

Diagnosis.—Dorsals imbricate, very heavily keeled, about 11 to the standard distance between tip of snout and eye; no differentiated middorsal zone; lateral crescentic grooves on rostral more or less apparent; throat scales keeled, at least laterally; female with dark stripes on head; body with dark irregular spots arranged transversely; flanks and tail with a dark light-edged stripe. Coloration of male unknown.

Type.—U.S.N.M. no. 81443, an adult female from South Caicos Island, Bahama Islands, July 29, 1930.

Description of the type.—Snout moderately short and broad, its length twice the diameter of the eye; eye slightly nearer ear than tip of snout; rostral large, with a median groove behind, bordered by faintly indicated crescentic grooves; nostril between rostral, an enlarged supranasal, a pair of postnasals of which the upper is the smaller, and the first supralabial; supranasals separated from each other by a single small scale; superciliary spine rather small; three subequal supralabials to a point below the center of the eye; a very large first infralabial and a much smaller second and third infralabial to the same point; top of head covered with keeled scales, larger and hexagonal on the snout, smaller and more elongate between the eyes, very small and nearly round on the occiput; scales of back small, very heavily keeled, imbricate, about 11 equalling the standard distance from snout to center of eye; no middorsal differentiated zone; laterals like the dorsals, 11 in the standard distance; mental moderately large, followed by two enlarged postmentals; scales of gular region small, smooth, not imbricate anteriorly, but becoming imbricate and decidedly keeled on the throat; scales of chest and belly smooth, rounded, imbricate, about 9 ventral scales to the standard distance, not perfectly regular in size; scales of limbs anteriorly and below like those of the belly, much smaller and granular posteriorly; 10 smooth lamellae under the fourth toe; scales of proximal part of tail above keeled, regular and obtusely pointed, on reproduced part smooth, irregular and rounded; below on the proximal part with a larger median and two smaller bordering rows of enlarged hexagonal scales, on the reproduced part with a median series of transversely enlarged plates, rather irregularly arranged.

Dimensions.—Head and body, 26 mm; tail (reproduced) 20 mm; width of head, 5 mm; tip of snout to ear, 7 mm; fore leg, 7 mm; hind leg, 9 mm.

Coloration in alcohol.—Female: body color above pinkish buff; head with a lateral sepia stripe beginning at the nostril, passing through the eye, widening behind the eye and passing upward to meet its fellow in a pair of diamond-shaped spots on the occiput; a dark median stripe beginning on the rostral, narrowing between the eyes, widening again and ending in a diamond-shaped spot on the posterior part of the head; traces of a dark stripe leading from the corner of the mouth onto the sides of the neck and then dorsally; back with numerous wide, dark, wavy crossbands which tend to break up posteriorly into very irregular transversely arranged spots; tail with a continuation of the posterior dorsal coloration; a wide, dark, light-edged stripe beginning on the flanks just anterior to the groin and continued onto the tail where there are traces of a dark line bordering it below; ventral surfaces pale olive-gray, suffused with very minute gray punctulations which are especially numerous on the posterior part of the belly and beneath the legs and tail; upper surfaces of limbs with alternating light and dark crossbars. The coloration of the male is not known.

Paratype.—A single paratype, U.S.N.M. no. 81447, also a female, was taken on Long Cay, off South Caicos, on the same day as the type. It is essentially the same in scalation, having 11 dorsals to the standard distance. Only the lateral scales of the throat of the paratype appear to be keeled; the central ones are smooth, like the gulars which precede them. There are nine lamellae on the fourth toe. The color pattern on the head is very similar to that of the type; the body however, is much paler because of the great reduction in the size and intensity of the spots. The lateral stripe on the flanks and tail is quite prominent.

Relationships.—This species falls in the key near to *corticolus* and *argus*. It differs from *corticolus*, however, in having the traces of crescentic grooves on the rostral, while its keeled throat scales serve to distinguish it from *argus*, as well as from *bartschi*, one of the other new forms described in this paper.

SPHAERODACTYLUS CINEREUS Wagler

Sphaerodactylus cinereus Wagler, Syst. Amph., p. 143. 1830.

U.S.N.M. nos. 81722-5 from the Cayo east of Boca Juan Gria, Camagüey Province, Cuba, September 8. 1930; nos. 81726-7 from Grande Cay, Doce Leguas, Camagüey, Cuba, September 9, 1930.

SPHAERODACTYLUS FESTUS Barbour

Sphaerodactylus festus Barbour, Proc. Biol. Soc. Washington, vol. 28, p. 13, 1915.

A young individual, apparently a female, U.S.N.M. no. 79061 from Diamond Hill, South Martinique, taken August 9, 1929, shows a characteristic pattern of light chevron-shaped markings across the back.

> I shot 16 lizards, mostly tree-climbing, but I got a small dark fellow under the muck and rubbish, probably a young one. . . . . Diamond Hill is a conical eminence rising quite abruptly to an elevation of 1,568 feet. It is rough and rocky near the summit, and in spots carries still a bit of woods. Very little of living stuff was found but we did get a splendid lot of muck and rubbish adding many things to our catch of yesterday.

SPHAERODACTYLUS MARIGUANAE, n. sp.

Diagnosis.—Dorsals imbricate, elongate, keeled; no differentiated middorsal zone; scales of middorsal region very slightly smaller than those of flanks, about 13 middorsals and about 11 dorsolateral scales in the standard distance between tip of snout and center of eye; supranasals large, normal, separated by one small scale; a more or less distinct crescentic groove on each side of median rostral groove; ventrals smooth; anterior gular scales faintly keeled; head relatively short and broad, body heavily built, size relatively large. Sexual dichromatism scarcely evident; males usually rather faintly spotted above, females somewhat more heavily spotted, both sexes with a more or less distinct light-centered, dark-edged nuchal crescent and several chevron-shaped bars across the tail.

Type.—U.S.N.M. no. 81381, an adult male from Booby Island, east of Mariguana Cay, Bahama Islands, taken July 21, 1930. Snout relatively short, its length only twice the diameter of the eye; eye slightly nearer ear than tip of snout; rostral large, with a median groove and a more or less distinct crescentic lateral groove; nostril between rostral, one large supranasal, two postnasals and the first supralabial; supranasals separated from each other by a single scale; superciliary spine moderate in size; three large supralabials to a point below the center of the eye, with a very small fourth one terminating the series; three infralabials to the same point, the first one very greatly enlarged, this series terminated likewise by a very small fourth scale; top of snout covered with keeled polygonal scales which decrease considerably in size between the eyes and become almost granular on the occiput, about 25 in a straight line across the head just anterior to the superciliary spine; scales of back small, keeled, imbricate, the middorsals slightly smaller than those of flanks; about 13 middorsals and about 11 dorsolaterals equalling the standard distance from tip of snout to center of eye; no middorsal granular zone; mental large, followed by two postmentals which are only slightly enlarged; scales of anterior gular region small, very faintly keeled, very slightly imbricate; scales of chest and belly smooth, rounded, imbricate; about 13 ventral scales to the standard distance, fairly regular in size; scales of limbs keeled above, smooth below, almost granular posteriorly; 14 smooth lamellae under the fourth toe; scales of tail above keeled, imbricating, below on the median line enlarged transversely into a series of irregular hexagonal plates; "escutcheon" of male prominent and wide, extending on the femur two-thirds of the distance to the knee, composed of thickened white scales in which traces of pigment appear only at the extreme posterior borders of those on the femur.

Dimensions.—Head and body, 38 mm; tail, 48 mm; width of head, 7 mm; tip of snout to ear, 9 mm; fore leg, 8.5 mm; hind leg, 11 mm.

Coloration in alcohol.—Upper parts fawn color with indistinct dorsal punctulations of sepia; a trace of a sepia-edged nuchal crescentic marking; tail with pronounced light chevrons edged with sepia, and with an interrupted lateral sepia stripe; top and side of head pale drab, immaculate; underparts pale olive-buff with very minute gray dots on the throat, and heavier dots below the thighs and on the edges of the enlarged plates beneath the tail; limbs immaculate, drab above, pale drab below.

Paratypes.—Seven specimens—three adult males (U.S.N.M. nos. 81379, 81380, and 81382), three females (nos. 81376-8) and a half-grown individual (no. 81383) were collected at the same time as the type. A field note follows:

One of the interesting finds of the day was a small, very dark brown, finely spotted lizard, probably a *Sphaerodactylus* of which we obtained eight specimens by quick work in turning over rocks and grabbing them before they could again slip under cover.

Variation.—The head scalation is similar in all the specimens, except in no. 81378, in which both supranasals are abnormally divided longitudinally, so that there are five subequal scales bordering the rostral between the nostrils, instead of an enlarged pair separated by a small scale, as in normal cases. The keels on the anterior gular region are faint but definite in all but one specimen, no. 81377; in this individual they are present on one or two transverse series of scales at the middle of the throat and must be looked for carefully even at that point. The crescentic grooves on the rostral plate are well marked in all the specimens but one (no. 81380). The number of dorsal scales in the standard distance varies between 11 and 13 depending on where the count is made; the middorsal scales are slightly smaller than those on the flanks, but not otherwise differentiated in any way. The ventral scales are likewise 11 to 13 in the standard distance, but are more irregular in size than the dorsals, so that different counts may be obtained by shifting a single scale-row in any direction.

As to color variation it appears that little if any sexual dichromatism appears in this species. Except for the nuchal crescent, three of the males are almost devoid of pattern, but so is the largest female. The fourth male has a definitely spotted and reticulated dorsum, intermediate between the remaining two females. The pattern is most highly developed in one of these females, no. 81377—there is a dark stripe beginning at the nostrils, passing through the eye and merging with the crescentic nuchal marks, here greatly elaborated. An anastomosing pattern of sepia lines covers the top of the head, and this is broken up on the body into an irregular series of spots and bars, which becomes more definite on the tail, where the crossbars have acquired light centers. The nuchal marking on some of the other specimens is not a true crescent; it may be represented by a pair of dark spots surrounded by an irregular indented parallelogram of dark lines. The dark stripe on the side of the head is apparent only in those specimens in which the pattern is well developed.

Relationships.—In the key this species falls near *oxyrhinus* and *argivus*, but differs from both of them in having the anterior gular scales faintly keeled, and even more radically in size and in color pattern. In fact, it cannot be said to be very close to any of the known species of the genus.

SPHAERODACTYLUS NOTATUS Baird

Sphaerodactylus notatus Baird, Proc. Acad. Nat. Sci. Philadelphia, 1858, p. 254.

A well-preserved male, U.S.N.M. no. 81270, from Mathewtown, Great Inagua, was collected on August 9, 1930. While Mathewtown is the type locality of the indigenous *Sphaerodactylus inaguae* Noble and Klingel, it is a port for West Indian shipping as well, and hence the occurrence of a form like *notatus*, known to be an inveterate traveler, is to be expected occasionally.

Another male, no. 81471, came from the cays adjacent to the South Channel cays of the Ragged Island group, collected on June 28, 1930.

In Cuba the species is rather common, as the following list will show:—U.S.N.M. nos. 81764-5 from the cay west of Channel, Havana Province, Cuba, September 20, 1930; nos. 81767-74 from Cayo Avillon, near Canapachi, Havana Province, Cuba, September 21, 1930; no. 81775 from the balconies of Cayo Contelos, Havana Province, Cuba, on the same date.

SPHAERODACTYLUS TORREI Barbour

Sphaerodactylus torrei Barbour, Mem. Mus. Comp. Zoöl., vol. 44, p. 260, 1914.

A banded female apparently referable to this species was collected at Rio Puerco in the Province of Oriente, Cuba, on August 29, 1930 (U.S.N.M. no. 81670).

A pair (U.S.N.M. nos. 81822-3) from Boqueron, Cuba, August 19, 1930, shows very well the sexual dichromatism occurring in this species. Unlike most vertebrates, in which the male shows the brilliant and spectacular coloring if such coloring is to appear at all in the species, it is the female of *Sphaerodactylus torrei* which is characterized by the brilliantly contrasting crossbands of black and yellow or red, while the male is without any trace of any such crossbands when fully adult, having at most only a spotting of irregular brown dots. In the case of the Boqueron male, the dorsal surfaces are a uniform dull drab without punctulations of any kind.

Another pair, U.S.N.M. nos. 81827-8, came from Puerto Portillo in Oriente Province, Cuba, August 29, 1930. In the female the characteristic pattern of bands appears as usual, but the male has a heavy spotting of coarse brown dots covering the entire dorsal surface from between the eyes to the beginning of the reproduced tail.

Two mutilated females, U.S.N.M. nos. 78921-2, from Rio Yaleritas, Oriente Province, are referred to this species also. They both are heavily crossbanded.

SPHAERODACTYLUS VINCENTI Boulenger

Sphaerodactylus vincenti Boulenger, Proc. Zool. Soc. London, 1891, p. 354.

A male, U.S.N.M. no. 79067, from Brighton, St. Vincent, August 14, 1929, measures 22 mm from snout to vent. It has a very distinct escutcheon of differentiated scales on the posterior surface of the abdomen. The epidermis covering this patch of differentiated scales in *Sphaerodactyli* is more opaque when drying than is the epidermis of the surrounding ventral parts. When the epidermis is removed, the differentiated scales appear coarser and thicker than do the ordinary ventral scales, and they are unpigmented and hence usually lighter in color than the other ventral scales.

Family IGUANIDAE

IGUANA IGUANA (Linnaeus)

Lacerta iguana Linnaeus, Syst. Nat. ed. 10, vol. 1, p. 206, 1758.

U.S.N.M. nos. 79211-6 from Los Robles, Margarita Island, September 8, 1929; no. 79229 from Orchilla Island, September 10, 1929; nos. 79321-2 from Aruba Island, September 17, 1929. In these examples there is a range of 46 to 58 in the number of enlarged scales in the dorsal crest, and the femoral pores are between 13 and 17. None of the individuals shows a tendency to have any of the median snout scales enlarged into the conical, soft tubercles which supposedly characterize the variety *rhinolopha*. The following color notes were made from living examples from Los Robles, Margarita Island, by Dr. Bartsch:

Head most intense green with a dark brown, almost black, spot on the middle of the top, another below and a third behind the eye, typanum gray. Neck green gold and striped with dark brown. Body green gold, marbled with white and almost black spotted. Comb warm red on neck, tending gradually toward green on the back. Underside of belly pale green spotted with various shades of brown. Dewlap faintly rose, edged with green and dotted and dashed with dark brown. Sides of body with zigzag, oblique bands of green, brown and white in the order mentioned, from the back forward. Scales of front legs green and brown, greener inside, with a whitish, greenish band on the shoulder, edged by dark dorsally. Hind legs like the front, whitish below. Tail green with broad bands of brown, usually edged with whitish or light brown on the posterior part, the light area being on the outer parts of the bands. The posterior half of the tail has alternating broad bands of light and dark brown.

DEIROPTYX BARTSCHI Cochran

Deiroptyx bartschi Cochran, Proc. Biol. Soc. Washington, vol. 41, p. 169, Oct. 15, 1928.

U.S.N.M. nos. 75797-806 from Baños San Vicente, Pinar del Río Province, Cuba, June 25, 1928; no. 75805 is the type of this species.

ANOLIS ACUTUS Hallowell

Anolis acutus Hallowell, Proc. Acad. Nat. Sci. Philadelphia, 1856, p. 228.

U.S.N.M. nos. 78929-39 from St. Croix, July 15, 1929.

ANOLIS ALLIACEUS Cope

Anolis alliaceus Cope, Proc. Acad. Nat. Sci. Philadelphia, 1864, p. 175.

U.S.N.M. nos. 79004-21 from Danes, east of Portsmouth, Dominica, August 4, 1929; nos. 79026-9 from East Cabrite Island, Dominica, taken on the same day.

ANOLIS ANGUSTICEPS Hallowell

Anolis angusticeps Hallowell, Proc. Acad. Nat. Sci. Philadelphia, 1856, p. 228.

U.S.N.M. no. 75816 from Sitio Perdido, Havana Province, Cuba, July 28, 1928.

ANOLIS ARGENTEOLUS Cope

Anolis (Gastrotropis) argenteolus Cope, Proc. Acad. Nat. Sci. Philadelphia, 1861, p. 213.

U.S.N.M. no. 81679 from the mouth of the Magdalena River, Oriente Province, Cuba, August 29, 1930; no. 81825 from Puerto Portillo, Province of Oriente, on the same date.

ANOLIS BIMACULATA Sparrman

Anolis (Lacerta) bimaculata Sparrman, Nya Handl. Sv. Vet. Akad. Stockholm, vol. 5, p. 169, 1874.

U.S.N.M. nos. 78981-7 from Mount Nevis, Nevis, July 27, 1929; nos. 78988-94 from St. Eustacius, July 25, 1929. Regarding the living coloration of this lizard on St. Eustacius the following color note has been drawn up from Dr. Bartsch's description: The top of the head in front of the eyes is peacock-blue, the larger scales with a pinkish flush that becomes intensified behind the eyes and on the temporal region. The pineal eye is gray brown. The side of the head anterior to the eyes is peacock-blue. The area about the eyes is intense, brilliant green. The top of the nape is blue with a pinkish flush. The main dorsal part of the body is yellowish green from the nape to the tail. This color extends from the base of the tail over the fore and hind legs, but these have a yellowish pink superimposed, which gradually fades into yellow-green on the belly. On the throat, and from there to the fore leg, are irregularly distributed spots of orange, the posterior portion being uniform in color. The inside of the legs corresponds in color with the belly. The posterior half of the upper side and the outside of the hind legs are marked with obscure spots of blue. An inch behind the base of the tail the same peacock-blue seen on the forehead reappears, slowly grading from the general dorsal color. The last 2 inches of the tail is pale brown. Here spots and splashes of dark brown, blue, and various shades of rose are irregularly scattered about. The median under part of the tail is a little paler than the ground color of the rest, and free from spots on the outer half, the posterior inch of the coarse, scaled portion being brown.

It may be noted here that the seven St. Eustacius lizards have a dark brown spot just above the white shoulder stripe. This is lacking in the 7 lizards from Nevis, but is slightly apparent in 12 from St. Kitts, according to the alcoholic specimens that I have examined. Color differences between the Nevis and St. Eustacius lizards were observed by Dr. Bartsch in the living animals, for in his field notes written after his excursion to Mount Nevis on July 27, he writes: " . . . . on the return I shot . . . a bunch of lizards—two kinds. The blue-green one is not so beautiful here as on St. Eustacius. I got one with two tails".

ANOLIS BONAIRENSIS Ruthven

Anolis bonairensis Ruthven, Occ. Pap. Mus. Zool. Univ. Michigan, no. 143, p. 4, July 9, 1923.

U.S.N.M. nos. 79258-70 from Bonaire Island, September 12-13, 1934. The gular fan of no. 79267 was primrose-yellow after having been preserved for 2 months.

ANOLIS BRUNNEUS (Cope)

Anolis principalis brunneus Cope, Proc. Acad. Nat. Sci. Philadelphia, 1864, p. 432.

Some scattered examples of this much disputed species were taken at the following places: U.S.N.M. nos. 81449-50 from Flamingo Cays of the Ragged Island Group on June 25, 1930; no. 81561 from Castle Island, south of Acklins Island, on July 8, 1930; no. 81649 from Pinnacle Hill, Acklins Island, on July 9, 1930; nos. 81525-27 from Cay Sal on June 17, 1930; nos. 81558-9 from Cotton Cay of the Cay Sal Group on June 23, 1930.

The lizards from the Cay Sal group have distinctly larger dorsal granules than do the others listed above. In other respects they seem to be very similar. An examination of the type of *Anolis brunneus*, or, lacking that, the careful study of topotypic material from Crooked Island must be made before a positive statement regarding the actual status of the species can be issued.

ANOLIS CONSPERSUS Garman

Anolis conspersus Garman, Proc. Amer. Philos. Soc., vol. 24, p. 273, 1887.

A good series, U.S.N.M. nos. 81732-41, was secured on Grand Cayman, September 15-16, 1930.

ANOLIS CRISTATELLUS Duméril and Bibron

Anolis cristatellus Duméril and Bibron, Erpét. Gén., vol. 4, p. 143, 1837.

U.S.N.M. nos. 78926-7 from Bordeaux Hill, St. John's, July 13, 1929, elevation 1,277 ft.; nos. 78940-8 from Bellevue Hill, Road Harbor, Tortola, July 17, 1929; nos. 78949-56 from Virgin Gorda, July 19, 1929.

ANOLIS EQUESTRIS Merrem

Anolis equestris Merrem, Syst. Amph., p. 45, 1820.

U.S.N.M. nos. 75811-5 from San Diego de los Baños, Pinar del Río Province, Cuba, June, 1928.

ANOLIS GENTILIS Garman

Anolis gentilis Garman, Bull. Essex Inst., vol. 19, p. 35, 1888.

U.S.N.M. nos. 79094-6 from Quatres Island, Grenadines, August 17, 1929; nos. 79106-7 from Mustique Island, Grenadines, same date; no. 79108 from Petit Nevis, same date; nos. 79109-10 from Petit Mustique, August 18, 1929; nos. 79113-7 from Baliceaux Island, August 18, 1929; nos. 79118-30 from Petit Martinique, August 21, 1929; nos. 79133-4 from Carriacou Island, same date; nos. 79150-1 from Frigate Island, August 22, 1929; nos. 79152-8 from Ronde Island, August 22, 1929; nos. 79159-60 from Caille Island, August 24, 1929; nos. 79162-5 from Diamond Island, August 23, 1929; no. 79196 from Mineral Springs, northeast Grenada, August 27, 1929.

A careful comparison of all these specimens with one of Garman's cotypes from Petit Martinique does not reveal any characters on which a different species could be based, and lizards from rather widely separated islands, such as Ronde and Mustique, appear to be identical in scalation.

ANOLIS GINGIVINUS Cope

Anolis gingivinus Cope, Proc. Acad. Nat. Sci. Philadelphia, 1864, p. 170.

U.S.N.M. nos. 78958-73 from St. Martin, July 22, 1929; nos. 78978-80 from St. Bartholomew, July 25, 1929.

ANOLIS HOMOLECHIS Boulenger

Anolis homolechis Boulenger, Cat. Lizards Brit. Mus., vol. 2, p. 28, 1885.

U.S.N.M. nos. 75766-70 from one-fourth mile south of La Guira Mansion near San Diego de los Baños, Pinar del Río Province, Cuba, June 16, 1928; nos. 75794-5 from Baños San Vicente, Pinar del Río Province, Cuba, June 25, 1928; no. 81655 from the north side of Guantanamo Bay, Cuba, August 14, 1930; nos. 81660-4 from Cusco Valley, Province of Guantanamo, Cuba, August 16, 1930; nos. 81675-7 from Rio Puerco, Province of Oriente, Cuba, August 29, 1930; no. 81686 from Cabo Cruz, Province of Oriente, Cuba, August 31, 1920; nos. 81817-20 from Boqueron, Oriente Province, Cuba, August 19, 1930.

ANOLIS LEACHII Duméril and Bibron

Anolis leachii Duméril and Bibron, Erpét. Gén., vol. 4, p. 153, 1837.

U.S.N.M. nos. 79030-1 from Grande Terre, Guadeloupe, July 30-31, 1929. This species differs noticeably from its relative *A. bimaculata* in having coarse scales on the occipital and temporal regions and coarser granules on the body. The weak ventral keels often seen in half grown examples of *A. leachii* are not found at any age in *A. bimaculata.*

ANOLIS LEUCOPHAEUS LEUCOPHAEUS (Garman)

Anolis leucophaeus Garman, Bull. Essex Inst., vol. 20, p. 109, 1888.

Between August 7 and 9, 1930, an excellent series of lizards of this species was collected on Great Inagua Island; U.S.N.M. nos. 81246-9 from a small islet in the center of Ocean Bight Bay, no. 81250 from Man of War Bay, nos. 81251-6 from Carmichael Point, nos. 81257-68 from Northwest Point, and no. 81269 from the vicinity of Mathewtown.

The ground color of the entire ventral surface of no. 81251 is canary-yellow, most intense on the hind legs and beginning of the tail, lightest on the chin. The skin of the gular fan is grayish wax-yellow, the scales on it being canary-yellow. The top of the head is lavender-gray, and the dorsal region is olive-buff, but the canary-yellow tone is found intermingled with the gray, especially on the limbs and tail, which are yellow above. The numerous black dots and splotches which are present all over the body excepting on the chin and on the lumbar region make a vivid and beautiful contrast to the soft yellowish tones of the ground color. The variation in pattern is great, however, and led Cope to give two names, *cinnamoneus* and *moorei*, to this Great Inagua lizard. There are sometimes pale brown stripes in the younger specimens, interspersed with a darker hue, the whole being overlaid with a fine dark reticulation. The underparts are olive-drab, and there are several longitudinal series of dark dots beginning on the labials and chin, and leading backwards to the sides of the neck. The number of subdigital lamellae on the third and fourth phalanges of the fourth toe vary from 19 to 25 in number. The supraorbitals are always in contact. The supraocular plates may be large or small, keeled or smooth. When large there are five or six. When small there may be as many as 11, of which 2 or 3 are conspicuously greater than the rest. The largest male, no. 81269, is 70 mm in length from snout to beginning of tail.

One example of *Anolis leucophaeus* Garman, now U.S.N.M. no. 81245, was collected on August 5, 1930, on Little Inagua Island. It is a half-grown male and cannot be distinguished from those on the larger neighboring island.

ANOLIS LEUCOPHAEUS ALBIPALPEBRALIS (Barbour)

Anolis albipalpebralis Barbour, Proc. Biol. Soc. Washington, vol. 29, p. 215, 1916.

From the Turks Island Group on July 31 and August 1, 1930, came a series of lizards, belonging to a species which Dr. Thomas Barbour described as *Anolis albipalpebralis* in 1916, but which he recently synonymized with *leucophaeus*,—U.S.N.M. no. 81285-9 from Long Cay; nos. 81290-8 (topotypes) from Grand Turks Island; nos. 81299-301 from Salt Cay; and no. 81302 from Cotton Cay of the Salt Cay group. None of the adults are as heavily spotted with black as are the adults from Great Inagua. The largest male, no. 81285, measures 74 mm from snout to beginning of tail. The skin and scales of the dewlap are olive-yellow posteriorly, becoming olive-gray anteriorly, where a small patch of the fan scales on either side is heavily dotted with slate color. The center of the throat and the malar region are ochraceous buff. The remainder of the ventral surface is olive-buff. The top of the head is light clay color and the upper surface of back, limbs, and tail are drab-gray, with a few indistinct sepia vermiculations on the nuchal region and behind the axilla. Some of the young and half-grown lizards show a distinct longitudinal striping of the back, consisting of a pale middorsal area and a double line of sepia on each side. Some show a light lateral stripe, which puts an abrupt termination to the clay color characteristic of the upper surfaces of the young lizards. Sometimes there are widely spaced square sepia spots down this middorsal light area, about six of them between occiput and tail, a suggestion of which we sometimes find in the young *leucophaeus* from Great Inagua.

The same subspecies appears again in the Caicos group, where the following localities are represented by lizards obtained from July 24 to August 4, 1930: U.S.N.M. nos. 81413-4 from French Cay; nos. 81415-28 from South Caicos; no. 81429 from Fort George Cay; nos. 81430-1 from Step Guano Cave on Cape Comete on East Caicos; no. 81432 from Pine Cay; 81433-7 from West Caicos; and nos. 81438-42 from Lorimer Creek on Grand Caicos. The largest male, no. 81419, measures 63 mm from snout to beginning of tail. The coloration of these Caicos lizards agrees with that of the neighboring Turks Island form, both being much paler than many of the Mariguana lizards, and much less spotted than the typical Inaguan form.

ANOLIS LEUCOPHAEUS MARIGUANAE Cochran

Anolis leucophaeus mariguanae Cochran, Journ. Washington Acad. Sci., vol. 21, no. 3, p. 40, Feb. 4, 1931.

Diagnosis.—Similar in form to *Anolis leucophaeus leucophaeus* (Garman), but differing from it in coloration. Ground color drab-gray above, lavender-gray beneath, often with a wide clove-brown lateral band which originates on the loreal region, passes through the eye and above the ear, and widens above the shoulder, continuing onto the base of the tail and gradually fading out; a light area usually bounding its lower border; a second dark lateral stripe beginning on the malar region just behind the mental, continuing back beneath the ear and merging in front of the shoulder with the upper lateral stripe in some cases, in other cases widening and suffusing the entire side of the throat and upper arm region with a dusky mottling; skin of gular fan lavender-gray, the scales white or olive-yellow. The young have dark latero-ventral reticulations, and the throat usually has a series of dark longitudinal lines. In adult males the tail fin is large and its upper edge is indistinctly mottled with dark in the region of the rays. Limbs sometimes unmarked, sometimes with wide, irregular dark bars. Scales on limbs a little smaller than in *leucophaeus* proper; scales of tail a little larger.

Type.—U.S.N.M. no. 81346, an adult male from Mariguana Cay, July 18, 1930.

Description of the type.—Top of head with two curving frontal ridges which enclose a shallow median depression; head scales very unequal in size, the small ones flat, the larger ones with a very indistinct ridge or keel; rostral low, much narrower than the mentals; four scales in a series between the nostrils; a median row of four or five transversely elongate scales on the prefrontal region, the last of which is in contact with the first scale of the supraorbital semicircle; supraocular disks composed of seven enlarged scales, the inner ones either in contact with the scales of the supraorbital semicircles or separated from them by an incomplete series of granular scales; supraorbital semicircles broadly in contact with each other, separated from the occipital by two very irregular series of scales; occipital a little smaller than the ear-opening; the scales of the occipital region considerably larger than the dorsals; canthus rostralis sharp, consisting of four elongated scales, the anterior small; superciliary ridge consisting of one long anterior scale followed by a double series of very small scales; three or four rows of granules separating the superciliaries from the supraocular disk; two medium-sized scales on the inner border of the elongate superciliary and just in front of the granules; loreal rows four, the scales keeled; subocular semicircles keeled, broadly in contact with the supralabials; supralabials eight or nine, the suture between the sixth and seventh being under the center of the eye; seven infralabials; temporals granular, with a bare indication of a supratemporal line; dorsals granular, keeled, with a median double series of slightly larger ones; ventrals imbricate, small posteriorly and with a very faint indication of a keel, larger anteriorly and with a somewhat more pronounced keel especially on the chest scales; those on the throat very small, rounded and elongate; fore legs above covered with sharply keeled scales, those on the upper arm as large as the posterior ventrals, those on the lower arm a little larger than the anterior ventrals; anterior face of femur and underside of tibia similarly covered, the scales of the former gradually decreasing on the underside, the upper side of both being covered with granules like those on the back; scales on fingers and toes sharply carinate; digital expansion moderate, about 22 lamellae on the second and third phalanges of the fourth toe; tail long, compressed, the proximal half with a high fin supported by about 14 bony rays; caudal verticils distinctly indicated by a vertical series of scales a little wider than those surrounding them and with straighter posterior margins, those between being pointed and narrower, in about seven irregular series, all imbricate and keeled; the scales covering the upper edge of the tail raised and slightly spinous, forming a serrated ridge, about five spines corresponding to each verticil in the basal portion; dewlap large, with distant series of scales, the anterior edge thickened; postanal scales well developed; a distinct nuchal and dorsal skin fold.

Dimensions.—Snout to beginning of tail, 54 mm; tail, 103 mm; snout to posterior border of ear, 18 mm; width of head, 11 mm; fore leg, 25 mm; hind leg, 48 mm.

Color (in alcohol).—Drab-gray above, lighter beneath; traces of a clove-brown lateral stripe beginning on the loreal region, continuing behind the eye over the ear to the shoulder region where it intensifies in hue, then widening and gradually fading out posteriorly; a second clove-brown stripe beginning on the malar region, continuing backward below the ear, and joining the upper stripe in front of the shoulder; upper parts of limbs and base of tail irregularly mottled with large clove-brown blotches; skin of gular fan lavender-gray, the scales white with a very fine powdering of minute black dots. Eyelid white, the inner edge dark clove-brown.

Paratypes.—U.S.N.M. nos. 81344-5 and 81347-50 from Mariguana Cay collected on July 18, 1930; nos. 81351-72 from Betsy Bay, Mariguana Cay, July 18-20, 1930; nos. 81373-5 from Booby Island, east of Mariguana Cay, July 21, 1930.

Variations.—Like its near relative *Anolis leucophaeus leucophaeus* from Inagua, and its more distant relative *A. cristatellus* from Puerto Rico and the Virgin Islands, the new subspecies is subject to considerable variation in the minor details of the head-plate arrangement, as well as in coloration. There may be only four scales between the nostrils, or twice that number. The supraocular disk may be in contact with the supraorbital semicircles, or separated by one or two rows of granules. The occipital may be set off from the supraorbital semicircles by two to four very irregular scales. The median transversely enlarged scales on the snout are often subdivided and scarcely enlarged, and may or may not touch the anterior supraorbitals. The color pattern is often much more distinct than it is in the type, especially in half-grown specimens. On the other hand, it may be obscured by a highly melanistic condition, in which the whole upper surface is suffused with blackish brown, extending even onto the ventral regions. Very rarely the whole body is pale drab.

Relationships.—The subspecies from Mariguana Island is more closely related to *leucophaeus albipalpebralis* than to the typical Inaguan *leucophaeus*, since the first two forms are without the leopard spots so characteristic of the last-named.

The two previously described forms seem to attain a larger size than the new subspecies, the largest individual of which is only 65 mm long from snout to vent, out of 33 examples. Several of the Inaguan and Turks Island lizards measure at least 70 mm, and appear to be heavier in structure, although the difference here is scarcely measurable. The Turks Island form is very light in color and does not have the broad dark lateral stripe which almost always appears on Mariguanan lizards.

The young of *leucophaeus mariguanae* are very similar to the adults, except that their colors are intensified. They have a very broad lateral stripe of black, set off at its lower margin by a narrow sepia lateral band. The middorsal area is chocolate-brown, with very few reticulations. The young of *leucophaeus albipalpebralis* have on the neck a few large light blotches edged with a fine dark line. A pale dorsal stripe is in some instances crossed by three or four large squarish blotches; in other cases these are much lightened, and the dark pigment is concentrated at the edges of the light stripe as two or more narrow lines. The young of typical *leucophaeus* are distinct from either of the others in having a very fine pattern of dark reticulations and spots all over the body and sides, which now have a light sepia tone, but which later in life fade to pale drab or olive-buff and leave the black spots standing out very markedly. Some of them have traces of four longitudinal light stripes separating slightly darker areas, and some have faintly delineated transverse dorsal blotches, but these are never so prominent as they are in the young from Turks Island.

ANOLIS LINEATUS Daudin

Anolis lineatus Daudin, Hist. Nat. Rept., vol. 4, p. 66, 1802.

U.S.N.M. nos. 79317-20 from Aruba Island, September 17, 1929. Two months afterward the gular fold of no. 79318, having retained its color in preserving fluid, was cadmium orange on the edges, turning to wax-yellow toward the throat, with several heavy black longitudinal stripes.

ANOLIS LUCIAE Garman

Anolis luciae Garman, Bull. Essex Inst., vol. 19, p. 44, 1887.

U.S.N.M. nos. 79062-5 from Mount Grenier, Santa Lucia, August 10, 1929.

ANOLIS LUCIUS Duméril and Bibron

Anolis lucius Duméril and Bibron, Erpét. Gén. vol. 4, p. 105, 1837.

U.S.N.M. nos. 75834-5 from El Salto de la Tinaga, Camagüey Province, Cuba, August 28, 1828; no. 75842 from Jumagua Hills, west of Sagua La Grande, Santa Clara Province, Cuba, August 2, 1928.

ANOLIS LUTEOSIGNIFER Garman

Anolis luteosignifer Garman, Bull. Essex Inst., vol. 20, p. 4, 1888.

One example, U.S.N.M. no. 81728, was taken on Cayman Brac, September 10, 1930.

ANOLIS MAYNARDII Garman

Anolis maynardii Garman, Bull. Essex Inst., vol. 20, p. 7, 1888.

Three lizards, U.S.N.M. nos. 81729-31 are from Little Cayman, taken September 12-13, 1930.

ANOLIS MESTREI Barbour and Ramsden

Anolis mestrei Barbour and Ramsden, Proc. Biol. Soc. Washington, vol. 29, p. 19, 1916.

U.S.N.M. no. 75796 from Baños San Vicente, Pinar del Río Province, Cuba, June 25, 1928; no. 75829 from El Rinconada, Sierra Camagua, Camagüey Province, Cuba, August 27, 1928; nos. 75832-3 and nos. 75836-7 from El Salto de la Tinaga, Camagüey Province, Cuba, August 28, 1928; no. 75838 from the Santa Cruz Mountains, Camagüey Province, Cuba, September 1, 1928.

ANOLIS ORDINATUS Cope

Anolis ordinatus Cope, Proc. Acad. Nat. Sci. Philadelphia, 1864, p. 175.

This species may be represented by the following examples: U.S.N.M. nos. 81528-32 from Cay Sal on June 17, 1930; nos. 81533-5 from Elbow Cay of the Cay Sal Group on June 19, 1930; nos. 81537-57 from Cotton Cay of the Cay Sal Group on June 23, 1930; no. 81474 from Knife Cay of the Ragged Island Group on June 28, 1930; no. 81480 from Margaret Island of the Ragged Island Group on July 2, 1930; nos. 81499-501 from Crooked Island on July 14, 1930.

The true status of this species is very doubtful and this identification is to be considered as provisional until specimens from all the places from which it is now recorded have been minutely compared.

ANOLIS PORCATUS Gray

Anolis porcatus Gray, Ann. Nat. Hist., vol. 5, p. 112, 1840.

U.S.N.M. nos. 75753-8 from one-fourth mile south of La Guira Mansion, near San Diego de los Baños, Pinar del Río Province, Cuba, June 16, 1928; no. 75825 from one-quarter mile northwest of Vega Alta, Cuba, August 12, 1928. To the last named specimen the following field note applies:

A heavy rain fell about 3:30 so we went under a cow shelter near a farmhouse. While waiting for the rain to stop we collected eight frogs [see 75817-24 *Hyla septentrionalis*] and one lizard under the eaves of this shelter.

ANOLIS PULCHELLUS Duméril and Bibron

Anolis pulchellus Duméril and Bibron, Erpét. Gén., vol. 4, p. 97, 1837.

U.S.N.M. no. 78957 from Virgin Gorda, July 19, 1929.

ANOLIS RICHARDII Duméril and Bibron

Anolis richardii Duméril and Bibron, Erpét. Gén., vol. 4, p. 141, 1837.

U.S.N.M. nos. 79090-3 from Admiralty Bay, Bequia Island, August 16, 1929; nos. 79135-8 from Carriacou Island, August 21, 1929; nos. 79139-46 from High Hill, about 2 miles east of Hillsborough, Big Carriacou Island, August 21, 1929; nos. 79167-89 from the Annandale Estate, Grenada, August 25, 1929; no. 79197, a young one taken at Mineral Springs, northeast Grenada, August 27, 1929.

A detailed comparison of the lizards from Bequia and Carriacou with specimens from Grenada, including one of the cotypes of *Anolis trossulus* Garman, makes it apparent that they are alike in every essential of scalation. If any valid color differences exist, they are not apparent in the material at hand.

ANOLIS ROQUET (Lacépède)

Lacerta roquet Lacépède, Hist. Nat. Quad. Ovip. Serp. vol. 1 (synopsis-méthod., div. 4), 1778.

U.S.N.M. nos. 79038-9 from High Mountains, Martinique, August 8, 1929; nos. 79040-55 from Diamond Hill, South Martinique, August 9, 1929; nos. 79056-9 from the north shore of Fort de France Harbor, Martinique, August 7, 1934. "Tree-climbing lizards".

ANOLIS SAGREI Duméril and Bibron

Anolis sagrei Duméril and Bibron, Erpét. Gén., vol. 4, p. 149, 1837.

U.S.N.M. nos. 75759-65 and nos. 75771-89 from one-fourth mile south of La Guira Mansion near San Diego de los Baños, Pinar del Río, Cuba, June 16, 1928; nos. 81690-4 from Palomito Cay, Oriente Province, Cuba, September 1, 1930; nos. 81695-6 from Blanco Cay, Camagüey Province, Cuba, September 6, 1930; nos. 81697-8 from Doce Leguas in Camagüey Province, Cuba, September 7, 1930; no. 81699 from Cachiboca Cay, Camagüey Province, Cuba, September 8, 1930; nos. 81762-3 from Sandy Cay, Cuba, September 19, 1930; no. 81824 from Puerto Portillo, Oriente Province, Cuba, August 29, 1930; no. 81891 from East Point, Second Cay, Cuba, September 19, 1930. A few weeks after being preserved, the gular skin of no. 75765 was burnt sienna, and the gular scales were light chrome-yellow; the dorsal light stripe was vinaceous-cinnamon, while the head, nuchal region, and shoulders were clove-brown. The sides of the body, as well as the limbs, were drab. The ventral surfaces were palely iridescent with blue, pink and green. In no. 75762, only the scales on the edge of the dewlap were chrome-yellow, the other gular scales being clove-brown like the gular skin itself.

ANOLIS STRATULUS Cope

Anolis stratulus Cope, Proc. Acad. Nat. Sci. Philadelphia, p. 209, 1861.

U.S.N.M. no. 78928 from Bordeaux Hill, St. John's, July 13, 1929; elevation 1,277 feet.

ANOLIS TERRAE-ALTAE Barbour

Anolis terrae-altae Barbour, Proc. Biol. Soc. Washington, vol. 28, p. 76, 1915.

U.S.N.M. nos. 78998-79001 from St. George (= Cabritt Island), Saints Islands, August 1, 1929; nos. 79002-3 from Mount Chameau, St. Peter, same date. A note with the St. George specimens states the dewlap was pale orange in life.

Since not all scientific collections may have examples of *Anolis leachii* (=*ferreus*) from Gaudeloupe, to which Barbour compared the Saints Island *A. terrae-altae* in his original diagnosis, it will not be amiss to include here a more detailed description of one of the six specimens of *A. terrae-altae* listed above:

An adult male, U.S.N.M. no. 79002, has the top of the head with two low diverging frontal ridges, disappearing before they reach the level of the nostrils and enclosing a feebly pronounced frontal hollow; head scales smooth, only the scales of the supraorbital disk showing faint keels; the distance between the anterior parts of the orbits very nearly equalling that from the orbit to the end of the snout; rostral low, slightly narrower than the mentals; four scales in a row between the narrow scales bordering each nostril above, the median pair somewhat enlarged; the median snout scales immediately behind these internasal scales in a single series, transversely enlarged; supraorbital semicircles composed of six or seven enlarged scales, the third the largest, the fourth and fifth separated from their fellows by a single row of small scales; occipital about two-thirds the size of the ear opening, separated from the supraorbital semicircles by two rows of scales rather irregular in shape; those posterior to the occipital more regular in shape and smaller than those in front of it; supraorbital disk composed of five polygonal, faintly keeled scales, narrowly separated from the semicircle by one row of granules, which in front of the disk form a patch of granules; canthus rostralis very sharp, consisting of three subequal elongated shields, merging with the superciliary ridge which also has three scales, of which the middle one is much the longest, the posterior one followed in turn by a double row of granules; five loreal rows; subocular semicircles keeled, widely in contact with the posterior supralabials; seven enlarged supralabials, the seventh under the center of the eye, followed by three or four granular labial scales; temporal granules a little larger than the dorsolaterals; a well-marked double series of small scales forming the supratemporal line; dorsal and lateral granules minute, tubercular; four or five median rows of slightly enlarged, keeled scales down the center of the back beginning on the nuchal region, continuing on the tail as a crest of considerably enlarged scales; ventral scales medium-sized, smooth, rectangular, those on the throat small and bluntly tuberculate; anterior face of fore and hind legs covered with large, weakly keeled scales much larger than the ventrals; scales covering the hands and feet above very faintly unicarinate; digital expansion wide, with about 24 lamellae under the second and third phalanges of the fourth toe, 39 under the entire toe; tail long, compressed, with very poorly-marked verticils of aligned scales; those between similar in size but not in alignment, in about five or six irregular rows, all imbricate, keeled and distinctly mucronate at the tips, surmounted by a strongly serrate edge of enlarged, keeled scales triangular in profile, four (sometimes three) to every verticil, the last of each group distinctly enlarged; dewlap with many closely set series of scales, whose posterior borders are projecting and mucronate; postanal plates large and well developed; a slight skin fold along the neck and back.

Dimensions.—Snout to vent, 59 mm; tail, 114 mm; orbit to tip of snout, 9.5 mm; orbit to orbit, 7 mm; snout to posterior ear, 19 mm; snout to center of eye, 12 mm; width of head, 11.5 mm; fore leg, 26 mm; hind leg, 42 mm; tibia, 15 mm.

Color in alcohol.—Entire head olive-buff; upper parts of body and limbs very pale immaculate glaucous-blue; lower surfaces and tail ecru-drab.

Variation.—The other specimen from St. Peter, U.S.N.M. no. 79003, a young female, differs slightly from the described specimen in having even weaker indications of keels on the supraocular disk, the supraocular semicircles mutually in contact for a short distance, larger preoccipital scales, and only one scale between the occipital and the semicircles.

The four specimens from St. George (Cabritt Island), U.S.N.M. nos. 78998-79001, an adult male and three young females, show a much browner cast of coloring. The male ranges from a wood-brown on the head to burnt umber and seal-brown on the back and sides, the tail dark fawn color, the throat and chest drab, the posterior underparts pale ecru-drab. One female, no. 79000, is almost the same in tone, while the other two are lighter. There is a faint suggestion of latero-ventral mottling on two of the females, but otherwise the lizards are immaculate.

ANOLIS VINCENTII Garman

Anolis vincentii Garman, Bull. Essex Inst., vol. 19, p. 46, 1887.

U.S.N.M. no. 79066 from Brighton, St. Vincent, August 14, 1929; nos. 79078-89 from Mount St. Andrews, St. Vincent, August 15, 1929.

NOROPS OPHIOLEPIS (Cope)

Anolis (*Dracontura*) *ophiolepis* Cope, Proc. Acad. Nat. Sci. Philadelphia, p. 211, 1861.

U.S.N.M. no. 75790 from one-fourth mile south of La Guira Mansion, near San Diego de los Baños, Pinar del Río Province, Cuba, June 16, 1928.

CYCLURA CARINATA CARINATA (Harlan)

Cyclura carinata Harlan, Journ. Acad. Philadelphia, vol. 4, p. 242, 1824.

An excellent series of nine lizards, U.S.N.M. nos. 81785-93, was collected on Long Cay of the Turks Island Group, on July 28, 1930; two more, nos. 81781-2, came from Long Cay south of South Caicos, July 29, 1930; another, no. 81783, from the west end of East Caicos on July 29, 1930; another, no. 81218, from Water Cay of the Fort George isles in the Caicos group on July 25, 1930; a series of 20, nos. 81219-33, nos. 81776-80, of all ages from Big Iguana Cay, East Caicos, July 28, 1930.

CYCLURA CARINATA BARTSCHI Cochran

Cyclura carinata bartschi Cochran, Journ. Washington Acad. Sci., vol. 21, no. 3, p. 39, Feb. 4, 1931.

Diagnosis.—Nasals broadly in contact with the rostral and with each other; a pair of supranasals also closely in contact with each other; the scales of the prefrontal region rather uniform in size and shape, and grading into the smaller frontal and parietal scales; supraorbital semicircles barely differentiated by an occasional somewhat enlarged scale; scales of the supraocular region distinctly smaller than the other upper head scutes; two to four enlarged vertical canthals on each side of the head; nuchal and caudal crests widely separated from the dorsal crest, which is 12 mm high (in adult males) and is composed of 60 to 73 spines (average in 6 specimens, 63.5); nuchal crest composed of 16 to 20 spines (average 17.1), the highest of which measures 15 mm; four vertical rows of small scales between the fifth and sixth verticils of the tail; eight supralabials (rarely nine) to a point below the center of the eye; rostral wider than the mental; three to four enlarged tibial scales equaling the vertical diameter of the tympanic membrane.

Type.—U.S.N.M. no. 81212 (collector's number 172), an adult male from Booby Cay, east of Mariguana Island, Bahamas, collected on July 21, 1930.

Description of the type.—Rostral wider than the mental and broadly in contact with the nasals, which are broadly in contact with each other; a pair of slightly enlarged triangular supranasals likewise in contact with each other, and lying in the angle behind the two nasals; no enlarged prefrontal, frontal or parietal scales; supraorbital semicircles barely differentiated by an occasional somewhat enlarged scale; scales of the supraocular region distinctly smaller than the other upper head scutes, with a very slight indication of a supraocular disk; occipital rather large and located well forward, surrounded by irregular scales which are smallest behind it and a little larger to the right and the left; all the scales of the head, except those on the snout, keeled but not tubercular; two or three enlarged, vertical canthals on each side of the head; a well-developed series of slightly keeled supraoculars carried back a little beyond the orbit; eight upper and nine lower labials to a point directly below the center of the eye; three or four rows of small scales separating the supralabials from the suboculars; no swollen scales in the temporal region, only a few slightly enlarged and spinose scales in front of the ear, and some enlarged smooth scales below the angle of the mouth; about two rows of faintly keeled scales separating the infralabials from the three or four rows of more heavily keeled malar scales; dorsal scales small, ventrals slightly larger; a nuchal crest composed of 16 spines, the longest of which measures 15 mm; a dorsal crest, completely separated from both nuchal and caudal crests, composed of 60 spines which are conspicuously uneven in basal width and in height, the longest of which measures 12 mm; the caudal crest low, the highest spine only 6 mm in length, every third spine being enlarged to correspond to the verticils of enlarged and highly spinose scales; four rows of small rectangular scales between the fifth and sixth verticils; upper surface of limbs with slightly imbricated, keeled, posteriorly pointed scales which are considerably larger than the body scales; on the upper arm about 9, on the lower arm about 7 of these scales to the vertical diameter of the tympanum; the scales on the outer tibia the largest, spinose, hexagonal, about four to the vertical diameter of the tympanic membrane; 18 and 20 femoral pores arranged in a single row; inner side of second toe with one comb, of third toe with two combs each consisting of three prominent and two small lobes; tail slightly compressed.

Color (in alcohol).—Head and scales of crest dull pea-green; skin of upper parts mouse-gray to dull olive-green with a very indistinct fine reticulation of lighter hue; skin of lower parts dull sage-green; under surfaces of feet and tail dark olive-buff.

Dimensions.—Head to posterior border of ear, 64 mm; width of head, 44 mm; vertical diameter of tympanum, 11 mm; head and body, 300 mm; tail (reproduced), 260 mm.

Variation.—There are five paratypes (U.S.N.M. nos. 87213-17), four of them adult females, and the fifth a very young one of indeterminate sex, all taken at the same time and place as the type specimen. The extreme variations are given in the specific diagnosis. In only one specimen do the nasals fail to touch; in this animal the inner border of each nasal plate is cut off by a suture, so that there are two small internasals abnormally formed. The femoral pores are rather low in number ranging between 16 and 20 in the present series, and averaging 17.9 for all. The only lizard with an approximately complete tail has a head and body length of 250 mm, the tail with tip missing measures 320 mm. The coloration in the adult females is much like that of the type. The young has a few light transverse dorsal saddles outlined with a darker tone.

Relationships.—The subspecies from Booby Cay is obviously a link between the typical *carinata* from Turks Island and *nuchalis* from Fortune Island. Booby Cay, east of Mariguana Cay, from which the new subspecies was collected, is just about midway between the other two type localities.

Cyclura carinata proper may be readily distinguished from *C. carinata bartschi* by a combination of several characters. True *carinata* has the nasals separated by a good-sized wedge-shaped scale; in *bartschi* the nasals are ordinarily in contact, agreeing in this respect with *nuchalis*. The new subspecies has as a rule more scale-rows between the caudal verticils, as well as larger tibial scales, more scales in the dorsal crest, and fewer supralabials than does the Turks Island form. Nevertheless, it is much closer to *carinata* than it is to *nuchalis* which has swollen enlarged scales on the snout and hence is at once separable from the other two forms under discussion.

We had been told upon inquiry all along Mariguana Cay that Booby Cay had iguanas upon it, and this information was confirmed, for shortly after our arrival we started off a huge fellow who went crashing through the brush and took refuge in a hole, for these iguanas den like rabbits and when pursued slip underground. We had made nooses of wire and tried to catch some of them alive, but the heavy weight of the animals quickly caused my copper wire to untwist at the loop and the old fellow went crashing through the brush scared by this new experience. Nye had a similar experience, only his wire parted at the stick and the iguana carried it off. I am afraid this will be a dead iguana, for I saw him choking. Further efforts to obtain these animals alive resulted in a waste of a great amount of time, and caused us to decide to give up this achievement. Later in the afternoon Chittick and Nye went iguana-hunting and secured four. I had shot one in the morning and we had caught a baby alive, which will give us six specimens for scientific study.

CYCLURA MACLEAYII Gray

Cyclura MacLeayii Gray, Cat. Lizards Brit. Mus., p. 190, 1845.

Examples of this handsome species are still fairly common on some of the cays, judging by the numbers brought back in recent collections. It is represented in the present collection by U.S.N.M. no. 81784 from Savilla Cay, Oriente Province, Cuba, September 4, 1930; nos. 81794-8 from Cabeza del Este, Caya Blanca, Doce Leguas, Cuba, September 8, 1930; nos. 81799-805 from Cachiboca Bay, Cuba, same date; no. 81806 from the cay east of Anclitos Cay, Cuba, September 8, 1930; no. 81810 from Cantilles Cay, Cuba, September 21, 1930, and no. 81811 from Mathias Cay, Cuba, September 22, 1930.

CYCLURA NUCHALIS Barbour and Noble

Cyclura nuchalis Barbour and Noble, Bull. Mus. Comp. Zoöl., vol. 60, p. 156, 1916.

Eleven examples of this interesting species (U.S.N.M. nos. 81234-44) were taken on Fish Cay of the Fortune Island Group on July 11, 1930. The number of spines in the dorsal crest ranges between 62 and 72, averaging 67.7. The nuchal crest has 15 to 19 spines, averaging 16.7, and these are irregular both in length and in basal width, as Barbour and Noble indicated. The femoral pores are numerous, running from 21 to 28, and averaging 24.7. On the distal part of the tail the verticils are not very distinct, but when they can be seen there are five rows of small scales separating them. The coloration of the adult male, U.S.N.M. no. 81239, is as follows: Ground color dull indigo-blue above lightening to glaucous blue beneath, with coarse reticulations of brick-red on the sides and back; posterior part of head indigo-blue, with the snout and frontal portions coral-red to rufous; the malar and labial scales orange chrome to coral-red, with a suggestion of these colors on the chin, which is mostly dull china-blue; nuchal spines pale olive-buff slightly tinged with flesh color; dorsal spines mostly light coral-red, with occasionally a dull china-blue one; tail light indigo, a few of the anterior caudal spines tinged with pink; upper surfaces of fore and hind feet black. The other adult specimens are similar in coloration, although they are not so bright in hue. A young specimen, no. 81242, is uniformly dull indigo, without any dorsal crossbands whatever or any indication of a reticulated pattern.

The largest specimen, no. 81239, measures 270 mm from snout to end of body; unfortunately its tail is reproduced. A smaller lizard measuring 215 mm in head and body has a complete tail 360 mm long. The young specimen already referred to is 140 mm from snout to vent.

We have been told repeatedly upon inquiring about iguanas that we would find them on Fish Cay, and so we did. We obtained a dozen good-sized specimens among the bushes by snaring them with string nooses on the end of a stick. We were considerably surprised, however, when we took them from our bag on board the ship to find that four of them were dead; evidently they have a way of committing suicide, similar to the ones we collected in the Gulf of California on Angel de la Guardia Island (*Sauromalus hispidus* now in the American Museum of Natural History). We have saved the eight remaining and hope to carry them through alive to Washington. Peters shot four more. The dead specimens I have injected with strong formalin-alcohol mixture and they have been put in alcohol. These iguanas are vegetable feeders. They are fairly tame and persisted in chasing the noose on the end of our sticks, instead of running their heads through them, or letting us place it around their necks. When hard pressed they finally dash into holes that look like huge sand crab burrows, or when near the coast, where there is a hurricane rampart, they seek refuge in the crevices of the rocks.

LEIOCEPHALUS CARINATUS CARINATUS (Gray)

Leiocephalus carinatus Gray, Philos. Mag., vol. 2, p. 208, 1837.

U.S.N.M. no. 75793 from Baños San Vicente, Pinar del Río Province, Cuba, June 21, 1928; no. 75810 from Puerta del Ancon, Pinar del Río Province, Cuba, June 29, 1928; no. 81658 from Macola Hill, Province of Guantanamo, Cuba, August 15, 1930; no. 81673 from Rio Puerco, Province of Oriente, August 30, 1930; no. 81687 from Cabo Cruz, Oriente, Cuba, August 31, 1930; nos. 81708-9 from

Doce Leguas, Camagüey Province, Cuba, September 7, 1930; no. 81710 from Grenada Cay, Doce Leguas, Cuba, September 9, 1930; nos. 81711-2 from Caballones, Doce Leguas, collected on the same day; nos. 81715-7 from Grande Cay, Doce Leguas, also on September 9, 1930; nos. 81742-9 from Cayman Brac, September 10 and 11, 1930.

At the present time it is not practicable to distinguish between the Cuban *carinatus* and the specimens listed below. A very detailed study of the variations of *carinatus* in Cuba will be necessary for an understanding of the status of the forms on some of the outlying islands.

These lizards came from cays in the Ragged Island Group as follows: U.S.N.M. nos. 81455-63 from Flamingo Cays on June 25, 1930; nos. 81465-70 from cays adjacent to South Channel Cays on June 28, 1930; nos. 81472-73 from Knife Cay on June 28, 1930; nos. 81476-78 from Johnson's Cay on July 2, 1930; no. 81479 from Double Breasted Cay on July 2, 1930.

Johnson's Cay.—We took a couple of lizards of the curled tailed type but the tail seems to be more spiny on the back than the previous type, but this may be pure imagination on my part.

As a matter of fact, the tail is very spiny in every adult specimen from all of the cays mentioned above. Those from Johnson's Cay, three in number, have an unusually enlarged middle supraocular, which appears to have come through the fusion of the third and fourth, or the second and third, as there is one less than the usual number of supraocular scales (six) found in specimens from the surrounding cays. A great many specimens from every cay will have to be studied before a definite decision as to the stability of this character can be made.

LEIOCEPHALUS CARINATUS PUNCTATUS Cochran

Leiocephalus carinatus punctatus Cochran, Journ. Washington Acad. Sci., vol. 21, no. 3, p. 39. Feb. 4, 1931.

Diagnosis.—Closely resembling the Cuban *Leiocephalus carinatus*, but differing from it in having a larger scale at the upper anterior region of the ear, as well as in possessing a more vivid color pattern with a somewhat different arrangement of light and dark pigment especially on the head.

Type.—U.S.N.M. no. 81560 (collector's no. 135) a male from the north shore of the bay at Jamaica Wells, Acklins Island, July 6, 1930.

Description of the Type.—Head shields large, the anterior smooth, the posterior very faintly ridged; four scales (an internasal and three prefrontals) in a line between the rostral and the beginning of the supraorbital ring; prefrontals and internasals embracing a partly discontinuous medial series of three scales, the first small and touching the rostral; the second prefrontal the largest, in contact with its fellow, separated from the canthals by a series of scales; two canthal scales, the second the larger, followed by five elongate superciliaries, the last one the smallest; six slightly ridged supraoculars, partially separated from the frontals by an incomplete series of small scales and from the superciliaries by two series except posteriorly where there is a single row; frontals moderate in size, mutually in contact along their entire inner borders; occipital small, with a small scale immediately following it, the two scales bordered on each side by two distinct parietals, the inner about half the size of the outer, which is about five times the area of the anterior occipital; an enlarged, heavily ridged scale at the outer posterior margin of the outer parietal; no other conspicuously enlarged post-parietals; five upper and five lower labials to a point below the center of the eye; malar scales large and conspicuous, the first two subequal and separated from the infralabials by a single row of scales; temporal scales small and mostly uniform in size, those just in front of the ear gradually enlarging, the upper one about three times as large as the surrounding scales; anterior border of the ear with five or six unequal projecting scales, the longest reaching one-third of the distance across the tympanum. Dorsal scales moderately large, imbricate, very slightly mucronate; laterals smaller than the dorsals, the gradation in size being very gradual; ventrals slightly smaller than the dorsals, smooth, their posterior borders slightly denticulate; about 61 dorsal scales from the occiput to a point directly above the vent; about 14 dorsal scales equivalent to the distance from snout to occiput; nuchal scales moderately small, those behind the ear and in the shoulder folds like the dorsals but very small; no lateral fold. The adpressed hind limb reaches to the center of the eye. Digits compressed, the fourth toe with 24 tricarinate lamellae, the scales on the upper surfaces of the limbs relatively small; a very distinct but low dorsal crest beginning at the occiput and continuing without interruption to the end of the tail, increasing on the posterior part of the body and becoming much higher on the tail; the caudal scales keeled and highly mucronate; no verticils; tail slightly compressed. The keels of the dorsals and laterals converge posteriorly. A pair of widely-separated and very inconspicuous postanals in the male.

Dimensions.—Snout to vent, 72 mm; head to posterior ear, 20 mm; tail (reproduced), 112 mm; fore leg, 28 mm; hind leg, 60 mm; width of head, 15 mm.

Color (in alcohol).—Body and limbs dull bottle green above, highly iridescent; top of head sepia, the supraocular region deep clove- brown;

a brilliant pattern of white spots on the prefrontals and frontals and a large white spot on the occipital; a white line beginning in front of the first supraocular and continuing backward on the outer edges of the supraoculars to the outer parietals, behind which the line widens and turns to an iridescent olive-green dorsolateral stripe, much invaded by darker pigment until it finally vanishes on the side of the tail; a similar much interrupted median dorsal line along the crest; a sepia lateral stripe beginning behind the eye, and widening and gradually losing itself about midbody; loreal region, lips, and anterior lower surfaces pea-green to sage-green; a faint sepia mottling on the throat; the posterior part of the body and under surfaces of hind legs lightening to olive-buff; some indistinct, transverse, lateroventral bars of pale china-blue, and a few small light spots of the same hue on the upper surfaces of the limbs; tail with alternate rings of sepia and white, widening distally.

Paratypes.—An excellent series of lizards of all sizes and ages was obtained on Acklins Island, U.S.N.M. nos. 81482-9 from the hills near Cornucopia taken on July 7, 1930, and no. 81481 from Jamaica Bay. From Castle Island, just south of Acklins came U.S.N.M. nos. 81562-9, taken July 8, 1930. The same form occurs on Crooked Island, for U.S.N.M. nos. 81492-6 were taken there on July 14, 1930.

Variation.—About the usual amount of variation is seen in the head plates of this new form. The second pair of prefrontals is usually larger than the others, and in broad contact, although sometimes the presence of an unusually large median snout scale prevents much contact. The frontals and supraoculars may be fully separated by a complete series of small scales, or this series may be much reduced and interrupted. As to coloration, the light longitudinal stripes are usually in evidence, while the dark head with the contrasting brillance of the light markings is an almost invariable condition. The females resemble the males in color. The very young ones, however, do not show such a definite pattern. U.S.N.M. nos. 81488 and 81489, respectively 36 mm and 32 mm snout to anus, have the top of the head drab-gray, with small sepia dots scattered uniformly over the head plates. The body likewise is drab-gray, with the light longitudinal lines plainly showing, and the dorsal region and upper limb surfaces are spotted with sepia, like the head. The throats of most of the adults have dark narrow lines converging anteriorly; in the type this pattern is greatly obscured and interrupted by the numerous very light-colored scales, which tend to form short transverse groups of three or four scales all over the throat and chest regions. One very old male, no. 81481 measuring 105 mm, has lost practically all traces of color pattern. Its scales are much more mucronate than is the case in other smaller ones, even the ventrals being angulate and bristling.

Relationships.—As one might expect, the new form is very closely related to the Cuban *carinatus*. The coloration is the most obvious distinguishing feature, but close examination reveals the fact that the scale above the ear is usually prominent in the Acklins and Crooked Island forms, while in the Cuban lizard it is seldom enlarged at all. The malar scales of the new subspecies are larger also, while the first two pairs are especially well marked and nearly square in shape. The Cuban form has shorter anterior malars. The scales on the upper surfaces of the limbs in the new form seem to be slightly smaller and less continuously keeled than in the Cuban lizard, although this feature is very difficult to express by scale counts. The similarities of the two forms outweigh these minor differences, and it is perferable to bestow only a trinomial on the new lizard until further study can be made of the typical *carinatus* from Cuba.

LEIOCEPHALUS CUBENSIS (Gray)

Tropidurus (*Leiolaemus*) *cubensis* Gray, Ann. Nat. Hist., vol. 5, p. 110, Apr., 1840.

U.S.N.M. no. 75831 from El Salto de la Tinaga, Camagüey Province, Cuba, August 28, 1928.

LEIOCEPHALUS INAGUAE Cochran

Liocephalus schreibersii (not of Gravenhorst) Garman, Bull. Essex Inst., vol. 20, p. 110, 1888; extr. p. 10 (Inagua, Bahamas).—Barbour, Mem. Mus. Comp. Zoöl., vol. 44, no. 2, p. 301 (part), 1914.

Liocephalus sp. Cope, Proc. Acad. Nat. Sci. Philadelphia, 1894 (1895), p. 436 (probably *L. schreibersii* Great Inagua).

Leiocephalus inaguae Cochran, Journ. Washington Acad. Sci., vol. 21, no. 3, p. 38, Feb. 4, 1931.—Noble, Amer. Mus. Novit., 549, p. 18, Aug. 11, 1932.

Since Garman concluded that the lizards from Inagua Island were identical with those from Hispaniola described by Gravenhorst as *Pristinotus schreibersii*, no fresh material had come under the observation of a student of West Indian herpetology until Dr. Bartsch brought back a large and well-preserved collection of *Leiocephali* from Inagua, an examination of which left no doubt whatever that the species merits full recognition and separation from the neighboring forms found on Hispaniola, Cuba, and the Bahama Islands.

Diagnosis.—A distinct lateral fold; four scales (an internasal and three prefrontals) between the rostral and the supraorbital ring; the second prefrontal large and in contact with its fellow; body scales moderately large, 70 to 82 dorsals between occiput and beginning of tail, 16 to 20 in the distance between end of snout and occiput; males with a row of large squarish black blotches on the shoulder region continuing down the sides and fading out rapidly; faint traces of two more rows of squarish blotches on the back.

Type.—U.S.N.M. no. 81277, an adult male from Man of War Bay, Great Inagua Island, collected on August 8, 1930.

Description of the type.—Head shields large, slightly ridged excepting those which border the rostral; four scales (an internasal and three prefrontals) in a line between the rostral and the beginning of the supraorbital ring; prefrontals and internasals embracing a partly discontinuous medial series of three scales, the first small and not touching the rostral; prefrontals separated from the canthals by a series of rather small scales; two canthal scales, the second much the larger, followed by four superciliaries, the third the longest, the last two rather small; seven bluntly ridged supraoculars, separated from the frontals by a single row of keeled scales and from the superciliaries by two rows of scales except posteriorly where there is a single row; frontals moderate in size, mutually in contact along their entire inner borders; occipital small, bordered on each side by two distinct parietals, the inner about half the size of the outer, which is about three times the size of the occipital; a transverse series of about eight postparietal scales, smallest at the nape, enlarging and becoming ridged and tubercular laterally, the outermost one lying along the posterior border of the outer parietal and nearly as large as the occipital; four upper and five lower labials to a point below the center of the eye; temporal scales rather uniform in size, those above the ear not enlarged; anterior border of the ear with three unequal projecting scales, the longest reaching one-third of the distance across the tympanum; dorsal scales moderately large, imbricate, mucronate; laterals very much smaller than the dorsals, the gradation in size being rather rapid; ventrals very slightly smaller than the dorsals, smooth, their posterior borders scarcely denticulate; about 70 dorsal scales from the occiput to a point directly above the vent; about 16 dorsal scales equivalent to the distance from snout to occiput; nuchal scales moderately small, those behind the ear very minute and sharply tubercular; those in the shoulder folds keeled like the dorsals but small; a distinct lateral fold present. The adpressed hind limb reaches to the anterior corner of the eye. Digits compressed, the fourth toe with 25 tricarinate lamellae. A very distinct dorsal crest beginning at the occiput and continuing unbroken to the end of the tail, increasing slightly on the posterior part of the body and highest on the distal half of the tail; the caudal scales keeled and mucronate; no verticils; tail compressed. The keels of the dorsals and of the laterals are directed backward and slightly upward, so that the rows of scales converge slightly. There are about 20 longitudinal rows of dorsals across the back. A transverse series of six conspicuously enlarged postanals in the male.

Dimensions.—Snout to vent, 83 mm; head to posterior ear, 22 mm; tail, 142 mm; fore leg, 37 mm; hind leg, 75 mm; width of head, 15 mm.

Color (in alcohol).—Body color olive-buff, the dorsal scales with a metallic greenish iridescence; a lateral series of about nine large, rectangular black spots, beginning behind the ear and continuing to above the groin, the posterior ones becoming much lighter; those behind the arm bordered above by traces of a scarlet vermilion stripe; from the lower borders of these spots issue narrow transverse bands of scarlet vermilion with pale blue scales scattered regularly in them; these transverse bands becoming very light towards the center of the belly and finally fading out; traces of paired dark spots down the back; head immaculate above; upper and lower labials with vertical pearl-gray markings on the sutures of the scales; throat with longitudinal pearl-gray broken stripes, which become much darker on the sides of the neck and are nearly black beneath the ear; fore legs faintly barred with pearl-gray; hind legs irregularly barred with scarlet vermilion, pale blue and olive-buff; tail with faint widely spaced bars of pale gray above, immaculate below. Posterior femur with a broad white stripe bordered by scarlet vermilion above and below.

Paratypes.—In addition to the specimen designated as the type, I have examined 13 paratypes from Great Inagua Island, as follows:—U.S.N.M. no. 81278, an adult female from Carmichael Point, August 7, 1930; no. 81256, a very young male from the same locality; no. 81279, an adult male from the center of Ocean Bight Bay; no. 81280, an adult male from the northeast peninsula, August 6, 1930; no. 81281, a young female from Northwest Point, August 8, 1930; and nos. 81282-4, an adult male and two young females from Mathewtown, August 9-10, 1930. I have likewise examined a fine series of five males, Mus. Comp. Zoöl. no. 6234 labeled simply "Inagua". These are the specimens to which Garman erroneously applied the name *schreibersii*.

Variations.—In the series of 14 specimens, the canthals and prefrontals do not touch in any instance. The supraocular plates vary from six to eight in number, six being unusual, eight fairly frequent, and seven the most frequent. There are always three prefrontals, the second of which is usually the largest. In one case the internasals are transversely divided. The median snout scales are three to six in number; when more than three are present, it is usually because one or more of the original series has longitudinally divided. The first of the series are usually in contact, but the third is usually separated from the second by the second prefrontals which are in contact. There are 70 to 82 dorsal scales between the occiput and the beginning of the tail, and from 16 to 20 dorsals in the distance from snout to the occiput. The adpressed hind leg reaches to the center of the eye or to its anterior corner in adults; in the very young male it reaches nearly to the nostril. The subdigital lamellae of the fourth toe number from 25 to 29. The tail when perfect is about one and three-quarters times the length of the head and body.

In coloration the variation between the sexes is at once apparent. The males have the very distinct square black patches on the shoulder region, with a sudden diminution in the intensity of these blotches both dorsally and posteriorly, so that they can hardly be discerned. The females, on the contrary, lack the black color entirely, the four rows of quadrangular blotches on back and sides being uniformly sepia, as are the transverse latero-ventral stripes, which in the males are so handsomely edged with scarlet vermilion. The very young male has a brilliant pattern of black blotches which appears even on the tail as widely spaced bars; on the middle of the back, however, the blotches are already beginning to lose their intensity and fade out gradually.

Dr. Noble has given additional notes on color and habits in his recent paper.

Relationships.—From the West Indian islands five species of *Leiocephalus* with a lateral fold have been described up to the present time. They are *schreibersii* and *melanochlorus* from Hispaniola, *raviceps* and *macropus* from Cuba, and *loxogrammus* from Rum Cay in the Bahamas. The new species from Great Inagua Island makes the sixth belonging to this group. It is intermediate in the size of its scales between *melanochlorus*, the largest-scaled species, and the other four known species, all of which have rather small scales. In coloration it suggests *loxogrammus* somewhat in the presence of the black blotches on the sides of the neck, but otherwise the patterns are not alike. It is true that *melanochlorus* has four sets of blotches on back and sides, as does *inaguae*, but in adult males of the former species those above the shoulder are not more prominent than those elsewhere on the body.

The prefrontals of *loxogrammus* are vastly different from those of the new species—the prefrontals of *loxogrammus* being only two in number, the posterior ones very large and elongate. Practically this same arrangement is found in *raviceps* of Cuba. In *macropus* of

Cuba, and *schreibersii* and *melanochlorus* of Hispaniola, the prefrontals, while three in number, are relatively small and uniform in size and as a rule are completely, or nearly completely, separated by the median series of scales on the snout. In *inaguae*, the second prefrontals are prominent, fairly large and usually in contact with each other.

LEIOCEPHALUS MACROPUS Cope

Liocephalus macropus Cope, Proc. Acad. Sci. Philadelphia, 1862, p. 184.

U.S.N.M. nos. 81671-2 and no. 81674 were collected at Rio Puerco, Province of Oriente, Cuba, on August 29 and 30, 1930; no. 81680 at the mouth of the Magdalena River in Oriente on August 29, 1930; nos. 81681-4 from Punta Icacos, Oriente Province, on August 30, 1930; nos. 81688-9 from Cabo Cruz on August 31, 1930.

LEIOCEPHALUS PSAMMODROMUS Barbour

Leiocephalus psammodromus Barbour, Copeia, vol. 85, p. 73, 1920.

Two series of almost topotypic lizards were collected in the Turks Island Group—U.S.N.M. nos. 81303-28 from Long Cay, August 1, 1930 and nos. 81329-43 from Sand Cay, August 2, 1930.

Several localities from the neighboring Caicos Group yielded the following specimens: U.S.N.M. nos. 81384-7 from Fort George Cay on July 24, 1930; nos. 81388-92 from Stubb Cay, Fort George Group, on July 25, 1930; nos. 81393-6 from Water Cay, Fort George Group, on July 24, 1930; nos. 81397-8 from Pine Cay on July 24, 1930; nos. 81399-409 from Long Cay near South Caicos on July 29, 1930; nos. 81410-11 from Lorimer Creek on Grand Caicos on July 26, 1930; no. 81412 from Sugar Loaf Island of the Providentiales Group on August 4, 1930.

On all the cays (Pine Cay, Water Cay, Fort George Cay) we found lizards and wherever possible secured specimens. There is a ground species that partly curls its tail, probably a relative of the curled tail lizard.

LEIOCEPHALUS RAVICEPS Cope

Liocephalus raviceps Cope, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 183.

As late as the publication of Barbour's "Herpetology of Cuba" in 1919, the scarcity of this species in collections made its distribution in Cuba a matter of uncertainty. Since that date, however, the species has been collected rather abundantly, and the following records of it for this particular collection are: U.S.N.M. nos. 81652-3 from the north side of Guantanamo Bay, Cuba, August 14, 1930; nos. 81656-7 from Macola Hill in Guantanamo Province, Cuba, August 15, 1930; no. 81659 from Cusco Valley in Guantanamo Province, Cuba, August 16, 1930; nos. 81713-4 from Cayo west of Cachiboca, Doce Leguas, Province of Camagüey, Cuba, September 8, 1930; and 81812-6 from Boqueron, Cuba, August 19, 1930.

The examination of the prefrontal scales makes this species rather easy to tell apart from the other three members of the genus likewise occurring on Cuba. *Leiocephalus raviceps* has two prefrontals between the internasal and the supraorbital semicircle—the anterior prefrontal small, the posterior considerably enlarged— while the other Cuban species have three more or less subequal prefrontals.

LEIOCEPHALUS VARIUS Garman

Liocephalus varius Garman, Proc. Amer. Philos. Soc., vol. 24, p. 274, 1887.

U.S.N.M. nos. 81750-3 from Grand Cayman, September 15 and 16, 1930.

TROPIDURUS TORQUATUS HISPIDUS (Spix)

Agama hispida Spix, Spec. Novae Lacert. Bras., p. 12, 1825.

U.S.N.M. nos. 79205-10 from the hill east of Pampater, Margarita Island, September 8, 1929; no. 79228 from Los Robles, Margarita Island, same day. The scales of the hands and feet appear to be elongated into spines to a much greater extent in the Margarita Island lizards than is the case in Venezuelan representatives, supposedly of the same subspecies. A very thorough generic revision is necessary before deciding how much weight can be attached to such a character in a genus subject to considerable specific variations as to structure of scales.

TROPIDODACTYLUS ONCA (O'Shaughnessy)

Norops onca O'Shaughnessy, Ann. Mag. Nat. Hist., Ser. 4, vol. 15 p. 280, 1875.

U.S.N.M. nos. 79226-7 from Los Robles, Margarita Island, September 8, 1929.

The larger of these two specimens has been compared with the types in the British Museum by H. W. Parker. He thinks that they are the same, although he notes that in both type specimens the scales of the sides are subimbricate and rather more lanceolate than in the United States National Museum example.

Family ANGUIDAE

CELESTUS SAGRAEI (Cocteau)

Diploglossus sagrae Cocteau, in R. de la Sagra, Hist. Cuba, Rept., p. 180, 1838.

U.S.N.M. no. 75840 from Senado, Camagüey Province, Cuba, September 2, 1928.

Family TEIIDAE

AMEIVA AQUILINA Garman

Ameiva aquilina Garman, Bull. Essex Inst., vol. 19, p. 3, 1887.

U.S.N.M. nos. 79111-2 from Petit Mustique Island, Grenadines, August 18, 1929; nos. 79147-9 from Frigate Island, Grenadines, August 22, 1929; nos. 79194-5 from Mineral Springs, northeast Grenada, August 27, 1929. In their "Revision of the Lizards of the Genus Ameiva" in 1915, Barbour and Noble say regarding this species that "it is probable that it also occurs in some of the Grenadines". This prediction is justified by the first two records given above. Comparative measurements and scale counts of all these specimens, including three additional Grenada specimens in the national collection, have been made as follows:

U. S. N. M. No.	Locality	Head and body	Ventrals		Femoral pores	Tail at 15th verticil	Lamellae under 4th toe
			Transverse	Longitudinal			
		mm	*Rows*	*Rows*		*Scale rows*	
43222	Grenada	88	32	10+2	20-20	40	37
43223	"	73	32	10+2	18-17	41	37
67234	"	62	33	10+2	18-18	41	36
79194	"	77	32	10+2	18-19	38	36
79195	"	82	32	10+2	17-17	41	35
79111	Petit Mustique Island	138	35	12	19-20	46	36
79112	"	129	35	10+2	20-21	42	37
79147	Frigate Island	139	33	10+2	20-21	43	33
79148	"	133	32	10+2	20-21	45	35
79149	"	150	33	10+2	21-21	44	34

The two adults from Petit Mustique Island show a pattern of relatively large pale dorsal spots surrounded by a heavy black reticulation, while the adults from Frigate Islands have the pale spots somewhat smaller and more sparsely scattered, and the black pigment is reduced to a narrow rim around the light spots and to some small patches between them and along the middle of the back.

Although the number of transverse rows of ventrals was given as 14 by Garman, and this count was later repeated by Barbour and Noble, I find only 10 rows of uniform-sized scales flanked by a row of much smaller scales at each side in most of the specimens before me.

Dr. Bartsch gives the following note on living coloration of the Petit Mustique lizards:

Punctations on sides greenish yellow; head, etc., marbled with brown streaks. Throat gray. Belly bright peacock-blue, most intense on the under side of tail. Upper side of tail dark, variegated.

AMEIVA AUBERI Cocteau

Ameiva auberi Cocteau, in R. de la Sagra, Hist. Cuba, Rept., p. 74, 1838.

Examples of this lizard are U.S.N.M. no. 81654 from the north side of Guantanamo Bay, Cuba, obtained August 14, 1930; nos. 81665-7 from Cusco Valley in the province of Guantanamo, Cuba, August 16, 1930; no. 81678 from Rio Puerco in Oriente, Cuba, August 29, 1930; no. 81700 from Doce Leguas, cay at longitude 78° 33′ W. on September 7, 1930; nos. 81701-3 from the southeast end of Doce Leguas, Cuba, on the same date; 81704 from Doce Leguas on September 8, 1930; nos. 81705-6 from Pilot Point on Anclitos Bay, Doce Leguas, on September 9, 1930; no. 81707 from Caballones, Doce Leguas, on the same day; nos. 81718-9 from Mathias Cays on September 22, 1930; no. 81766 from Cayo Avillon near Canapachi on September 21, 1930; no. 81821 from Boqueron, Cuba, on August 19, 1930.

AMEIVA FUSCATA Garman

Ameiva fuscata Garman, Bull. Mus. Comp. Zoöl., vol. 19, p. 5, 1887.

U.S.N.M. no. 79023 from Danes, east of Portsmouth, Dominica, August 4, 1929; no. 79024 from the Botanic Gardens in Rousseau, Dominica, August 6, 1929.

AMEIVA MAYNARDII MAYNARDII (Garman)

Ameiva maynardii Garman, Bull. Essex Inst., vol. 20, p. 10, 1888.

Four lizards belonging to this species were taken from August 7 to 10, 1930, on Great Inagua Island,—U.S.N.M. nos. 81271-2 from Mathewtown, and 81275-6 from Man of War Bay.

The scale formulae for these lizards are very similar. The femoral pores vary between 10 and 14; the subdigital lamellae are 34 to 39; the tail at the fifteenth verticil has in every case 23 rows of scales; the transverse rows of ventrals number 33 to 35, and the longitudinal rows are 8 in all cases.

AMEIVA MAYNARDII UNIFORMIS Noble and Klingel.

Ameiva maynardii uniformis Noble and Klingel, Amer. Mus. Novit. no. 549, p. 23, 1932.

U.S.N.M. nos. 81373-4 from the center of Ocean Bight Bay, August 7, 1930, are referred to this subspecies. They are a uniform drab-gray above, slightly bluer on the limbs, and lightening to immaculate pearl-gray on the under parts. There are absolutely no traces of the three wide black stripes which characterize Garman's *Ameiva maynardii*. There are 12 femoral pores in both specimens of *A. m. uniformis*; sub-digital lamellae 36; the tail at the 15th verticil with 20 and 22 scales respectively; the transverse rows of ventrals 31 and 35, and the longitudinal rows 8.

AMEIVA PLEI Duméril and Bibron

Ameiva plei Duméril and Bibron, Erpét. Gén., vol. 5, p. 114, 1839.

U.S.N.M. nos. 78974-7 from St. Martin, July 22, 1929.

AMEIVA THORACICA Cope

Ameiva thoracica Cope, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 64.

This lizard is represented by examples from the following places: U.S.N.M. nos. 81451-4 from Flamingo Cays of the Ragged Island Group, June 25, 1930; no. 81475 from Raccoon Cay of the Ragged Island Group, June 30, 1930; nos. 81497-8 from Crooked Island, July 14, 1930. The three from Flamingo Cays are much lighter in coloration than is the usual case, the black dorsolateral line being barely in evidence on the posterior part of the body, and not present at all anteriorly. Since the lizard from the not-far-distant Raccoon Cay presents an entirely normal style of coloration, and since there seems to be no urgent reason for describing a subspecies from so few specimens, which likewise are considerably mutilated by the small shot used to obtain them, it is best to consider them as aberrant individuals.

SCOLECOSAURUS ALLENI Barbour

Scolecosaurus alleni Barbour, Mem. Mus. Comp. Zoöl., vol. 44, p. 315, 1914.

U.S.N.M. no. 79190 from the Annandale Estate, Grenada, August 25, 1929.

CHEMIDOPHORUS MURINUS ARUBENSIS (Lidth de Jeude)

Cnemidophorus arubensis Lidth de Jeude, Notes Leyden Mus., vol. 9, p. 132, 1887.

U.S.N.M. nos. 79323-5, 79327-31 from Aruba Island, September 17, 1929. One of the original series, no. 79326, was sent to the Museum of Comparative Zoölogy as an exchange.

CNEMIDOPHORUS MURINUS MURINUS (Laurenti)

Seps murinus Laurenti, Synops. Rept., p. 63, 1768.

U.S.N.M. nos. 79271-2 from a hill 1½ miles west of Kralendijk, Bonaire Island, September 12; 79273-303 from Bonaire Island, September 13-14, 1929; nos. 79304-14 from Curaçao, September 16, 1929.

CNEMIDOPHORUS LEMNISCATUS LEMNISCATUS (Linnaeus)

Lacerta lemniscata Linnaeus, Syst. Nat., ed. 10, p. 209, 1758.

U.S.N.M. nos. 79219-23 from Los Robles, Margarita Island, September 8, 1929.

CNEMIDOPHORUS LEMNISCATUS NIGRICOLOR (Peters)

Cnemidophorus nigricolor Peters, Sitz. Ber. Ges. Nat. Freunde Berlin, p. 76, 1873.

U.S.N.M. no. 79230 from Orchilla Island, September 10, 1929; nos. 79232-54 from El Roque, September 11, 1929. Most of the adults of the latter series are dull black in color, either uniform or with minute white dots.

The low trailing shrubbery on the beach south of the village [on the leeward side of El Roque Island] had many lizards of two kinds, or probably three: one sooty, one plain brownish, and one spotted. These, when followed, would dive in the crab burrows for shelter and thus elude the pursuer.

Family AMPHISBAENIDAE

AMPHISBAENA CUBANA Peters

Amphisbaena cubana Peters, Mon. Berlin Acad. Wiss., p. 780, 1878.

U.S.N.M. no. 75861 from Santa Cruz Mountains in Camagüey Province, Cuba, September 1, 1928.

Family SCINCIDAE

MABUYA AENEA (Gray)

Tiliqua aenea Gray, Griffith's Cuvier's Animal Kingdom, vol. 9, Synops. Rept., p. 70, 1831.

U.S.N.M. no. 79131, from Petit Martinique, Grenadines, August 21, 1929. This handsome specimen has the supranasals separated, 28 scale rows, and 54 scales from vent to chin.

MABUYA SLOANII (Daudin)

Scincus sloanei Daudin, Hist. Nat. Rept., vol. 4, p. 287, 1803.

A much mutilated lizard, U.S.N.M. no. 81448, apparently of this species was taken on West Caicos on August 4, 1930. Its coloration is much like that of the type of *nitida* from San Domingo described by Garman. The supranasals in *nitida* are barely in contact; in the lizard from West Caicos they are slightly separated; in the Puerto Rican examples of *sloanii* they are very broadly in contact. In the Puerto Rican and Hispaniolan forms the first supraocular is very minute, while the second is very large indeed. The specimen from West Caicos, although badly damaged about the head, nevertheless shows a fairly large first supraocular and a correspondingly reduced second supraocular. In this specimen one pair of enlarged nuchal scales is present, with a trace of a second pair in some fused scales on one side of the neck. With so little material from Hispaniola, and with this single injured specimen from the Bahamas, it is best to let the name *Mabuya sloanii* cover these forms until more material has given a conclusive decision about their status.

Suborder SERPENTES

Family BOIDAE

EPICRATES ANGULIFER Bibron

Epicrates angulifer Bibron in R. de la Sagra's Hist. Cuba, Rept., p. 215, 1843.

U.S.N.M. no. 75865, a shed skin of a snake of this species, was found at La Caridad de Mendoza, Senado, Camagüey Province, Cuba, on September 2, 1928.

BOA HORTULANA COOKII (Gray)

Corallus cookii Gray, Zool. Misc., p. 42, 1842.

For the two specimens, U.S.N.M. nos. 79097-8 from Quatres Island, Grenadines, taken August 17, 1929, I adopt the name proposed by Amaral (Mem. Inst. Butantan, vol. 4, p. 143, 1929). A careful inspection of scale counts of 29 West Indian examples of *Boa* appears to establish the fact that the number of scale rows in this region lies between 39 and 47, with over half of the specimens having either 41 or 43 scale rows. Those from the mainland appear to fall into two groups, one having 43 to 47 scale rows, the other 51 to 55. These two groups are found in separate geographical ranges, the first group occurring in Venezuela, British Guiana and Colombia, the second in Surinam, Brazil and Peru. As an intergrading probably occurs where the ranges come together in the Guianas, subspecific names are desirable for both forms. The name of the northern mainland form appears to be applicable to the island species as well, since they do not seem to be separable by any valid characteristic. No. 79097, a male, has 39 scale rows, 260 ventrals, and 107 subcaudals; no. 79098, a half-grown specimen, has 39 scale rows, 258 ventrals, and 108 subcaudals.

> . . . . The surprise, however, came when Pasqual came to me in consternation, saying that he had seen a snake, so I hastened to the place and sure enough there was a slender black snake [see *Drymobius boddaertii*, U.S.N.M. no. 79099]. Later I asked Pasqual to get me an orchid in a large tree some distance above ground, and he almost fell off when he discovered another snake in the bunch of orchids. I could scarcely believe him, but handing him a stick had him poke it out and sure enough a slender, beautifully colored animal slipped out and sped along the branch. My .22 game-getter stopped him, but his tail was wound so tightly about a small limb that we had considerable trouble unwinding it. This species is evidently a splendid climber. Not 10 minutes later Pasqual, peeping into a broken-off limb hollowed out by decay, came near a second tumble as he bounced back with an "Ave Maria—una utra calebra." He again poked him out and a shot from the .22 also dropped him. I hope we have a pair.

TROPIDOPHIS MACULATUS MACULATUS (Bibron)

Leionotus maculatus Bibron, in R. de la Sagra's Hist. Cuba, Rept., p. 212, 1840.

U.S.N.M. no. 75826 from La Sierra, north of Vega Alta, Santa Clara Province, August 14, 1928.

TROPIDOPHIS MELANURUS (Schlegel)

Boa melanura Schlegel, Ess. Phys. Serp., vol. 2, p. 399, 1837.

U.S.N.M. no. 75828 from El Rinconada, Sierra Camagua, Cuba, August 27, 1928; no. 75839 from the Cubitas Mountains near Senado, Cuba, September 5, 1928; no. 76879 from Central Senado, Camagüey Province, Cuba, September 6, 1928.

TROPIDOPHIS PARDALIS PARDALIS (Gundlach)

Boa pardalis (part) Gundlach, Arch. Naturg., 1840, p. 359.

A young snake attributed to this species is now U.S.N.M. no. 81536, from Double Headed Shot Cay of the Cay Sal Group taken on June 20, 1930. There are 23 scales around the middle of the body, 157 ventrals, a single anal, and 32 subcaudals.

Family COLUBRIDAE

TRETANORHINUS VARIABILIS Duméril and Bibron

Tretanorhinus variabilis Duméril and Bibron, Erpét. Gén., vol. 7, p. 349, 1854.

U.S.N.M. no. 75807 from Baños San Vicente, Pinar del Río Province, Cuba, June 21, 1928.

DRYMOBIUS BODDAERTII BODDAERTII (Sentzen)

Coluber boddaertii Sentzen, Meyer's Zool. Arch., vol. 2, p. 59, 1796.

U.S.N.M. no. 79225 from Los Robles, Margarita Island, September 8, 1929, has 17 scale rows, 181 ventrals, a divided anal, 82 subcaudals, 9 supralabials, oculars 1 + 2, temporals 2 + 2.

DRYMOBIUS BODDAERTII BRUESI (Barbour)

Alsophis bruesi Barbour, Mem. Mus. Comp. Zoöl., vol. 44, no. 2, p. 337, 1914.

U.S.N.M. no. 79099, a female from Quatres Island, Grenadines, August 17, 1929; scales 17, ventrals 201, anal divided, caudals 125, supralabials 8, oculars 1 + 2, temporals 1 + 2.

U.S.N.M. no. 79166, a male from Union Island, Grenadines, August 20, 1929; scales 17, ventrals 201, anal divided, caudals 125 + tip, supralabials 9, oculars 1 + 2, temporals 1 + $\frac{1}{2}$.

U.S.N.M. no. 79161, a male from Caille Island, Grenadines, August 24, 1929; scales 17, ventrals 197, anal divided, caudals 128, supralabials 9, oculars 1 + 2; temporals 1 + 2.

U.S.N.M. no. 79191, a female from the Annandale Estate, Grenada, August 25, 1929; scales 17, ventrals 199, anal divided, caudals 115, supralabials 9, oculars 1 + 2, temporals 1 + 2.

U.S.N.M. no. 79193, a female from Baltazar, near the east coast of Grenada, August 25, 1929; scales 17, ventrals 204, anal divided, caudals 122, supralabials 9, oculars 1 + 2, temporals 1 + 2.

This species, when found on the mainland, ordinarily has two anterior temporals, and Barbour's original series of *Alsophis bruesi* from near St. George's, Grenada, had "a large anterior temporal with almost always a small scale intercalated above it, anteriorly". In all of the National Museum specimens listed above—three of them from the Grenadines and two from Grenada—there is but one anterior temporal, and the intercalated small scale is lacking in every instance.

ALSOPHIS ANGULIFER Bibron

Alsophis angulifer Bibron, in R. de la Sagra's Hist. Cuba, Rept., p. 222, 1840.

U.S.N.M. no. 75830 from El Salto de la Tinaga, Camagüey Province, Cuba, August 28, 1928.

ALSOPHIS VUDII Cope

Alsophis vudii Cope, Proc. Acad. Nat. Sci. Philadelphia, 1862, p. 74.

On Flamingo Cays of the Ragged Island Group a snake of this species was collected on June 27, 1930, U.S.N.M. no. 81464. It has 17 scale rows, 164 ventrals, a divided anal, 128 caudals, 8 upper labials, oculars 1 + 2, temporals 1 + 3. It seems to be a normal individual in every way.

LEIMADOPHIS ANDREAE Reinhardt and Lütken

Leimadophis andreae Reinhardt and Lütken, Vid. Med. Nat. For. Kjöbenhavn, p. 214, 1862, (1863).

U.S.N.M. no. 75808 from Baños San Vicente, Pinar del Río Province, Cuba, June 1, 1928; no. 75809 from Puerta del Ancon, Pinar del Río Province, Cuba, June 29, 1928; no. 75827 from Macomento del Rio, Cuba, August 7, 1928; nos. 75844-5 from Rio San Juan, Pinar del Río Province, Cuba, June 9, 1928.

LEIMADOPHIS JULIAE (Cope)

Aporophis juliae Cope, Proc. Amer. Philos. Soc., vol. 18, p. 274, 1879.

A young individual, U.S.N.M. no. 79022 from Danes, east of Portsmouth, Dominica, August 4, 1929. Its scale formula is: Scales 17, ventrals 156, anal divided, caudals 82, supralabials 8, oculars $1+2$, temporals $1+\frac{1}{2}$.

A female, no. 79025 from the Botanic Gardens in Rousseau, Dominica, August 6, 1929, has the following scale count: Scales 17, ventrals 159, anal divided, caudals 78, supralabials 8, oculars $1 + 2$, temporals $1+2$.

RHINOSTOMA GUIANENSE (Troschel)

Heterodon guianensis Troschel in Schomb. Reise Brit. Guiana, vol. 3, p. 653, 1848.

U.S.N.M. no. 79224 from Los Robles, Margarita Island, September 8, 1929. This appears to be the first insular record for this species. The specimen in hand has 19 scale rows; 191 ventrals; anal undivided; subcaudals 51+, the tail tip being defective; temporals $2+3$.

Subclass Synapsida

Order TESTUDINATA

Family TESTUDINIDAE

TESTUDO TABULATA Walbaum

Testudo tabulata Walbaum, Chelonogr., p. 122, 1782.

Unfortunately no example of this species reached the United States National Museum. As to its occurrence on two of the Grenadines, I quote the field notes made by Dr. Bartsch:

Aug. 17, 1929. Quatres Id., off Cheltenham. . . . . On returning, the pilot told us that there were land tortoises here and an enquiry brought three to me on our return, large clumsy beasts, for which I paid 50 cents. . . . . *Aug. 18, 1929. West side of Baliceaux Id.* . . . . I was greatly surprised to find here many of the land tortoises. I turned over half a dozen large ones, hoping to find them upon our downward trip, but we didn't. They had righted themselves and taken shelter in the grass tufts or shrubbery. As it was, we carried five aboard.

SAMUEL PIERPONT LANGLEY, 1834-1906

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 8

SAMUEL PIERPONT LANGLEY

(WITH SIX PLATES)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(PUBLICATION 3281)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 22, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

SAMUEL PIERPONT LANGLEY

By C. G. ABBOT
Secretary, Smithsonian Institution

(With Six Plates)

August 22, 1934, marks the centenary of the birth of the third Secretary of the Smithsonian Institution. Samuel Pierpont Langley was born at Roxbury, near Boston, Massachusetts, August 22, 1834, and died at Washington, February 27, 1906. After his graduation from the Boston High School in 1851, he studied and practiced civil engineering and architecture until 1864. Then he traveled extensively in Europe, frequently visiting observatories and learned societies there. He and his brother, afterward Prof. John W. Langley, had long been ardent amateur astronomers, and being of mechanical tastes, they had constructed a small reflecting telescope. Returning from his European trip, the future Secretary devoted himself to astronomy. After a short assistantship at Harvard College Observatory and a very brief tenure as assistant professor of mathematics and director of the observatory at the Naval Academy at Annapolis, Md., he was in 1866 appointed director of the Allegheny Observatory, near Pittsburgh, and professor of physics in the Western University of Pennsylvania. He remained there for more than 20 years, during which his remarkable pioneering astronomical work along several different lines gave him a foremost standing in astronomy, along with that triumvirate of distinguished American astronomers of those days, Simon Newcomb, Edward C. Pickering, and Charles E. Young. He raised considerable revenue for the Allegheny Observatory by the then novel device of furnishing astronomical time to the Pennsylvania Railroad. The wealthy Pittsburgh philanthropist, William Thaw, was his helpful friend. By Langley's encouraging advice, John A. Brashear, a steel worker, was transformed from a timid amateur mirror-grinder to the founder of that great optical concern, the John A. Brashear Optical Company, of Allegheny, Pa., and was ever his grateful friend and helper in preparing novel apparatus for his pioneering experiments.

Owing to the failing health of the distinguished naturalist, Spencer F. Baird, second Secretary of the Smithsonian Institution, Langley was appointed Assistant Secretary in 1887. After Baird's death, he was elected by the Board of Regents to be Secretary on November 18, 1887. He retained this position until his death, February 27, 1906. During his tenure, Secretary Langley founded the Astrophysical Observatory, the National Zoological Park, the Regional Bureau for the United States of the International Catalogue of Scientific Literature, and the National Gallery of Art. He broke ground for the beautiful Natural History Building of the National Museum. His strong interest in children led him to set aside and beautify a special room for them in the Smithsonian Building, where the choicest specimens in zoology and geology were assembled to rouse their admiration and wonder. Several bequests came to the endowment of the Institution, notably the Hodgkins Fund for the study of atmospheric air. By annual journeys to Europe, Langley kept the Institution prominently before the eyes of Old World scientists and kept them informed at first hand of his notable researches in astrophysics and aviation.

Langley was a man of varied and discriminating tastes in art and literature. As an author he showed great clarity of expression and delightful rhythm and choice in words. He could never satisfy his fastidious taste in composition, but continually altered and polished his writings up to the very last stage. Only in bound form could they elude his further alterations. Having a generous sense of humor, he found a special pleasure in reading the works of George Borrow. The novelist, William Dean Howells, was a valued friend, from whom he even took lessons in composition, so much did Langley admire the polished style of Howells' writing.

Though unmarried, Langley was a great favorite with children. I have seen him at the resort, Marshall Hall, swinging with two little girls, one on either knee, while he told them fairy stories. He was afflicted by great shyness, and like some others thus handicapped, he carried for the outer world a shell of hauteur, very unrepresentative of the warm heart within. A man of great accomplishment himself, he was often unfairly impatient with assistants, and would betray irascibility by unduly raising his voice when things did not get on to suit him. For these reasons many failed to understand the innate kindliness of the man, so well known to those in closest association with him.

The older men of the Smithsonian Institution still remember many incidents illustrative of Langley's character that would make delightful reading if they could be written without loss of flavor. He often told witty stories, or used bon mots to impress indelibly some point in conversation. He was fond, for instance, of the expressions: "Let sleeping dogs lie"; "The written word remains"; "What has posterity done for us that we should care so much for the opinion of posterity?" One day when he was going to some function he came hurriedly out of his room and said "William, my hat." The colored man ran and got his derby. "I said a HAT!" shouted Langley, as he threw the derby down the hall. He used always to have a messenger boy accompany him when he walked to outlying offices. As befitted his chief's dignity, the boy always walked two paces behind, perhaps carrying an overcoat or a portfolio. In his youthful exuberance, and especially if some crony was looking on, the boy might cut some slightly disrespectful capers. But if so, he reckoned without his chief's knowledge of optics. For observing the boy indistinctly by reflection from the rear of his glasses, Langley would turn around suddenly at a critical moment, to the boy's great discomfiture. These little idiosyncrasies were a spice to us at the time, and endear the memory of our great chief as we look back over more than a quarter century.

In the remainder of this memoir I propose to let Langley tell in his own words of some of his leading pioneer investigations. A list of the exact references to these articles will be found at the end of this paper.

"ON THE MINUTE STRUCTURE OF THE SOLAR PHOTOSPHERE"

"Before we turn with these aids to the study of the photosphere, it will be well to describe briefly appearances presented by the solar surface in telescopes of moderate size.

"Here we see a disk of nearly uniform brightness, which is yet sensibly darker near the circumference than at the center. Usually seen relieved against this gray and near the edges, are elongated and irregular white patches (*faculae*), and at certain epochs trains of spots are scattered across the disk in two principal zones equidistant from the solar equator. On attentive examination it is further seen that the surface of the sun everywhere—even near the center and where commonly neither faculae nor spots are visible—is not absolutely uniform, but is made up of fleecy clouds, whose outlines are all but indistinguishable. The appearance of snow flakes which have fallen sparsely upon a white cloth, partly renders the impression, but no strictly adequate comparison can perhaps be found, as under more painstaking scrutiny, we discern numerous faint dots on the white ground, which seem to aid in producing the impression of a mosslike structure in the clouds, still more delicate, and whose faint intricate outlines tease the eye, which can neither definitely follow them, nor analyze the source of its impression of their existence.

" These appearances have been mentioned, lest they should be confounded in any way with the far minuter structure now to be described.

" Under high powers used in favorable moments, the surface of any one of the fleecy patches is resolved into a congeries of small, intensely bright bodies, irregularly distributed, which seem to be suspended in a comparatively dark medium, and whose definiteness of size and outline, although not absolute, is yet striking by contrast with the vagueness of the cloud-forms seen before, and which we now perceive to be due to their aggregation. The 'dots' seen before are considerable openings caused by the *absence* of the white nodules at certain points, and the consequent exposure of the gray medium which forms the general background. These openings have been called pores; their variety of size makes any measurements nearly valueless, though we may estimate in a very rough way the diameter of the more conspicuous at from 2″ to 4″. The bright nodules are themselves not uniformly bright (some being notably more brilliant than their fellows and even unequally bright in portions, of the same nodule), neither are they uniform in shape. They have just been spoken of as relatively definite in outline, but this outline is commonly found to be irregular on minute study, while it yet affects, as a whole, an elongated or oval contour. Mr. Stone has called them rice-grains, a term only descriptive of their appearance with an aperture of three to four inches, but which I will use provisionally. It depicts their whiteness, their relative individuality, and their approximate form, but not their irregular outline, nor a certain tendency to foliate structure which is characteristic of them, and which has not been sufficiently remarked upon. This irregularity and diversity of outline have been already observed by Mr. Huggins. Estimates of the mean size of these bodies vary very widely. Probably Mr. Huggins has taken a judicious mean in averaging their longer diameter at 1″.5, and their shorter at 1″, while remarking that they are occasionally between 2″ and 3″ and sometimes less than 1″ in length. . . . .

" In moments of rarest definition I have resolved these 'rice-grains' into minuter components, sensibly round, which are seen singly as points of light, and whose aggregation produces the 'rice-grain' structure. These minutest bodies, which I will call *granules,*[1]

[1] As this word is already in use, with another meaning, attention should be given to the restricted and definite significance which is here assigned to it.

it will appear subsequently can hardy equal 0".3 in diameter, and are probably less. (Secchi is the only observer, as far as I know, who appears to have seen and measured them. He observed them in the edges of the pores, and reckons their size at ".$\frac{1}{3}$ to "$\frac{1}{5}$, but does not estimate their number or point out their relations to the 'rice-grains.') They are irregularly distributed, with a tendency to aggregation in little clusters (the clusters being the rice-grains), and their existence accounts for the diversity and irregularity in the outline of the latter. Mr. Huggins has acutely remarked upon, while it of course makes clear the reason of the apparent increase in the number of 'rice-grains' with increasing telescopic power.

. . . .

"We are now prepared to study the minute structure of the photosphere under another aspect, as it appears in the spots. It is impossible to make such a drawing as that here given from any single delineation, owing to the rapidity with which spots change their form. I have accordingly, while taking the general contour and many details from drawings of the great spot of March 5 and 6, 1873, added the results of numerous studies of detail in other spots, made during the past two years. . . . .

"To represent the gradations of light from the intensest splendor to the darkness of the nuclei, we have here only the limited range between a white and a black pigment. This almost compels partial falsity in the degrees of shade, and there is, for instance, in the drawing, a relative exaggeration of the shade which marks the outer boundary of the penumbra, and without which the important details would be hardly visible.

. . . .

"It is practically impossible, in the brief intervals of perfect definition during which such work can be carried on, to so multiply micrometric measurements, that from their concordance any idea of their probable error is obtainable by the usual treatment. Measurements taken at different times, and on different parts of the penumbra, by counting the number of filaments in a given space, give from 0".7 to 1".0 as the average distance from center to center of parallel filaments separated by scarcely measurable intervals; at the same time that the distance in some parts is greater, it is in others much less.

. . . .

"Solar cyclones, which, even without the aid of the spectroscope, we see are incomparably more violent than our own tropical tornados, act on the filaments without destroying their identity. It is probable that both the filaments and the granules I have so minutely described, may hereafter be resolved into smaller components still, but their persistent individuality as a whole under such disturbance, impresses me as a most striking feature, and one for which, under similar circumstances, we have no exact analogy in our own meteorology.

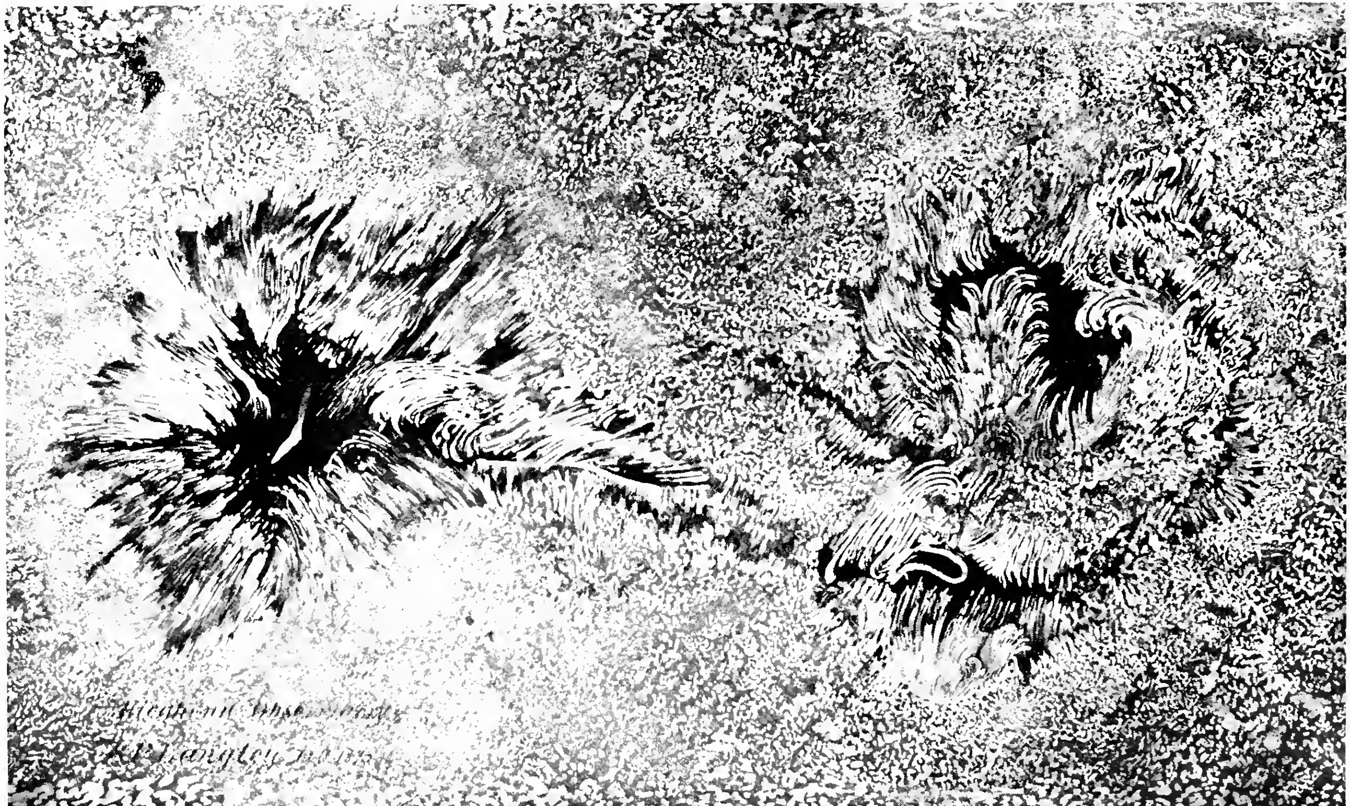
. . . .

"Are these round, nearly central openings, so that looking into one we are looking into the axis of the cyclone to which the spot is due—into the vortex of the great whirl *down* which the chromospheric vapors are being sucked by mechanical action? Are they ragged apertures—the craters as it were of eruptions whence metallic vapors are being forced *up?* The answer to this question, were there but these two alternatives, would be definitive as to our choice between the principal theories of solar circulation."

Dr. George E. Hale has told me that the better he perceives by photography or vision with the great outfits at Pasadena and Mount Wilson the features of sun spots and the photosphere, the more do they approach Langley's drawings and descriptions of them. It is interesting to add that photography has plainly shown that high-lying solar clouds of matter are indeed sucked into the umbrae of sun spots just as Langley suggested.

"THE TOTAL SOLAR ECLIPSE OF JULY 29, 1878: OBSERVATIONS AT PIKE'S PEAK, COLORADO"

" Upon the 22d Prof. John W. Langley arrived, and, as the rain poured freely through the roof upon the boxes which lay in the wet, as the best means of protecting the telescope, we mounted it in the open air on a partly level spot of a few feet square some yards from the hut. Procuring some lard from the kitchen, I covered every part of the steel-work with it, and wrapped the instrument in a piece of canvas. Upon the 23d Prof. Cleveland Abbe, of the Signal Service, arrived, and on the same evening two tents were pitched, which had been sent by the order of General Myer. There was no piece of level ground or rock large enough to lie upon; but we procured some logs which had been brought up for fire-wood, and, laying these between the bowlders, spread on them a sack of hay for each, and blankets which had been brought up in the rain; these were all damp, and our first night under canvas in a cold and high wind was not agreeable, particularly as the difficulty of breathing decidedly increased rather than diminished. In the morning all of the party were ill. The day was passed in fruitless attempts to adjust the equatorial. In the morn-



DRAWING OF SUN SPOT MADE BY S. P. LANGLEY AT ALLEGHENY OBSERVATORY, 1873

ing the canvas which covered it was frozen and loaded with hail. A little later the sun shone out suddenly and with surprising warmth, turning the hail to water. I commenced unwrapping the canvas, and was lifting it off, when the sun disappeared as suddenly as it came out, and, before I could put the cover on again, it was hailing once more, and we were involved in dense cloud. This cloud was continuous, except for several brief moments of sunshine, during which I uncovered the instrument several times to no purpose. I may say briefly that this was nearly the history of the weather for the ensuing week, during which we had several clear sunrises and sunsets, but in the course of which neither Professor Abbe nor myself got so much as the requisite observations for adjusting our equatorials, which remained on the day of the eclipse in the position in which they were first set up. During the first days, our illness increased, and, with a great difficulty of breathing and greatly increased action of the heart, we felt constant and severe headache, and nearly every symptom which attends sea-sickness. Exertion was extremely difficult, and that of building the stone piers for the heliostat, photometer, and other instruments for which we had at first no assistance, was carried on only by a very strong effort of will as well as of strength.

" Not to enlarge on the personal discomforts of a week which we all had reason to wish over, I may add that towards its close Professor Abbe's condition gave us cause for alarm. His symptoms were the same as my brother's and my own, but much aggravated, and while we grew rather better, he grew worse, and upon Sunday morning he was unable to rise. At this time the tents were not the place for an invalid. The snow, which had blown into one during the night and spread thickly over one of the sleepers, I remember finding ten inches deep beside me when I woke. Professor Abbe's own resolution to stay, if possible, was unaltered; but one of our party, a physician, pronouncing his life endangered by another day, he was, on the evening of the 28th, put into a litter and carried down to a lower altitude, where his recovery was rapid.

. . . .

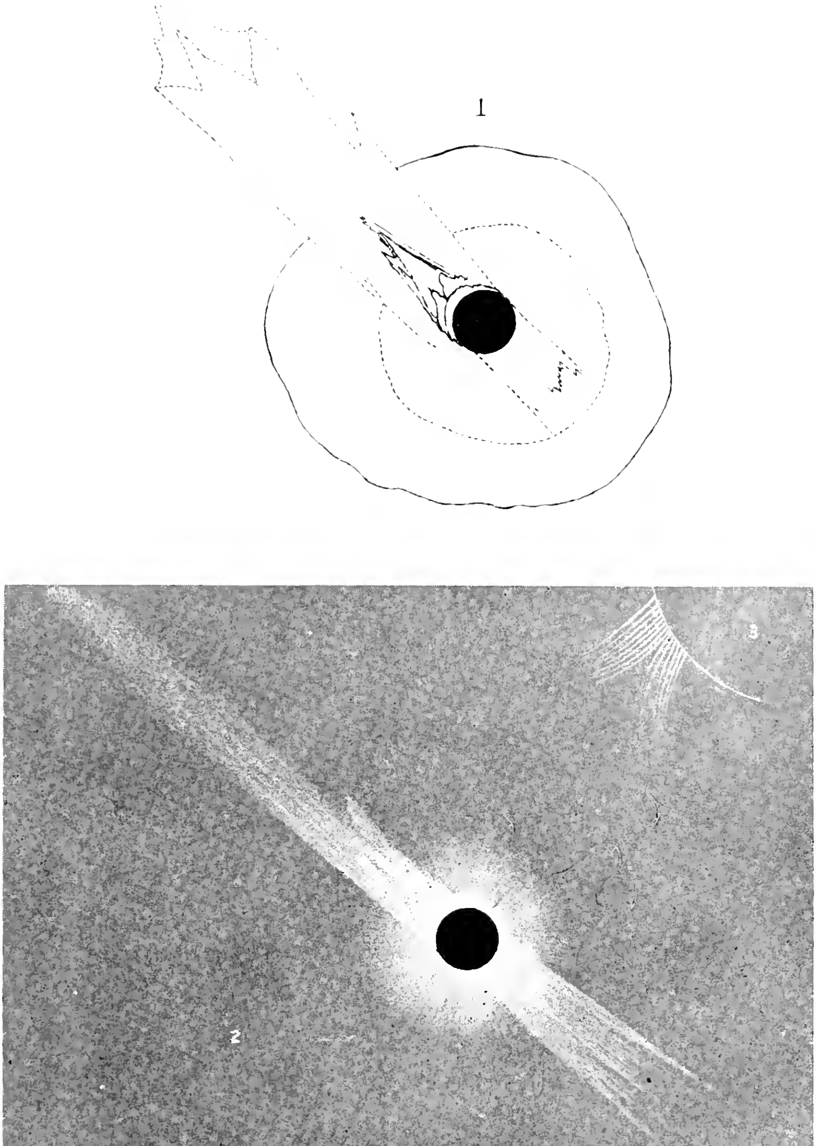
" The morning of the 29th was clear, and the whole of the important day was a complete contrast to its predecessors, the sky being almost cloudless and of a deep and transparent blue never seen near the Atlantic coast. . . . .

" I pass over phenomena preceding totality, observed by myself, as of little value, with a reference to the letters of Messrs. Shields and Manning, given below. At the moment of totality I removed the dark glass.

"As original records of an observation are trustworthy in proportion as they have been presented in their first crude state, I endeavor to give the impressions as they rose in my mind, and will comment on them later. My first impression, then, of the corona was, 'It is not so bright as those I have seen before'; my second, 'but it is far more extended.' I had before me a sheet of drawing-paper with a $\frac{3}{4}$-inch circle on it to represent the sun, and on this I traced an outline (Plate 3, Fig. 1) of what I then saw, before the eye had recovered its sensibility. The sun was surrounded by a narrow ring—hardly more than a line—of vivid light, presenting to the naked eye no trace of structure; which faded with great suddenness into a nebulous luminosity that at first appeared to extend to a distance of about two and one-half solar diameters all around. . . . .

" There were but a few moments left when I turned to the telescope. It happened to be directed toward the northern part of the sun. I adjusted the eye-piece for distinct vision, which appeared excellent, but the view after this lasted, I think, not more than four or five seconds before totality was over. What I saw thus momentarily was not in the least what I expected. If there were any structure in the very inner corona, it had escaped me when I had searched for it in a previous eclipse (Jeres, in 1870). It is true that the sky was hazy on that occasion, and that on this it was exquisitely clear. Now what I saw in this brief view was a surprisingly definite filamentary structure [2] somewhat coarser and decidedly more sharply defined than I have ever seen filaments in the photosphere, not disposed radially, or only so in the rudest sense, sharpest and much the brightest close to the disc, fading rapidly away into invisibility at a distance of five minutes of arc or more (possibly in some cases of ten). The salient point to me was this very remarkable definiteness and precision of these forms, and this *impression*, made on my mind in that too brief moment, is reproduced in this sketch (Plate 3, Fig. 3), taken from one made within ten minutes of the event. It is in no way a 'picture' but a reproduction of the original memorandum of the first impres-

[2] The action which produces these definite forms goes on over the surface of a sphere, in reality, and not a disc, and they are doubtless presented to us under all possible foreshortenings, and, questionless, lie one behind and across another, so that, *a priori* one would expect they would obscure one another, and that such definiteness would not, in fact, exist. But, to me, the actual appearance was very much like that which we might have if the sun were not a globe at all, but a flat disc, fringed with such threads. Doubtless, there was really an intricate cross-hatching of them, and various obscurer forms might have been made out with time for study.



TOTAL SOLAR ECLIPSE, JULY 29TH, 1878, PIKE'S PEAK, COLORADO

Drawings by S. P. Langley

sion of the features of the (telescopic) inner corona, which were, to repeat: (1) Extraordinary sharpness of filamentary structure; (2) arrangement not radial, or only so in the rudest sense; (3) generally curved, not straight lines; (4) curved in different directions; (5) *very* bright close to the edge, and fading *very* rapidly—fading out wholly at from 5 to 10 minutes from it."

"THE BOLOMETER AND RADIANT ENERGY"

"Our knowledge of the distribution of heat in the solar spectrum really begins with this century and the elder Herschel, ...

"No one, so far as I know, has hitherto succeeded in measuring the heat from a diffraction grating except in the gross, ...

"I have tried at intervals for the past four years to do this, and having long familiarity with the many precautions to be used in delicate measures with the thermopile, and a variety of specially sensitive piles, had flattered myself with the hope of succeeding better than my predecessors. I found, however, that though I got results, they were too obscure to be of any great value, and that science possessed no instrument which could deal successfully with quantities of radiant heat so minute.

"I have entered into these preliminary remarks as an explanation of the necessity for such an instrument as that which I have called the Bolometer (*βολή, μέτρον*), or Actinic Balance, to the cost of whose experimental construction I have meant to devote the sum the Rumford Committee did me the honor of proposing that the Academy should appropriate.

"Impelled by the pressure of this actual necessity, I therefore tried to invent something more sensitive than the thermopile, which should be at the same time equally accurate—which should, I mean, be essentially a '*meter*' and not a mere *indicator* of the presence of feeble radiation. This distinction is a radical one. It is not difficult to make an instrument far more sensitive to radiation than the present, if it is for use as an indicator only; but what the physicist wants, and what I have consumed nearly a year of experiment in trying to supply, is something more than an indicator—a *measurer* of radiant energy.

"The earliest design was to have two strips of thin metal, virtually forming arms of a Wheatstone's Bridge, placed side by side in as nearly as possible identical conditions as to environment, of which one could be exposed at pleasure to the source of radiation. As it was warmed by this radiation and its electric resistance proportionally increased over that of the other, this increased resistance to the flow of the current from a battery would be measured (by the disturbance of the equality of the 'bridge' currents) by means of a galvanometer.

. . . .

"This promptness in the action of the metal strip gives it a great advantage over the thermopile for measures of precision. But, beside this, the deflection produced by the single strip and bridge is greater than that from the thermopile, if the element of time enter into the comparison, and still more if the relative areas exposed to radiation be considered.

"Although (for the reasons just cited) far from as sensitive as we can make it, such a strip then is yet more sensitive than the pile. A number of thermopiles, selected as the most sensitive in the writer's collection, have been exposed to the same source of radiation, placed at the same distance as in the previous experiments. They were . . . . as follows:

"*A.* Large thermopile, by Elliott (Tyndall-lecture pattern), composed of sixty-three couples, ...

"*B.* Very sensitive thermopile of extra small elements (16 couples) . . . .

"*C.* Delicate linear thermopile (7 couples). Working face about 1 mm. by 10 mm. = 10 sq. mm. . . . .

"*S.* The iron strip, which was about 7 mm. by .176 mm. and whose working face was therefore about 1 sq. mm. . . . .

"The time of exposure was about five seconds for the thermopiles and about one-half this for the strip, the latter time corresponding to the rapid swing of the (designedly) insensitive galvanometer.

"In the table, the first column gives the name of instrument; the second, the cross-section of the beam of radiant heat which is received upon it; the third is the actual deflection in galvanometer divisions; and the fourth the deflection for each square millimetre of exposed surface. . . . .

Instrument	Area sq. mm.	Deflection div.	Sensitiveness
A	240	211	.9
B	34	125	3.7
C	10	147	14.7
S	1	204	204.0

"After nearly a year's labor (I began these researches systematically in December 1879), I have procured a trustworthy instrument. It aims, as will have been inferred from the preceding remarks, to use the radiant energy, not to develop force directly as in the case of the pile, but indirectly, by causing the feeble energy of the ray to modulate the distribution of power from a practically unlimited source.

"To do this I roll[3] steel, platinum, or palladium into sheets of from 1/100 to 1/500 of a millimetre thickness; cut from these sheets strips one millimetre wide and one centimetre long, or less; and unite these strips so that the current from a battery of one or more Daniell's cells passes through them. The strips are in two systems, arranged somewhat like a grating; and the current divides, one half passing through each, each being virtually one of the arms of a Wheatstone's Bridge. The needle of a delicate galvanometer remains motionless when the two currents are equal. But when radiant heat (energy) falls on one of the systems of strips, and not on the other, the current passing through the first is diminished by the increased resistance; and, the other current remaining unaltered, the needle is deflected by a force due to the battery directly, and mediately to the feeble radiant heat, which, by warming the strips by so little as 1/10000 of a degree Centigrade, is found to produce a measurable deflection. A change in their temperature of 1/100000 degree can, I believe, be thus noted; and it is evident that from the excessive thinness of the strips (in English measure from 1/2000 to 1/12500 inches thick) they take up and part with the heat almost instantly. The instrument is thus far more prompt than the thermopile; and it is also, I believe, more accurate, as under favorable circumstances the probable error of a *single* measure with it is less than one percent. When the galvanometer is adjusted to extreme instability, the probable error of course is larger; but I have repeated a number of Melloni's measurements with the former result.

"I call the instrument provisionally the 'Bolometer,' or 'Actinic Balance,' because it measures radiations and acts by the method of the 'bridge' or 'balance,' there being always two arms, usually in juxtaposition, and exposed alike to every similar change of temperature arising from surrounding objects, air-currents, etc., so that the needle is (in theory at least) only affected when radiant heat, from which one balance-arm is shielded, falls on the other.

. . . .

"The first measures, on nearly homogeneous rays in the *diffraction* (reflection) spectrum, ever taken by any one that I know of, were

[3] Experiments are now in progress with still thinner films of metal produced by electrical or by chemical deposition. I have had the good fortune in experiments now making in this direction, to secure the aid of Professor A. W. Wright of Yale College, and of Mr. Outerbridge of the United States Mint at Philadelphia.

taken by this instrument on Oct. 7, 1880, used with an extremely delicate reflecting galvanometer by Elliot, of about 20 ohms resistance and a reflecting grating on speculum metal by Mr. Rutherford of 681 lines to the millimetre. Measures have been taken every fair day since, the source of energy being the sun.

. . . . The 'Balance' then, whose acting face is only about 1/30 the length of the visible spectrum, and less than 1/100 the length within which energy is found in a degree sufficient for it to measure, receives nearly homogeneous rays (which have passed through no absorbing medium whatever except the solar and terrestrial atmospheres), and this extremely minute amount of heat is found to give a galvanometer deflection of some hundred divisions, where thermopiles have hitherto failed to register any (on homogeneous rays).

". . . . They are hitherto unpublished, and they at least, though as yet approximate, show that the *heat maximum in a normal spectrum is not in the ultra-red, but is at least as far up the spectrum as the orange near D;* and this result may be relied on, any smaller values below $\lambda = .0007$, as well as all favorable atmospheric circumstances (high sun, blue sky, etc.), rather tending to move it toward the violet."

"ON THE AMOUNT OF THE ATMOSPHERIC ABSORPTION"

"Let us first suppose the radiation of the heavenly body to be really composed before absorption of two portions, A and B. Let A have a special coefficient of transmission (a), and B another, special to itself (b). Then, if we assume (still for considerations of convenience only) that each of these portions, is, separately considered, homogeneous, we may write down the results in the form of two geometrical progressions, thus:

TABLE 1

Original radiation	Ratio	Radiation received after absorption by one stratum	By two strata	By three strata	By four strata, etc.
A	a	Aa	Aa^2	Aa^3	Aa^4
B	b	Bb	Bb^2	Bb^3	Bb^4
A + B		Aa + Bb = (M)	Aa^2 + Bb^2 = (N)	Aa^3 + Bb^3 = (O)	Aa^4 + Bb^4 = (P)

"Then will

$$\frac{Aa+Bb}{A+B} < \frac{Aa^2+Bb^2}{Aa+Bb} < \frac{Aa^3+Bb^3}{Aa^2+Bb^2} < \frac{Aa^4+Bb^4}{Aa^3+Bb^3} < \text{etc.}$$

and

$$\frac{Aa^2+Bb^2}{Aa+Bb} < \left(\frac{Aa^3+Bb^3}{Aa+Bb}\right)^{\frac{1}{2}} < \left(\frac{Aa^4+Bb^4}{Aa+Bb}\right)^{\frac{1}{3}} < \text{etc.} \ldots\ldots$$

"The fractions here are the coefficients of transmission, as deduced from observations at different zenith distances. They evidently differ, and (as will be shown) each is larger than the preceding.

"In the above $Aa+Bb$ is the sum of the two kinds of radiation as observed after absorption by one unit stratum (sec.$\zeta=1$) by the photometer, or actinometer; Aa^2+Bb^2 is the sum of the radiations observed after absorption by two strata (sec.$\zeta=2$) etc.; but we are here supposed to independently know the really dual constitution of the radiation, which the photometer or actinometer does not discern. According to the usual hypothesis, the coefficient of transmission, which is the quotient obtained by dividing the value after n absorptions by that after n – 1 absorptions, or more generally that from the expression

$$\left(\frac{\text{Value after } n \text{ absorptions}}{\text{Value after } m \text{ absorptions}}\right)^{\frac{1}{n-m}}$$

is a constant. It is in fact not a constant, as we shall prove later; but we shall first show that, if we proceed upon the ordinary assumption, the value obtained for the original light of the star before absorption will in this case be too small. For, if we observe by a method which discriminates between the two radiations, we shall have, if we separately deduce the original lights from our observation of what remains after one and again after two absorptions, the true sum

$$A+B=\frac{(Aa)^2}{Aa^2}+\frac{(Bb)^2}{Bb^2}$$

while if we observe by the ordinary method, which makes no discrimination, we shall have the erroneous equation

$$A+B=\frac{(Aa+Bb)^2}{Aa^2+Bb^2}$$

which is algebraically less than the first, or correct value, for the expression

$$\frac{(Aa)^2}{Aa^2}+\frac{(Bb)^2}{Bb^2} > \frac{(Aa+Bb)^2}{Aa^2+Bb^2}$$

readily reduces to the known form

$$a^2+b^2 > 2ab.$$

Moreover since $a^2+b^2-2ab=(a-b)^2$, *the error increases with the difference between the coefficients.*

"Now, in the general case, if we suppose the original radiation L to be composed before absorption, of any number of parts A_1, A_2, A_3, + ... having respectively the coefficients of absorption a_1, a_2, a_3, + ... the true value of L is given by a series of fractions which may be written in the form

$$L = \frac{\Sigma(Aa)^2}{\Sigma Aa^2} = \Sigma A$$

whereas the value of the original energy by the customary formula would be

$$L_1 = \frac{\Sigma(Aa)^2}{\Sigma Aa^2}$$

so that, all the quantities being positive, by a known theorem, $L > L_1$, and for the same values of A_1, A_2, A_3, ... this inequality is greater, the greater the difference in the values of the coefficients a_1, a_2, a_3, ...

"But this is stating in other words that the true values, found by observing separate coefficients of transmission, are always greater than those found when we do not distinguish between the radiations of which the light (or heat) of the star or sun is composed, and also that the amount by which the true values are greater, increases with the difference between the coefficients.

"We have stated above that the usual hypothesis makes the coefficient of transmission a constant. It will be seen from the above table, however, that it varies from one stratum to the next; that it is least when obtained by observations near the zenith; and that it *increases progressively as we approach the horizon.*"

"RESEARCHES ON SOLAR HEAT AND ITS ABSORPTION BY THE EARTH'S ATMOSPHERE. A REPORT OF THE MOUNT WHITNEY EXPEDITION."

"If the observation of the amount of heat the sun sends the earth is among the most important and difficult in astronomical physics, it may also be termed the fundamental problem of meteorology, nearly all whose phenomena would become predictable, if we knew both the original quantity and kind of this heat; how it affects the constituents of the atmosphere on its passage earthward; how much of it reaches the soil; how, through the aid of the atmosphere, it maintains the surface temperature of this planet; and how, in diminished quantity and altered kind, it is finally returned to outer space.

. . . .

". . . . We are trying to estimate the amount of solar heat before absorption (the *solar constant*).

" Could we ascend above the atmosphere, this heat might be directly measured. Evidently, since this is impossible, and since we can only observe the portion which filters down to us after absorption, we must add to this observed remnant a quantity equal to that which the atmosphere has taken out, in order to reproduce the original amount.

" To find what it has taken out, we must study the action in detail, and, from the knowledge thus gained frame a rule or formula which shall enable us to infer the loss since we cannot directly determine it.

" It is because the exact determination of the solar constant thus presupposes a minute knowledge of the way in which the sun's heat is affected by the earth's atmosphere; and because every change in our atmosphere comes from this same heat, that the solution of the problem interests meteorology as well as astronomical physics.

". . . . Let us consider what the problem appears to be at a first glance, and what the first suggestion is for solving it. If a beam of sunlight enters through a crevice in a dark room, the light is partly interrupted by the dust particles in the air, the apartment is visibly illuminated by the light reflected from them, and the direct beam having lost something by this process, is not so bright after it has crossed the room as before it entered it. If a quarter of the light was thus scattered, and the beam after it crossed the room would be but three-fourths as bright as when it entered it, and if we were to trace the now diminished beam through a second apartment altogether like the other, it seems at first reasonable to suppose that the same proportion, or three-fourths of the remainder, would be transmitted, and so on, and that the light would be the same kind of light as before, and only diminished in amount. The assumption originally made by Bouguer [4] and followed by Herschel and Pouillet was that it was in this manner that the solar heat was interrupted by our atmosphere, and that by using such a simple progression the original heat could be calculated.

" Now, it is no doubt true that a very sensible portion of light and heat are scattered by an analogous process in our atmosphere; but we have in our present knowledge to consider that heat is not a simple emanation, but a compound of an infinite number of radiations, and that these are affected in an infinite diversity of ways by the different

[4] Bouguer, Traité de la lumière. Paris, 1760.

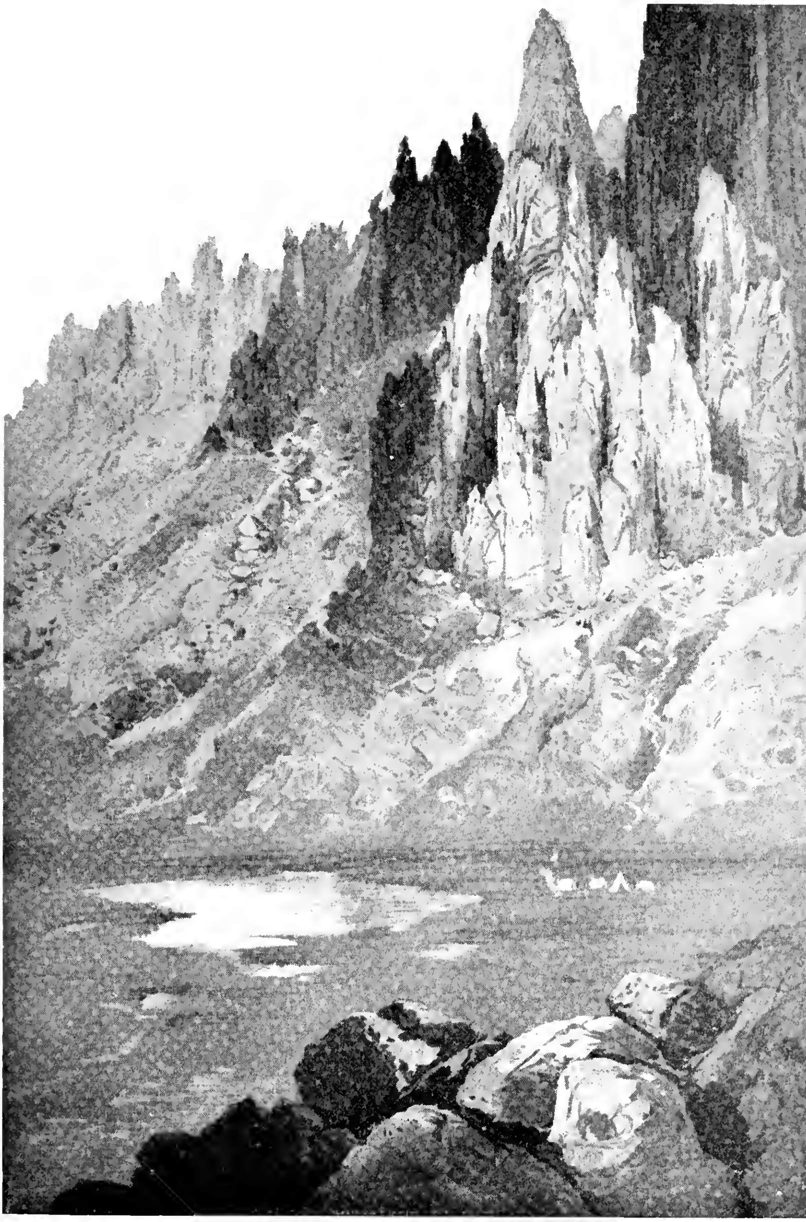
atmospheric agents, the grosser dust particles affecting them nearly all alike, or with a general absorption; the minuter ones beginning to act selectively, or, on the whole, more at one end of the spectrum than another; smaller particles, whether of dust or mist, and smaller still, forming a probably continuous sequence of more and more selective action down almost to the actual molecule, whose action is felt in the purely selective absorption of some single ray.

"The effect of the action of the grosser particles then is to produce a general and comparatively indifferent absorption of all rays, so that the spectrum after such an absorption would simply seem less bright or less hot. The effect of the smaller ones is, as has just been said, to act more at one end of the spectrum than another, with a progressive absorption, so that the quality of the radiation is sensibly affected as well as its quantity. The effect of the molecular absorption is to fill the spectrum with evidences of the selective action in the form of the dark telluric lines, taking out some kinds of light and heat and not others, so that after absorption what remains is not only less in amount but *quite altered in kind*. . . . .

"The writer has demonstrated that in neglecting to observe approximately homogeneous rays we not only commit an error, but an error which always has the same sign, and that the absorption thus found is always too small. He accordingly devoted much time to the construction of an instrument (the bolometer, which will be described in its place) for the special study of such heat rays, and, with this, observations were carried on in the years 1880 and 1881 at Allegheny, with the conclusions which have just been stated. With this instrument the heat in some approximately homogeneous ray (that is in some separate pencil of rays of nearly the same wave-length) is measured in the pure and normal spectrum at successive hours of the day, and the calculation of the absorption on Bouguer's principle (justly applicable to strictly homogeneous waves) gives the heat outside the atmosphere in this approximately homogeneous portion with a degree of approximation, depending on the actual minuteness of the part examined. The process is then repeated on another limited set of rays, and another, until the separate percentage and the separate original heat is found for each heat pencil directly or by interpolation, and then finally the whole heat, by the summing of its parts, the result being that the solar constant is much greater than it was believed to be, and the absorption of the atmosphere much greater.

. . . .

"Toward the close of 1880 it had already become clear that the gain in our knowledge by repeating the observations then in prog-



MOUNTAIN CAMP, MOUNT WHITNEY

From a sketch by T. Moran

ress at the Allegheny Observatory, at the base and at the summit of a lofty mountain, would justify the labor and expense of such an undertaking. There would have been little probability, however, of such a plan being carried out by the Observatory, were it not for the generosity of a citizen of Pittsburgh [William Thaw], who placed at its disposal the considerable means demanded for the outfit of an expedition for this purpose.

. . . .

"Upon the objects of the expedition and their bearings upon meteorology becoming known to the Chief Signal Officer of the United States Army, he consented to give it the advantage of his official direction and the aid of Signal Service Observers, and upon the reasons which made the choice of its objective point in a remote part of the United States territory being approved by him, he contributed further material aid in transportation. . . . . Finally, upon the advice of Mr. Clarence King, and with the concurrently favorable opinion of officers of the Coast Survey and others familiar with that region, Mount Whitney, in the Sierra Nevada Range of Southern California—approximate longitude, 118° 30′ (7h.54m.); latitude, 36° 35′—was found to be, on the whole, most desirable. Its height was known to be between 14,000 and 15,000 feet. Its eastern slopes are so precipitous that two stations can be found within 12 miles, visible from each other, and whose difference of elevation is 11,000 feet, and it rises from and overlooks one of the most desert regions of the continent, while its summit is almost perpetually clear during June, July, August, and September."

On account of limitations of space, it is impossible to give by quotations a fair idea of this extraordinary expedition. Space even forbids that we should quote from the inspiring description Langley gives of the expedition, its guard of soldiers, the desert journey, the insufferable heat under which observations were nevertheless made at Lone Pine, the ascent of the mountain, its grandeur, the dark blue of its cloudless sky, the long delays waiting for the mule train and instruments, and the observations at Mountain Camp.

Many kinds of observations were carried through. Measurements of total radiation of the solar beam by the globe and the Violle actinometers; measurements of homogeneous solar rays by the linear spectrobolometer; measurements of the brightness of the sky by day and by night; measurements of the temperature and humidity of the air at frequent intervals; barometric measurements for determining the then only approximately known elevation of Mount Whitney;

measurements of the percentage of carbonic acid in the atmosphere. Besides all these, even other types of measurements were made in profusion at Lone Pine, at Mountain Camp, and to some extent on the peak of Mount Whitney. The reduction of this immense mass of evidence was a task which occupied Langley's small force for two years, though it included the immortal Keeler and the assiduous Very. The great object was to determine the transparency of the atmosphere with such certainty, by these operations in one of the purest atmospheres of the world, as to fix the value of the solar constant of radiation. Langley thought to check the determination by computing from the results at Lone Pine what ought to be found on Mount Whitney. No less than a fifth of the atmosphere lay between these observing stations. Unfortunately Langley was misled by this apparently reasonable idea. For at Lone Pine he measured the average transparency for all atmospheric layers to the limit of the atmosphere, a transparency obviously greater than that of the more humid and dusty layers between him and Mountain Camp. He could not fairly use his average results at Lone Pine to compute, as he did, what ought to be observed at Mountain Camp. By this error of logic, aggravated by a moderate plus error in the absolute readings of his actinometers, Langley persuaded himself that the Mount Whitney Expedition indicated 3.07 calories per square centimeter per minute as the solar constant of radiation, a value more than 50 percent too high. His justly great authority maintained this erroneous value for more than 20 years.

But it is not this unfortunate aspect of the reduction of Mount Whitney observations, but the tremendous driving power and fertility of invention of this astonishing pioneer that should fix our attention. He practiced for the first time what the problem demanded, namely: occupation of a high-level desert station, observations of both total radiation and homogeneous rays, and their combination after a definite method. These essentials are still the basis of solar-constant work. He traced and accurately outlined the energy spectrum of the sun far beyond all previous observers. He obtained for the first time accurate transmission coefficients for homogeneous rays. In short, Langley by the Mount Whitney Expedition set up the ideal toward which all later observers strive to approximate.

"THE TEMPERATURE OF THE MOON"

"That the moon gives light, but no sensible heat, has been a matter of observation even by the unaided senses of the primitive man, and the idea that we should expect heat to be associated with the light seems to be essentially a modern one. This modern view, until very recently, has been that the light of the moon penetrated to us, while the rays which give only heat were kept back by our own atmosphere. Melloni, the most conspicuous early asserter of our present doctrine that radiant heat and light are but different manifestations of the same energy, was led to pursue his lunar heat work on Mount Vesuvius by these a priori considerations, and his perseverance was justified by obtaining finally most minute yet real indications of heat. Save the observations of Piassi Smyth on the Peak of Teneriffe, and of M. Marie-Davy in France, we shall find, however, that with the exception of Lord Rosse, of the persons who have sought to observe the heated moon, nearly all have left only records of failure or of purely imaginary and therefore misleading, successes.

"Lord Rosse's work excels greatly in importance that of his predecessors, as he not only obtained unquestionable evidence of lunar heat, but was able to make the important generalization that since a considerable part of this is intercepted by glass, a great deal of the moon's heat is probably radiated from her soil. As regards the temperature of the sunlit surface of the moon, Lord Rosse determined in his first paper that it ranges through 500° of the Fahrenheit scale; but in a subsequent memoir in the Philosophical Transactions of the Royal Society for 1873, this range is stated to be more nearly 200° Fahrenheit, a large error having crept into the previous work. The assiduous labor of observation and the instrumental means employed in these researches have acquired great and deserved repute; but few perhaps have noticed minutely that in the computation of the ratio of solar to lunar radiation, the error of assumption is made that all, or nearly all, of the invisible heat is stopped by glass, with other postulates equally inadmissible in the light of our present knowledge. We must, then, while rendering a tribute of respect and even admiration to the conscientious labors of observation and reduction point out that some of the values derived from them by their author must be revised, as resting on assumptions which the progress of science has contradicted.

. . . .

"In a previous memoir [5] we have given the results of various experiments in regard to the distribution of light in the lunar spectrum

[5] On the Temperature of the Surface of the Moon, Mem. Nat. Acad. Sci., vol. III.

together with bolometric measurements of the total lunar radiation and its transmission, which we here briefly summarize.

"Experiment showed that the moon sends us a little more than 1/100000 part of the heat which we receive from the sun. Of this lunar radiation we found at the beginning of December only 14 percent transmitted by a specimen of glass which allowed over 75 percent of the solar rays to pass. An ebonite disk, which was almost completely opaque to light, transmitted 32 percent of the solar and only 7 percent of the lunar radiation. Very little difference was found in the apparent transmission of the solar and of the lunar beam by the earth's atmosphere as inferred from comparisons at high and low altitudes above the horizon.

"Photometric spectral comparisons showed that sunlight is much richer in the violet rays than moonlight, indicating a selective reflection by the lunar surface, which, however, becomes less marked as the red end of the spectrum is approached.

"Comparisons, made in the month of December, 1884, between the total radiation of the moon and that from a blackened vessel of hot water, subtending the same angle, showed that the heating effect of the moon (as received through our absorbing atmosphere) could be replaced by the (unabsorbed) heat of a lamp-blacked surface at about +80°C., or 353°C. above absolute zero. A part of the lunar radiation is reflected from the sun and a part never reaches us, being absorbed by the atmosphere. Due allowance for the former would diminish, and for the latter would increase, the indicated lunar temperature; but owing to the selective character of the reflection to which we have already alluded, to our ignorance of the moon's emissive power, and to the fact that the radiations of our atmosphere itself are of a wave-length similar to a considerable part of those we now study, no precise deduction can be made. . . . .

"We have in the last three years pursued these researches with constantly improving instrumental means, and the following pages are a description of them and of the results. It will be seen that the great labor bestowed on them has been given, not to determine a point of abstract or merely theoretical interest, but that it is justified by the fact that the whole subject of terrestrial radiation, the temperature of the surface of our planet, and the conditions of organic life upon it are intimately related to that of our present research. The entire radiation of the soil of our earth towards space goes on in a spectral region of which we have hitherto known nothing. These observations, in connection with those recently published on invisible spectra and the wave-lengths of extreme infra-red rays[6] give us our first knowledge of this *terra incognita*. I say 'knowledge,' with the admission that this knowledge is as yet alloyed with those imperfections which are inherent in the most painstaking work in an utterly new field. All here is so new that the difficulties themselves are of a quite unfamiliar kind; for it is well to bear in mind that though all our observations, from first to last, are made on an amount of heat which may be well called infinitesimal, it is still the kind of radiations which produce this heat rather than the amount which forms the greatest difficulty. This, as we shall see, is because this heat seems to be largely that absorbed and reradiated from the substance of the lunar soil, and whose temperature is consequently so low as to be in constant danger of being confused with the heat from the terrestrial media it has passed and from the different parts of the apparatus itself—a difficulty which, when the thing in question is to ordinary sense both invisible and inappreciable, constitutes an obstacle almost insurmountable, when we design to go beyond those features which Lord Rosse succeeded in noting. We notice, in particular, that however successfully we may protect our apparatus from the radiations of surrounding objects, we must always, in the nature of the case, either actually or virtually, interpose a screen at intervals to interrupt the heat we are measuring. In ordinary spectrothermal work, as in that on the sun, the radiations of this screen are perfectly negligible, and would be so if the sun's heat, while the same in kind as now, were no greater in amount than the moon's. Here, on the contrary, because they are of the same *kind* as those radiated from the moon's cold surface, they become of the first importance, so that a special study of the radiation of the screen becomes a necessity.

. . . .

"There are three principal methods of investigation: First, the measurement of the total heat of the moon with a concave mirror of short focus, concentrating it as much as possible and admitting the interposition of a sheet of glass to rudely indicate the quality of lunar rays as compared with those of the sun. This method, which was that employed by Lord Rosse, has been very thoroughly practiced here with results which have been partly given in the previous memoir. The second method has been to form, usually with this same mirror, an image of the moon, but this now falls upon the slit of a special spectroscope

[6] See Am. Journ. of Sci., XXXII, August, 1886, 'On Hitherto Unrecognized Wave-Lengths'; also an article in Annales de Chim. et de Phys., 6 ser., T. IX, December, 1886, 'Sur les spectres invisibles.'

provided with a train of rock-salt lenses and a salt prism of exceptional size and purity; and after expanding this excessively minute heat in this way it has been found possible, with late improvements in the apparatus, to measure by the bolometer the different degrees of heat in the different parts of this lunar spectrum; and the doing of this, with its results, forms the principal subject of the present memoir. . . . . Third. Since such a mirror as that just mentioned, owing to its short focus, forms an extremely small lunar image, in certain observations, carried on, however, only during a limited time, we have taken advantage of the sensitiveness of our apparatus to explore a large lunar image with the bolometer in spite of the diminished heat in such a one. For this purpose a special mirror 303 mm in diameter and 3,137 mm focus, giving a lunar image of about 30 mm diameter, has been employed.[7] On the special occasion of a lunar eclipse the last-named apparatus has also been used.

. . . .

"Let it be remembered that every observation on radiant heat, however conducted, whether by the thermometer, the bolometer or thermopile, on the sun or moon, or on a neighboring candle—every observation in radiant heat, we repeat, involves the use of a screen at some stage in the process; since its use is inherent from the very nature of the observation. Again, let it be remembered that, in this peculiar case, the screen itself not only intercepts other rays, but contributes radiations of its own of like quality and amount to those which we would study, and the importance of the investigation to be shortly given on its theory becomes manifest. It will be seen later that the screen is used as little as possible, and that to this end every observation on the moon is preceded by one on the adjacent sky to the east and followed by one on the adjacent sky to the west; and that the lunar radiation is compared in every case immediately with the mean of the last two and only mediately with that of the screen, whose use we might here appear to be able to dispense with, but which is in fact imposed upon us, we repeat, at some time in the course of the observations by conditions inherent in the nature of the observations themselves.

. . . .

"The conclusion of the whole matter is, that we have been dealing with a subject almost on the limit of our power of investigation with

[7] This special mirror has been kindly loaned to us by Mr. J. A. Brashear, of Allegheny.

the present means of science, and have reached no conclusions which we are absolutely sure of. As regards the main point, concerning the radiant heat of the moon, we know that it is divided into two salient kinds, reflected and emitted heat, and that the latter overlaps the former and extends probably between the deviation 40° of a rock-salt 60° prism (corresponding to $\lambda = 1^{\mu}.03$) and a deviation of over 33° in the extreme infra-red (λ=perhaps 50^{μ}). Contrary to all previous expectations, it nevertheless reaches us, thus bringing evidence of the partial transparency of our terrestrial atmosphere even to such rays as are emitted by the soil of our planet. It is probable, as remarked elsewhere, that even of the heat of arctic ice some minute portion escapes by direct radiation into space.

"If beyond this we can be said to be sure of anything, it is that the actual temperature of the lunar soil is far lower than it is believed to be; but the evidence does not warrant us in fixing its maximum temperature more nearly than to say it is little above 0° centigrade; but, it will be seen, the writer is sensible that this conclusion militates against one drawn by him from the Mount Whitney observations, according to which the soil of an airless planet at the moon's distance would have a temperature not greatly above −225°C. Great experimental labor on this expedition was expended in ascertaining the excess of temperature which a thermometer-bulb would attain in space at the earth's distance from the sun, which was found to be approximately 48° centigrade. From this observation, which appears to be quite trustworthy, the writer drew the inference that the sunward surface of an airless planet would be very greatly below the zero of the centigrade thermometer, and materially colder than the moon's surface appears by these observations to be. As between my observations and my inferences, I hold to the former; and since later and long-continued observations, of the character detailed in this volume, show that the temperature of the sunward surface of the moon (which is certainly nearly airless) is almost as certainly not greatly below zero, I have been led to believe myself mistaken in one of the inferences drawn from former experiments, in themselves exact, where this inference is not supported by these later observations.

. . . .

"Several methods have been tried for obtaining the ratio of the total radiation of the full moon to that of the sun, with results ranging from 1/70000 to 1/110000. The liability to error in the comparison of such diverse quantities is obvious; but a portion of the discrepancy is undoubtedly due to variation in the transmissibility of our atmosphere to the peculiar rays emitted by the moon.

. . . .

"From measures in different parts of the lunar image, we find that the rays absorbed by glass are present in greater proportion in the radiation coming from the dark areas, or so-called "seas". . . . . The smaller radiation of the dark regions is presumably due to the presence of a larger proportion of those longer waves to which our atmosphere is partially opaque.

"Measurements in the lunar image during an eclipse of the moon showed a very rapid diminution of the heat as the eclipse progressed, a small amount (not over 2 percent, however) remaining in the umbra, of a quality to which glass was entirely opaque. The increment of the lunar radiation on the passing of the eclipse was apparently almost as rapid as its previous decrease.

"Less rapid than the change during an eclipse, but still strongly marked, is the transposition which occurs in the degree of heat observable at the east and west limbs, respectively, a few hours before and after the full. Thirty-six hours before the full the radiation of the west limb in terms of that from the central region of the moon was 0.958, that of the east limb being 0.574; while thirteen hours after the full the order was reversed, the west limb giving 0.611 and the east 0.727.

. . . .

"We next give the observations reduced to the full and to a mean distance, but uncorrected for atmospheric absorption, arranged according to the season in two groups; the object of this arrangement being to compare any systematic variation of the atmospheric absorption with the change of season. [Only the mean values given here.]

Lunar Spectrum—Winter Observations (November to April), Reduced to Full Moon and Mean Distance

No. ..	40°00′	39°45′	39°30′	39°15′	39°00′	38°45′	38°30′	38°15′	38°00′	37°45′	37°30
Mean..	16.9	15.6	17.4	16.1	15.3	14.1	11.4	12.4	24.1	39.2	48.8
No.		37°15′	37°00′	36°45′	36°30′	36°15′	36°00′	35°45′	35°30′	35°15′	35°00
Mean		43.0	36.0	38.4	32.2	25.9	25.6	21.8	18.3	17.4	11.6

Lunar Spectrum—Summer Observations (May to October), Reduced to Full Moon and Mean Distance

Mean..	15.7	22.5	19.9	17.8	15.0	6.5	4.8	4.2	10.1	30.5	35.7
Mean		41.0	37.1	33.9	20.4	27.4	15.5	17.2	13.0	10.7	9.7

"It will be seen from the above table and from the curves in Plate 11 that there is on the whole a slight increase in the atmospheric absorption in the summer. This increase would be still more marked if only the coldest and driest days of winter had been compared with the most humid of summer. . . . .

". . . . The most reliable spectrum comparisons with a blackened screen show an average 'effective lunar temperature' of +45.°C. near the time of full moon.

". . . . A measurement . . . . gives for the ratio of

$$\frac{\text{reflected radiation}}{\text{emitted radiation}} = 1 : 4.$$

This, it is to be remembered, is the ratio after absorption by the earth's atmosphere; but the extreme infra-red rays may have suffered unduly in passing this barrier. . . . ."

These researches on the temperature and spectrum of the moon entailed observations at Allegheny on more than 50 nights spread over the coldest of winter and the hottest of summer, as well as in months less trying to the observers, from October 1884 to February 1887. The spectrum observations alone, absolutely pioneering in character, of which only mean values are quoted here, occupied 22 nights, besides the preparation for them on uncounted days.

In order to avoid errors from the scattering of the more abundant rays of other wave lengths into the weaker regions observed in the lunar spectrum, Langley was obliged to use two spectroscopes in tandem, each employing a rock-salt prism because glass is opaque to such rays as are emitted by cool bodies like the moon. The common experience of the salt shaker at the dinner table has taught us how readily rock salt absorbs water. The slightest cloud of mist upon a rock-salt prism is prejudicial to its optical performance. It is easy to imagine, therefore, how often in summer the spectral observations of the moon were interrupted, and Dr. Langley's good friend Mr. Brashear came to the rescue by resurfacing the prisms.

"ON HITHERTO UNRECOGNIZED WAVE-LENGTHS"

"We are led to take this labor, not primarily to settle the theoretical questions involved in determining the relation between dispersion and wave-length (though these are most interesting), but with the object of providing a way which will hereafter enable any observer to determine the visible or invisible wave-lengths of any heat, whether from a celestial or terrestrial source, observed in any prism; and thus to gain that knowledge of the intimate constitution of radiant bodies which an acquaintance with the vibratory period of their molecules can usually alone afford us. It is this considerable end—the opening up to research of the whole unexplored region of infra-red energy, not only from celestial but from terrestrial sources—which will, we trust, justify the labor devoted to the following determinations."

He describes the arrangement of his apparatus, which includes a diffraction grating and a prism in tandem. A beam of radiation from the sun or the electric arc first traverses the diffraction grating spectroscope, whereby a group of rays of even multiples of the wave length of a certain selected visible ray are all concentrated upon the slit of the prismatic spectroscope. In the latter, the prismatic deviations are measured, and from them are readily computed the indices of refraction of each of these rays of selected wave lengths.

"There are in fact, passing through the same slit and lying superposed on one another by an unavoidable property of the grating, an infinite number of spectra in theory, of which in this case nearly twenty are actually recognizable, by photography, by the eye, or by the bolometer, and of which, to consider only those where the wave length is equal to or greater than that of the sodium line D_2[8] we have six spectra as follows:

					Wave length
a. (visible)	6th	spectrum		D_2..................	$\lambda = 0^{\mu}.5890$
b. "	5th	"	6/5	D_2..................	0 .7068
c. (invisible)	4th	"	6/4	D_2..................	0 .8835
d. "	3d	"	6/3	D_2..................	1 .1780
e. "	2d	"	6/2	D_2..................	1 .7670
f. "	1st	"	6	D_2..................	3 .5341

"It is in this invisible underlying first spectrum, buried, so to speak, beneath five others, of which three are themselves invisible also, that lies the wave-length we are seeking; consequently, there are (to consider no others) at least six qualities of heat, of six distinct refrangibilities, whose wave-lengths are equal to or greater than that of D_2, which pass simultaneously through the slit S_2. They pass through the prism, and on looking through a telescope occupying the position of the bolometer tube, we shall by suitably directing the arm of the spectroscope see the light from the sixth one at *a*. Its wave-length will be $0^{\mu}.5890$, corresponding to a measured deviation (in the case of the rock-salt prism, of an angle of 60°00′00″ and a temperature of 20°C.) of 41°05′40″. Now on replacing the telescope by the

[8] We have heretofore adopted Ångström's notation in calling the more refrangible sodium line 'D_1'. We shall hereafter, however, in conformity with the now more general usage, call this line, whose wave-length in Ångström is 5889, 'D_2'. The corrections to Ångström are due to the researches of Messrs. Peirce and Rowland.

bolometer, the bolometer wire will feel this same ray which the eye has just recognized by its light, and, if the galvanometer be in a sensitive condition, the image will be thrown by the heat off the scale, while a little on either side of this position no indication will be given. The beam and the slit S_2 remaining in the same position, let us next suppose that the bolometer arm is carried toward b, in the direction of B. There will be no sensible deflection until it reaches the position b in the red, corresponding to a wave-length of $0^{\mu}.7068$, and in the prism to an angle of $40°33'$ nearly, for there is no sensible heat except in the successive images of slit S_2 formed by the prism P in the line PB. Passing farther toward B we come into the heat in c, and next to the heat in d which is less than 1/100 that in the direct prismatic image, when no grating is employed.

"This was the utmost limit of our power of measurement in 1883, beyond this point radiations from the grating being then absolutely insensible, and the radiation at the point d itself being excessively minute, even in the solar spectrum, where the heat, so far as any is found, is as a rule far greater than that in the spectrum of the arc. Accordingly I have elsewhere observed that these measures could be carried on as well by a large electric arc as by the sun; but in fact, owing to the difficulties attendant on bringing the arc, which must be of immense heat, close to slit S_1, and to other causes, the sunlight would be preferable wherever it could be used.

"Our observation of June 7, 1882, gave the value of the index of refraction corresponding to $\lambda = 2^{\mu}.356$, which was the lowest possibly attainable by our then apparatus. Incessant practice and study, resulting in improvements already referred to, have enabled us finally to measure down to a wave-length of $9 \times \lambda D_2$ corresponding to a position much below f. We may add that in doing so, it is sometimes convenient to employ a bolometer wide enough to overlap the images in the other adjacent spectra of the higher orders, which we may usually do without confusing them, owing to their feebleness compared with that of the first spectrum in which we are searching.

"We usually, however, employ a bolometer of not more than 1 mm aperture, and this demands excessive delicacy in the heat-measuring apparatus, since the heat here is, approximately speaking, about 1/10000 of that in the region between the sodium lines in the direct spectrum of a rock-salt prism. This is near the limit of our present measuring powers with the grating, even when every possible device is used to increase the extremely feeble heat in this part of the spectrum.

"We commenced by using an electric arc with carbons 12 mm in diameter in the position indicated. These were supplied by an engine of three horse-power; but even in this case the pit of the crater did not nearly cover the very short slit (its length is 8 mm). For these last and most difficult measurements, we have been obliged to procure the use of an engine of twelve horse-power and carbons 25 mm (one inch) in diameter. With this enormous current the hottest part is not easily maintained in place. To keep it directly in front of the slit we have tried various plans, such as boring out the carbons lengthwise, so as to form hollow cylinders of them, and filling the core with a very pure carbon tempered to the requisite solidity. Ordinarily it will be sufficient however to first form the central crater by a drill. This gives us a persistent crater, whose light, in the position shown in the engraving, filled a slit whose vertical height is 8 mm. It is probably the intensest artificial heat ever subjected to analysis.

. . . .

"In the following brief table we have summarized the results of all this labor. Our working method gave the index in terms of the wave-length, but since ordinarily the former is the known, and the latter the unknown quantity, we here give the mean probable error as finally corrected as a function of the latter.

Given indices of refraction in rock-salt prism	Wave-lengths from direct observation (*a*) by the eye (*b*) by the bolometer
1.5442	$\lambda D_2 = 0^{\mu}.5890 \pm 0.000$ (*a*)
1.5301	$2 \times \lambda D_2 = 1\ .1780 \pm 0.002$ (*b*)
1.5272	$3 \times \lambda D_2 = 1\ .7670 \pm 0.005$ (*b*)
1.5254	$4 \times \lambda D_2 = 2\ .3560 \pm 0.009$ (*b*)
1.5243	$5 \times \lambda D_2 = 2\ .9451 \pm 0.013$ (*b*)
1.5227	$6 \times \lambda D_2 = 3\ .5341 \pm 0.019$ (*b*)
1.5215	$7 \times \lambda D_2 = 4\ .1231 \pm 0.029$ (*b*)
1.5201	$8 \times \lambda D_2 = 4\ .7121 \pm 0.043$ (*b*)
1.5186	$9 \times \lambda D_2 = 5\ .3011 \pm 0.065$ (*b*)"

Compared to our later determinations and those of Paschen, these observed indices of refraction of rock salt are found to differ but one or two units in the fourth place of decimals from the true values. To estimate the wave lengths of his lunar spectrum, Langley extrapolated, using the best formula then available. As this formula was erroneous for these great wave lengths, its results gave him exaggerated impressions of the greatness of the wave lengths he actually observed. For instance, in Appendix No. 1 of his paper "The Solar and Lunar Spectrum," he gives a wave length as 21.5 microns which, corrected by modern data, should read 10.7 microns. Similarly the latter values of the table which concludes "On Hitherto Unrecognized Wave-Lengths" are considerably too great.

ANNALS OF THE ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN INSTITUTION, VOLUME 1

As indicated in the remarkable passage already quoted from the Mount Whitney Report, Langley's prophetic instinct told him that in the study of the sun's radiation rested the main hope of long-range weather forecasting. He moved toward the establishment of solar research at the Smithsonian Institution soon after becoming Secretary. He writes:

"This book is the result of a research originally due to a discovery, made in the year 1881 with the then newly invented bolometer, in the clear air of an altitude of over 12,000 feet, of solar heat in a then unknown spectral region now called the 'lower infra-red spectrum.' The bolometer has since been used to explore and to map the region in question, through the long succeeding intervals, in the latter part of which it has reached an accuracy and a sensitiveness greater than I could once have hoped for.

"This map is now (June 18, 1900), after years of constant work, finally published in the present form; not because this edition is final, but because the long labor must come to some term, and because I desire to see its results published while I may hope to see them made useful.

. . . .

"While we are far from looking forward to foretelling by such means the remoter changes of weather which affect the harvests, or to results of such importance as the power of such a prevision would indicate, still it is hardly too much to say that we appear to begin to move in that direction, and it seems to me that my own early hopes of making the study of the solar energy not simply an interesting scientific pursuit, but one of material usefulness, may one day be justified.

. . . .

"In the reports of the Secretary of the Smithsonian Institution for the years ending June 30, 1888 and 1889, mention is made of the hope then cherished of erecting and equipping an observatory for astrophysical research; and in the year following, 1890, he is at last 'able to say that this object has assumed definite shape in the construction of a temporary shed, begun on November 20, 1889 and . . . . completed about the 1st of March, 1890. This building is of the most inexpensive character, and is simply intended to protect the instruments temporarily, though it is also arranged so that certain preliminary work can be done here. Its position, however, immediately south of the main Smithsonian building, is not well suited to refined physical investigations, on account of its proximity to city streets and its lack of seclusion.'

. . . .

"The distinct object of astrophysics is, in the case of the sun, for example, not to mark its exact place in the sky, but to find out how it affects the earth and the wants of man on it; how its heat is distributed, and how it in fact affects not only the seasons and the farmer's crops, but the whole system of living things on the earth, for it has lately been proven that in a physical sense it, and almost it alone, literally first creates and then modifies them in almost every possible way.

"From the beginning of regular operations at the observatory in June, 1891, till the 1st of March, 1892, efforts were chiefly directed to getting the apparatus in satisfactory condition for observations. Much time was spent on the improvement of galvanometers, in testing bolometers and prisms, and in the determination of their constants.

"At length, on March 2, 1892, a 'rehearsal' occurred, in which the procedure followed in the bolometric investigations of the infra-red solar spectrum at Allegheny, already referred to on a previous page, was gone through with for the first time at the observatory. A second rehearsal occurred on the following day, and on reviewing it an entry was made by the writer March 4, 1892, in the record book in use by Dr. William Hallock, from which the following quotation is taken:

"I think your yesterday's spectral maps were quite successful for a first attempt—indeed, notably so, and give evidence of the goodness both of the system and of the instrumental means. The salient defect of the latter is in the 'drift' of the galvanometer, which, though reduced to limits which are insignificant compared to those which it had when I first began the study, is still a barrier to the best work.

"My idea (if drift could be eliminated) would be to have a vertical strip of sensitive paper rolled perpetually upward by a clockwork in the focus of the galvanometer mirror. The sides of this paper are marked in degrees and minutes, corresponding to divisions of the spectrometer circle, whose arm is moved by the same clockwork (through electric or other intermediary), so that when the circle is turned through *n* minutes of arc, the paper is moved upward linearly by a quantity corresponding to the same angular measure. A light is reflected from the mirror onto the paper, on which are traced the movements of the mirror due to the varying heat of the spectrum and to passing inequalities of the sky transmission. (The mirror movement has to be dampened so that there is no sensible swing.) The whole spectrum could be thus traversed in five minutes or less, as many as twelve curves could be taken in an hour, and a composite photograph would eliminate the accidental disturbances.

"All this implies that 'drift,' if not eliminated, is to be greatly reduced. Please consider this 'drift,' as well as the little movements of the needle due to changes in the apparatus itself, under these three heads:

(*a*) Changes due to alterations in the galvanometer.

(*b*) Changes due to alterations in the bolometer.

(*c*) Changes due to alterations in the battery, and all other sources.

"It seems quite certain that these are due largely to temperature.

. . . .

"*Our object hereafter is to map the lines.*"

Under his assistants, Hallock, Wadsworth, and R. C. Child, this program was so far fulfilled that in the year 1894 Langley exhibited at the Oxford meeting of the British Association for the Advancement of Science a map of the infrared solar spectrum as far as a wave length of 4.2 microns. This was based on automatic energy curves produced by continuous photographic records of the warming and cooling of the strip of the fine linear bolometer, as expressed in the swings of the sensitive galvanometer.

The present writer and his colleague, Mr. Fowle, continued this mapping of the infrared solar spectrum. Volume 1 of the Annals of the Astrophysical Observatory contained a discussion of the apparatus, a map of the infrared solar spectrum containing 579 lines and bands between wave lengths 0.76 and 5.3 microns, a highly accurate measurement of the dispersion of rock salt to 5.3 microns, and various subsidiary reports. The finest details of the infrared spectral map depended on a decision by the observers as to whether small nicks in the energy curves denoted solar or atmospheric absorption, or merely accidental error from shaking or electrical disturbance. This led Langley to what seemed to me the smoothest piece of dictation I ever heard. Unfortunately the stenographer was inexperienced, and it lost something before printing, even though Langley spent considerable time over it in manuscript and proofs. It is as follows:

"When we approach the limits of vision or audition, or of perception by any other of the human senses, no matter how these may be fortified by instrumental aid, we finally perceive, and always must perceive, a condition still beyond, where certitude becomes incertitude, although we may not be able to designate precisely where one ceases and the other begins.

"This is always the case, it would seem, on the boundaries of our knowledge in every department, and it is so here.

"It is impossible, for instance, to look at the great and notable deflection of a line such as *A*, or to the deflections corresponding to yet larger bands below it, and to see these in exactly the same place on scores of plates taken for years together without feeling an absolute certitude of their real existence as regions of special absorption in the solar or terrestrial atmosphere. After longer study it is found that as absolute a certainty exists as to many hundred smaller lines seen in the same conditions, and yet as we improve our apparatus and recognize still minuter solar deflections, we finally come to a condition where these are reduced to the same order of magnitude as those which may be due to earth tremors and to similar accidental disturbances, which are here represented by the irregular line which is called the 'battery record.'

"But, it may be asked, are we not entitled to demand that these last should somehow be eliminated altogether and the 'battery record' become a perfectly smooth line? The answer is, that this can never be.

"As seismography improves, it becomes more clear that there is no part of the earth's surface free from constant tremor; as the refinements of electrical science advance we constantly discover earth currents where they were not perceived before; as we multiply the sensitiveness of our measuring apparatus, till it comes to what seems almost indefinite delicacy, we find that the most massive apparatus and the most refined precautions which we may take, do not prevent the existence of all but infinitesimally small accidental disturbances, nor of the notation of their sensible effects if the record itself be only minute enough, for this record is a testimony, in fact, to the sensitiveness of the apparatus itself, and minute disturbances are always to be found if the observation itself which deals with them provides in itself the means of detecting them.

"It fell to the writer once to establish a permanent meridian instrument whose supports he desired to build up with every condition of stability which experience and caution could suggest. He personally looked to the obtaining of the required blocks of granite at the quarry and to laying them in the same way in the foundation of the observatory on its bed rock as they lay in the original bed, and he superintended the placing of those, one upon the other, until the foundation was laid for the piers which finally supported the instrument, and which were chosen with the same care. He believed that this instrument was as solidly mounted as anything on the earth could be. He used it for many years in his observations with a confidence justified by the results; but these observations required a powerful telescope, and there was no time at which a tap of the fingers on the side of the monolothic piers which carried the telescope would not be accompanied by an apparent leap in the heavens of the star on which it was directed—a statement which will not surprise any professional astronomer. It is made here to emphasize the like statement that there is, then, no limit to our power of perception of tremors. These are, it will be remembered, instances which may be paralleled in illustrations drawn from the use of other senses, and not peculiar to the present observation.

"Clearly, we may never distinguish the entire number of solar lines which exist here more than we could in visible spectra by the use of the eye or by photography. In every case there must finally come a time when we must stop our investigations because we have reached a degree of minuteness in the solar lines corresponding to the intervening disturbances due to terrestrial causes, which we can never eliminate."

"ON A POSSIBLE VARIATION OF THE SOLAR RADIATION AND ITS PROBABLE EFFECT ON TERRESTRIAL TEMPERATURES"

This was Langley's last important paper. It was based on observations by Mr. Fowle and the present writer made at Washington. After long experience in far better observing locations we cannot suppose that the solar variations indicated in 1903 were real. Nevertheless they embarked us on a long endeavor to determine accurately the limits of the solar variation and its effects on weather. This investigation now [1934] seems certain to be of quite as great importance as Langley ever dreamed, for it gives promise of long-range weather forecasting, not only for seasons but for years in advance. But let us quote from the paper.

"The purpose of the present communication is primarily to discuss the validity of a surmise we may entertain, founded on observation here, as to certain possible changes in the solar constant. There is especially discussed a possible falling off of solar radiation about the close of March 1903, as indicated by certain recent values of solar radiation computed from observations here, and compared with actually observed temperatures for eighty-nine stations of the North Temperate Zone.

. . . .

"The homogeneous rays are observed here by the bolometer, and the bolographic curves from which the atmospheric extinction of radiation is inferred, traced by the movement of the spot of light upon the galvanometer scale, are now very much more satisfactory than formerly. They represent an immense gain over the conditions operating when I began the work at Allegheny. The light-spot should move only by an impulse from the Sun, but, owing to extraneous causes, it was at first frequently impossible to keep it upon the scale of the galvanometer during so short a time as a single minute. The apparatus now, however, operates so well that such drift and tremor is relatively unknown, and the zero of the galvanometer is found almost unchanged for weeks together. . . . ."

After discussing the methods of observing, the solar constant of radiation, and giving a table of 25 values of it observed at Washington in 1902, 1903, and 1904, Langley continues:

"Looking at the general results, these seem then to indicate a possibility that a rapid fall of solar radiation occurred about the close of March,[9] and that subsequently the radiation continued nearly or quite 10 percent less than before. This, if certain, would be important, and we may inquire what causes on the Sun could produce such a change, and what effects might be expected to be produced on the Earth if it occurred.

"The writer showed nearly thirty years ago[10] that the envelope of the Sun profoundly influences by its absorption the radiation received by the Earth. While the absorption in the solar envelope is not exactly known, still so much is known that we may infer that if it were absent for a moment the Earth would receive nearly double its present amount of heat. If a variation of 10 percent in the transparency of this envelope occurred, nearly 10 percent of change in the solar radiation outside the Earth's atmosphere would follow.

"If a fall of solar radiation did occur, there ought to have been a similar change of terrestrial temperatures afterward, and we may inquire how great this fall of temperature should be.

"The Earth may be regarded as a body at a mean temperature of 290° absolute (17°C.), maintained at approximately constant temperature by a balance between solar radiation received and terrestrial radiation emitted. It is here assumed that all sources of heat other than the solar radiation are negligible, but if any or all of them are not so, the effect of their presence will be to reduce the effect on temperature of a fall in solar radiation.

"Recent studies of German physicists have experimentally verified, for the perfect radiator, Stefan's law that the emission of a heated

---

[9] It is of interest to note that a marked increase of Sun spots occurred on March 21. See Report of the Council, Monthly Notices of the Royal Astronomical Society, 64, 357.

[10] Comptes Rendus, 81, 436, Sept. 6, 1875.

body is proportional to the fourth power of the temperature.[11] Other bodies not perfect radiators depart from this law in the sense that, while radiating less absolutely than the perfect radiator, their emission is more nearly proportional to a power of the temperature higher than the fourth.[12] Suppose T_1 to be the mean temperature of the Earth corresponding to a rate of solar radiation S_1, and T_2, that corresponding to S_2. Assume further that the reflecting power of the Earth remains unchanged, and that no appreciable heat is received from other sources than the Sun. Then

$$\left(\frac{T_2}{T_1}\right)^x = \frac{S_2}{S_1}, \text{ where } x>4.$$

Accordingly if, as supposed, S_2 is $9/10\ S_1$,

$$T_2>0.974T_1.$$

"If $T_1=290°$, then $T_2>282.°5$, and $T_1-T_2<7°.5C$.

"It may then be stated that if the solar radiation remained for a long period of time at a value which would maintain the Earth's surface at a mean temperature of 17°C., and then fell 10 percent, and so remained indefinitely, the fall of temperature of the Earth's surface would be less than 7°.5C.

"But if the solar radiation fluctuated between limits separated by 10 percent, the fluctuation of terrestrial temperature would be less, according to the frequency of the fluctuations of solar radiation. Again, parts of the Earth's surface most closely associated with the oceans by the influences of winds, ocean currents, and rainfall would be least affected by such solar fluctuations, and would respond most slowly to a permanent alteration of solar radiation.

"From the foregoing considerations we may then infer that the effect of a fall of 10 percent in the solar radiation should diminish the mean temperature of the Earth not more than 7°.5C., and indefinitely less according to the shortness of the time elapsing before the radiation regained its former value. Stations near the sea, or subject to ocean currents and winds, or to heavy rainfall, would lag far behind stations in the interior of great continents in their temperature fluctuations.

"When we come to the study of actual temperatures over the Earth's surface, we find that all collections of temperature data for single stations in the interior of great continents, covering long periods

---

[11] O. Lummer, Rapports Présentés au Congrès International de Physique, 2, 78-81, 1900.

[12] H. Kayser, Handbuch der Spectroscopie, 2, 77-82.

of time, exhibit nearly every year such considerable irregular variations from the normal temperatures that we are at no loss to find variations comparable in dimensions with those we are supposing to be caused by a fluctuating solar radiation. But it is only within the last year that we have the series of radiation measures with which to compare temperatures, and we now turn to recent temperatures as published in the Internationaler Dekadenberichte of the Deutsche Seewarte for nearly one hundred stations, for each ten-day period of 1903, and accompanied by normal temperatures representing the mean for the same ten-day periods of many former years.[13] . . . .

"On comparing the observed temperatures of 89 stations, distributed over the North Temperate Zone, with the mean temperatures of the same stations for many previous years, it is found that an average decrease of temperature of over 2°C. actually did follow the possible fall of the solar radiation, while the temperature continued low during the remainder of the year. Stations remote from the retarding influence of the oceans show a much greater variation than that of the general mean.

"While it is difficult to conceive what influence, not solar, could have produced this rapid and simultaneous reduction of temperatures over the whole North Temperate Zone, and continued operative for so long a period, the evidence of solar variation cannot be said to be conclusive. Nevertheless, such a conclusion seems not an unreasonable inference from the data now at hand, and a continuation of these bolographic studies of solar radiation is of increasing interest, in view of their possible aid in forecasting terrestrial climatic changes, conceivably due to solar ones."

"EXPERIMENTS IN AERODYNAMICS"

We now turn from astronomy, Langley's primary field, to aviation, a subject which intrigued him from boyhood's days, and in which in his later years he made advances so great that he barely missed the goal of achieving human flight in heavier-than-air machines. While still at the Allegheny Observatory, he began experiments on the lift and resistance of rapidly moving surfaces in air, employing a whirling arm to carry them, and ingenious automatic instruments of his own design to record the results. This work he continued at Washington, resulting in a publication "Experiments in Aerodynamics."

[13] The writer is indebted to Professor Cleveland Abbe and to Dr. W. F. R. Phillips, librarian of the U. S. Weather Bureau, for their aid in making accessible the publications of temperature data in possession of the Weather Bureau.

"Schemes for mechanical flight have been so generally associated in the past with other methods than those of science, that it is commonly supposed the long record of failures has left such practical demonstration of the futility of all such hopes for the future that no one of scientific training will be found to give them countenance. While recognizing that this view is a natural one, I have, however, during some years, devoted nearly all the time at my command for research, if not directly to this purpose, yet to one cognate to it, with a result which I feel ought now to be made public.

. . . .

"Further than this, these new experiments, (and theory also when reviewed in their light,) show that if in such aerial motion, there be given a plane of fixed size and weight, inclined at such an angle, and moved forward at such a speed, that it shall be sustained in horizontal flight, then the more rapid the motion is, the less will be the power required to support and advance it. This statement may, I am aware, present an appearance so paradoxical that the reader may ask himself if he has rightly understood it. To make the meaning quite indubitable, let me repeat it in another form, and say that these experiments show that a definite amount of power so expended at any constant rate, will attain more economical results at high speeds than at low ones—*e. g.*, one horse-power thus employed, will transport a larger weight at 20 miles an hour than at 10, a still larger at 40 miles than at 20, and so on, with an increasing economy of power with each higher speed, up to some remote limit not yet attained in experiment, but probably represented by higher speeds than have as yet been reached in any other mode of transport—a statement which demands and will receive the amplest confirmation later in these pages.

. . . .

"The reader, especially if he be himself skilled in observation, may perhaps be willing to agree that since there is here so little yet established, so great a variety of tentative experiments must be made, that it is impossible to give each of them at the outset all the degree of accuracy which is ultimately desirable, and that he may yet find all trustworthy within the limits of their present application.

"I do not, then, offer here a treatise on aerodynamics, but an experimental demonstration that we already possess in the steam-engine as now constructed, or in other heat engines, more than the requisite power to urge a system of rigid planes through the air at a great velocity, making them not only self-sustaining, but capable of carrying other than their own weight. This is not asserting that they can be steadily and securely guided through the air, or safely brought to the ground without shock, or even that the plane itself is the best form of surface for support; all these are practical considerations of quite another order, belonging to the yet inchoate art of constructing suitable mechanisms for guiding heavy bodies through the air on the principles indicated, and which art (to refer to it by some title distinct from any associated with ballooning) I will provisionally call aerodromics.[14] With respect to this inchoate art, I desire to be understood as not here offering any direct evidence, or expressing any opinion other than may be implied in the very description of these experiments themselves.

. . . .

"The experiments in question, for obtaining first approximations to the power and velocities needed to sustain in the air such heavy inclined planes or other models in rapid movement, have been principally made with a very large whirling table, located on the grounds of the Allegheny Observatory, Allegheny, Pa. (lat. 40°27′41.6″; long. $5^h20^m2.93^s$; height above the sea-level, 1,145 feet).

"The site is a hill on the north of the valley of the Ohio and rising about 400 feet above it. At the time of these observations the hill-top was bare of trees and of buildings, except those of the observatory itself. . . . .

"The whirling table consists essentially of two symmetrical wooden arms, each 30 feet (9.15 meters) long, revolving in a plane eight feet above the ground. . . . . The whirling table was driven first by a gas-engine of about 1½ horse-power, but it was found inadequate to do the work required, and, after October 20, 1888, a steam-engine giving 10 horse-power was used in its stead. . . . .

"This system gives for 120 revolutions of the steam-engine per minute, driving—

18 in. pulley, 48 revolutions of turn-table per minute = 100 + miles per hour at end of arm.

25½ in. pulley, 24 revolutions of turn-table per minute = 50 + miles per hours at end of arm.

36 in. pulley, 12 revolutions of turn-table per minute = 25 + miles per hour at end of arm.

"By regulating the speed of the engine any intermediate velocities can be obtained, and thus the equipment should be susceptible of furnishing speeds from 10 to 100 miles per hour (4.5 to 45 meters per second); but owing to the slipping of belts the number of turn-

[14] From ἀεροδρομέω, to traverse the air; ἀεροδρομος, an air-runner.

table revolutions was less than this for the higher velocities, so that the highest attained in the experiments did not reach this upper limit, but was a little over 100 feet (30 meters) per second, or about seventy miles per hour. The precise velocity actually attained by the turn-table is determined, quite independently of the speed of the engine, by an electrical registration on the standard chronograph in the observatory."

Langley devised ingenious recording instruments called the "suspended plane," the "resultant pressure recorder," the "plane dropper," the "component pressure recorder," the "dynamometer chronograph," the "counterpoised eccentric plane," and the "rolling carriage," all illustrated in the paper under discussion, and with these made many experiments.

"The most important general inference from these experiments, as a whole, is that, so far as the mere power to sustain heavy bodies in the air by mechanical flight goes, *such mechanical flight is possible with engines we now possess*, since effective steam-engines have lately been built weighing less than 10 pounds to one horse-power, and the experiments show that if we multiply the small planes which have been actually used, or assume a larger plane to have approximately the properties of similar small ones, one horse-power rightly applied, can sustain over 200 pounds in the air at a horizontal velocity of over 20 meters per second (about 45 miles an hour), and still more at still higher velocities. These numerical values are contained in the following table, repeated from p. 66. It is scarcely necessary to observe that the planes have been designedly loaded, till they weighed 500 grammes each, and that such a system, if used for actual flight, need weigh but a small fraction of this amount, leaving the rest of the sustainable weight indicated, disposable for engines and other purposes. I have found in experiment that surfaces approximately plane and of 1/10 this weight are sufficiently strong for all necessary purposes of support.

"Data for soaring of 30 × 4.8 inch planes; weight, 500 grammes

Angle with horizon a	Soaring speed V		Work expended per minute		Weight with planes of like form that 1 horse-power will drive through the air at velocity V	
	Meters per second	Feet per second	Kilogram-meters	Foot-pounds	Kilo-grammes	Pounds
45	11.2	26.7	336	2,434	6.8	15
30	10.6	34.8	175	1,268	13.0	29
15	11.2	36.7	86	623	26.5	58
10	12.4	40.7	65	474	34.8	77
5	15.2	49.8	41	297	55.5	122
2	20.0	65.6	24	174	95.0	209

"I am not prepared to say that the relations of power, area, weight, and speed, here experimentally established for planes of small area, will hold for indefinitely large ones; but from all the circumstances of experiment, I can entertain no doubt that they do so hold far enough to afford assurance that we can transport (with fuel for a considerable journey and at speeds high enough to make us independent of ordinary winds), weights many times greater than that of a man.

"In this mode of supporting a body in the air, its specific gravity, instead of being as heretofore a matter of primary importance, is a matter of indifference, the support being derived essentially from the inertia and elasticity of the air on which the body is made to rapidly run. The most important and it is believed novel truth, already announced, immediately follows from what has been shown, that whereas in land or marine transport increased speed is maintained only by a disproportionate expenditure of power, within the limits of experiment in *such aerial horizontal transport, the higher speeds are more economical of power than the lower ones.*

"While calling attention to these important and as yet little known truths, I desire to add as a final caution, that I have not asserted that planes such as are here employed in experiment, or even that planes of any kind, are the best forms to use in mechanical flight, and that I have also not asserted, without qualification, that mechanical flight is practically possible, since this involves questions as to the method of constructing the mechanism, of securing its safe ascent and descent, and also of securing the indispensable condition for the economic use of the power I have shown to be at our disposal—the condition, I mean, of our ability to guide it in the desired horizontal direction during transport—questions which, in my opinion, are only to be answered by further experiment and which belong to the inchoate art or science of *aerodromics* on which I do not enter.

"I wish, however, to put on record my belief that the time has come for these questions to engage the serious attention, not only of engineers, but of all interested in the possibly near practical solution of a problem, one of the most important in its consequences, of any which has ever presented itself in mechanics; for this solution, it is here shown, cannot longer be considered beyond our capacity to reach."

The data secured by these experiments have long since been superseded by more accurate observations in modern wind tunnels. Even the conclusions would not now all be considered sound. For instance, "Langley's law," that the more rapid the horizontal flight the less is the power required for support and advance, does not hold for speeds much higher than those he tried. His assumption that skin friction is negligible is also invalid at higher speeds. But a great impetus to aviation was given by the fact that so great a scientist as Langley had devoted himself to a subject which was generally regarded then as the refuge of cranks, nearly in the same class with perpetual motion.

Langley's meditations on soaring flight of birds led in 1893 to his brilliant paper:

"THE INTERNAL WORK OF THE WIND"

"It has long been observed that certain species of birds maintain themselves indefinitely in the air by 'soaring,' without any flapping of the wing, or any motion other than a slight rocking of the body; and this, although the body in question is many hundred times denser than the air in which it seems to float with an undulating movement, as on the waves of an invisible stream.

"No satisfactory mechanical explanation of this anomaly has been given, and none would be offered in this connection by the writer, were he not satisfied that it involves much more than an ornithological problem, and that it points to novel conclusions of mechanical and utilitarian importance. They are paradoxical at first sight, since they imply that, under certain specified conditions, very heavy bodies entirely detached from the earth, immersed in, and free to move in, the air, can be sustained there indefinitely, without any expenditure of energy from within.

"These bodies may be entirely of mechanical construction, as will be seen later, but for the present we will continue to consider the character of the invisible support of the soaring bird, and to study its motions, though only as a pregnant instance offered by Nature to show that a rational solution of the mechanical problem is possible.

"Recurring, then, to the illustration just referred to, we may observe that the flow of an ordinary river would afford no explanation of the fact that nearly inert creatures, while free to move, although greatly denser than the fluid, yet float upon it; which is what we actually behold in the aerial stream, since the writer, like others, has satisfied himself, by repeated observation, that the soaring vultures and other birds appear as if sustained by some invisible support, in the stream of air, sometimes for at least a considerable fraction of an hour. It is frequently suggested by those who know these facts only from books, that there must be some quivering of the wings, so rapid as to escape observation. Those who do know them from observation, are aware that it is absolutely certain that nothing of the kind takes place, and that the birds sustain themselves on pinions which are quite rigid and motionless, except for a rocking or balancing movement involving little energy.

"The writer desires to acknowledge his indebtedness to that most conscientious observer, M. Mouillard,[15] who has described these actions of the soaring birds with incomparable vividness and minuteness, and who asserts that they, under certain circumstances, without flapping their wings, rise and actually advance against the wind.

"To the writer, who has himself been attracted from his earliest years to the mystery which has surrounded this action of the soaring bird, it has been a subject of continual surprise that it has attracted so little attention from physicists. That nearly inert bodies, weighing from 5 to 10, or even more, pounds, and many hundred times denser than the air, should be visibly suspended in it above our heads, sometimes for hours at a time, and without falling—this, it might seem, is, without misuse of language to be called a physical miracle; and yet, the fact that those whose province it is to investigate nature, have hitherto seldom thought it deserving attention, is perhaps the greater wonder.

". . . . The common 'Turkey Buzzard' (*Cathartes aura*) is so plenty around the environs of Washington that there is rarely a time when some of them may not be seen in the sky, gliding in curves over some attractive point, or, more rarely moving in nearly straight lines on rigid wings, if there be a moderate wind. On the only occasion when the motion of one near at hand could be studied in a very high wind, the author was crossing the long 'Aqueduct Bridge' over the Potomac, in an unusually violent November gale, the velocity of the wind being probably over 35 miles an hour. About one-third of the distance from the right bank of the river, and immediately over the right parapet of the bridge, at a height of not over 20 yards, was one of these buzzards, which, for some object which was not evident, chose to keep over this spot, where the gale, undisturbed by any surface irregularities swept directly up the river with unchecked violence. In this aerial torrent, and apparently indifferent to it, the bird hung, gliding, in the usual manner of its species, round and round in a small oval curve whose major axis (which seemed toward the wind) was not longer than twice its height from the water. The bird was therefore at all times in close view. It swung around repeatedly, rising and falling slightly in its course, while keeping, as a whole, on one level, and over the same place, moving with a slight swaying both in front and

[15] L. P. Mouillard, L'Empire de l'Air, Paris: G. Masson.

lateral direction but in such an effortless way as suggested a lazy yielding of itself to the rocking of some invisible wave.

"It may be asserted that there was not only no flap of the wing, but not the quiver of a wing feather visible to the closest scrutiny, during the considerable time the bird was under observation, and during which the gale continued. A record of this time was not kept, but it at any rate lasted until the writer, chilled by the cold blast, gave up watching and moved away, leaving the bird still floating, about at the same height in the torrent of air, in nearly the same circle, and with the same aspect of indolent repose.

. . . .

"Light came to him through one of those accidents which are commonly found to occur when the mind is intent on a particular subject, and looking everywhere for a clue to its solution.

"In 1887, while engaged with the 'whirling-table' in the open air at the Allegheny Observatory, he had chosen a quiet afternoon for certain experiments, but in the absence of the entire calm which is almost never realized, had placed one of the very small and light anemometers made for hospital use, in the open air, with the object of determining and allowing for the velocity of what feeble breeze existed. His attention was called to the extreme irregularity of this register, and he assumed at first that the day was more unfavorable than he had supposed. Subsequent observations, however, showed that when the anemometer was sufficiently light and devoid of inertia, the register always showed great irregularity, especially when its movements were noted, not from minute to minute, but from second to second.

"His attention once aroused to these anomalies, he was led to reflect upon their extraordinary importance in a possible mechanical application. He then designed certain special apparatus hereafter described, and made observations with it which showed that 'wind' in general was not what it is commonly assumed to be, that is, air put in motion with an approximately uniform velocity in the same strata; but that, considered in the narrowest practicable sections, wind was always not only not approximately uniform, but variable and irregular in its movements beyond anything which had been anticipated, so that it seemed probable that the very smallest part observable could not be treated as approximately homogeneous, but that even here, there was an internal motion to be considered, distinct both from that of the whole body, and from its immediate surroundings. It seemed to the writer to follow as a necessary consequence, that there might be a potentiality of what may be called 'internal work'[16] in the wind.

"On further study it seemed to him that this internal work might conceivably be so utilized as to furnish a power which should not only keep an inert body from falling, but cause it to rise, and that while this power was the probable cause of the action of the soaring bird, it might be possible through its means to cause any suitably disposed body, animate or inanimate, wholly immersed in the wind, and wholly free to move, to advance against the direction of the wind itself. By this it is not meant that the writer then devised means for doing this but that he then attained the conviction both that such an action involved no contradiction of the laws of motion, and that it was mechanically possible (however difficult it might be to realize the exact mechanism by which this might be accomplished)."

He then goes on with experiments made with extremely light and sensitive anemometers to show that the apparently continuous flow of a wind is in reality made up of an extreme contrariety of gusts, capable, if they could be taken advantage of, not only of supporting a body in air, but even of causing it to rise and advance against the general direction of the wind.

"From this, then, we may now at least see that it is plainly within the capacity of an intelligence like that suggested by Maxwell, and which Lord Kelvin has called the 'Sorting Demon,' to pick out from the internal motions those whose direction is opposed to the main current, and to omit those which are not so, and thus without the expenditure of energy to construct a force which will act against the main current itself.

"But we may go materially further, and not only admit that it is not necessary to invoke here, as Maxwell has done in the case of thermodynamics, a being having a power and rapidity of action far above ours, but that, in actual fact, a being of a lower order than ourselves, guided only by instinct may so utilize these internal motions.

"We might not indeed have conceived this possible, were it not that nature has already, to a large extent, exhibited it before our eyes in the soaring bird, which sustains itself endlessly in the air with nearly

[16] Since the term "internal work" is often used in thermo-dynamics to signify molecular action, it may be well to observe that it here refers not to molecular movements, but to pulsations of sensible magnitude, always existing in the wind, as will be shown later, and whose extent and extraordinary possible mechanical importance it is the object of this research to illustrate. The term is so significant of the author's meaning that he permits himself the use of it here, in spite of the possible ambiguity.

motionless wings, for without this evidence of the possibility of action which now ceases to approach the inconceivable, we are not likely, even if admitted its theoretical possibility, to have thought the mechanism solution of this problem possible. But although to show how this physical miracle of nature is to be imitated, completely and in detail, may be found to transcend any power of analysis, I hope to show, that this may be possible without invoking the asserted power of 'Aspiration' relative to curved surfaces, or the trend of upward currents, and even to indicate the probability that the mechanical solution of this problem may not be beyond human skill.

. . . .

"Let me resume the leading points of the present memoir in the statement that it has been shown:

"(1) That the wind is not even an approximately uniform moving mass of air, but consists of a succession of very brief pulsations of varying amplitude, and that, relatively to the mean movement of the wind, these are of varying direction.

"(2) That it is pointed out that hence there is a potentiality of 'internal work' in the wind, and probably of a very great amount.

"(3) That it involves no contradiction of known principles to declare that an inclined plane or suitably curved surface, heavier than the air, freely immersed in, and moving with the velocity of the mean wind, can, if the wind pulsations here described are of sufficient amplitude and frequency, be sustained or even raised indefinitely without expenditure of internal energy, other than that which is involved in changing the aspect of its inclination at each pulsation.

"(4) That since (A) such a surface, having also power to change its inclination, *must* gain energy through falling during the slower, and expend energy by rising during the higher, velocities; and that (B) since it has been shown that there is no contradiction of known mechanical laws in assuming that the surface *may* be sustained or may continue to rise indefinitely, the mechanical possibility of some advance against the direction of the wind follows immediately from this capacity of rising. It is further seen that it is at least possible that this advance against the wind may not only be attained relatively to the position of a body moving with the speed of the mean wind, but absolutely, and with reference to a fixed point in space.

"(5) The statement is made that this is not only mechanically possible, but that, in the writer's opinion, it is realizable in practice.

. . . .

"The final application of these principles to the art of aerodromics seems then to be that, while it is not likely that the perfected aerodrome will ever be able to dispense altogether with the ability to rely at intervals on some internal source of power, it will not be indispensable that this aerodrome of the future shall, in order to go any distance—even to circumnavigate the globe without alighting,—need to carry a weight of fuel which would enable it to perform this journey under conditions analogous to those of a steamship, but that the fuel and weight need only be such as to enable it to take care of itself in exceptional moments of calm."

How plainly here does Langley foreshadow the achievements of gliding a third of a century later.

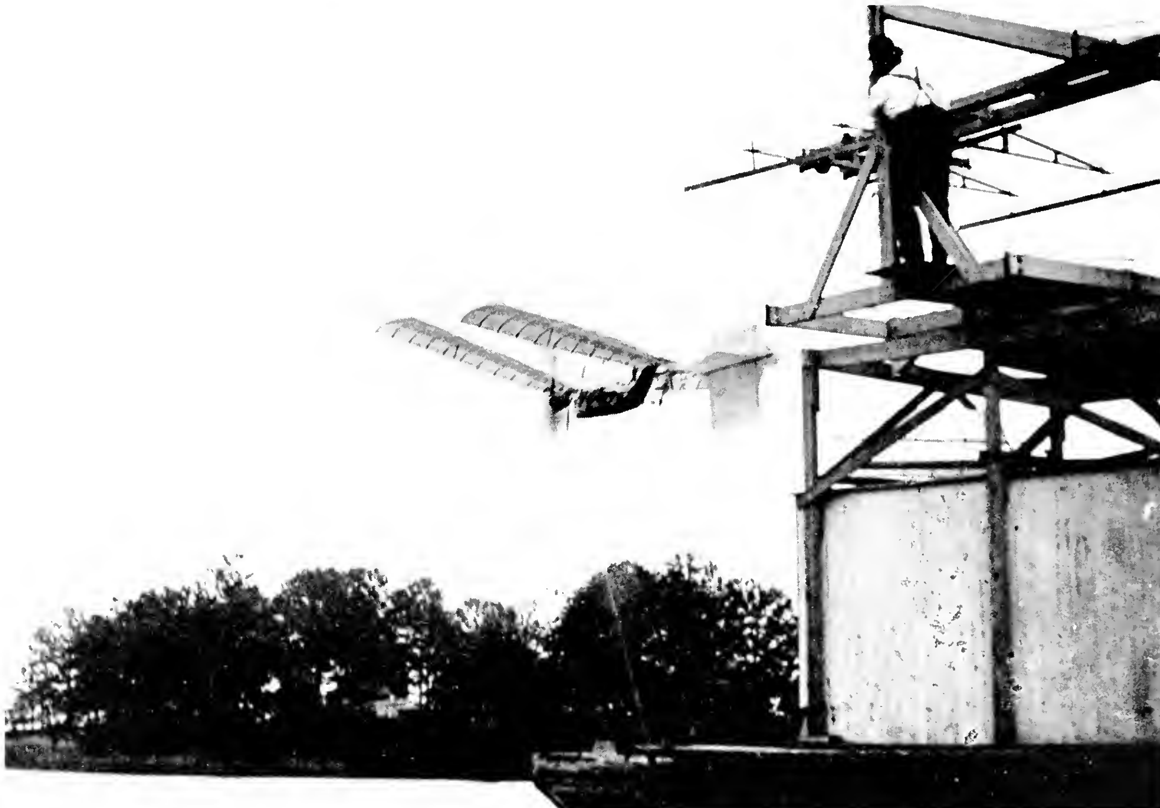
After completing the two papers just referred to, Langley proceeded to use the data gained in a serious attempt to obtain mechanical flight with large heavier-than-air machines. After several years of experimentation in which not only the difficulties of light construction and automatic balance but also of the invention of a very light steam engine were overcome, Langley on May 6, 1896, in the presence of Alexander Graham Bell and others, successfully catapulted from a houseboat on the Potomac a 13-foot steam-powered model which flew over one-half mile and landed softly unharmed upon the water. In November of the same year, another large model made an even longer flight of three-quarters of a mile. Of these experiments Langley said [17]:

" I have thus far had only a purely scientific interest in the results of these labors. Perhaps if it could have been foreseen at the outset how much labor there was to be, how much of life would be given to it, and how much care, I might have hesitated to enter upon it at all. And now reward must be looked for, if reward there be, in the knowledge that I have done the best I could in a difficult task, with results which it may be hoped will be useful to others. I have brought to a close the portion of the work which seemed to be specially mine—the demonstration of the practicability of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is probable that the world may look to others. The world, indeed, will be supine if it do not realize that a new possibility has come to it, and that the great universal highway overhead is now soon to be opened."

"EXPERIMENTS WITH THE LANGLEY AERODROME"

" The experiments undertaken by the Smithsonian Institution upon an aerodrome, or flying machine, capable of carrying a man have been

[17] The Langley Aerodrome, Ann. Rep. Smithsonian Inst., 1900, p. 197, 1901.



LANGLEY MODEL NO. 5 IN FLIGHT, MAY 6, 1896

suspended from lack of funds to repair defects in the launching apparatus without the machine ever having been in the air at all. As these experiments have been popularly, and of late repeatedly, represented as having failed on the contrary, because the aerodrome could not sustain itself in the air I have decided to give this brief though late account, which may be accepted as the first authoritative statement of them.

"It will be remembered that in 1896 wholly successful flights of between one-half and one mile by large steam-driven models, unsupported except by the mechanical effects of steam engines, had been made by me. In all these the machine was first launched into the air from 'ways,' somewhat as a ship is launched into the water, the machine resting on a car that ran forward on these ways, which fell down at the extremity of the car's motion, releasing the aerodrome for its free flight. I mention these details because they are essential to an understanding of what follows, and partly because their success led me to undertake the experiments on a much larger scale I now describe.

"In the early part of 1898 a board, composed of officers of the Army and Navy, was appointed to investigate these past experiments with a view to determining just what had been accomplished and what the possibilities were of developing a large-size man-carrying machine for war purposes. The report of this board being favorable, the Board of Ordnance and Fortification of the War Department decided to take up the matter, and I having agreed to give without compensation what time I could spare from official duties, the Board allotted $50,000 for the development, construction, and test of a large aerodrome, half of which sum was to be available immediately and the remainder when required. The whole matter had previously been laid before the Board of Regents of the Smithsonian Institution who had authorized me to take up the work and to use in connection with it such facilities of the Institution as were available.

"Before consenting to undertake the construction of this large machine, I had fully appreciated that owing to theoretical considerations, into which I do not enter, it would need to be relatively lighter than the smaller one; and later it was so constructed, each foot of sustaining surface in the large machine carrying nearly the same weight as each foot in the model. The difficulties subsequently experienced with the larger machine were, then, due not to this cause, but to practical obstacles connected with the launching, and the like.

" I had also fully appreciated the fact that one of the chief difficulties in its construction would lie in the procuring of a suitable engine of sufficient power and, at the same time, one which was light enough. (The models had been driven by steam engines whose water supply weighed too much for very long flights.) The construction of the steam engine is well understood, but now it would become necessary to replace this by gas engines, which for this purpose involve novel difficulties. I resolved not to attempt the task of constructing the engine myself, and had accordingly entered into negotiations with the best engine builders in this country, and after long delay had finally secured a contract with a builder who, of all persons engaged in such work, seemed most likely to achieve success. It was only after this contract for the engine had been signed that I felt willing to formally undertake the work of building the aerodrome.

" The contract with the engine builder called for an engine developing 12 brake horsepower, and weighing not more than 100 pounds, including cooling water and all other accessories, and with the proviso that a second engine, exactly like this first one, would be furnished on the same terms. The first engine was to be delivered before the close of February, 1899, and the frame of the aerodrome with sustaining surfaces, propellers, shafting, rudders, etc., was immediately planned, and now that the engine was believed to be secured, their actual construction was pushed with the utmost speed. The previous experiments with steam-driven models which had been so successful, had been conducted over the water, using a small houseboat having a cabin for storing the machine, appliances and tools, on top of which was mounted a track and car for use in launching. As full success in launching these working models had been achieved after several years spent in devising, testing and improving this plan, I decided to follow the same method with the large machine, and accordingly designed and had built a house boat, in which the machine could not only be stored, but which would also furnish space for workshops, and on the top of which was mounted a turntable and track for use in launching from whatever direction the wind might come.

" Everything connected with the work was expedited as much as possible with the expectation of being able to have the first trial flight before the close of 1899, and time and money had been spent on the aerodrome, which was ready, except for its engine, when the time for the delivery of this arrived. But now the builder proved unable to complete his contract, and, after months of delay, it was necessary to decrease the force at work on the machine proper and its launching appliances until some assurance could be had of the final success of the engine. . . . .

"It was recognized from the very beginning that it would be desirable in a large machine to use 'superposed' sustaining surfaces (that is, with one wing above another) on account of their superiority so far as the relation of strength to weight is concerned, and from their independence of guy wiring; and two sets of superposed sustaining surfaces of different patterns were built and experimented with in the early tests. These surfaces proved, on the whole, inferior in lifting power, though among compensating advantages are the strength of a bridge construction which dispenses with guy wires coming up from below, which, in fact, later were the cause of disaster in the launching.

"It was finally decided to follow what experiment had shown to be successful, and to construct the sustaining surfaces for the large machine after the 'single-tier' plan. This proved to be no easy task, since in the construction of the surfaces for the small machines the main and cross ribs of the framework had been made solid, and, after steaming, bent and dried to the proper curvature, while it was obvious that this plan could not be followed in the large surfaces on account of the necessity, already alluded to, of making them relatively lighter than the small ones, which were already very light. After the most painstaking construction, and tests of various sizes and thicknesses of hollow square, hollow round, I-beam, channel, and many other types of ribs, I finally devised a type which consisted of a hollow box form, having its sides of tapering thickness, with the thickest part at the point midway between contiguous sides and with small partitions placed inside every few inches in somewhat the same way that nature places them in the bamboo. These various parts of the rib (corresponding to the quill in a wing) were then glued and clamped together, and after drying were reduced to the proper dimensions and the ribs covered with several coats of a special marine varnish, which it had been found protected the glued joints from softening, even when they were immersed in water for twenty-four hours.

"Comparative measurements were made between these large cross ribs, 11 feet long, and a large quill from the wing of a harpy eagle, which is probably one of the greatest wonders that nature has produced in the way of strength for weight. These measurements showed that the large, 11-foot ribs ('quills') for the sustaining surfaces of the large machine were equally as strong, weight for weight, as the quill of the eagle; but much time was consumed in various constructions and tests before such a result was finally obtained.

" During this time a model of the large machine, one-fourth of its linear dimensions, was constructed, and a second contract was made for an engine for it. The delay with the large engine was repeated with the small one, and in the spring of 1900 it was found that both contract engines were failures for the purpose for which they were intended, as neither one developed half of the power required for the allotted weight.

" I accordingly again searched all over this country, and, finally, accompanied by an engineer (Mr. Manly), whose services I had engaged, went to Europe, and there personally visited large builders of engines for automobiles, and attempted to get them to undertake the construction of such an engine as was required. This search, however, was fruitless, as all of the foreign builders, as well as those of this country, believed it impossible to construct an engine of the necessary power and as light as I required (less than 10 pounds to the horsepower without fuel or water). I was therefore forced to return to this country and to consent most reluctantly, even at this late date, to have the work of constructing suitable engines undertaken in the shops of the Smithsonian Institution, since, as I have explained, the aerodrome frame and wings were already constructed. This work upon the engines began here in August, 1900, in the immediate care of Mr. Manly. These engines were to be of nearly double the power first estimated and of little more weight, but this increased power and the strain caused by it demanded a renewal of the frame as first built, in a stronger and consequently in a heavier form, and the following sixteen months were spent in such a reconstruction simultaneously with the work on the engines.

" The flying weight of the machine complete, with that of the aeronaut, was 830 pounds; its sustaining surface, 1,040 square feet. It therefore was provided with slightly greater sustaining surface and materially greater relative horsepower than the model subsequently described which flew successfully. The brake horsepower of the engine was 52; the engine itself, without cooling water, or fuel, weighed approximately 1 kilogram to the horsepower. The entire power plant, including cooling water, carburetor, battery, etc., weighed materially less than 5 pounds to the horsepower. Engines for both the large machine and the quarter-size model were completed before the close of 1901, and they were immediately put in their respective frames and tests of them and their power-transmission appliances were begun.

. . . .

"The engines themselves were successfully completed before the close of 1901, and were of much more power than those originally designed; but nearly a year and a half had been spent not only in their completion, but in properly coordinating the various parts of the frame carrying them, repairing the various breakages, assembling, dismounting, and reassembling the various parts of the appliances, and in general rebuilding the frame and appurtenances to correspond in strength to the new engines.

"There are innumerable other details, for the whole question is one of details. . . . .

"It is impossible for anyone who has not had experience with such matters to appreciate the great amount of delay which experience has shown is to be expected in such experiments. Only in the spring of 1903, and after two unforeseen years of assiduous labor, were these new engines and their appurtenances, weighing altogether less than 5 pounds to the horsepower and far lighter than any known to be then existing, so coordinated and adjusted that successive shop tests could be made without causing injury to the frame, its bearings, shafts, or propellers.

"And now everything seemed to be as nearly ready for an experiment as could be, until the aerodrome was at the location at which the experiments were to take place. The large machine and its quarter-size counterpart were accordingly placed on board the large house boat, which had been completed some time before and had been kept in Washington as an auxiliary shop for use in the construction work, and the whole outfit was towed to a point in the Potomac River, here 3 miles wide, directly opposite Widewater, Va., and about 40 miles below Washington and midway between the Maryland and Virginia shores, where the boat was made fast to moorings which had previously been placed in readiness for it.

"Although extreme delays had already occurred, yet they were not so trying as the ones which began immediately after the work was thus transferred to the lower Potomac.

. . . .

"In order to test the quarter-size model it was necessary to remove its launching track from the top of the small house boat and place it upon the deck of the large boat, in order to have all the work go on at one place, as it was impossible, on account of its unseaworthiness, to moor the small house boat in the middle of the river.

". . . . These difficulties might have partly been anticipated, but there were others concerning which the cause of the deterioration and disarrangement of certain parts and adjustments was not immediately detected, and consequently when short preliminary shop tests of the small machine were attempted just prior to launching it, it was found that the apparatus did not work properly, necessitating repairs and new constructions and consequent delay. Although the large house boat with the entire outfit had been moved down the river on July 14, 1903, it was not until the 8th of August that the test of the quarter-size model was made, and all of this delay was directly due to changed atmospheric conditions incident to the change in locality. This test of the model in actual flight was made on the 8th of August, 1903, when it worked most satisfactorily, the launching apparatus, as always heretofore, performing perfectly, while the model, being launched directly into the face of the wind, flew directly ahead on an even keel. The balancing proved to be perfect, and the power, supporting surface, guiding, and equilibrium-preserving effects of the rudder also. The weight of the model was 58 pounds, its sustaining surface 66 square feet, and the horsepower from $2\frac{1}{2}$ to 3.

"This was the first time in history, so far as I know, that a successful flight of a mechanically sustained flying machine was made in public.

. . . .

"I have spoken of the serious delays in the test of the small machine caused by changed atmospheric conditions, but they proved to be almost negligible compared with what was later experienced with the large one. . . . .

". . . . . Something of the same troubles which had been met with in the disarrangement of the adjustments of the small engine was experienced in the large one, although they occurred in such a different way that they were not detected until they had caused damage in the tests, and these disarrangements were responsible for broken propellers, twisted shafts, crushed bearings, distorted framework, etc., which were not finally overcome until the 1st of October. After again getting everything in apparent readiness there then ensued a period of waiting on the weather until the 7th of October (1903), when it became sufficiently quiet for a test which I was now beginning to fear could not be made before the following season. In this, the first test, the engineer took his seat, the engine started with ease and was working without vibration at its full power of over 50 horse, and the word being given to launch the machine, the car was released and the aerodrome sped along the track. Just as the machine left the track, those who were watching it, among whom were two representatives of the Board of Ordnance,[18] noticed that the machine was jerked violently down at the front (being caught, as it subsequently appeared, by the falling ways),[19] and under the full power of its engine was pulled into the water, carrying with it its engineer. When the aerodrome rose to the surface it was found, that while the front sustaining surfaces had been broken by their impact with the water, yet the rear ones were comparatively uninjured. As soon as a full examination of the launching mechanism had been made, it was found that the front portion of the machine had caught on the launching car, and that the guy post, to which were fastened the guy wires which are the main strength of the front surfaces, had been bent to a fatal extent.

"The machine, then, had never been free in the air, but had been pulled down as stated.

"The disaster just briefly described had indefinitely postponed the test, but this was not all. As has been said before, the weather had become very cold and the so-called equinoctial storms being near it was decided to remove the house boat at the earliest time possible, but before it could be done, a storm came up and swept away all the launches, boats, rafts, etc., and in doing so completely demolished the greater part of them, so that when the house boat was finally removed to Washington, on the 15th of October, these appurtenances had to be replaced. It is necessary to remember that these long series of delays worked other than mere scientific difficulties, for a more important and more vital one was the exhaustion of the financial means for the work.

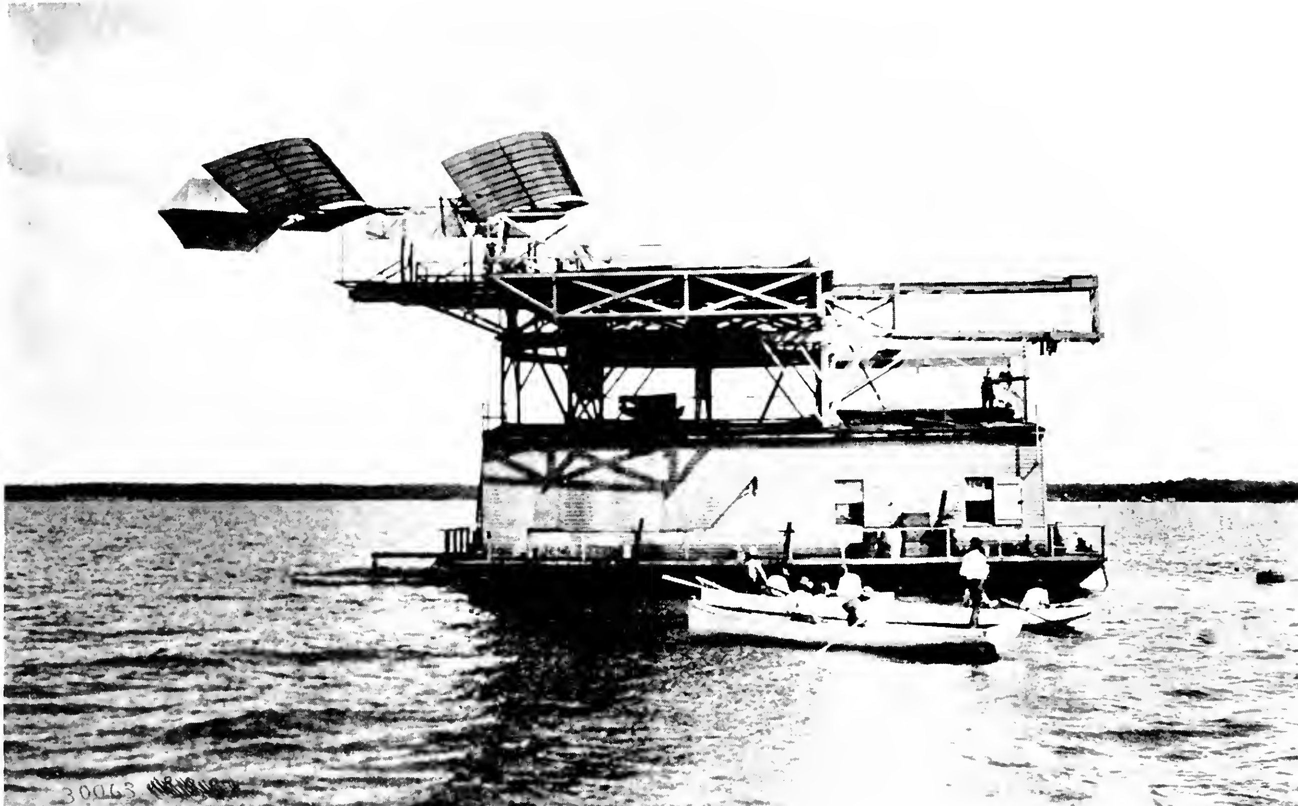
"Immediately upon getting the boat to Washington the labor of constructing new sustaining surfaces was begun, and they were completed about the close of November. It was proposed to make a

[18] Major Macomb, of the Board of Ordnance, states in his report to the Board, that "the trial was unsuccessful because the front guy post caught in its support on the launching car and was not released in time to give free flight, as was intended, but, on the contrary, caused the front of the machine to be dragged downward, bending the guy post and making the machine plunge into the water about 50 yards in front of the house boat."

[19] This instantaneous photograph, taken from the boat itself and hitherto unpublished, shows the aerodrome in motion before it had actually cleared the house boat. On the left is seen a portion of a beam, being a part of the falling ways in which the front wing was caught, while the front wing itself is seen twisted, showing that the accident was in progress before the aerodrome was free to fly.

second attempt near the city, though in the meantime the ice had formed in the river. However, on the 8th of December, 1903, the atmosphere became very quiet shortly before noon and an immediate attempt was made at Arsenal Point, quite near Washington, though the site was unfavorable. Shortly after arriving at the selected point everything was in readiness for the test. In the meantime the wind had arisen and darkness was fast approaching, but as the funds for continuing the work were exhausted, rendering it impossible to wait until spring for more suitable weather for making a test, it was decided to go on with it if possible. This time there were on hand to witness the test the writer, members of the Board of Ordnance, and a few other guests, to say nothing of the hundreds of spectators who were waiting on the various wharves and shores. It was found impossible to moor the boat without a delay which would mean that no test could be made on account of darkness, so that it was held as well as possible by a tug, and kept with the aerodrome pointing directly into the wind, though the tide, which was running very strong, and the wind, which was blowing 10 miles an hour, were together causing much difficulty. The engine being started and working most satisfactorily, the order was given by the engineer to release the machine, but just as it was leaving the track another disaster, again due to the launching ways, occurred.[20] This time the rear of the machine, in some way still unexplained, was caught by a portion of the launching car, which caused the rear sustaining surfaces to break, leaving the rear entirely without support, and it came down almost vertically into the water. Darkness had come before the engineer, who had been in extreme danger, could aid in the recovery of the aerodrome, the boat and machine had drifted apart, and one of the tugs, in its zeal to render assistance, had fastened a rope to the frame of the machine in the reverse position from what it should have been attached and had broken the frame entirely in two. While the injury which had thus been caused seemed almost irreparable to one not acquainted with the work, yet it was found upon close examination that only a small amount of labor would be necessary in order to repair the frame, the engine

[20] Major Macomb again states in his official report to the Board: "The launching car was released at 4.45 p. m. . . . . The car was set in motion and the propellers revolved rapidly, the engine working perfectly, but there was something wrong with the launching. The rear guy post seemed to drag, bringing the rudder down on the launching ways, and a crashing, rending sound, followed by the collapse of the rear wings, showed that the machine had been wrecked in the launching; just how it was impossible to see."



SIDE VIEW OF THE FULL-SIZE MAN-CARRYING AERODROME ON THE HOUSEBOAT JUST BEFORE THE TRIAL OF OCTOBER 7, 1903

This shows the track on which the machine was propelled by springs and shot off into the air

itself being entirely uninjured. Had this accident occurred at an earlier period, when there were funds available for continuing the experiments, it would not have been so serious, for many accidents in shop tests had occurred which, while unknown to the general public, had yet caused greater damage and required more time for repair than in the present case. But the funds for continuing the work were exhausted, and it being found impossible to immediately secure others for continuing it, it was found necessary to discontinue the experiments for the present, though I decided to use, from a private fund, the small amount of money necessary to repair the frame so that it itself, together with its engine, which was entirely uninjured, might be available for further use if it should later prove possible, and that they themselves might be in proper condition to attest to what they really represent as an engineering achievement.

"Entirely erroneous impressions have been given by the account of these experiments in the public press, from which they have been judged, even by experts; the impression being that the machine could not sustain itself in flight. It seems proper, then, to emphasize and to reiterate, with a view to what has just been said, that the machine has never had a chance to fly at all, but that the failure occurred on its launching ways; and the question of its ability to fly is consequently, as yet, an untried one.

"There have, then, been no failures as far as the actual test of the flying capacity of the machine is concerned, for it has never been free in the air at all. The failure of the financial means for continuing these expensive experiments has left the question of their result where it stood before they were undertaken, except that it has been demonstrated that engines can be built, as they have been, of little over one-half the weight that was assigned as the possible minimum by the best builders of France and Germany; that the frame can be made strong enough to carry these engines, and that, so far as any possible prevision can extend, another flight would be successful if the launching were successful; for in this, and in this alone, as far as is known, all the trouble has come.

"The experiments have also given necessary information about this launching. They have shown that the method which succeeded perfectly on a smaller scale is insufficient on a larger one, and they have indicated that it is desirable that the launching should take place nearer the surface of the water, either from a track upon the shore or from a house boat large enough to enable the apparatus to be launched at any time with the wings extended and perhaps with wings independent of support from guys. But the construction of this new launching apparatus would involve further considerable expenditures that there are no present means to meet; and this, and this alone, is the cause of their apparent failure.

"Failure in the aerodrome itself or its engines there has been none; and it is believed that it is at the moment of success, and when the engineering problems have been solved, that a lack of means has prevented a continuance of the work."

A regrettable controversy has arisen regarding the capacity of this machine for flight. As our purpose here is only to recall the work and attainments of Langley, and as far as possible by his own words, we may well leave that question as he himself stated it.

Our summary of Langley's work is far from complete. Such important papers as "The Solar and Lunar Spectrum," "The Cheapest Form of Light," "Energy and Vision," "Observation of Sudden Phenomena," "Good Seeing," "The History of a Doctrine," and others have been entirely omitted. But space forbids further following of the steps of this great man except to quote in closing that inimitable parable from the final pages of his charming book "The New Astronomy":

"I have read somewhere a story about a race of ephemeral insects who live but an hour. To those who are born in the early morning the sunrise is the time of youth. They die of old age while its beams are yet gathering force, and only their descendants live on to midday; while it is another race which sees the sun decline, from that which saw it rise. Imagine the sun about to set, and the whole nation of mites gathered under the shadow of some mushroom (to them ancient as the sun itself) to hear what their wisest philosopher has to say of the gloomy prospect. If I remember aright, he first told them that, incredible as it might seem, there was not only a time in the world's youth when the mushroom itself was young, but that the sun in those early ages was in the eastern, not in the western, sky. Since then, he explained, the eyes of scientific ephemera had followed it, and established by induction from vast experience the great 'Law of Nature,' that it moved only westward; and he showed that since it was now nearing the western horizon, science herself pointed to the conclusion that it was about to disappear forever, together with the great race of ephemera for whom it was created.

"What his hearers thought of this discourse I do not remember, but I have heard that the sun rose again the next morning."

REFERENCES

(Listed in order quoted in this paper.)

ON THE MINUTE STRUCTURE OF THE SOLAR PHOTOSPHERE. Amer. Journ. Sci. and Arts, vol. 7, pp. 3-10, Feb. 1874.

THE TOTAL SOLAR ECLIPSE OF JULY 29, 1878. OBSERVATIONS AT PIKE'S PEAK, COLORADO. Astronom. and Meteorol. Observations 1876 U.S. Naval Obs., pt. 2, app. 3, pp. 205-209, Washington, 1880

THE BOLOMETER AND RADIANT ENERGY. Proc. Amer. Acad. Arts and Sci., vol. 16, pp. 342-358, 1881.

ON THE AMOUNT OF THE ATMOSPHERIC ABSORPTION. Amer. Journ. Sci., 3d ser., vol. 28, no. 165, pp. 168-170, Sept. 1884.

RESEARCHES ON SOLAR HEAT AND ITS ABSORPTION BY THE EARTH'S ATMOSPHERE. A REPORT OF THE MOUNT WHITNEY EXPEDITION. Prof. Papers Signal Service, no. 15, pp. 11, 13-14, 15, 35, 36, U. S. War Dept., 1884.

THE TEMPERATURE OF THE MOON. Nat. Acad. Sci., vol. 4, pt. 2, 3d. Mem., pp. 107, 108-109, 113, 193, 194, 196, 197, 1889.

ON HITHERTO UNRECOGNIZED WAVE-LENGTHS. Amer. Journ. Sci., 3d ser., vol. 32, no. 188, pp. 83-84, 87-89, 100, Aug. 1886.

ANNALS OF THE ASTROPHYSICAL OBSERVATORY OF THE SMITHSONIAN INSTITUTION, vol. 1, pp. iii, 1, 2, 22, 23, 129-130, 1900.

ON A POSSIBLE VARIATION OF THE SOLAR RADIATION AND ITS PROBABLE EFFECT ON TERRESTRIAL TEMPERATURES. Astrophys. Journ., vol. 19, no. 5, pp. 305, 307, 315-318, 321, June 1904.

EXPERIMENTS IN AERODYNAMICS. Smithsonian Contr. Knowl., vol. 27, art. 1, pp. 3, 5-6, 7, 9, 10, 107-108, 1891.

THE INTERNAL WORK OF THE WIND. Smithsonian Contr. Knowl., vol. 27, art. 2, pp. 1-4, 13-14, 22-23, 1893.

THE LANGLEY AERODROME. Ann. Rep. Smithsonian Inst., 1900, p. 216, 1901.

EXPERIMENTS WITH THE LANGLEY AERODROME. Ann. Rep. Smithsonian Inst., 1904, pp. 113-115, 115-117, 117-118, 119-120, 122-125, 1905.

THE NEW ASTRONOMY, pp. 250-251. Houghton, Mifflin & Co., Boston and New York, 1900.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 9

THE SKELETAL MUSCULATURE OF THE BLUE CRAB, CALLINECTES SAPIDUS RATHBUN

BY
DORIS M. COCHRAN
Assistant Curator, Division of Reptiles and Batrachians
U. S. National Museum

(Publication 3282)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JANUARY 22, 1935

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE SKELETAL MUSCULATURE OF THE BLUE CRAB, CALLINECTES SAPIDUS RATHBUN

By DORIS M. COCHRAN
Assistant Curator, Division of Reptiles and Batrachians
U. S. National Museum

CONTENTS

INTRODUCTION

The need for detailed morphologic study of the muscles of crustaceans is apparent upon making a survey of the very scanty literature dealing with the myology of so diverse and important a suborder. The taxonomy and the concurrent analysis of the external anatomy of crustaceans have received a great deal of attention, and their physiologic reactions to stimuli have likewise been given a comparatively large amount of study. The internal structure and particularly the myology have been surprisingly neglected.

Huxley (1880) made a now historic contribution in his book on the crayfish, and his masterly dissections were unequalled for over a quarter of a century. Then the German school of zoology at Leipzig began a symposium on the crayfish, and the rechecking of the musculature was undertaken by Walter Schmidt, who made a most thorough and scholarly revision, in which he came upon several important points which Huxley had failed to emphasize.

The next complete myological study of a crustacean was published by Alfreda Berkeley in 1928. Her study of the shrimp *Pandalus danae* was executed in the general manner of Schmidt's treatment, so that their two papers are readily comparable.

Several papers by R. J. Daniel have since appeared dealing with the very complicated abdominal musculature of shrimps, but these papers have little bearing upon the following study, because the shrimp and the crab are structurally dissimilar in regard to their abdominal organization.

I am particularly indebted to R. E. Snodgrass, of the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture, for his invaluable assistance and advice in interpreting, describing, and figuring the muscles of the blue crab, and in comparing them with those of other arthropods.

I am likewise indebted to Prof. C. J. Pierson, of the Department of Zoology of the University of Maryland, for many suggestions, and to Dr. R. V. Truitt, of the same department, for directing my preliminary survey of other anatomical features of the blue crab.

My sincere thanks are due also to Dr. Waldo L. Schmitt, curator of the division of marine invertebrates of the United States National Museum, for donating comparative material for dissection and for making available much of the literature dealing with crustaceans.

The work on the appendages of the blue crab was done in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the University of Maryland.

PART I. THE MUSCLES OF THE TRUNK AND ITS APPENDAGES

The Trunk

The complete fusion of the segments of head and body in the blue crab has resulted in the disappearance of those intersegmental muscles which in crustaceans like the shrimp and the crayfish give a high degree of flexibility to the movements of the body.

The crab's head and body are encased in a hard, unjointed covering, which shows no trace whatever of segmentation on its dorsal surface, although ventrally the sternal thoracic segments on which the basal leg muscles originate are well marked. Of all the extremely complex and numerous body muscles that one encounters in the shrimp and crayfish, there is but one, the attractor of the epimera, which finds a counterpart in the blue crab, where it performs the same function of holding the gill chamber in its proper relation to the carapace.

While the abdomen of the crayfish and shrimp is extremely pliable and is much used in swimming, the abdomen of the blue crab, in the male at least, is apparently progressing toward a condition of partial rigidity, as the third, fourth, and fifth segments are immovably fused in that sex. This fusion is not yet completely established, however, as the former segmentation is still partly maintained in its musculature. The female's abdomen has six distinct segments, all of which have the muscles well developed. The structure of the hard parts of the abdomen of the male is such that it can not be extended behind the body in line with the back, but at most can assume a position at right angles to the dorsal surface of the body. The abdomen in both sexes normally lies closely adpressed against the posterior region of the thorax. In this position, the dorsal part of the abdomen is underneath the body and actually ventral in position. In the text, however, it is described by the term "dorsal," applied to that part which would be uppermost in a normal crustacean abdomen extending backward behind the thorax.

1. Musculus ventralis superficialis thoraco-abdominalis (fig. 1 B).—This muscle arises on the outer posterior surface of the last segment of the thorax and is inserted on the anterior border of the first abdominal segment near the midline, where it helps to pull the abdomen toward the thorax. This is the only trace in the blue crab of the ventral superficial thoracic muscles, which are so prominent between the highly movable body segments in both *Astacus* and *Pandalus*.[1]

[1] In the particular discussion of the muscles, the comparisons made to homologous parts in the shrimp and crayfish refer only to the species *Pandalus danae* and *Astacus fluviatilis*.

Although this muscle is paired, as are all the other abdominal muscles, the members of the pair are so closely crowded toward the middle line that they appear as one median bundle of muscle fibers.

2-6. Musculi ventrales superficiales abdominis (fig. 1 B).—These muscles are arranged regularly in accordance with the original segmentation of the abdomen in the male, and the fusion of the third, fourth, and fifth abdominal somites in this sex has evidently not affected the ventral musculature at all, since the latter is similar in

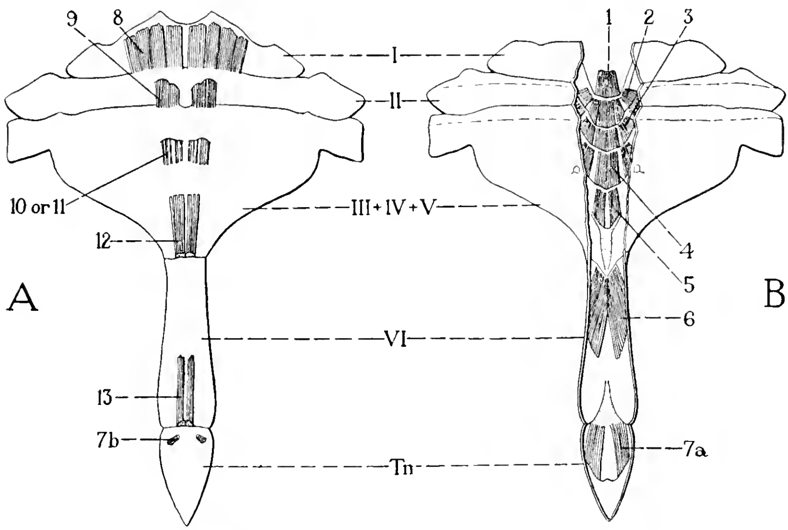


FIG. 1.—Muscles of the abdomen of the male blue crab.

A, dissection of the abdomen from the ventral side to show the dorsal muscles: *7b*, small branch of musculus dilatator ani; *8-13*, musculi dorsales superficiales abdominis.

B, dissection of the abdomen from the dorsal side to show the ventral muscles: *1*, musculus ventralis superficialis thoraco-abdominis; *2-6*, musculi ventrales superficiales abdominis; *7a*, main branch of musculus dilatator ani.

I-VI, abdominal somites 1 through 6; *Tn*, telson.

both sexes. The muscles of the first pair (*2*) arise on the membrane of the anterior border of the first segment and are inserted on the heavy sclerotized ridge marking the second segment. Each muscle of the pair splits into several diverging branches, the two inner ones being practically confluent on the midline. The second (*3*) and third (*4*) pairs are similar to the first. Each muscle of the fourth (*5*) is definitely in a single piece, however, and its posterior attachment is made upon an arrow-shaped cartilagelike thickening of the membrane in the middle of the segment. The muscles of the fifth and last pair (*6*) are likewise undivided, the two muscles lying very close together at their origin but diverging toward their insertion upon the outer walls in the middle of the sixth segment. There is no ventral muscle connecting the sixth segment with the telson in either sex. The ventral superficial muscles are much heavier in the female than in the male, owing no doubt to the fact that the "locking" device for the male's abdomen precludes the necessity for any strong contraction toward the body. The female, on the other hand, has no such locking device but must hold the abdomen bent forward under the body or curled around the egg mass, this position of the abdomen necessitating heavier muscles.

7 a, b. Musculus dilatator ani (fig. 1 A, B).—The main part of this muscle arises on a triangular cartilagelike thickening on the ventral membrane lying between the posterior border of the sixth somite and the anterior border of the telson. It is inserted ventro-medially by the side of the anal opening. The small second part arises in the same cartilagelike thickening on the ventral membrane, and is inserted on the anterior dorsal wall of the telson. By the contractions of the two muscles the anus is opened and widened, while the elasticity of the membrane around the anus opposes them.

8-13. Musculi dorsales superficiales abdominis (fig. 1 A).—While *Astacus* has its first superficial dorsal muscle connecting the thorax with the abdomen, this muscle does not occur either in *Pandalus* or in *Callinectes*. A very heavy U-shaped membrane connects the first abdominal segment with the thorax in *Callinectes*, and at the base of this membrane arises the first pair of dorsal superficial muscles (*8*), which thus corresponds to the second pair in *Astacus*. Each muscle of this pair is in several parts lying side by side. The next pair (*9*) arises near the middle of the second segment behind a heavy sclerotized ridge and is inserted on the anterior border of the following segment, which in the male crab represents the complete fusion of the third, fourth, and fifth abdominal somites. In the center of this fused section there is still, strange to say, a pair of definite patches of muscle tissue arising on a heavy ridge, the marks of attachment of which may be seen going through to the dorsal integument as two slight shallow depressions. This pair of muscles (numbered "*10 or 11*" in the figure) probably represents either the fourth or fifth pair of dorsal superficial muscles. It appears to have no function, as the hinge to its somite is entirely immovable. The adjacent pair of muscles has completely disappeared in the male. The sixth pair (*12*) arises some distance within the fused segment and is inserted on a cartilagelike outgrowth from the anterior border of the sixth segment. The seventh pair (*13*) is long and very slender, to correspond to the shape of the male's abdomen, and is inserted on cartilagelike outgrowths emanating from the anterior border of the telson, which receives all its power of motion from this muscle, as no flexors of the telson exist in either sex. The female's dorsal superficial muscles are like those of the male, except that all six abdominal segments are distinct and hence the full complement of six pairs of muscles is present and functional. The dorsal muscles serve to extend the abdomen backward, but as this position of the abdomen is not habitual in the blue crab, occurring only at the time of mating, the muscles are very weakly developed.

14. Musculus attractor epimeralis (figs. 12 A, 13 B).—All that remains of this muscle, extensive in both *Astacus* and *Pandalus,* is a small patch of short muscle fibers uniting the epimeral plates and the carapace, between the metabranchial and the cardiac regions. It extends only for a short distance from the posterior angle of the first epimeral plate. It holds the gill chamber in place in the body, beneath the branchial lobe and the posterior part of the protogastric region, on which the muscle originates.

The Eye

The eye of the blue crab is a highly complex organ, which presents many specializations in its structure and musculature. The shortening and broadening of the body contour have also been repeated in the changes that have taken place in the eyes. The crayfish and shrimp, both with elongate, narrow bodies, have the eyes close together on short stalks, which project forward in front of the head. The blue crab, on the other hand, has eyes which project on very long stalks at right angles to the axis of the body. The middle cylinder (*I* in fig. 2), quite distinct and having its own muscles in the crayfish and shrimp, is completely fused [2] to the chitinous middle ring in the blue crab, and the muscles of these parts, formerly separated, are now forced to interlace in a very constricted area. The second segment, on the contrary, is immensely elongated in the blue crab. Its proximal part contains no muscles, but only a deep groove in which lie the blood-vessels feeding the eye. Ventrally, this part of the segment is separated from the head by a thin membrane. This membrane thickens considerably toward its distal boundary, and on this membrane the adductor muscle arises, which is not the case in either the crayfish or the shrimp. The muscles arising on the distal border of the second segment, or on the heavy tendinous outgrowths from it, bear much the

[2] The entire fused structure will hereafter be spoken of as the middle cylinder.

same relations to one another as in the crayfish and shrimp. There are two branches to the abductor and three to the dorsal retractor, the result being that the blue crab has excellent control of its eye movements.

15. Musculus oculi basalis anterior (fig. 2).—This muscle arises medially on the epistome from a short, curved, movable rod, which projects first at right angles from the center of the epistome and then slopes downward and backward over the esophagus and enlarges to a buttonlike knob. From this knob the muscle runs dorsally and soon divides into two short but relatively thick branches, which find attachment side by side below the proximal edge of the chitinous middle

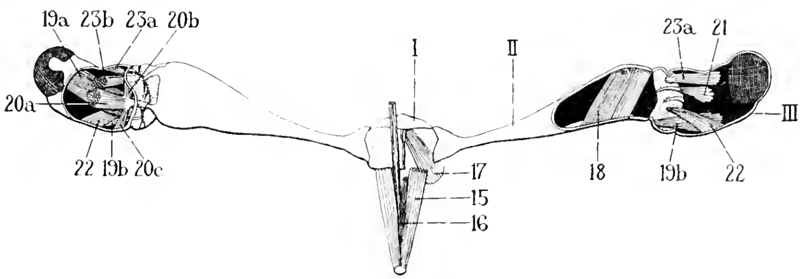


FIG. 2.—Dorsal dissection of the eye of the blue crab. On the right side the deeper muscles are exposed.

15, musculus oculi basalis anterior; *16*, musculus oculi basalis posterior; *17*, musculus oculi attractor; *18*, musculus oculi adductor; *19a* and *19b*, musculus oculi abductor; *20a*, *20b* and *20c*, musculus oculi retractor dorsalis; *21*, musculus oculi retractor ventralis; *22*, musculus oculi retractor lateralis; *23a* and *23b*, musculus oculi retractor medialis.

I, middle cylinder; *II*, second segment; *III*, optic cup.

cylinder which unites the optic peduncles. The distal part of each peduncle, bearing the retina, is thereby moved forward in a horizontal plane, so that the eyes are brought slightly nearer together. At the same time the second joint may be rotated slightly.

16. Musculus oculi basalis posterior (fig. 2).—This muscle arises on the knoblike part of the supporting rod of the preceding muscle. It runs unpaired dorsally for a short distance, closely adherent to the dorsally directed part of the preceding. Then it divides into two very fine but exceedingly strong branches which diverge slightly as they continue dorsally between the branches of the anterior basal muscle to their attachment on the frontal region of the carapace of the head, where their presence is marked usually by two small indentations.

17. Musculus oculi attractor (fig. 2).—This short compact muscle arises on the head carapace near its junction with the middle cylinder.

The muscles of this pair converge slightly before reaching their insertions on a T-shaped infolding of the ventral part of the middle cylinder, in front of the attachment of the anterior basal muscle. As this middle cylinder is cartilagelike and hence somewhat pliable, the attractor can assist the anterior basal muscle in depressing it and hence in bringing the solid joints attached to it nearer together. It may likewise oppose the basal muscle in rotating the second joint.

18. Musculus oculi adductor (fig. 2).—This heavy and powerful but short muscle arises on the thick membrane separating the ventral part of the second joint from the head. It travels forward and outward to its insertion along the anterior distal wall of the second segment not far from the base of the optic cup, which is rotated strongly by its contraction.

19 a, b. Musculus oculi abductor a and b (fig. 2).—Originating posteriorly on the heavy membrane which connects the second joint to the optic cup, the main part (*a*) of this muscle is inserted on the posterior wall of the optic cup near to the corneal surface. This is the largest and heaviest of any of the muscles lying in the cup. The second branch (*b*) originates beside the first but juts off at an angle toward the ventral surface, where it is soon inserted not far from the proximal border of the optic cup. It is much shorter than the main branch, from which it is separated near its insertion by the lateral retractor muscle. Both branches oppose the adductor by pulling the eye away from the midline and rotating it in the opposite direction.

THE RETRACTOR MUSCLES OF THE EYE

Like the crayfish and shrimp, the blue crab possesses four retractor muscles, all of which originate on the membrane bordering the distal edge of the second segment and are inserted on the sides of the optic cup near the cornea. They bring the cup nearer to the second segment or rotate it. The insertion of each muscle is marked externally by a characteristically different texture in the surface of the optic cup.

20 a-c. Musculus oculi retractor dorsalis a, b, and c (fig. 2).—This muscle has three branches, all of which arise from a heavy ossiclelike projection lying in the membrane and originating on the dorsal distal wall of the second segment. The main branch, the central one of the three, travels outward to its attachment on the dorsal surface of the optic cup, where its insertion is marked externally by a small area of a slightly granular texture different from the smooth surface around it. The second branch (*b*) projects forward at right angles to the first and is attached on the front wall of the optic cup near its proximal border. The third branch (*c*) projects also at right angles but in an opposite direction to *b*, and is attached to the posterior wall of the optic cup near its proximal edge. The three branches taken together with the ossiclelike piece from which they originate form a cross, and the attachment at the extremities of the cross produces a mechanical device of great strength for moving the optic cup dorsally and for rotating it from side to side.

21. Musculus oculi retractor ventralis (fig. 2).—This is a relatively small and weak muscle, which arises ventrally in the membrane emanating from the distal edge of the second segment and is inserted on the ventral wall midway to the cornea. Since it runs parallel with the axis of the eye, it cannot act as a rotator. Its only function is to retract the optic cup.

22. Musculus oculi retractor lateralis (fig. 2).—This muscle originates in a tendinous structure in the membrane of the posterior ventral wall of the second segment, and passes diagonally backward and upward between the two parts of the abductor to its insertion on the posterior wall of the optic cup just above the insertion of the shorter branch of the abductor. It has a strong rotatory function, owing to its position diagonal to the axis of the eye.

23 a, b. Musculus oculi retractor medialis a and b (fig. 2).—This muscle has two branches, both of which arise from an exceedingly heavy ossiclelike projection from the anterior distal wall of the second segment. The upper branch (*a*) proceeds straight along the anterior wall of the optic cup to its attachment not far from the cornea. The lower branch (*b*) diverges slightly downward to its attachment on the anteroventral wall of the optic cup not far forward of the insertion of the ventral rotator. The medial retractor has the rotatory function in addition to being a retractor, as its diverging branches testify.

The Appendages

The problem of choosing names for the various muscles governing the appendages has proved to be a very puzzling one, especially in regard to those muscles governing the mandible, the maxillae, and the maxillipeds. It is often impossible in the living crab to assign to a definite one of the many complex muscles surrounding the base of each appendage a particular motion observed in that part of the appendage. In the telopodite the case is much simpler, as there are but two muscles governing each segment, and but two corresponding directions of motion. In the dissected crab, the many slender muscles controlling the various basal parts of the leg are likely to break if enough tension is put upon them to show in what manner they influence the distal segments. Even the coarse and heavy muscles on tendons which do not break cannot invariably be assumed to cause the same motion in the segment of the stiffened dead tissue that they do in the pliable living organism. Thus it frequently becomes very difficult to determine whether a muscle in function is a promotor or an adductor, a remotor or an abductor. Coupled with this difficulty is the fact that the crab is so highly specialized away from the ancestral primitive condition that some of the appendages now lie in a partly reversed position, and one appendage, the mandible, is completely reversed. This makes it equally hard to give the muscles positional names according to their points of attachment, and there are, besides, so many small muscles controlling the basal segments that one soon has to resort to the expedient of giving some of them merely a number, having exhausted the available adjectives descriptive of their locations.

It is possible, however, to divide the muscles according to their place of origin, all the muscles originating on the carapace being called dorsal muscles, and those coming from the ventral surface and the sternal apodemes being referred to as ventral muscles.

Only those segments anterior to the second maxilla have both dorsal and ventral muscles. The second maxilla and the segments behind it lack dorsal muscles, but are fully equipped with ventral muscles.

The dorsal and ventral muscles are all extrinsic, meaning that they originate in the body itself beyond the boundaries of the true appendage. The intrinsic muscles are contained entirely within the appendage itself and control the distal segments of the limb and the flagellum if one be present.

As far as it has seemed possible to do it, I have followed the nomenclature adopted by Schmidt and later by Berkeley, in their respective anatomical analyses, to facilitate comparison between the three forms involved. The muscles of the blue crab do not always present perfect analogies in either position or function to those of the crayfish and the shrimp, however, and where a difference in function seems possible, the positional name may be given as first choice, with Schmidt's or Berkeley's corresponding name in synonymy. When so many muscles were found that the positional name of the one in question could not be given with the use of only one or two qualifying adjectives, the whole muscle has been referred to merely by its number. It is not well to be too arbitrary in assigning definite names to some of the more obscure muscles of the blue crab until such time as other representatives of the order Decapoda shall have been dissected and compared carefully, muscle by muscle. It is quite possible that other genera of crabs may show up interrelationships of muscles that are quite obscure in *Callinectes*.

THE FIRST ANTENNA (ANTENNULE)

In the blue crab this appendage is similar to that of the shrimp and of the crayfish in regard to its high degree of flexibility. The comparatively large size of the first segment is due to the presence of a large statocyst to which no muscles are attached, these tissues being entirely sensory in function. The structure of the two flagella in the shrimp

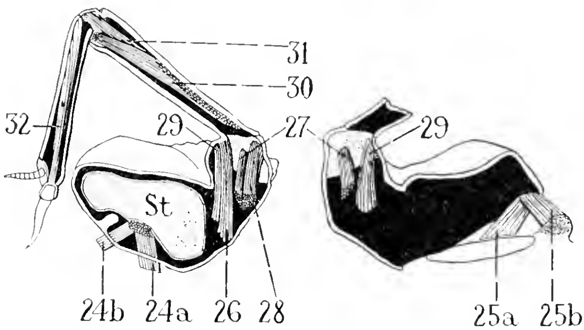


FIG. 3.—Dorsal dissection of the first antenna of the blue crab with the deeper muscles laid bare on the right side.

24a and *24b*, musculus promotor I antennae; *25a* and *25b*, musculus remotor I antennae; *26*, musculus productor₂ I antennae; *27*, musculus reductor₂ I antennae; *28*, musculus adductor₂ I antennae; *29*, musculus abductor₂ I antennae; *30*, musculus productor₃ I antennae; *31*, musculus reductor₃ I antennae; *32*, musculus reductor₄ I antennae.
St, statocyst.

and crayfish, as well as in the blue crab, does not give any support to Huxley's opinion that these flagella represent an endopodite and an exopodite, nor can the joint from which they arise be considered as a modified basipodite.

24 a, b. Musculus promotor a and b I antennae (fig. 3).—This muscle originates in two places on the posterior border of the aperture that connects the interior of the body with the interior of the antennule. Both parts are attached close together on an infolding of the membrane lying beneath the statocyst chamber in the first joint. The promotor raises the first joint, bringing it toward the midline and rotating it slightly in its socket.

25 a, b. Musculus remotor a and b I antennae (fig. 3).—One part of this short but heavy muscle arises on a round cartilaginous disk on the lateral edge of the aperture connecting body and antennule. It is attached to a tendon on the outer dorsal part of the first joint. The other branch of the remotor arises on the outer anterior border of the aperture, and runs to its attachment on the opposite side of the tendon to which the first branch goes. Both remotors pull the first joint strongly downward toward the body, at the same time rotating it in its socket.

26. Musculus productor $_2$ I antennae (fig. 3).—This muscle arises dorsally on the inner proximal border of the first segment and passes forward to its attachment on the heavy basal membrane on the lateral proximal border of the second segment, on which it exerts a strong downward pull.

27. Musculus reductor $_2$ I antennae (fig. 3).—This short muscle originates on the inner posterior wall of the first segment and is inserted anteriorly on the membrane of the proximal part of the second joint. It opposes the productor $_2$ by bringing the joint upward toward the midline.

28. Musculus adductor$_2$ I antennae (fig. 3).—This is the largest of the four muscles governing the second joint of the antenna. It arises on the inner posterior wall of the first segment and is inserted anteriorly on the membrane at the inner basal part of the second segment. It thus parallels the reductor $_2$ and nearly conceals it. Like the latter, it brings the second joint upward and toward the midline. No adductor occurs in *Astacus* in any of the joints of its first antenna.

29. Musculus abductor$_2$ I antennae (fig. 3).—This muscle arises on the inner proximal border of the first segment, directly beneath the origin of the productor $_2$, paralleling it almost to its insertion on the membrane below the outer proximal edge of the second segment. It brings the second segment strongly backward and outward.

30. Musculus productor $_3$ I antennae (fig. 3).—This muscle arises on the outer proximal part of the second joint and is attached to the cartilage emanating from the outer proximal edge of the third joint, which is pulled downward and outward by it.

31. Musculus reductor $_3$ I antennae (fig. 3).—Also arising on the outer proximal wall of the second joint, this muscle goes to its attachment on the membrane of the inner proximal border of the third joint, which it brings inward and upward in opposition to the productor $_3$.

32. Musculus reductor $_4$ I antennae (fig. 3).—This is the only muscle lying in the third segment. It arises on the inner proximal wall and is inserted on the membrane lying between the two flagella, which are pulled sharply together by its contraction, while the elasticity of the membrane pulls them sharply apart. Apparently there are no special muscles within the flagella themselves.

THE SECOND ANTENNA

In the blue crab the second antenna is so different in structure from the corresponding appendage in the crayfish and shrimp that it is not feasible to attempt to draw a parallel very closely between them. The second antenna in the crayfish, as Schmidt remarks in his masterly analysis (Schmidt, 1915, p. 205), is the most highly segmented of all the head appendages, and hence possesses the greatest ability for motion. The same complicated structure was observed by Miss Berkeley in the shrimp *Pandalus*. Both these crustaceans have a well-developed, heavily muscled exopodite, as well as an endopodite in which all the typical segments may be recognized, the flagellum being taken to represent the dactylopodite in both cases.

There is no jointed exopodite in the blue crab; the only trace of it is a hard protuberance on the outer part of the basipodite. Since a complete fusion has taken place between the basipodite and the head carapace, there are no depressor or levator muscles. The coxopodite is reduced externally to a membranous pocket lying anteriorly between the basipodite and the head carapace, in which the fusion occurs posteriorly. Arising from the basipodite, and forming the base of the endopodite, come two segments which I shall arbitrarily call the ischiopodite and the meropodite, which are provided with the typical reductor and productor muscles. Following these is a long annulated flagellum without definite muscles inside it. It is impossible to say whether the flagellum represents the division of the last three segments of the normal endopodite—carpopodite, propodite, and dactylopodite—or of the carpopodite alone, if one wishes to assume the complete loss of the other two. Because of this uncertainty, the muscles lying in the so-called meropodite and controlling the action of the flagellum are referred to as the reductor and productor of the flagellum.

33. *Musculus promotor II antennae* (fig. 4).—This muscle arises on the dorsal carapace in the protogastric region, and runs inward and forward to its attachment on a slender tendonlike structure which thickens and hardens into a sickel-shaped rod, which curves outward and forward beneath the membranous pouch lying between the basipodite and the head carapace, and finally attaches itself to this same cartilagelike membrane, which is moved forward and inward by its action.

34. Musculus remotor II antennae (fig. 4).—This short muscle arises partly on the head carapace where it fuses with the basipodite and partly on the upper edge of the membranous pouch below the basipodite. It passes backward to its insertion on the posterior part of the sickel-shaped rod mentioned above. The membranous pouch is pulled backward and downward by its contraction.

35. Musculus productor ischiopoditis II antennae (fig. 4).—This muscle arises on the proximal median portion of the basipodite and is attached to the outer proximal border of the ischiopodite, which it moves outward and downward.

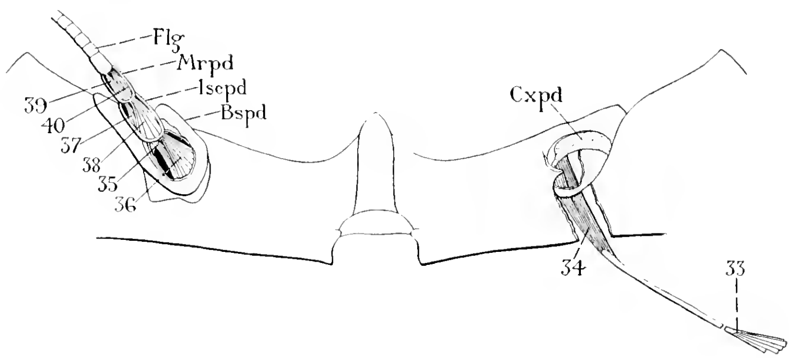


FIG. 4.—The second antenna.

33, musculus promotor II antennae; *34*, musculus remotor II antennae; *35*, musculus productor ischiopoditis II antennae; *36*, musculus reductor ischiopoditis II antennae; *37*, musculus productor meropoditis II antennae; *38*, musculus reductor meropoditis II antennae; *39*, musculus productor flagellaris II antennae; *40*, musculus reductor flagellaris II antennae.

Cxpd, coxopodite; *Bspd*, basipodite; *Iscpd*, ischiopodite; *Mrpd*, meropodite; *Flg*, flagellum.

36. Musculus reductor ischiopoditis II antennae (fig. 4).—A little heavier than the preceding, this muscle arises near it on the inner proximal wall of the basipodite, and is inserted on the inner proximal margin of the ischiopodite, which is pulled strongly inward toward the center by its action.

37. Musculus productor meropoditis II antennae (fig. 4).—This muscle arises on the outer proximal wall of the ischiopodite and is inserted on the outer proximal margin of the meropodite, on which it exerts an outward and downward pull.

38. Musculus reductor meropoditis II antennae (fig. 4).— Like the preceding in size and shape, this muscle originates on the inner proximal wall of the ischiopodite and goes to its insertion on the inner proximal edge of the meropodite, which receives a pull toward the center from it.

39. Musculus productor flagellaris II antennae (fig. 4).—Arising on the proximal posterior wall of the meropodite, this muscle is inserted on the base of the first annulus of the flagellum, which is pulled outward and backward by its contraction.

40. Musculus reductor flagellaris II antennae (fig. 4).—This muscle arises on the anterior wall of the meropodite and is inserted on the anterior part of the first ring of the flagellum, causing the latter to be brought inward and forward.

THE MANDIBLE

As in the crayfish, shrimp, and lobster, the mandible in the blue crab is firmly fixed at two articulations (*x* and *xx*, fig. 5) and hence cannot rotate.

The position of these articulations, however, is quite different in the blue crab from that of corresponding articulations in the crayfish and its allies, and a different mechanism for controlling the mandible is required. In the crayfish, shrimp, and lobster, one of the articulations is at the extreme upper anterior corner of the mandible, and the other is at the lower posterior corner. Therefore any muscles connecting the lower anterior corner with the skeletal part near the midline will pull the lower halves of the mandibles strongly together, functioning thus as adductors. A muscle attached to the upper posterior edge of the mandible, and running from the same central skeletal foundation, perhaps beside and even parallel to the adductors just described, will pull the mandibles just as strongly apart, performing the function of abductors. This opposition is made possible by the widely separated points of articulation of the mandible, which allow its upper and lower borders to pivot inward and outward between their hinges. This swinging motion is further intensified by such additional abductors and adductors as give sufficient power to the masticatory function of the mandible.

In the blue crab the articulations of mandible with head skeleton are both anterior, one at the upper and one at the lower corner of the mandible. Because of these anterior articulations, any muscles going from the central foundation to any available spot on the inner posterior surface of the mandible behind these forward-lying hinges are bound to open the mandible, functioning as abductors. Hence there is no anterior adductor in the blue crab, and the thin sheetlike muscle of the blue crab, which corresponds to that muscle in the crayfish, functions now as a major abductor of the mandible, and all the work of closing the mandible has to be done by the very heavy and powerful posterior and lateral adductors.

In this appendage a division of the extrinsic muscles into those with dorsal origin and those with ventral origin is first clearly apparent. There is as a matter of fact only one ventral muscle, the greater abductor (*41*, fig. 5 A, C), and this might be referred to as *musculus ventralis mesalis,* the mesal ventral muscle of the mandible, if positional names were adopted. There are three dorsal muscles of the

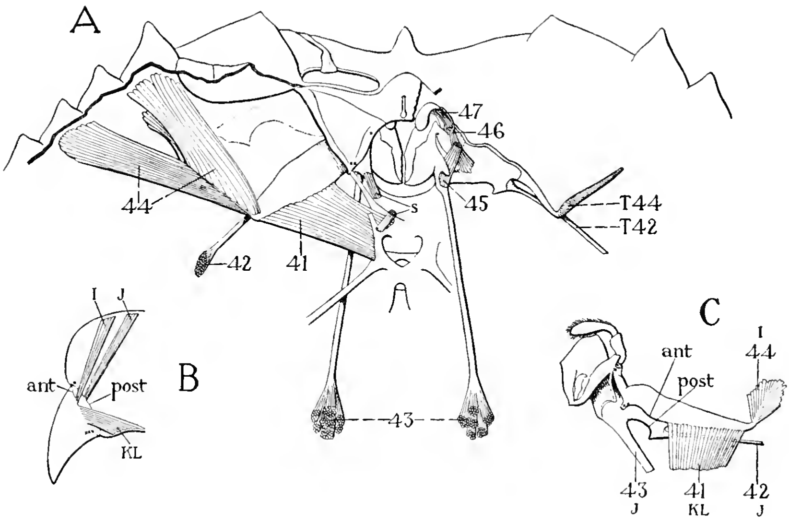


FIG. 5.—The mandible.

A, dorsal view of the mandible in place.
B, analysis of the mandible as an appendage.
C, mesal view of the mandible.
41, musculus abductor maior mandibulae; *42,* musculus abductor minor mandibulae; *43,* musculus adductor posterior mandibulae; *44,* musculus adductor lateralis mandibulae; *45,* musculus extensor palpi mandibulae; *46,* musculus flexor *a* palpi mandibulae; *47,* musculus flexor *b* palpi mandibulae.
x-xx, hinges of the mandible; *T42,* tendon of musculus abductor minor mandibulae; *T44,* tendon of musculus adductor lateralis mandibulae; *S,* cut ends of two stomach muscles; *I,* the dorsal promotor; *J,* the dorsal remotor; *KL,* the ventral promotor and ventral remotor combined; *Ant,* anterior border of the mandible; *Post,* posterior border of the mandible.

mandible, a posterior outer (*42*), a posterior inner (*43*), and a third one (*44*), in function a lateral adductor, which is very puzzling to name as to position, since it attaches itself to the now outer posterior angle of the mandible, which has reversed itself in the blue crab from its primitive anterior position.

It has been repeatedly stated that the blue crab is a highly specialized creature, which departs in certain noticeable ways from the more generalized morphological aspects of many other crustacean types. Hence many of the blue crab's appendages might be expected to show a variation from the usual structure, and this expectation is fulfilled when the mandible is examined and compared specifically to that of the crayfish and shrimp. Because of its two anterior articulations, to which reference has already been made, the mandible of the blue crab lies in a partly reversed position; as a matter of fact, its true anterior border now is its upper posterior border when the crab occupies a normal attitude, and its true posterior surface is now entirely ventral in position.

The primitive appendage, as shown by R. E. Snodgrass in his "Evolution of the Insect Head and the Organs of Feeding," [3] has essentially

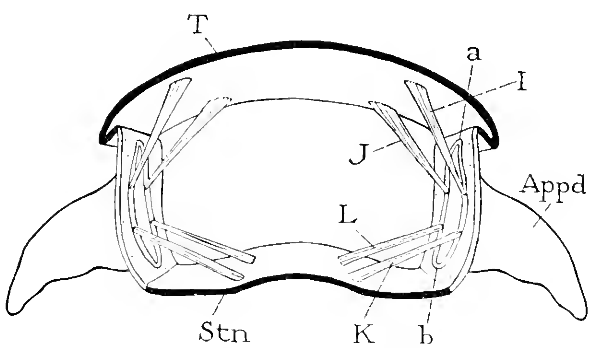


FIG. 6.—Diagram of the theoretical elementary musculature of the segmental appendages (after Snodgrass).

a-b, primitive dorsoventral axis of the appendage.
I, dorsal promotor muscle; *J*, dorsal remotor; *K*, ventral promotor; *L*, ventral remotor; *T*, tergum; *Stn*, sternum; *Appd*, appendage. (After R. E. Snodgrass, "The Thoracic Mechanism of a Grasshopper and its Antecedents," Smithsonian Misc. Coll., vol. 82, no. 2, p. 10, 1929.)

four muscles to control the movements of its basal part, two of which originate in the dorsal region of the body, and two on the ventral region (see fig. 6). The dorsal muscle, which is inserted on the anterior upper border of the rim of the appendage, is called the dorsal promotor (*I*), and the corresponding muscle inserted on the posterior upper border is the dorsal remotor (*J*). The muscle inserted on the anterior lower rim of the appendage is the ventral promotor (*K*), and the corresponding muscle with a posterior lower insertion is the ventral remotor (*L*).

An attempt has been made (fig. 5 B.) to analyze the extrinsic muscles of the mandible in the blue crab to see just how they conform to the simple ancestral type. It was found that the dorsal muscle numbered

[3] Smithsonian Rep. 1931, p. 465, fig. 14, 1932.

44, functioning as the lateral adductor, corresponds to the primitive muscle *I* with insertion on the upper anterior rim of the appendage. The two remaining dorsal muscles, the minor abductor (*42*) and the posterior adductor (*43*) together represent the muscle *J*, since both originate dorsally and are inserted on the posterior (now ventral!) rim of the appendage. In the same way the muscle numbered *41*, acting as the major abductor, represents a combination of the ventrally-rising primitive muscles *K* and *L*, since *41* is the only muscle of the appendage having a ventral origin.

41. Musculus abductor maior mandibulae (fig. 5 A, C).—Appearing as a broad sheetlike muscle, this muscle originates in two places on the head apodeme, and runs outward to its insertion along the posterior part of the mandible, which it helps to open.

42. Musculus abductor minor mandibulae (fig. 5 A, C).—This muscle arises laterally on the dorsal head carapace on the inner part of the epibranchial region and is inserted by a very slender but strong tendon on the lower outer part of the mandible, which is opened by it.

43. Musculus adductor posterior mandibulae (fig. 5 A, C).—This very strong muscle arises on the urogastric region of the carapace in several heavy muscle bundles, which shortly fuse together into a long and extremely heavy tendon that passes forward and downward to its attachment on the mandible at the point of its lower articulation with the head skeleton. It brings the mandible strongly toward the midline.

44. Musculus adductor lateralis mandibulae (fig. 5 A, C).—This extremely heavy muscle arises on the head carapace partly at the base of the first spine and partly at the base of the third spine, the parts uniting on a heavy tendon attaching them to the outer posterior end of the mandible, which they bring strongly toward the midline.

45. Musculus extensor palpi mandibulae (fig. 5 A).—This muscle arises on the inner surface of the mandible near the base of the tendon of the posterior adductor muscle. It is inserted on the heavy membrane connecting the palp and the mandible, and its contraction straightens the palp and brings it away from the center, opposing flexor *a* in its action. There is no extensor for the distal segment of the palp.

46. Musculus flexor a palpi mandibulae (fig. 5 A).—This short but stout muscle arises on the outer part of the mandible and travels forward and slightly inward to its attachment on the posterior proximal border of the first segment of the palp. Its function is to lower the palp, thereby bringing it toward the median plane.

47. Musculus flexor b palpi mandibulae (fig. 5 A).—This muscle fills the whole of the first segment of the palp. It arises in the membrane proximal to this first segment, and is inserted on the proximal joint of the last (second) segment. It lowers this last segment, thus bringing it toward the center.

THE FIRST MAXILLA

The first maxilla in the blue crab, as in the crayfish and shrimp, is flattened, and while it normally lies close to the outer anterior surface of the mandible, it has a considerable degree of freedom of motion. This is due to the fact that its basal part is really in two pieces, the posterior half rather loosely attached to the lower distal margin of the anterior half, and the two halves working together somewhat like the blades in a pair of scissors. The anterior half has been called the basipodite by Huxley, Schmidt, Berkeley, and some other investigators, but since there are no muscles between it and the posterior half, and since the body muscles go to both of them equally, it appears that the structure is in reality a coxopodite, semi-divided and provided with hinges to give necessary pliability. Borrodaile also considers that both parts belong to the coxopodite. It appears that the true basipodite is completely fused with and indistinguishable from the inner border of the coxopodite, as the endopodite arises from this region.

Three dorsal muscles run to the first maxilla, although it is impossible to separate them at their origin because of their extremely attenuate form. They separate distinctly into three strands as they pass behind the mandible to their respective points of insertion on the first maxilla. The first of these (fig. 7, *51*) is the anterior inner, which may be called *musculus dorsalis anterior mesalis* and whose functional name is the anterior adductor of the coxopodite. The next (*52*) is a posterior inner, *musculus dorsalis posterior mesalis,* which acts as a posterior adductor to the coxopodite. There is but one outer dorsal muscle, which may be referred to as *musculus dorsalis externalis* and which functions as an abductor of the coxopodite.

The ventral muscles may be classed as follows:

54. Upper inner: *Musculus ventralis superior mesalis* (levator).
55. Lower inner: *Musculus ventralis inferior mesalis* (depressor).
48. Anterior outer: *Muculus ventralis anterior externalis* (promotor).
49. Posterior outer: *Musculus ventralis posterior externalis* (remotor *a*).
50. Median outer: *Musculus ventralis medialis externalis* (remotor *b*).

The only intrinsic muscle in this appendage is *56,* the adductor of the endopodite.

48. Musculus promotor I maxillae (fig. 7).—This muscle arises on the head apodeme and runs forward and outward to its dorsal insertion in the extreme lateral part of the coxopodite beneath a disklike ossification near the inner hinge of the coxopodite. This muscle moves the coxopodite forward and upward.

49-50. Musculus remotor I maxillae a and b (fig. 7).—The shorter branch of the remotor (*49*) arises on the ventral part of the head

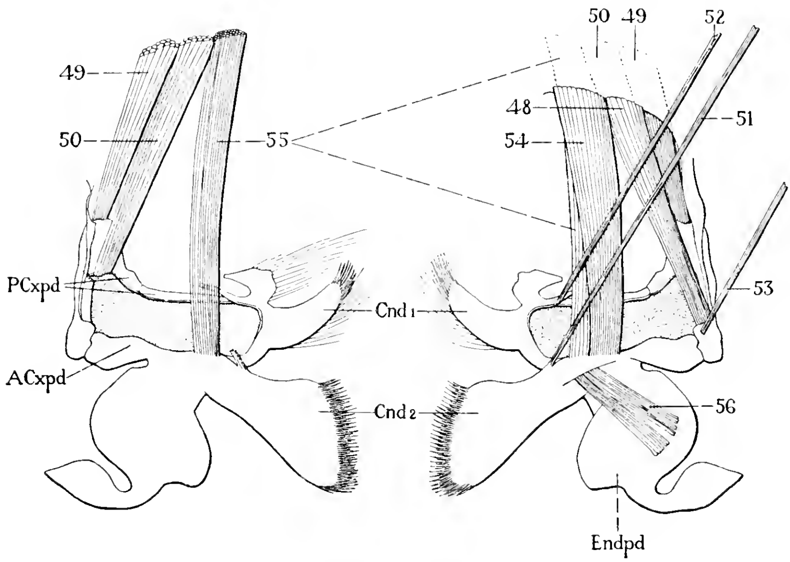


FIG. 7.—The first maxilla.

48, musculus promotor I maxillae; *49-50*, musculus remotor I maxillae; *51*, musculus adductor anterior I maxillae; *52*, musculus adductor posterior I maxillae; *53*, musculus abductor coxopoditis I maxillae; *54*, musculus levator I maxillae; *55*, musculus depressor I maxillae; *56*, musculus adductor endopoditis I maxillae.

ACxpd, anterior part of the coxopodite; *PCxpd*, posterior part of the coxopodite; *Cnd*$_1$ and *Cnd*$_2$, first and second endites of the coxopodite; *Endpd*, endopodite.

apodeme external to the origin of the main branch, traveling parallel to the latter to its insertion on the posterior dorsal angle of the basal rim of the coxopodite beneath and slightly median to the insertion of the promotor. Lying directly below the promotor, the longer branch of the remotor (*50*) arises on the ventral surface of the head apodeme somewhat posterior to the origin of the promotor. It is inserted ventrally in the anterior dorsal angle of the basal rim of the coxopodite at a point considerably posterior to the insertion of the promotor and near the union of the coxopodite with the ringlike outgrowth which encircles it and holds it near to the mandible. Both remotor muscles oppose the promotor by lowering the coxopodite.

51. Musculus adductor anterior coxopoditis I maxillae (fig. 7).—This exceedingly long and slender muscle arises on the epibranchial region of the head carapace and is inserted without a tendon on the anterior margin of the base of the coxopodite near its mesal end. It brings the free end of the coxopodite toward the mouth.

52. Musculus adductor posterior coxopoditis I maxillae (fig. 7).—This very slender, long muscle originates on the head carapace with the preceding and is indistinguishable from it at first; it travels forward, inward and ventrally to its insertion on the posterior margin of the base of the coxopodite, which it pulls forward and inward.

53. Musculus abductor coxopoditis I maxillae (fig. 7).—Arising on the head carapace at the origin of the preceding two and at first indistinguishable from them, this muscle, likewise very slender, is attached dorsally to the extreme outer border of the coxopodite on the same disk-shaped ossification that gives attachment to the promotor. It opposes the adductor in pulling the coxopodite away from the midline.

54. Musculus levator I maxillae (fig. 7).—This muscle arises on the anterior part of the head apodeme, just median to the promotor, traveling forward to the dorsal median proximal border of the inner half of the coxopodite, which it raises.

55. Musculus depressor I maxillae (fig. 7).—Arising on the ventral surface of the head apodeme under and slightly posterior to the origin of the levator, this muscle continues forward directly under the levator to its insertion on the ventral proximal border of the inner half of the coxopodite, which it pulls downward.

56. Musculus adductor endopoditis I maxillae (fig. 7).—This muscle arises on the inner proximal border of the inner half of the coxopodite and branches into a fanlike formation at its manifold insertion in the central part of the endopodite, which it brings toward the center of the body. The basipodite is no longer distinguishable as such in this appendage, and its position is postulated only by the presence of the endopodite, which when present always arises from the basipodite.

THE SECOND MAXILLA

Although this appendage has the most complex system of muscles of any in the blue crab, yet its muscles correspond more closely to those in *Astacus* and in *Pandalus* than do the muscles of its other appendages. The muscles leading to the parts bordering the mouth are relatively slender and weak, so that the appendage evidently does not assist greatly in the process of food-taking. Its true function is shown in the great development and complexity of the muscles controlling the scaphognathite, which cause the currents of water to pass continually over the gills. These muscles are attached to a very thick swelling, continuous at its outer end with the skeletal ridge running across the membrane covering the gill chamber. Its inner course borders the juncture of scaphognathite and coxopodite in a crooked and irregular swelling, which finally comes to an end as a cuplike thickening that bounds the outer proximal borders of endopodite and basipodite. This cup gives origin on its inner side to the adductor muscle of the endopodite and on its outer side to the flexor of the scaphognathite. No tendons are found in any muscles of the second maxilla. There is no levator muscle in this appendage in *Callinectes, Astacus,* or *Pandalus.*

The coxopodite bears two mesal bilobed endites, the anterior of which has been assigned to the basipodite by Brooks and many later writers. There is no distinguishable basipodite present as such in either of the two maxillae in the blue crab, but in both maxillae the coxopodite is so irregularly shaped that its appearance does not suggest superficially that it is in reality all one structure. As in the first maxilla, the position of the basipodite in the second maxilla is to be inferred only by the position of the endopodite. This region is so irregularly convoluted and infolded to give sufficient room for insertion to the complex and numerous respiratory muscles that the original boundaries between coxopodite, basipodite, scaphognathite, and endopodite are completely obliterated in the blue crab. In describing the muscles of the second maxilla, no further reference will be made to a basipodite.

As all the dorsal muscles are missing in this as in all the following segments, the naming of the ventral muscles remaining might appear to be an easy task, but such is not the case. The myological plan of the second maxilla is greatly complicated by the presence of no less than seven respiratory muscles, some of which are extrinsic, some intrinsic. As a matter of fact, the only muscle which permits of an easily descriptive positional name is *60,* an anterior inner ventral muscle, *musculus ventralis mesalis,* which functions as an adductor of the coxopodite. The remaining extrinsic ventral muscles (fig. 8) are *57,* promotor; *58,* remotor; *59,* depressor; and *63* through *66,* the anterior respiratory muscles.

The remaining respiratory muscles (*67* through *69*), are intrinsic, as are likewise the adductor of the endopodite (*61*), and the flexor of the scaphognathite (*62*).

57. Musculus promotor II maxillae (fig. 8).—This long, cylindrical muscle originates on the dorsal surface of the endopleurite of the last head segment, which segment coalesces with the first two thoracic segments. It runs straight forward to its insertion on the skeletal ridge that borders the proximal part of the coxopodite. It brings the coxopodite backward and upward, at the same time causing a similar movement in the attached anterior part of the scaphognathite.

58. Musculus remotor II maxillae (fig. 8).—Almost hidden by the respiratory muscles, the remotor arises on the dorsal surface of the endosternite of the same segment just in front of the apodemal fora-

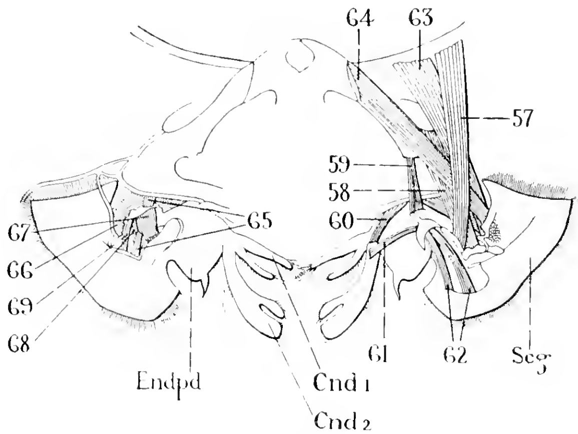


FIG. 8.—The second maxilla.

57, musculus promotor II maxillae; *58*, musculus remotor II maxillae; *59*, musculus depressor II maxillae; *60*, musculus adductor coxopoditis II maxillae; *61*, musculus adductor endopoditis II maxillae; *62*, musculus flexor scaphognathitis II maxillae; *63-69*, musculi respiratorii II maxillae.

*Cnd*1 and *Cnd*2, first and second endites of the coxopodite; *Endpd*, endopodite; *Scg*, scaphognathite.

men, and passes forward and outward between respiratory muscles one and two to its insertion on the thickened edge of the coxopodite slightly lateral to and below that of the promotor. It brings the coxopodite upward and somewhat toward the center.

59. Musculus depressor II maxillae (fig. 8).—This is the smallest and weakest muscle in the entire appendage. It arises ventrally on the endosternite, appearing as two very thin branches which travel forward through the coxopodite to their insertion on its proximal border. It causes the coxopodite to move downward and inward. In *Astacus* this muscle also has two branches.

60. Musculus adductor coxopoditis II maxillae (fig. 8).— This relatively short and slender but strong muscle arises on the inner anterior corner of the endosternite, running inward and forward to its insertion on the inner proximal border of the coxopodite. It pulls the coxopodite strongly backward and thus toward the center.

61. Musculus adductor endopoditis II maxillae (fig. 8).—This slender threadlike muscle arises on the inner proximal part of the coxopodite, passing laterally to its insertion on the cuplike swelling at the lateral outer border of the endopodite. It causes the endopodite to be bent somewhat toward the inner region.

62. Musculus flexor scaphognathitis II maxillae (fig. 8).—This muscle originates in the cuplike thickening that borders the outer part of coxopodite and endopodite, and runs outward with pronounced ramification through the scaphognathite to its attachment on the cartilaginous fold which parallels the outer border of the scaphognathite. This segment is bent by means of the flexor muscle. In *Pandalus* there is an additional superior flexor muscle which is unbranched.

63-69. Musculi respiratorii II maxillae (fig. 8).—Arising on the dorsal surface of the endopleurite just mesal to the origin of the promotor, the first of these muscles, *musculus respiratorius primus* (*63*), goes forward and outward beneath the promotor to its insertion on the lateral part of the skeletal swelling between coxopodite and scaphognathite. This and the remaining respiratory muscles induce a strong undulating motion in the scaphognathite, thus forcing the water that is drawn into the gill chamber to flow forward. The second muscle, *musculus respiratorius secundus* (*64*), heavy and powerful like the first, arises mediodorsally on the head apodeme, runs outward and forward, and passes above the first and below the promotor to reach its insertion just over the first. The third, *musculus respiratorius tertius* (*65*), is a small and slender muscle completely hidden until the more dorsal muscles are removed. It originates on the thickened skeletal ridge on the anterior part of the head apodeme, and runs forward and slightly outward to its insertion on the skeletal swelling of the scaphognathite just below the insertion of the remotor. The fourth, *musculus respiratorius quartus* (*66*), is an exceedingly heavy but short muscle arising under the third on the same skeletal ridge of the head apodeme, running outward to its insertion on the scaphognathite, between two angles of the skeletal swelling marking its proximal border. The fifth, *musculus respiratorius quintus* (*67*), is a small, powerful muscle arising on an infolding of the apodemal membrane behind the fourth, then passing forward and slightly inward to its insertion on the skeletal swelling just beneath the insertion of the promotor. The sixth muscle, *musculus respiratorius sextus* (*68*), arises on the same infolding just lateral to the fifth, and proceeds straight forward to its insertion on the swelling, directly below the insertion of the third. The seventh muscle, *musculus respiratorius septimus* (*69*), like the sixth, is short and slender, arising laterally to it on the infolding and being inserted on the swelling midway between the insertions of the fourth and the sixth.

THE FIRST MAXILLIPED

The resemblance of this appendage to the maxillae rather than to the typical thoracic appendage has already been commented upon by several authors. The endopodite is weakly developed and devoid of muscles in the blue crab, but as its basal part is partly fused to the exopodite, it naturally partakes of the motion of the exopodite caused by the adductor muscle of the latter. The exopodite is relatively heavily muscled. The muscle extending through the flagellum originates entirely within the proximal segment of the flagellum, which is considerably enlarged. This origin is similar to that found in *Astacus*. In *Pandalus* the origin of this muscle is in the basal lobe of the first segment of the exopodite. The extremely poor development of the abductor of the flagellum in *Pandalus* appears to throw the whole task of moving the flagellum upon the flagellar muscle itself, which therefore needs the wider attachment space. In *Astacus* and *Callinectes,* where the abductor of the flagellum is relatively very large, the flagellar muscle is rather slender and weak.

Of the extrinsic muscles in the first maxilliped of the blue crab, it is possible to name positively only the promotor and the attractor of the epipodite. The small anomalous muscles which take the place of reductor, levator, and depressor have been referred to by number only, as their true function is as yet obscure. Further dissection of other representative decapods may subsequently reveal some species in which the functions of the corresponding muscles will be more apparent, and it may be possible in this way to assign names by analogy to these which it is now inadvisable to attempt to name arbitrarily.

As in both maxillae, the basipodite of the first maxilliped is no longer traceable as a distinct segment, being either eliminated completely or indistinguishably fused with the coxopodite. Its normal position if it were present may be ascertained in relation to the origins of endopodite and exopodite. In that case it would have lain between the second endite of the coxopodite and the epipodite.

70. Musculus promotor medialis I pedis maxillaris (fig. 9).—This strong but slender muscle arises on the inner anterior border of the paraphragm between the first and second thoracic segments near the midline of the body. It passes forward and slightly outward to its tendinous insertion on the tough membrane composing the dorsal surface of the coxopodite. It causes the coxopodite, and with it to some extent the inner part of the whole appendage, to be brought upward and inward.

71. Musculus promotor lateralis I pedis maxillaris (fig. 9).—This muscle is hidden partly beneath the first of the attractors of the epipodite and partly by the fused lamellae of the first and second thoracic paraphragms, on the outer ventral surface of which it arises. It runs

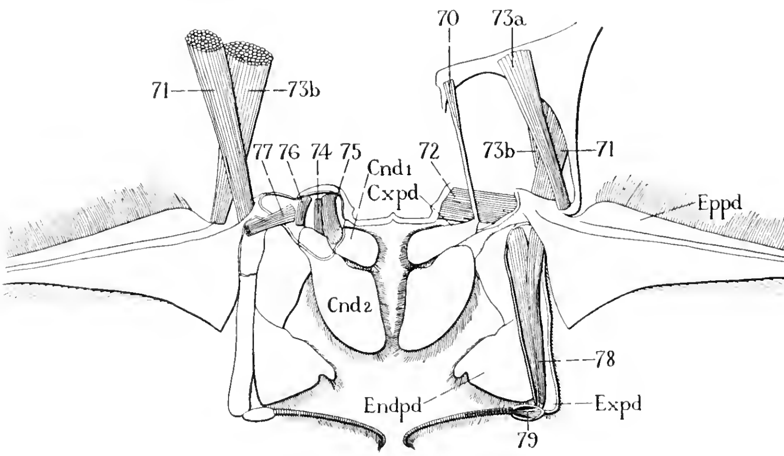


FIG. 9.—The first maxilliped.

70, musculus promotor medialis I pedis maxillaris; *71*, musculus promotor lateralis I pedis maxillaris; *72*, unnamed muscle; *73a-b*, musculus attractor epipoditis I pedis maxillaris; *74*, unnamed muscle; *75*, unnamed muscle; *76*, unnamed muscle; *77*, musculus adductor exopoditis I pedis maxillaris; *78*, musculus abductor flagelli exopoditis I pedis maxillaris; *79*, musculus flagellaris exopoditis I pedis maxillaris.

Cnd$_1$ and *Cnd*$_2$, first and second endites of the coxopodite; *Cxpd*, coxopodite; *Endpd*, endopodite; *Eppd*, epipodite; *Expd*, exopodite.

forward and slightly inward to its attachment on the lateral border of the coxopodite just at the point of origin of the epipodite. It helps to raise the appendage but otherwise opposes the medial promotor by exerting an outward pull.

72. (Fig. 9).—This powerful but short muscle originates on the endosternite, passing outward beneath the median promotor to its insertion on the extreme outer ventral borders of the coxopodite without a tendon. It is not feasible to attempt to name this muscle functionally, as no definite movement of the appendage can be assigned solely to it. It appears to lie in approximately the same position as does the levator muscle in *Astacus*.

73 a, b. Musculus attractor epipoditis a and b I pedis maxillaris (fig. 9).—One branch of this muscle arises on the dorsal portion of the paraphragm between the first and second thoracic segments, lying directly below the first respiratory muscle of the second maxilla. It passes outward and forward to its insertion on the outer dorsal proximal border of the epipodite, which it raises strongly, at the same time causing it to move backward and inward. The second branch, larger and more powerful than the first, passes under the first on its forward and outward path to its insertion beneath it on the ventral proximal border of the epipodite, which it brings strongly backward and downward.

74. (Fig. 9).—This short muscle arises deeply within a cuplike membrane beside the inner epistomal rim and is inserted at the base of the first endite on the coxopodite. It is impracticable to give a functional name to this muscle, although it undoubtedly controls the coxopodite in some way. It might perform the duties of a levator, but this can not be ascertained directly.

75. (Fig. 9).—This short but thick muscle arises on the mesal edge of the same cuplike membrane as does the preceding muscle, and is inserted deeply within the first endite of the coxopodite. It is not possible to name it as to function, although it presumably causes whatever motion the first endite is capable of making. Its position is somewhat similar to that of the depressor in *Pandalus* and *Astacus.*

76. (Fig. 9).—This short but heavy muscle arises on the lateral edge of the same cuplike membrane which gives origin to the two preceding muscles and is inserted beside and lateral to *74*, where the first and second endites come together. Again a functional name is not forthcoming as no positive motion can be assigned to this particular muscle.

77. Musculus adductor exopoditis I pedis maxillaris (fig. 9).—This muscle originates on the posterior surface of the coxopodite just lateral to the insertion of *76*, and runs laterally to its insertion on the outer anterior proximal border of the exopodite just above the origin of *78*. It brings the exopodite, and with it the partly fused endopodite, away from the epipodite and toward the center. Berkeley mentions a well-developed *abductor exopoditis* in *Pandalus,* not present in the blue crab. The endopodite of the blue crab has no muscles of its own.

78. Musculus abductor flagelli exopoditis I pedis maxillaris (fig. 9).—Arising in two places on the inner ventral proximal wall of the exopodite, this powerful muscle unites and passes to its insertion on the inner proximal edge of the enlarged first segment of the flagellum. It causes a strong upward and outward movement in the flagellum.

79. Musculus flagellaris exopoditis I pedis maxillaris (fig. 9).—Originating in the proximal segment of the enlarged first joint of the flagellum, this muscle runs outward through the various segments nearly to the tip of the flagellum, giving off small fibers in each segment which attach themselves to the wall, thus giving a high degree of pliability to the flagellum.

THE SECOND MAXILLIPED

In this appendage the first true hinges between the segments appear, just as they do in both *Astacus* and *Pandalus.* In section, the ischiopodite is found to be fused with the basipodite. The exopodite is merely an annulated flagellum as in *Pandalus.* The promotor appears to be inserted by a tendon, as are some of the muscles at the distal segments of the endopodite. A long, flat epipodite and two podobranchiae are present, with a slender attractor muscle to control the epipodite. In *Astacus* there are two podobranchiae and no epipodite; in *Pandalus,* a single podobranchia and an epipodite are present.

80. Musculus promotor II pedis maxillaris (fig. 10).—This muscle arises usually in two parts on the inner median edge of the paraphragm between the first and second thoracic segments in a very broad attachment. The muscle fibers rapidly converge into a single thin tendon, which is attached to the extreme inner edge of the coxopodite. It causes the entire endopodite to move inward and upward.

81. Musculus remotor II pedis maxillaris (fig. 10).—This muscle arises on a more lateral part of the two paraphragms next to the gill-chamber, and proceeds forward and inward to its insertion on the outer posterior border of the coxopodite. It lowers the outer part of the coxopodite, bringing it distinctly outward and backward.

82. Musculus levator II pedis maxillaris (fig. 10.)—This muscle arises as a heavy and massive muscle on the inner lateral edge of the paraphragm between the first and second thoracic segments, and passes without diminution in size to its insertion on the dorsal proximal membranous portion of the basi-ischiopodite. There is but one levator in *Callinectes;* both *Astacus* and *Pandalus* have two.

83 a, b. Musculus depressor a and b II pedis maxillaris (fig. 10).—The main branch of the depressor arises on the inner edge of the paraphragm between the first and second thoracic segments midway between the origins of promotor and levator. It parallels these two muscles to its insertion on the inner posterior border of the coxopodite. It gives a strong inward and downward pull to the coxopodite and hence to the whole of the endopodite. The small depressor *b* arises near the junction of the coxopodite with the paraphragm and is inserted just ventral to the main branch. It assists in lowering the coxopodite.

84. Musculus attractor epipoditis II pedis maxillaris (fig. 10).—Arising laterally on the meeting point of the body wall and the coxopo-

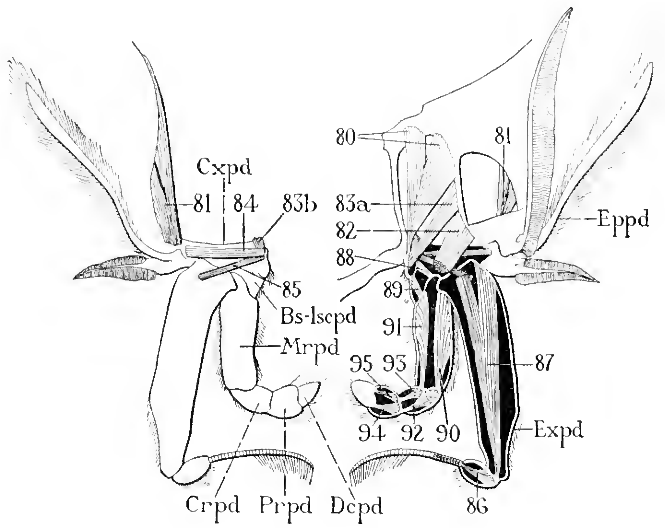


FIG. 10.—The second maxilliped.

80, musculus promotor II pedis maxillaris; *81*, musculus remotor II pedis maxillaris; *82*, musculus levator II pedis maxillaris; *83a-b*, musculus depressor a-b II pedis maxillaris; *84*, musculus attractor epipoditis II pedis maxillaris; *85*, musculus abductor exopoditis II pedis maxillaris; *86*, musculus flagellaris exopoditis II pedis maxillaris; *87*, musculus abductor flagelli exopoditis II pedis maxillaris; *88*, musculus productor meropoditis II pedis maxillaris; *89*, musculus reductor meropoditis II pedis maxillaris; *90*, musculus abductor carpopoditis II pedis maxillaris; *91*, musculus adductor carpopoditis II pedis maxillaris; *92*, musculus productor propoditis II pedis maxillaris; *93*, musculus reductor propoditis II pedis maxillaris; *94*, musculus productor dactylopoditis II pedis maxillaris; *95*, musculus reductor dactylopoditis II pedis maxillaris. *Bs-Iscpd*, basi-ischiopodite; *Crpd*, carpopodite; *Cxpd*, coxopodite; *Dcpd*, dactylopodite; *Eppd*, epipodite; *Expd*, exopodite; *Mrpd*, meropodite; *Prpd*, propodite.

dite, this slender muscle travels laterally to its insertion on the proximal border of the epipodite, which it moves slightly inward.

85. Musculus abductor exopoditis II pedis maxillaris (fig. 10).—This muscle arises ventrally in the outer side of the coxopodite and proceeds laterally to its attachment on the median ventral proximal part of the exopodite. It causes the exopodite to move outward and forward.

86. Musculus flagellaris exopoditis II pedis maxillaris (fig. 10).—This muscle arises on the proximal border of the enlarged first ring of the flagellum and runs nearly to the tip, giving off short fibers at every annulation. As a consequence the flagellum has a considerable degree of mobility.

87. Musculus abductor flagelli exopoditis II pedis maxillaris (fig. 10).—This muscle arises in two parts on the proximal dorsal side of the basal segment of the exopodite, fuses and runs to its insertion on the first ring of the flagellum, to which it imparts a strong outward motion.

88. Musculus productor meropoditis II pedis maxillaris (fig. 10).—This muscle arises on the ventral lateral border of the basi-ischiopodite and is inserted on the inner ventral proximal edge of the meropodite. The muscle is short but powerful. It moves the meropodite forward.

89. Musculus reductor meropoditis II pedis maxillaris (fig. 10).—More slender than *88* but likewise short, this muscle rises on the dorsal proximal border of the basi-ischiopodite and is inserted on the lateral proximal border of the meropodite. It tends to pull the meropodite backward.

90. Musculus abductor carpopoditis II pedis maxillaris (fig. 10).—This muscle originates in many bundles of fibers near the inner proximal border of the meropodite and is inserted on the proximal inner edge of the carpopodite. It moves the carpopodite upward and outward.

91. Musculus adductor carpopoditis II pedis maxillaris (fig. 10).—About the same size as the preceding, this muscle arises in a bundle of fibers on the inner surface of the meropodite and is inserted on the proximal inner edge of the carpopodite which it moves downward and inward.

92. Musculus productor propoditis II pedis maxillaris (fig. 10).—Arising on the outer proximal wall of the carpopodite, this muscle narrows rapidly to its tendinous insertion on the outer proximal edge of the propodite, which it moves strongly forward.

93. Musculus reductor propoditis II pedis maxillaris (fig. 10).—This relatively small muscle arises on the inner proximal part of the carpopodite and is inserted by a tendon on the inner proximal border of the propodite which it bends backward, and hence toward the mouth.

94. Musculus productor dactylopoditis II pedis maxillaris (fig. 10).—Arising on the outer proximal part of the propodite, this muscle is inserted by a short tendon on the outer proximal border of the dactylopodite, which it moves forward.

95. Musculus reductor dactylopoditis II pedis maxillaris (fig. 10).—Like the preceding in size and shape, this muscle arises on the inner proximal part of the propodite and passes quickly to its tendinous insertion on the inner proximal edge of the dactylopodite, which is brought inward and backward.

THE THIRD MAXILLIPED

This appendage in the blue crab, as in the crayfish, retains its function of a true mouthpart, and is essentially similar to the second maxilliped in structure. In the shrimp, on the other hand, the third maxilliped no longer assists in the taking of food, but is pediform and has completely lost its exopodite, while its endopodite has fewer segments, a characteristic condition in the *Caridea*. The endopodite in the blue crab is bent inward in its natural position; in fact, it can not be straightened perfectly, owing to the shape of the segments and the uniformly weak development of all the extensors except the one controlling the dactylopodite.

The coxopodite and the basipodite of the third maxilliped of the blue crab appear to be represented by a single segment, the protopodite. Brooks (1882) has labeled as "basipodite" the narrowed proximal part of the ischiopodite, which externally appears to be set off from the main part of the segment by a suture. An examination of the musculature of this segment, however, shows no evidence that it is composed of two elements. Furthermore, the exopodite does not originate upon this proximal region of the ischiopodite, which it would naturally do if a true basipodite were involved here.

96. Musculus promotor III pedis maxillaris (fig. 11).—This muscle arises mostly on the dorsal side of the endosternite of the third thoracic segment, and partly on the ventral (now anterior) side of the paraphragm, which is very narrow here. It is a powerful and wide muscle, narrowing and thickening as it goes forward to its insertion on a heavy tendinous ligament of the dorsal proximal inner corner of the protopodite, which is moved inward and forward by it.

97. Musculus remotor III pedis maxillaris (fig. 11).—Arising laterally on the endosternite, this strong muscle is inserted by a tendon on the lateral proximal edge of the protopodite. It opposes the promotor effectively, although it is somewhat less developed.

98 a-c. Musculus levator a, b, and c III pedis maxillaris (fig. 11).—This muscle is much smaller than the preceding. Its main branch (*a*) arises on the endosternite beneath the promotor and is inserted near the center of the posterior wall of the protopodite. The shortest branch (*b*) originates near the main branch on the endosternite, and joins the main branch before its insertion on the protopodite.

Another branch (*c*) arises in the extreme lateral border of the protopodite not far from the insertion of the remotor and passes inward to its insertion anterior to that of the main branch on the posterior wall of the protopodite. The levators move the basipodite outward and forward.

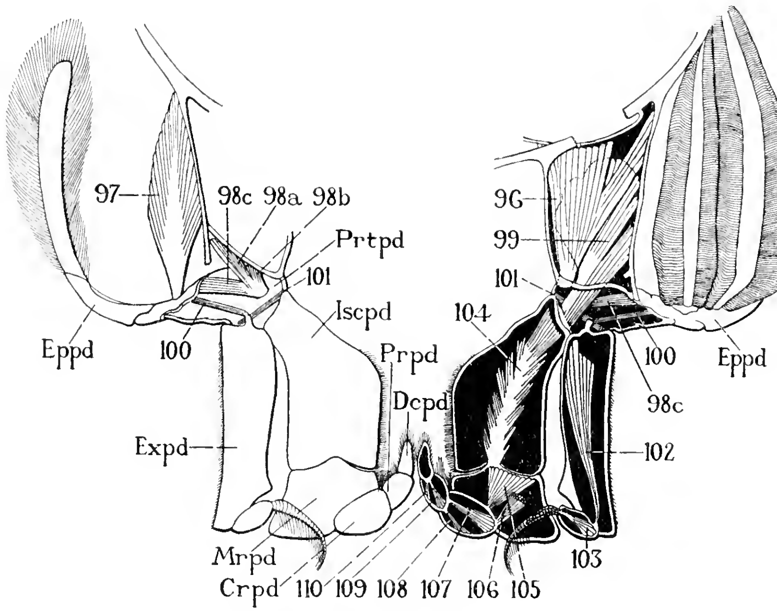


FIG. 11.—The third maxilliped.

96, musculus promotor III pedis maxillaris; *97,* musculus remotor III pedis maxillaris; *98a-c,* musculus levator a-c III pedis maxillaris; *99,* musculus depressor III pedis maxillaris; *100,* musculus adductor exopoditis III pedis maxillaris; *101,* musculus abductor exopoditis III pedis maxillaris; *102,* musculus abductor flagelli III pedis maxillaris; *103,* musculus flagellaris exopoditis III pedis maxillaris; *104,* musculus flexor meropoditis III pedis maxillaris; *105,* musculus extensor meropoditis III pedis maxillaris; *106,* musculus flexor carpopoditis III pedis maxillaris; *107,* musculus flexor propoditis III pedis maxillaris; *108,* musculus extensor propoditis III pedis maxillaris; *109,* musculus flexor dactylopoditis III pedis maxillaris; *110,* musculus extensor dactylopoditis III pedis maxillaris.

Crpd, carpopodite; *Dcpd,* dactylopodite; *Eppd,* epipodite; *Expd,* exopodite; *Iscpd,* ischiopodite; *Mrpd,* meropodite; *Prpd,* propodite; *Prtpd,* protopodite.

99. Musculus depressor III pedis maxillaris (fig. 11).—This is a very heavy muscle which originates over a relatively broad area on the epimeral plate beneath and beside the promotor, as well as the dorsal side of the endopleurite. Its many branches run forward and inward to join before the insertion of the muscle on the ventral median distal part of the protopodite. It opposes the levators.

100. Musculus adductor exopoditis III pedis maxillaris (fig. 11).—This slender but strong muscle originates in the extreme distal anterior part of the protopodite and runs inward to its insertion on a short, hard projection of the inner proximal border of the exopodite, which is pulled strongly toward the midline by the contraction of the muscle. The crayfish does not appear to have this muscle.

101. Musculus abductor exopoditis III pedis maxillaris (fig. 11).—This is a short, loosely-knit muscle arising ventrally on the median border of the protopodite and running obliquely outward and forward to its insertion on the heavy membrane attached to the ventral proximal wall of the exopodite. It moves the exopodite away from the center and slightly outward.

102. Musculus abductor flagelli III pedis maxillaris (fig. 11).—This strong muscle originates in two places on the proximal part of the exopodite. The two sections soon unite, and the muscle is inserted by a tendon on the outer proximal edge of the greatly enlarged first segment of the flagellum, which is moved strongly upward and outward by its action.

103. Musculus flagellaris exopoditis III pedis maxillaris (fig. 11).—Originating on the proximal wall of the enlarged first segment of the flagellum, this muscle goes almost to the tip of the flagellum, giving off fibers to each annulus, and thus insuring freedom of motion to the flagellum.

104. Musculus flexor meropoditis III pedis maxillaris (fig. 11).—This muscle arises in numerous groups of fibers on both dorsal and ventral walls of the ischiopodite. These fibers all join a tendon before their final insertion on the inner proximal edge of the meropodite, which is strongly pulled down by their action. There is apparently no extensor muscle, the tension of the joint itself being sufficient to bring the meropodite back into position after its contraction by the flexor.

105. Musculus extensor carpopoditis III pedis maxillaris (fig. 11).—This very slender and weak muscle originates midway on the walls of the meropodite and is inserted on the outer proximal edge of the carpopodite, which it pulls upward rather weakly.

106. Musculus flexor carpopoditis III pedis maxillaris (fig. 11).—As might be expected from the condition in the preceding segment, this muscle, which causes the bending toward the center, is very well developed. It originates widely on the proximal margin of the meropodite and narrows to its tendinous insertion on the inner proximal margin of the carpopodite.

107. Musculus flexor propoditis III pedis maxillaris (fig. 11).—This muscle is similar to the flexor in the preceding segment in size and function. It originates on the outer walls of the carpopodite, narrowing to an insertion on the outer proximal edge of the propodite.

108. Musculus extensor propoditis III pedis maxillaris (fig. 11).—Originating on the inner proximal walls of the carpopodite and inserted by a tendon on the inner proximal corner of the propodite, this muscle is like the corresponding one in the preceding segment in form and function.

109. Musculus flexor dactylopoditis III pedis maxillaris (fig. 11).—This muscle originates on the outer proximal border of the propodite and is inserted by a tendon on the outer proximal edge of the dactylopodite. Relative to the size of its opposing extensor, it is better developed than any other flexor in this endopodite, and apparently can exert a strong outward pull upon the dactylopodite.

110. Musculus extensor dactylopoditis III pedis maxillaris (fig. 11).—Originating on the inner proximal margin of the propodite, this muscle is inserted on the inner proximal edge of the dactylopodite, which is brought strongly downward by it. In this segment the extensor and the flexor are nearly the same in size and apparent strength.

THE PEREIOPODS

The five pairs of pereiopods, or true legs, occur upon the last five of the eight thoracic segments. The promotor, the remotor, and the levator muscles of each pereiopod are extrinsic in the origin of all their parts. The depressor of the telopodite, however, is both extrinsic and intrinsic in origin, for the larger and heavier branches originate in the body wall or some of its apodemes, while there are usually two or more branches originating proximally on the anterior and posterior walls of the coxopodite.

The functions of the different pairs of legs become evident upon examining their distal segments. On the first pair of legs, the dactylopodite arises on the anterior (preaxial) border of the propodite nearly at the middle; the unhampered tip of the propodite curves and tapers to a point, while the dactylopodite curves in a way to oppose it effectively, the two forming a powerful pinching claw, the chela, which is rendered still more effective by the horny teeth that have developed on the opposable surfaces. The claw is held out in front of the carapace, and may swing widely forward and sidewise in a horizontal plane, and less widely in a perpendicular plane, both movements serving as the means to repulse an enemy or to seize and tear up food. The extension of the leg forward has caused it to assume a position half-turned from the normal one, and now the true anterior (preaxial) surface of the first pereiopod is uppermost.

The second, third, and fourth pereiopods resemble one another rather closely, as they are nearly the same in size and perform the same kinds of motions, being adapted for walking. In these, the dactylopodite arises on the distal part of the propodite, tapering rapidly and becoming much flattened. The tip is pointed and sharp, and on these tips the crab is able to walk. The overhang of the carapace allows little upward motion to these legs, and so they have retained the normal position of hanging downward beneath the body. The anterior surface of these legs is preaxial, as is usually the case in arthropods.

The fifth and last pereiopod is the swimming leg, and projects backward and upward behind the carapace when the crab is swimming. Its basal muscles are very powerful, especially the remotor, which is relatively weak in the preceding pereiopods. The terminal segment is very thin and flat like the blade of a paddle, ovoid in shape, and propels the crab sidewise very swiftly. Like the first pereiopod, the fifth is also a half-turn away from its normal position, but in a direction opposite to that of the first, so that its anterior (preaxial) face is now downward, and its postaxial face uppermost.

Since the muscles of the segments distal to the basipodite are essentially similar in all the pereiopods, those of the third pereiopod have been chosen to be described in detail, while the corresponding muscles of the other legs may be referred to the third as a model, taking into consideration the fact that the first and fifth legs are not identical with it in position. The basal muscles are sufficiently different in each leg to merit a full description.

A cross-section of the body at the level of the anterior part of the fourth and of the sixth thoracic segments shows the relations of some of the muscles of the first and third legs to their respective surroundings. (See fig. 13.)

The promotor of the fifth pereiopod deserves notice because of the peculiar disposition of its anterior branch. This projects forward through the thorax into the fourth thoracic segment, surrounded by a membrane, on the posterior surface of which its own fibers originate, and on the anterior surface of which about a dozen branches of muscles pertaining to the legs of the fourth, fifth, sixth, and seventh segments also take their origin.

Another feature of the endoskeletal structure must here be explained. An intermediate endopleurite exists in the center of each of the basal chambers occupied by the fourth, fifth, sixth, and seventh segments. This endopleurite is fastened to the membrane covering the

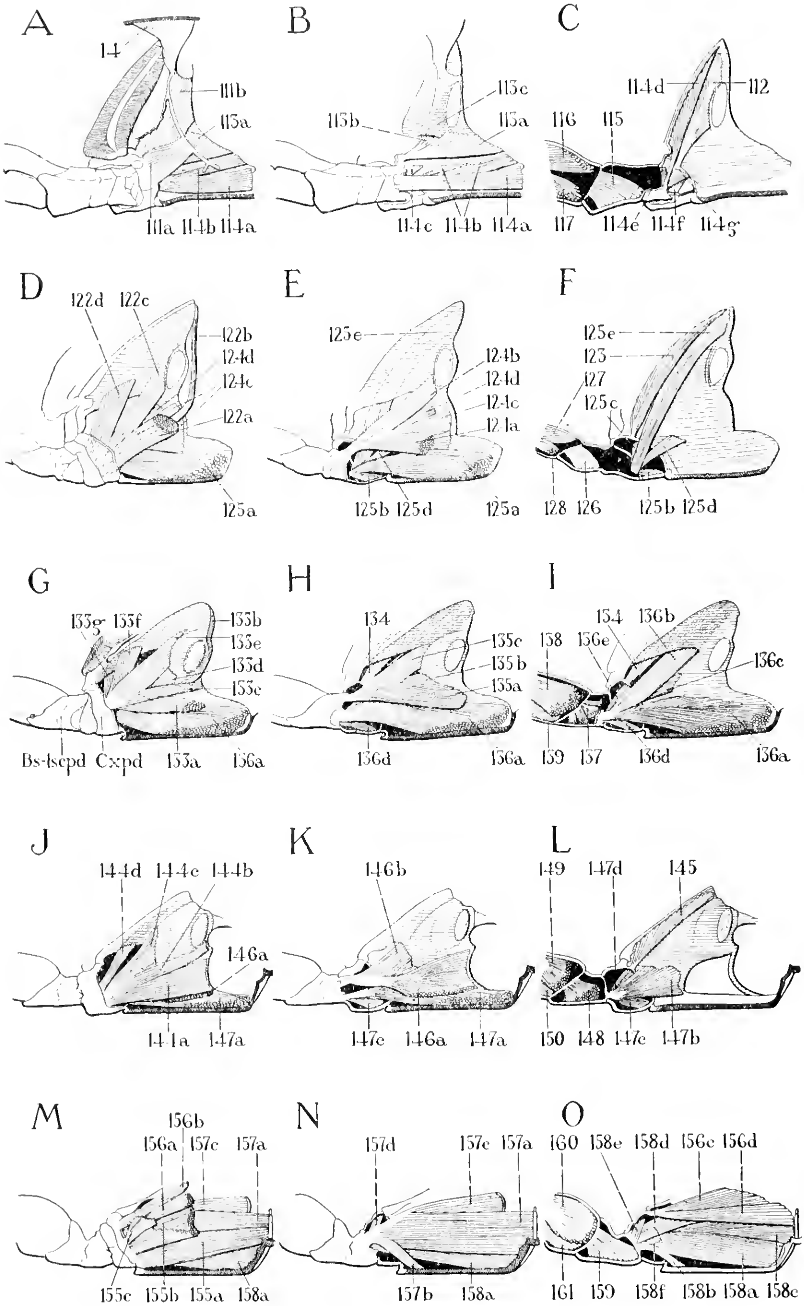


FIG. 12. (For legend see next page.)

anterior projection of the promotor of the fifth pereiopod, and gives additional room for attachment to the numerous branches of muscles governing the movements of the leg base.

THE FIRST PEREIOPOD

111 a, b. Musculus promotor a and b (figs. 12 A, 13 B).—The anterior branch (*a*) originates upon a narrow, curved apodeme which comes inward and forward from the floor of the gill chamber and attaches itself laterally by a process to the sternum and medially to the endosternite between the third and fourth thoracic segments. The muscle passes outward and downward to its attachment on a heavy membrane coming from the preaxial proximal border of the coxopodite. The posterior branch (*b*) originates on the anterior border of the intermediate endopleurite of this segment and ends upon a heavy tendon attached to the anterior border of the coxopodite and directly behind the attachment of branch *a*. These two parts give a strong forward pull to the basal part of the leg.

112. Musculus remotor (fig. 12 C). This is the only unbranched muscle controlling the leg base. It takes origin partly on the lateral surface of the membrane enclosing the anterior promotor of the fifth pereiopod behind *113 c* and partly on the anterior part of the endopleurite separating the fifth and sixth thoracic segments. It is inserted

---

FIG. 12.—The pereiopods.

A, B, C, the first pereiopod.

14, musculus attractor epimeralis; *111a-b*, musculus promotor *a-b*; *112*, musculus remotor; *113a-c*, musculus levator *a-c*; *114a-g*, musculus depressor *a-g*; *115*, musculus reductor meropoditis; *116*, musculus abductor carpopoditis; *117*, musculus adductor carpopoditis.

D, E, F, the second pereiopod.

122a-d, musculus promotor *a-d*; *123*, musculus remotor; *124a-d*, musculus levator *a-d*; *125a-e*, musculus depressor *a-e*; *126*, musculus reductor meropoditis; *127*, musculus abductor carpopoditis; *128*, musculus adductor carpopoditis.

G, H, I, the third pereiopod.

133a-g, musculus promotor *a-g*; *134*, musculus remotor; *135a-c*, musculus levator *a-c*; *136a-e*, musculus depressor *a-e*; *137*, musculus reductor meropoditis; *138*, musculus abductor carpopoditis; *139*, musculus adductor carpopoditis.

Bs-Iscpd, basi-ischiopodite; *Cxpd*, coxopodite.

J, K, L, the fourth pereiopod.

144a-d, musculus promotor *a-d*; *145*, musculus remotor; *146a-b*, musculus levator *a-b*; *147a-d*, musculus depressor *a-d*; *148*, musculus reductor meropoditis; *149*, musculus abductor carpopoditis; *150*, musculus adductor carpopoditis.

M, N, O, the fifth pereiopod.

155a-c, musculus promotor *a-c*; *156a-b*, musculus remotor a-b; *157a-c*, musculus levator *a-c*; *158a-f*, musculus depressor *a-f*; *159*, musculus reductor meropoditis; *160*, musculus abductor carpopoditis; *161*, musculus adductor carpopoditis.

on a heavy tendon attached to the upper postaxial border of the coxopodite. The leg base is pulled backward by the contraction of this muscle.

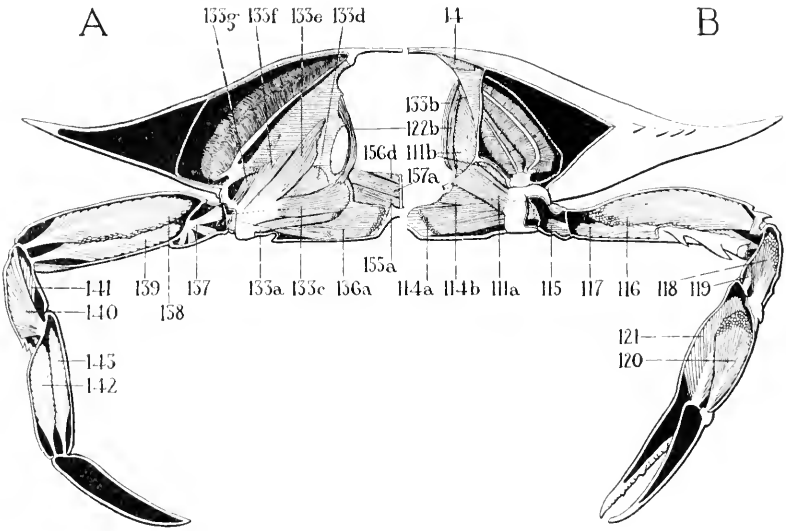


FIG. 13.—Transverse section of the thorax.

A, section through the third pereiopod.

122b, branch of musculus promotor of second pereiopod; *133c-g*, branches of musculus promotor of third pereiopod; *136a*, branch of musculus depressor of third pereiopod; *137*, musculus reductor meropoditis of third pereiopod; *138*, musculus abductor carpopoditis of third pereiopod; *139*, musculus adductor carpopoditis of third pereiopod; *140*, musculus productor propoditis of third pereiopod; *141*, musculus reductor propoditis of third pereiopod; *142*, musculus abductor dactylopoditis of third pereiopod; *143*, musculus adductor dactylopoditis of third pereiopod; *155a*, branch of musculus promotor of fifth pereiopod; *156d*, branch of musculus remotor of fifth pereiopod; *157a*, branch of musculus levator of fifth pereiopod.

B, section through the first pereiopod.

14, musculus attractor epimeralis; *111a-b*, branches of musculus promotor of first pereiopod; *114a*, branch of musculus depressor of first pereiopod; *115*, musculus reductor meropoditis of first pereiopod; *116*, musculus abductor carpopoditis of first pereiopod; *117*, musculus adductor carpopoditis of first pereiopod; *118*, musculus productor propoditis of first pereiopod; *119*, musculus reductor propoditis of first pereiopod; *120*, musculus abductor dactylopoditis of first pereiopod; *121*, musculus adductor dactylopoditis of first pereiopod; *122b*, branch of musculus promotor of second pereiopod; *133b*, branch of musculus promotor of third pereiopod.

113 a-c. Musculus levator a-c (fig. 12 A, B).—The first branch (*a*) originates on the anterior border of the endosternite separating the fourth and fifth thoracic segments. It passes outward to its insertion on the upper postaxial proximal border of the coxopodite. A second and much shorter branch (*b*) begins on the lower rim of the intermediate endopleurite. A third branch (*c*) begins behind this endopleurite on the lateral surface of the membrane holding the anterior promotor branches of the fifth pereiopod which extends forward through the thorax and gives attachment to many muscles, and runs into branch *b* at their mutual insertion. These muscle parts act together in raising the leg base.

114 a-g. Musculus depressor a-g (figs. 12 A, B, C; 13 B).—The first branch (*a*) originates mesally on the sternum and passes outward to its insertion on the tendon attached to the membrane on the preaxial proximal border of the basi-ischiopodite. The second branch (*b*) is very indistinctly separated from the first, originating in several sections along the anterior edge of the endosternite separating the fourth and fifth thoracic segments. A third branch (*c*) which appears to be quite distinct, originates on the extreme lateral part of the same endosternite beneath *113 a*, and comes forward to its insertion on the membrane of the lower proximal border of the basi-ischiopodite. The fourth branch (*d*) begins behind the intermediate endopleurite on the under surface of the pleural wall separating the gill chamber from the fifth thoracic segment. The remaining branches (*e*, *f*, and *g*) originate at different points in the posterior part of the coxopodite. These three last-named branches are not compact, and it is possible to subdivide them still further than this. The distinctness of these minor branches varies considerably according to the state of preservation of the tissues, and consequently appears to be much less evident in some individuals than in others. They are inserted side by side along the lower and postaxial proximal margins of the basi-ischiopodite. The depressor muscle as a whole gives a very strong downward movement to the leg base.

115. Musculus reductor meropoditis.—See *137*.

116. Musculus abductor carpopoditis.—See *138*.

117. Musculus adductor carpopoditis.—See *139*.

118. Musculus productor propoditis.—See *140*.

119. Musculus reductor propoditis.—See *141*.

120. Musculus abductor dactylopoditis.—See *142*.

121. Musculus adductor dactylopoditis.—See *143*.

THE SECOND PEREIOPOD

122 a-d. Musculus promotor a-d (fig. 12 D).—The most anterior part (*a*) arises on the posterior surface of the endosternite separating the fourth and fifth thoracic segments, passing downward and outward to its insertion on a heavy tendon coming from the proximal preaxial rim of the coxopodite. The long and slender branch (*b*) originates mesally on the prolongation of the endopleurites where they come together just below the attractor of the epimera. It travels ventrally for half its length, separated from the visceral cavity only by a very thin sheet of tissue. It passes at last into the fifth thoracic segment behind branch *a* of the promotor, where it finally attaches itself to the same tendon. The third branch (*c*) originates on the lateral part of the membrane covering the anterior promotor of the fifth pereiopod, which extends forward through the thorax as previously stated. The most lateral branch (*d*) originates on the lateral anterior surface of the intermediate endopleurite, being inserted beside branch *c* on the broad tendon common to all branches of the promotor. The contraction of this muscle causes the leg base to be moved strongly forward.

123. Musculus remotor (fig. 12 F).—As in the first leg, this is the only unbranched muscle belonging to the leg base. It arises on the anterior surface of the endopleurite separating the fifth and sixth thoracic segments, passing downward and outward to its tendinous insertion on the upper postaxial border of the coxopodite. It opposes the promotor.

124 a-d. Musculus levator a-d (fig. 12 D, E).—This heavy muscle appears to be divided into four main parts, although the third and fourth are not very distinct from each other. The first branch (*a*) arises on the posterior surface of the endosternite between the fourth and fifth thoracic segments and is inserted by an extremely strong tendon on the upper (in this case postaxial) border of the basi-ischiopodite. A second branch (*b*) arises on the lateral part of the membrane encasing the anterior promotor of the fifth pereiopod. The two remaining branches (*c* and *d*) arise close together, on the anterior surface of the endosternite between the fifth and sixth thoracic segments, and are inserted between branches *a* and *b* on the same strong tendon. The entire muscle causes the leg to be raised.

125 a-e. Musculus depressor a-e (fig. 12 D, E, F).—The first branch (*a*) originates mesally on the posterior surface of the endosternite separating the fourth and fifth thoracic segments, as well as on the sternal wall of the fifth segment. It is inserted on the lower (in this case preaxial) rim of the basi-ischiopodite. A very short branch (*b*) runs from the anterior part of the coxopodite to the same insertion, while a similar short branch (*c*) originates in the rear of the coxopodite. A slightly longer branch (*d*) begins on the outer part of the sternal wall near the endosternite between the fifth and sixth thoracic segments. The longest branch (*e*) originates on the anterior wall of the endopleurite separating the fifth and sixth segments, coming forward and downward to its insertion with the other branches. The muscle as a whole opposes the levator.

126. Musculus reductor meropoditis.—See *137*.

127. Muculus abductor carpopoditis.—See *138*.

128. Musculus adductor carpopoditis.—See *139*.

129. Musculus productor propoditis.—See *140*.

130. Musculus reductor propoditis.—See *141*.

131. Musculus abductor dactylopoditis.—See *142*.

132. Musculus adductor dactylopoditis.—See *143*.

THE THIRD PEREIOPOD

133 a-g. Musculus promotor a-g (figs. 12 A; 13 A).—The anterior branch (*a*) originates on the posterior surface of the endosternite separating the fourth and fifth thoracic segments, going outward to its insertion on the tendon attached to the anterior proximal rim of the coxopodite. The second branch (*b*) originates on the same prolongation of the endopleurites on which *122 b* of the preceding segment takes origin. It travels ventrally beside *122 b*, separated from the visceral masses only by a thin membrane, passing finally under the anterior extension of the promotor of the fifth pereiopod until it joins its tendon. Branch *c* originates mesally on the anterior upper edge of the endosternite separating the sixth and seventh segments near to its point of fusion with the endopleurite. The next two branches (*d* and *e*), not very distinct from each other, arise on the lateral part of the membrane encasing the anterior promotor of the fifth pereiopod. Branch *f* arises on the anterior lateral surface of the intermediate endopleurite, while branch *g* arises just behind it on the posterior surface of the same endopleurite. All these go to the same insertion with branch *a*. The muscle pulls the leg base forward.

134. Musculus remotor (fig. 12 H, I).—This unbranched muscle arises on the pleural wall and on the endosternite separating the sixth and seventh segments. Its insertion is on the proximal postaxial border of the coxopodite. Its contraction causes the leg base to be drawn backward.

135 a-c. Musculus levator a-c (fig. 12 H).—The most ventral branch (*a*) begins on the anterior wall of the sixth and seventh thoracic segments. The branch *b*, originating just above it on the same endosternite, is perhaps not truly distinct from it. The third branch (*c*) originates on the lateral part of the membrane covering the anterior promotor of the fifth pereiopod. These three branches are all inserted upon a heavy tendon attached to the proximal postaxial rim of the basi-ischiopodite. The leg base is raised by their contraction.

136 a-e. Musculus depressor a-e (figs. 12 G, H, I, 13 A).—The first (*a*) of the numerous branches to this muscle originates partly on the posterior wall of the endosternite between the fifth and sixth thoracic segments, partly on the anterior wall of the endosternite between the sixth and seventh segments, and partly on the sternal wall between. It passes to a heavy tendon attached to the tough membrane bordering the proximal anterior rim of the basi-ischiopodite. The next branch (*b*) begins on the endopleurite between the sixth and seventh segments just above the anterior prolongation of the promotor of the fifth pereiopod. The next branch (*c*) lies partly behind branch *b*, originating on the endosternite near its fusion with the endopleurite separating the sixth and seventh segments. Branch *d* originates anteriorly in the coxopodite, and branch *e* posteriorly in the same segment. All these are inserted on the heavy tendon or on the membrane beside it. Their mutual contraction pulls the leg base forcibly downward.

137. Musculus reductor meropoditis (figs. 12 I; 13 A).—This fan-shaped muscle begins in several places on the preaxial part of the basi-ischiopodite, and is inserted postaxially on the proximal border of the meropodite. The hinge between these two segments is only slightly developed preaxially, and not much more so postaxially, so that the rearward motion imparted by this muscle is slight. It is opposed by the stiffness of the preaxial connection which causes the leg to become straightened again after its contraction.

138. Musculus abductor carpopoditis (figs. 12 I, 13 A).—This large muscle originates in a great many bundles of fibers attached on the whole dorsal surface of the meropodite from its anterior to its posterior walls. These bundles run together before their insertion on a long bladelike tendon which is inserted on the posterior dorsal proximal border of the carpopodite. This muscle extends the carpopodite so that it lies in a straight line with the meropodite.

139. Musculus adductor carpopoditis (figs. 12 I, 13 A).—This originates in the same way as the abductor but lies ventrally in its segment and is inserted similarly by a very long tendon leading to the anterior ventral proximal border of the carpopodite. This muscle is therefore in perfect opposition to the adductor, bending the carpopodite at right angles to the meropodite.

140. Musculus productor propoditis (fig. 13 A).—This densely-fibered fanlike muscle originates on the entire outer border of the carpopodite, its parts coming together on a heavy leaf-shaped tendon which is inserted on the proximal median anterior border of the propodite, to which it gives a strong forward motion.

141. Musculus reductor propoditis (fig. 13 A).—This muscle arises on the outer and postaxial walls of the carpopodite, narrowing to its tendinous insertion on the posterior proximal border of the propodite, which is moved backward by it.

142. Musculus abductor dactylopoditis (fig. 13 A).—This rather slender and feather-shaped muscle arises in many small fibers on the preaxial wall of the propodite. It is inserted by a very long bladelike tendon on the outer proximal edge of the dactylopodite, which is moved outward by its action.

143. Musculus adductor dactylopoditis (fig. 13 A).—Very similar to the preceding in shape and size, this muscle arises largely on the postaxial part of the protopodite and is inserted also on a bladelike tendon to the inner proximal border of the dactylopodite. The terminal segment is bent strongly toward the midline by this muscle.

THE FOURTH PEREIOPOD

144 a-d. Musculus promotor a-d (fig. 12 J).—The first branch (*a*) originates mesally on the endosternite between the seventh and eighth thoracic segments and is inserted on a heavy tendon attached to the membrane on the anterior border of the coxopodite. The second branch (*b*) originates dorsally to *a* on the same endosternite and just below the membrane covering the anteriorly extending promotor muscle of the fifth pereiopod. The branch *c* originates partly on the lateral surface of the membrane of the promotor of the fifth pereiopod and partly on the endosternite separating the seventh and eighth segments. The branch *d* originates on the posterior surface of the intermediate endopleurite, which in this segment is very small. All these branches are inserted with or beside the first one. The whole muscle moves the leg base forward.

145. Musculus remotor (fig. 12 L).—As in the three preceding pereiopods, the remotor of the fourth pereiopod is unbranched. It originates on the lower surface of the pleural wall, passing outward and downward to its tendinous insertion on the upper posterior rim of the coxopodite. It opposes the promotor by bringing the leg backward.

146 a-b. Musculus levator a and b (fig. 12 J, K).—The first branch (*a*) originates partly on the posterior wall of the endosternite separating the sixth and seventh segments above *147 a*, and partly on the anterior wall of the endosternite separating the seventh and eighth segments. The second branch (*b*) originates on the anterior wall of the endosternite between the seventh and eighth segments. It would be possible to separate this part into smaller subdivisions, as several strands go more deeply than others. The branches of this muscle go to a mutual insertion on a heavy tendon coming from the upper proximal border of the coxopodite. Their contraction causes the leg base to be elevated.

147 a-d. Musculus depressor a-d (fig. 12 J, K, L).—The first branch (*a*) originates partly on the posterior wall of the endosternite separating the sixth and seventh segments, partly on the sternal wall of the seventh segment, and partly on the anterior surface of the endosternite between the seventh and eighth segments of the thorax. The second branch (*b*) lies behind the posterior part of the first branch, spreading in a fan shape over the endosternite between the seventh and eighth segments of the thorax. It might be considered as being more than a single branch, as it is not very compact at its source. The third and fourth branches (*c* and *d*) begin on the anterior and posterior walls respectively of the coxopodite. All branches of this muscle go to the same heavy tendon fastened to the proximal ventral rim of the basi-ischiopodite. The muscle opposes the levator effectively.

148. Musculus reductor meropoditis.—See *137*.

149. Musculus abductor carpopoditis.—See *138*.

150. Musculus adductor carpopoditis.—See *139*.

151. Musculus productor propoditis.—See *140*.

152. Musculus reductor propoditis.—See *141*.

153. Musculus abductor dactylopoditis.—See *142*.

154. Musculus adductor dactylopoditis.—See *143*.

THE FIFTH PEREIOPOD

155 a-c. Musculus promotor a-c (fig. 12 M).—The longest and heaviest branch (*a*) originates anteriorly on the median plate and passes posteriorly and laterally to its insertion on the tendon on the membrane at the anteroventral border of the coxopodite. The next branch (*b*) is very prominent, originating on the posterior surface of the membrane which projects diagonally forward through the preceding segments and on the anterior surface of which some of the branches of muscles of the second, third, and fourth pereiopods were attached. The third branch (*c*) is the smallest. It arises on the posterior surface of the endosternite between the seventh and eighth segments, being inserted above branch *b* on its tendon. The muscle imparts a forward motion to the leg.

156 a and b. Musculus remotor a-b (fig. 12 M, O).—In this pereiopod the remotor differs from the corresponding muscle in the other pereiopods in that it is branched and also much more strongly developed than in the other legs, owing to the fact that it has to give a powerful backstroke to this fifth leg, which serves as the paddle and which alone causes the very effective swimming movements of the crab. The first branch (*a*) originates dorsally on a T-shaped part of the endopleurite which is attached mesally on the median plate. The posterior branch (*b*) originates on the posterior wall of the eighth segment. Both branches are inserted on a heavy tendon attached to the membrane on the proximal postaxial (in this case dorsal) border of the basi-ischiopodite. The muscle as already stated directs the leg backward.

157 a-c. Musculus levator a-c (fig. 12 M, N).—The large first branch (*a*) originates on the median plate just posterior to the first branch of the promotor. It travels laterally beneath the second branch of the promotor and beneath the dorsal half of the remotor also, to its insertion on a heavy tendon attached to the anterior (dorsal) proximal border of the basi-ischiopodite. The second branch (*b*) is small and weak. It originates on the sternum between the main branches of the promotor and the depressor, and goes upward and laterally to its insertion on the same tendon. The third branch (*c*) is a heavy and strong one, arising on the sternal wall near to the wedge formed by the first abdominal segment. The entire muscle pulls the leg strongly upward.

158 a-f. Musculus depressor a-f (fig. 12 M, N, O).—The first branch (*a*), very large and heavy, originates mesally on the sternal wall of the eighth thoracic segment. Branch *b* is very small, originating laterally on the sternal wall. Branch *c* parallels the first branch, beginning partly on the sternal wall and partly on the median plate. The fourth branch (*d*) originates on the posterior sternal wall at the end of the thorax. The fifth and sixth branches (*e* and *f*) originate on the dorsal and posterior walls respectively of the coxopodite. All these branches converge upon an extremely heavy tendon attached to the proximal preaxial (in this case posterior) border of the basi-ischiopodite. This extraordinarily powerful muscle pulls the leg base downward.

159. Musculus reductor meropoditis.—See *137.*

160. Musculus abductor carpopoditis.—See *138.*

161. Musculus adductor carpopoditis.—See *139.*

162. Musculus productor propoditis.—See *140.*

163. Musculus reductor propoditis.—See *141.*

164. Musculus abductor dactylopoditis.—See *142.*

165. Musculus adductor dactylopoditis.—See *143.*

THE PLEOPODS

THE MALE

In the male blue crab, appendages occur only on the first two segments of the abdomen. The distal abdominal segments are much narrower than in the female, and the third, fourth, and fifth segments are fused so that their original sutures are scarcely visible, as I have pointed out earlier in this study.

In the first pleopod of the male the coxopodite is large and partially sclerotized. The basipodite is irregularly shaped, and its distal border is a membrane that attaches the long, whiplike flagellum and gives it the necessary freedom of movement. In this membrane is likewise a pocket in which the flagellum of the second pleopod normally rests.

The name " flagellum " is chosen arbitrarily for the distal part of the pleopod, as it does not show the character of a true flagellum. But neither is there sufficient evidence for considering it a highly modified endopodite or exopodite.

The second pleopod is very much weaker than the first, which completely covers it. Its coxopodite is very thin-walled and partly membranous. A small basipodite is present, controlled by a single muscle originating in the coxopodite. The basipodite and flagellum are sclerotized, but an extensive membrane lies between them, as in the first pleopod. Preaxially, the basipodite is represented only by a membrane, as its sclerotized part is entirely postaxial in position.

166. Musculus promotor coxopoditis I pedis spurii (fig. 14 A).—This muscle originates on the ventral surface of the last thoracic somite just lateral to the origin of the first ventral superficial abdominal muscle. It is inserted on the inner preaxial proximal border of the coxopodite, which it erects strongly. This is the only extrinsic muscle belonging to the first pleopod.

167. Musculus abductor basipoditis I pedis spurii (fig. 14 A).—Arising on the walls of the outer part of the coxopodite, this muscle is inserted on the outer proximal margin of the basipodite, which is pulled away from the center by its contraction.

168. Musculus adductor basipoditis I pedis spurii (fig. 14 A).—This is a heavy muscle arising on the inner proximal walls of the coxopodite. It is inserted on the inner proximal border of the basipodite, which is pulled toward the center by its action.

169. Musculus abductor flagelli I pedis spurii (fig. 14 A).—This small and compact muscle arises on the distal postaxial border of the basipodite, and is attached to the extended proximal edge of the flagellum. It causes the tip of the flagellum to move strongly outward.

170. Musculus promotor coxopoditis II pedis spurii (fig. 14 B). This heavy muscle arises on the anterior margin of the second abdominal segment lying entirely beneath the first pleopod. It is inserted on the inner proximal part of the coxopodite, which is erected by its contraction.

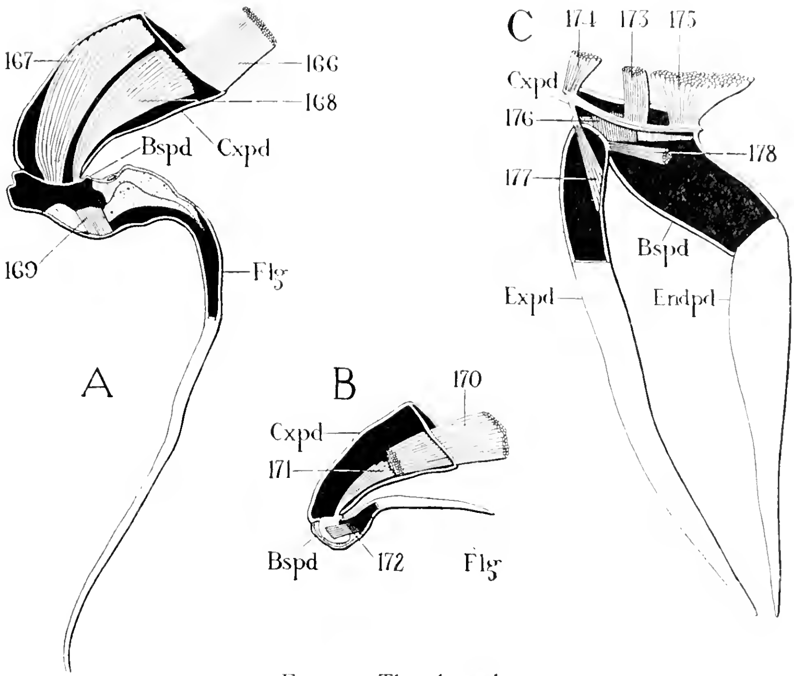


FIG. 14.—The pleopods.

A, the first pleopod of the male.
166, musculus promotor coxopoditis I pedis spurii; *167*, musculus abductor basipoditis I pedis spurii; *168*, musculus adductor basipoditis I pedis spurii; *169*, musculus abductor flagelli I pedis spurii.
B, the second pleopod of the male.
170, musculus promotor coxopoditis II pedis spurii; *171*, musculus adductor basipoditis II pedis spurii; *172*, musculus abductor flagelli II pedis spurii.
C, the first pleopod of the female.
173, musculus promotor coxopoditis I pedis spurii; *174*, musculus abductor coxopoditis I pedis spurii; *175*, musculus adductor coxopoditis I pedis spurii; *176*, musculus reductor basipoditis I pedis spurii; *177*, musculus abductor exopoditis I pedis spurii; *178*, musculus adductor exopoditis I pedis spurii.

171. Musculus adductor basipoditis II pedis spurii (fig. 14 B.)—Arising in numerous strands on the inner postaxial wall of the coxopodite, this muscle is attached to the inner proximal border of the basipodite, which is brought toward the center by its contraction. No abductor of the basipodite is present in this appendage, as the elasticity of the membrane apparently gives the necessary opposition to the adductor.

172. Musculus abductor flagelli II pedis spurii (fig. 14 B).—Like the corresponding muscle in the first abdominal appendage, this muscle arises on the lateral part of the wall of the basipodite and terminates on the proximal preaxial border of the flagellum, which is brought away from the center as well as slightly forward by its action.

THE FEMALE

The first and sixth abdominal segments of the female blue crab lack appendages. The second, third, fourth, and fifth segments each have pleopods which become increasingly smaller posteriorly. The coxopodite and basipodite are separated by a membrane on the postaxial surface; preaxially the two are fused. A description of the muscles pertaining to the first abdominal appendage, attached to the second abdominal segment, applies to the other three pairs of abdominal appendages, in which the muscles are similar but weaker.

173. Musculus promotor coxopoditis I pedis spurii (fig. 14 C).—This muscle arises on the dorsal border of the second abdominal segment and is inserted on the middle of the preaxial proximal border of the coxopodite, which it brings strongly forward.

174. Musculus abductor coxopoditis I pedis spurii (fig. 14 C).—This muscle likewise originates on the dorsal border of the second abdominal segment lateral to the origin of the promotor. It passes slightly outward to its insertion on the extreme lateral proximal border of the coxopodite. The appendage is moved away from the midline by its action. In the three pleopods which follow this one, the abductor of the coxopodite takes its origin below and behind that of the promotor muscle, so that in the last pleopod it is nearly obscured by the promotor when viewed preaxially. This is the only noteworthy difference in any of the muscles of the following three appendages as compared with those of the first appendage, except that they become smaller as the appendages themselves decrease in size.

175. Musculus adductor coxopoditis I pedis spurii (fig. 14 C).—This muscle is much larger than its opponent, the abductor. It arises on the median dorsal border of the second abdominal somite from almost the midline to the origin of the promotor. It is inserted at the extreme median proximal margin of the coxopodite, which it pulls inward and forward.

176. Musculus reductor basipoditis I pedis spurii (fig. 14 C).—This is a very short but rather powerful muscle arising laterally along the proximal posterior border of the coxopodite at the only place where the fusion is not complete between basipodite and coxopodite.

It runs inward without narrowing to its insertion along the proximal posterior wall of the basipodite, which is moved backward by its action.

177. Musculus abductor exopoditis I pedis spurii (fig. 14 C).—Arising on the lateral anterior border of the basipodite near the insertion of the abductor of the basipodite, the abductor of the exopodite is inserted on the lateral wall of the exopodite, on which it produces a feeble outward pull.

178. Musculus adductor exopoditis I pedis spurii (fig. 14 C).—This rather slender muscle arises on the median proximal preaxial wall of the basipodite and extends outward to its insertion on the inner proximal end of the exopodite, which is moved inward by its pull.

There are no muscles to govern the endopodite, which moves only as the basipodite moves.

179. Musculus promotor coxopoditis II pedis spurii.—See *173.*
180. Musculus abductor coxopoditis II pedis spurii.—See *174.*
181. Musculus adductor coxopoditis II pedis spurii.—See *175.*
182. Musculus reductor basipoditis II pedis spurii.—See *176.*
183. Musculus abductor exopoditis II pedis spurii.—See *177.*
184. Musculus adductor exopoditis II pedis spurii.—See *178.*
185. Musculus promotor coxopoditis III pedis spurii.—See *173.*
186. Musculus abductor coxopoditis III pedis spurii.—See *174.*
187. Musculus adductor coxopoditis III pedis spurii.—See *175.*
188. Musculus reductor basipoditis III pedis spurii.—See *176.*
189. Musculus abductor exopoditis III pedis spurii.—See *177.*
190. Musculus adductor exopoditis III pedis spurii.—See *178.*
191. Musculus promotor coxopoditis IV pedis spurii.—See *173.*
192. Musculus abductor coxopoditis IV pedis spurii.—See *174.*
193. Musculus adductor coxopoditis IV pedis spurii.—See *175.*
194. Musculus reductor basipoditis IV pedis spurii.—See *176.*
195. Musculus abductor exopoditis IV pedis spurii.—See *177.*
196. Musculus adductor exopoditis IV pedis spurii.—See *178.*

The Skeleton

A brief survey of some of the skeletal peculiarities found in the blue crab is not out of place in a study of its myology, since the shape of the skeleton and the arrangement of the muscles attached upon it are mutually interdependent.

The segments of the head and thorax of the crab are immovably ankylosed, as I have repeatedly emphasized. To some extent, this fact simplifies the musculature, as it at once precludes the presence of true trunk muscles which are necessary only when the segments move individually. (See figs. 15 and 16.)

The muscles of the last five thoracic segments are separated internally by a series of irregularly shaped partitions. Each of these partitions consists of two thin plates, formed by the anterior wall of one segment closely applied to the posterior wall of the preceding segment.

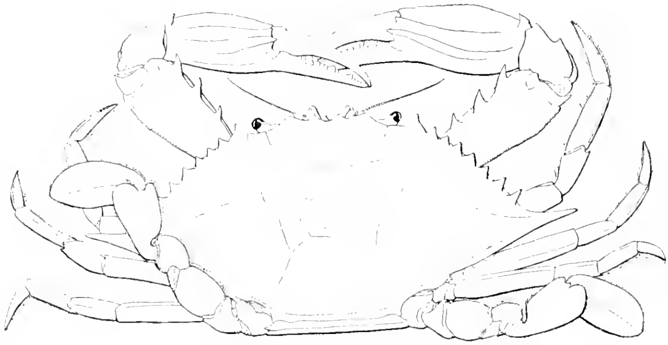


FIG. 15.—Dorsal view of the blue crab.

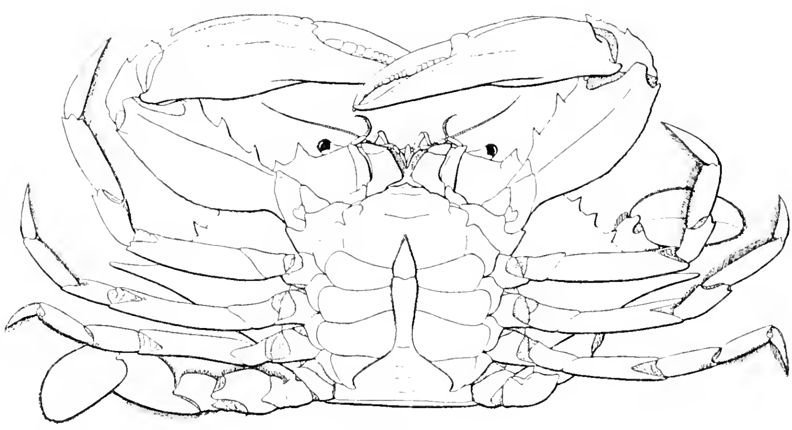


FIG. 16.—Ventral view of the blue crab.

The lower half of each partition is formed by a pair of the plates arising from the sternal borders of neighboring segments and is called an endosternite. The upper half of each partition is similarly formed by a pair of the plates which originate on the pleural walls of neighboring segments and is called an endopleurite. Each endosternite coalesces with its corresponding endopleurite, and it is at this line of coalition that the break occurs during ecdysis to allow the crab to molt completely. (See figs. 17 and 18.)

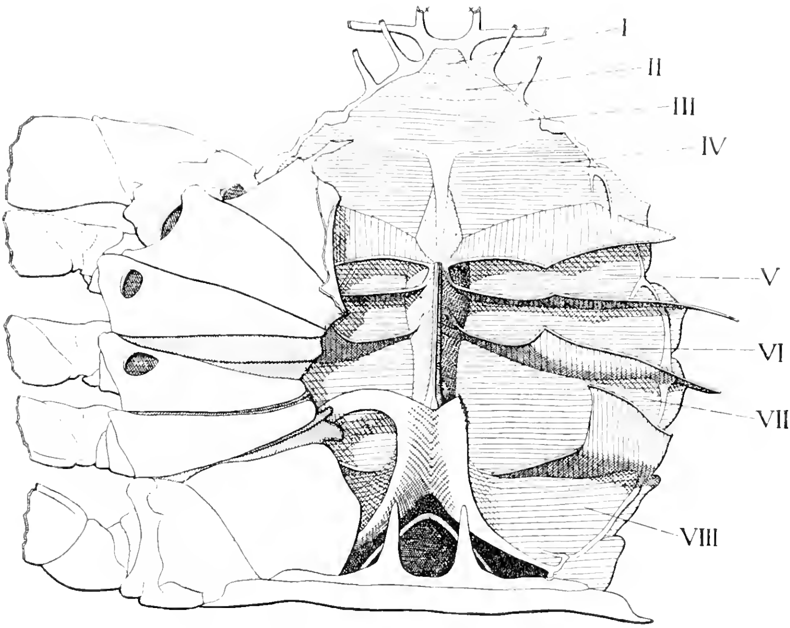


FIG. 17.—Dorsal view of thorax with carapace removed to show internal skeletal parts.

I-VIII, first through eighth somites of thorax.

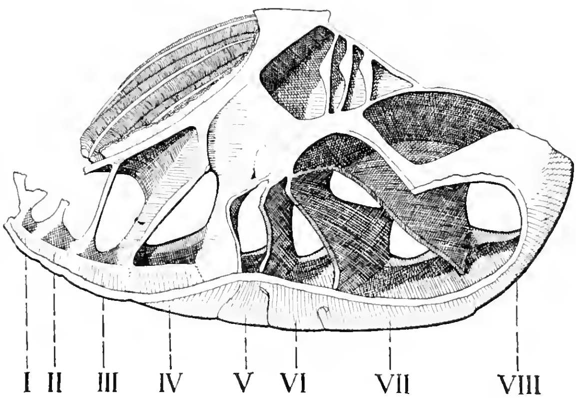


FIG. 18.—Lateral section of thorax showing internal skeletal parts.

I-VIII, first through eighth somites of thorax.

The endosternites and endopleurites formed in the manner just described are entirely intersegmental. A secondary infolding of the pleural wall occurs, however, in the fourth, fifth, sixth, and seventh thoracic segments. To this infolded structure, which is strictly intrasegmental, I have given the name of secondary endopleurite. No corresponding infolding occurs in the sternal parts of these segments. The secondary endopleurite is firmly attached at its inner margin to the anterior surface of the membrane encasing the promotor of the fifth pereiopod. The remotor muscle always finds its origin behind the secondary endopleurite, while some of the branches of the depressor and levator do so likewise in certain segments. This indicates that these partitions are in truth only secondary, since the remotor of a particular segment would not arise outside its own segment.

The endoskeletal partitions of the last five segments of the thorax present an interesting complexity due to the overdevelopment of the fifth pereiopod, as I have already noted. The muscle attachments of this pereiopod have been increased by the forward prolongation of a branch of the promotor muscle through the three preceding segments. The pocketlike membrane that encases this part of the muscle serves as a place of attachment for the several endopleurites where they meet the endosternites, as well as for the secondary endopleurites, and these attachments hold it firmly in place to resist the heavy pull which the muscle exerts upon it. The anterior termination of this prolongation may be seen upon the posterior wall of the fourth thoracic segment, where it appears as an oval, semi-transparent window partly separating the endopleurite and endosternite lying between the fourth and fifth thoracic segments.

Although the median plate extends forward as far as the endosternite separating the first and second pereiopods, it serves exclusively as a place of origin for branches of the four basal muscles of the telopodite of the fifth pereiopod. Some part of each of these muscles originates upon the median plate, although none of the muscles originates entirely upon it.

The third maxilliped and the first pereiopod bear a pair of gills, which lie side by side in the gill chamber. The second maxilliped likewise possesses two gills, one of which lies in the extreme anterior part of the gill chamber in front of the gills belonging to the pereiopods, and which can be distinguished from them only by its smaller size and its anterior position. The other gill of the second maxilliped lies at right angles to the first, extending outward and backward from the anterior corner of the gill chamber. The second and third pereiopods each possess a single gill. The first maxilliped and the fourth and fifth pereiopods lack gills.

The General Structure of the Crustacean Appendage

In order to understand the true relationships between the exceedingly diverse and often highly specialized crustaceans that exist today, it is a matter of importance to attempt to reconstruct a generalized ancestral type, from which all these existing divergences may have arisen by various evolutionary processes.

A typical leg of any of the higher crustaceans consists of not more than seven segments, including the basal segment called the coxopodite, which is followed by the basipodite bearing the endopodite of five segments, each segment having a pair of muscles to move it. Any or all of these seven segments may be provided with exites—lobes growing on the external part of the limb, or endites—lobes growing on the internal part of the limb. These exites and endites, when they are large and movable, may have special muscles of their own.

In the insects the basal segment of the leg is obviously divided into a coxa and a subcoxa, the latter forming sclerotized plates in the pleural wall of the thorax. In the crustaceans it is possible to trace a similar development of the limb basis. Consequently, we may look upon the coxopodite as being equivalent to the coxa of the insect, while the sternal and possibly the pleural regions of the thorax in the blue crab represent the subcoxal regions of the legs of the insect.

The coxopodite is sometimes ankylosed with the basipodite, in which case the resulting structure goes by the name of protopodite. The coxopodite may exist by itself, as in the mandible and the two maxillae of the isopod and the amphipod (fig. 21 A, B, C; fig. 22 A, B, C), or it may give rise to a basipodite with or without an exopodite and endopodite. The coxopodite may have one or more epipodites (fig. 24 E, F), which are usually gill-like, nonsegmented structures forming a part of the respiratory system.

In the lower crustaceans the leg has an exopodite as well as an endopodite, both of which always arise from the basipodite. In the higher crustaceans the exopodite still persists in the maxillipeds and the pleopods.

The exopodite may have any number of joints, and its distal part may be modified to form a flagellum, as in the maxilliped and true legs of the mysid (fig. 19 D; fig. 20 A, B, C). The endopodite, on the contrary, is very definitely limited to a maximum of five segments. Frequently, the distal segments are not present, and some of the proximal ones may have ankylosed. The endopodite exists in its typical form as a walking leg in the higher crustaceans, the names of its segments being the ischiopodite, the meropodite, the carpopodite, the propodite, and the dactylopodite. The typical crustacean leg has two principal places for bending—one at the basal joint between the coxopodite and the basipodite, and the other at the "knee" joint between the meropodite and the carpopodite. Hence there are typically three segments between the basal joint and the "knee" joint, and three

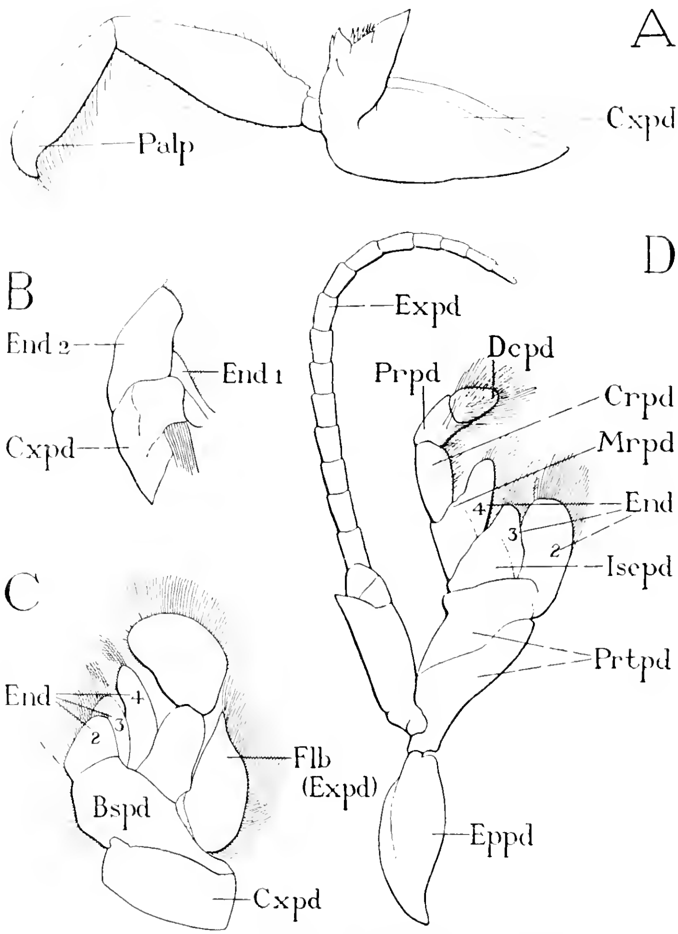


FIG. 19.—Appendages of *Michtheimysis stenolepis*.

A, the mandible.
B, the first maxilla.
C, the second maxilla.
D, the first maxilliped.
Bspd, basipodite; *Crpd*, carpopodite; *Cxpd*, coxopodite; *Dcpd*, dactylopodite; *End*, endite; *Eppd*, epipodite; *Expd*, exopodite; *Flb*, flabellum; *Iscpd*, ischiopodite; *Mrpd*, meropodite; *Prpd*, propodite; *Prtpd*, protopodite.

more beyond the "knee" joint. When fewer segments occur in either section, we may know that the leg is not entirely typical. For instance, in the second maxilliped of the amphipod (fig. 23 A), only two segments occur distal to the "knee" joint, and therefore we know that the dactylopodite is absent or fused. In the leg of the blue crab (fig. 12 A, B), two movable segments occur between the basal joint and the "knee" joint. One can easily see in this case that the

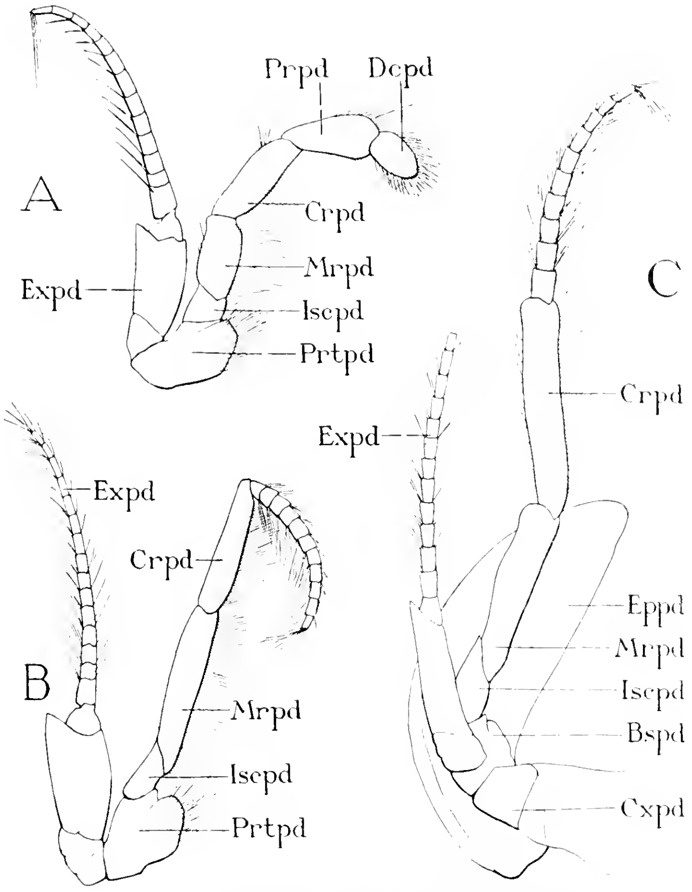


FIG. 20.—Appendages of *Michtheimysis stenolepis.*

A, the second maxilliped.
B, the third maxilliped.
C, the fifth pereiopod.
Bspd, basipodite; *Crpd*, carpopodite; *Cxpd*, coxopodite; *Dcpd*, dactylopodite; *Eppd*, epipodite; *Expd*, exopodite; *Iscpd*, ischiopodite; *Mrpd*, meropodite; *Prpd*, *propodite;* Prtpd, *protopodite.*

basipodite is nearly ankylosed with the ischiopodite, the resulting structure thereby becoming a basi-ischiopodite. In the leg of the higher crustaceans the exopodite is absent. The basipodite plus the endopodite is often referred to as the telopodite.

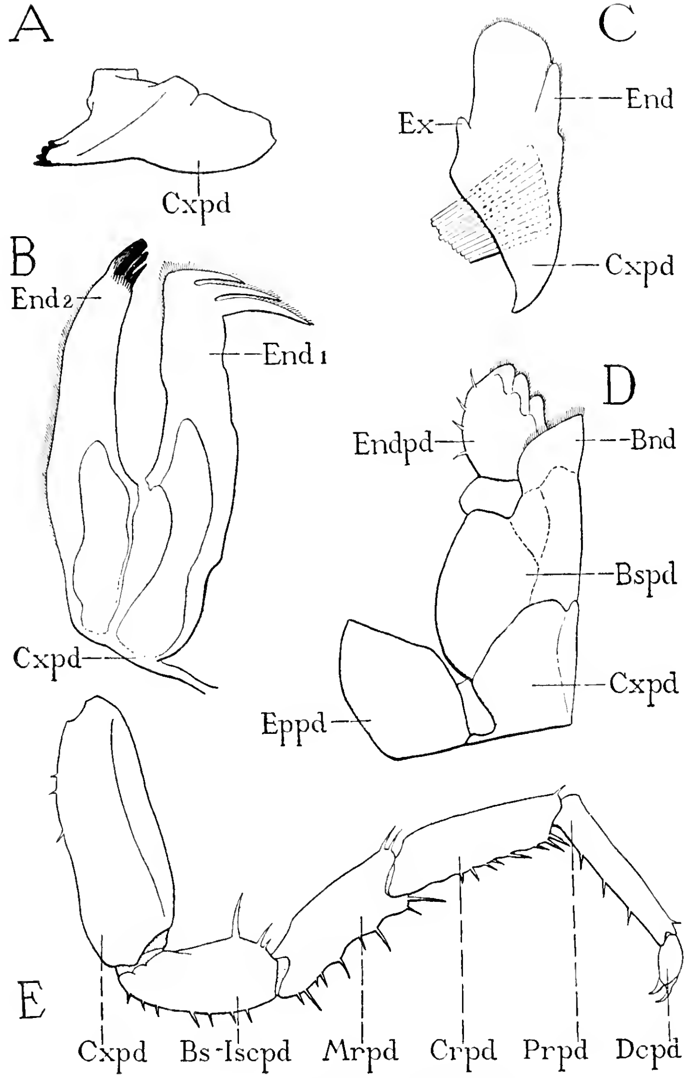


FIG. 21.—Appendages of *Ligia exotica*.

A, the mandible.
B, the first maxilla.
C, the second maxilla.
D, the maxilliped.
E, the first pereiopod.
Bnd, endite of the basipodite; *Bs-Iscpd*, basi-ischiopodite; *Bspd*, basipodite; *Dcpd*, dactylopodite; *End*, endite; *Endpd*, endopodite; *Eppd*, epipodite; *Ex*, exite; *Mrpd*, meropodite; *Prpd*, propodite.

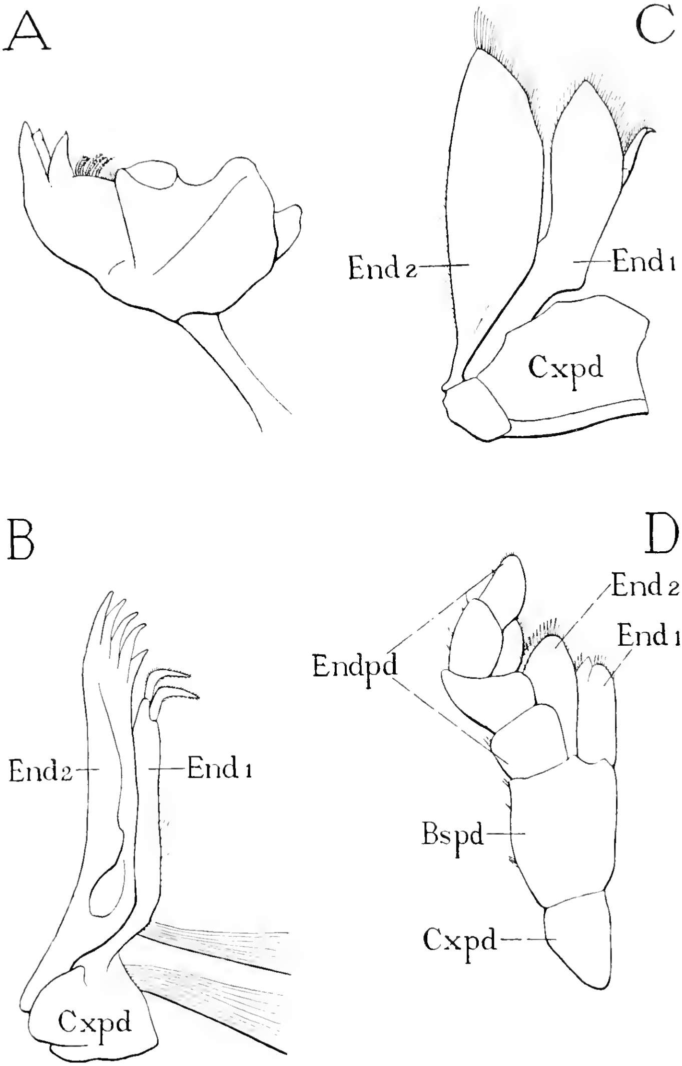


FIG. 22.—Appendages of *Orchestoidea californiana.*

A, the mandible.
B, the first maxilla.
C, the second maxilla.
D, the first maxilliped.
Bspd, basipodite; *Cxpd,* coxopodite; *End,* endite; *Endpd,* endopodite.

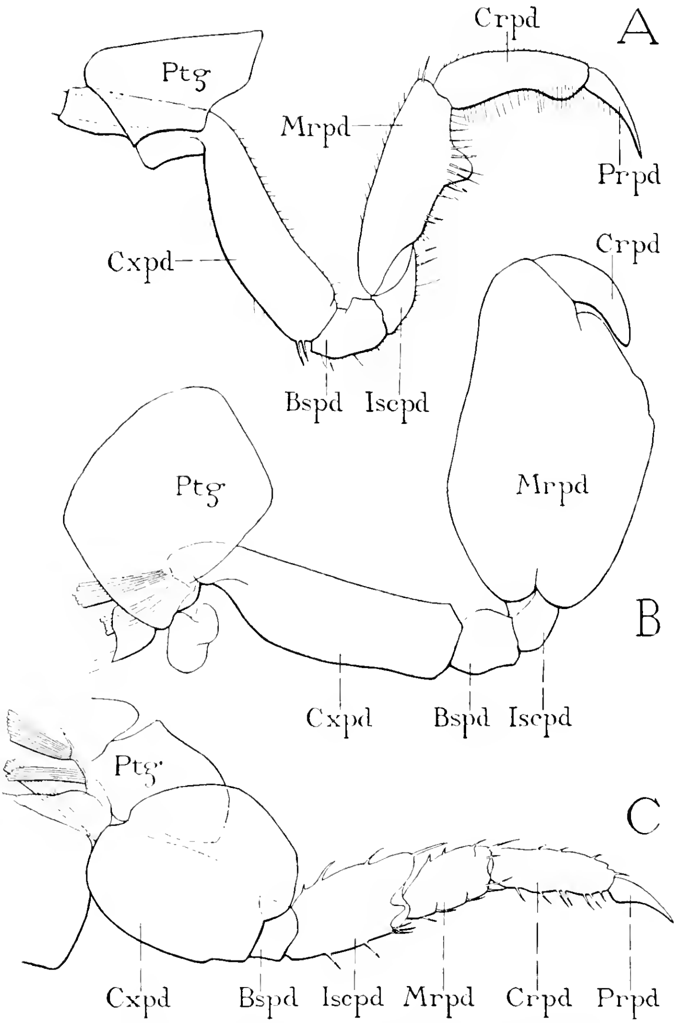


FIG. 23.—Appendages of *Orchestoidea californiana*.

A, the second maxilliped.
B, the third maxilliped.
C, the fifth pereiopod.
Bspd, basipodite; *Crpd*, carpopodite; *Cxpd*, coxopodite; *Iscpd*, ischiopodite; *Mrpd*, meropodite; *Prpd*, propodite; *Ptg*, paratergite.

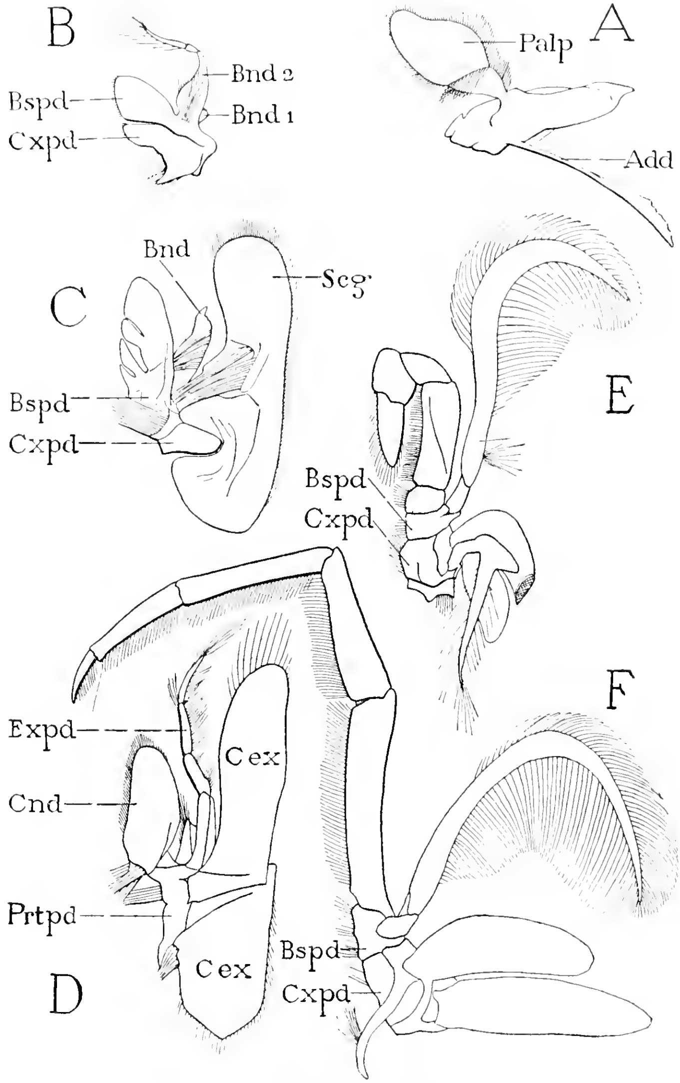


FIG. 24.—Appendages of *Penaeus setiferus*.

A, the mandible.
B, the first maxilla.
C, the second maxilla.
D, the first maxilliped.
E, the second maxilliped.
F, the third maxilliped.

Add, tendon of the adductor muscle of the mandible; *Bnd*, endite of the basipodite; *Bspd*, basipodite; *Cex*, exite of the coxopodite; *Cxpd*, coxopodite; *Expd*, exopodite; *Prtpd*, protopodite; *Scg*, scaphognathite.

When more than seven segments appear to be visible externally, as is the case in the syncarid *Anaspides,* the additional supposed segments are due to slight creases or furrows in the body wall and are not true segments with their necessary complement of muscle. Some shrimps also apparently have many additional segments in the distal part of the legs, but neither are these true segments, as their myology proves.

The so-called exopodite of the trilobite leg arises on the actual basal segment of the limb, and the question has been raised as to whether it is a true exopodite or an epipodite. If it is an exopodite homologous with that of living crustaceans, then it throws the trilobite definitely into the class Crustacea. If, on the other hand, it is an epipodite, then it makes the trilobite ancestral to all the Arthropoda so far as the structure of its legs is concerned.

PART II. THE OSSICLES AND MUSCLES OF THE STOMACH

Although it was not at first intended to do more than list the muscles of the appendages, the structure of the stomach appeared to be so interesting that I have prepared a second part to my paper including the muscles of the stomach and listing the ossicles on which they find their attachment. The literature on the stomach muscles is even less extensive than is that on the appendage muscles, and I find that some of the muscles of the pyloric region of the stomach of decapod crustaceans have not been figured or described.

It is logical to include the stomach muscles in the same paper with the muscles of the appendages that originate on the body wall, for developmental studies of invertebrates have demonstrated that the gastric mill is merely an invaginated part of the body wall, so that the muscles pertaining to it are as truly " skeletal " as are those of the appendages.

The word " stomach " is, as a matter of fact, a misnomer. The enlarged part of the alimentary canal immediately following the esophagus, although popularly referred to as a stomach, is a part of the stomodaeum of arthropods and performs the same function as does the gizzard in birds—that is, to pulverize the fragments of food and render them small enough to be acted upon effectively by the true digestive juices, which are secreted in the pylorus, a relatively small section of the alimentary canal which follows the stomodaeum.

But it is convenient to speak of the whole structure from the mouth to the beginning of the intestine as the " stomach." As this has been done in most of the preceding discussions by former authors, the term has been used in the present discussion in the same broad sense.

Ossicles of the Stomach

In order to give the necessary rigidity to the stomach in the breaking up of food particles to aid in their rapid assimilation, the stomach is equipped with a complicated mechanism composing the so-called "gastric mill." A series of strategically placed ossicles gives places of attachment externally to the muscles, and inside the stomach most of the ossicles are tooth-bearing so that they may effectively pulverize the food before it passes on to the next stage of digestion. These ossicles may be considered under separate headings according to their function and position.

OSSICLES OF THE "GASTRIC MILL"

I. Mesocardiac ossicle. Single.—This small median ossicle lies in the dorsal wall of the cardiac region of the stomach and is almost completely fused with the urocardiac ossicle, which lies behind it. In front it is bounded on either side by the pterocardiac ossicles. It gives a firm attachment to the anterior ends of the cardiopyloric muscles, since it is especially thickened at this point. (Figs. 25 A, 27, 28.)

II. Pterocardiac ossicles. One pair.—These ossicles lie on either side of the foregoing and meet each other in front of it, projecting on either side with their wing-shaped outer ends nearly at right angles to the midline of the stomach. One of the pair of anterior gastric muscles (*197*) is inserted on the widened inner border of each ossicle. The attenuate tip of the ossicle approaches the outer border of the zygocardiac ossicle, with which it is closely connected. (Figs. 25 A, 27, 28.)

III. Zygocardiac ossicles. One pair.—This pair of ossicles lies in the superolateral wall of the cardiac region of the stomach and is the largest and strongest of the ossicles. Externally, they appear as slender curved structures, the anterior end in close connection with the tips of the pterocardiac ossicles, and their posterior end with the exopyloric ossicles. When the stomach is opened, the zygocardiac ossicles are found to project inward, thickening greatly and bearing on their inner opposed surfaces the "lateral teeth," consisting of one very heavy denticle of tough chitinous material followed by two smaller single ones and by a double row composed altogether of about 20 very pointed small denticles, directed inward and growing smaller in size posteriorly, the area between them without ridges. (Figs. 25 A, B, 26, 27.)

IV. Exopyloric ossicles. One pair.—These ossicles appear externally as short and nearly straight structures lying diagonally near the lateral posterior border of the stomach. The outer end of each ossicle

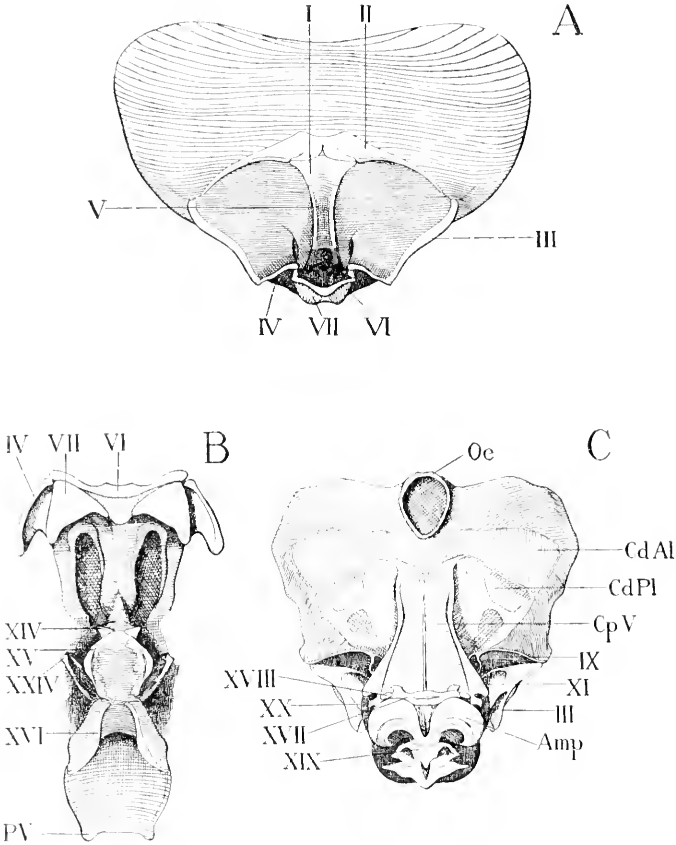


FIG. 25.—External views of stomach showing ossicles.

A, ossicles of the fully distended stomach viewed from above, all muscles removed.

I, mesocardiac ossicle; *II*, pterocardiac ossicle; *III*, zygocardiac ossicle; *IV*, exopyloric ossicle; *V*, urocardiac ossicle; *VI*, propyloric ossicle; *VII*, pyloric ossicle.

B, ossicles of the posterior wall of stomach and dorsal pyloric region.

IV, exopyloric ossicle; *VI*, propyloric ossicle; *VII*, pyloric ossicle; *XIV*, anterior mesopyloric ossicle; *XV*, posterior mesopyloric ossicle; *XVI*, urpyloric ossicle; *XXIV*, middle pleuropyloric ossicle; *PV*, pyloric valve.

C, ventral view of stomach, walls partly collapsed, all muscles removed.

III, zygocardiac ossicle; *IX*, prepectineal ossicle; *XI*, inferolateral cardiac ossicle; *XVII*, antero-inferior pyloric ossicle; *XVIII*, pre-ampullary ossicle; *XIX*, postero-inferior pyloric ossicle; *XX*, anterior supra-ampullary ossicle.

Amp, ampulla; *CdAl*, anterolateral cardiac plates; *CdPl*, posterolateral cardiac plates; *CpV*, cardiopyloric valve; *Oe*, esophagus.

is directly behind the posterior termination of the zygocardiac ossicle, to which it is closely articulated, and its inner upper border is the point of insertion for the outer cardiopyloric muscle (*210 a*). Inwardly, the ossicles project as small triangular plates lying below the median tooth of the urocardiac ossicle. (Figs. 25 A, B, 26, 27.)

V. Urocardiac ossicle. Single.—This ossicle is a broad, shield-shaped median plate which is almost completely fused with the mesocardiac ossicle on its anterior border. It projects backward and finally

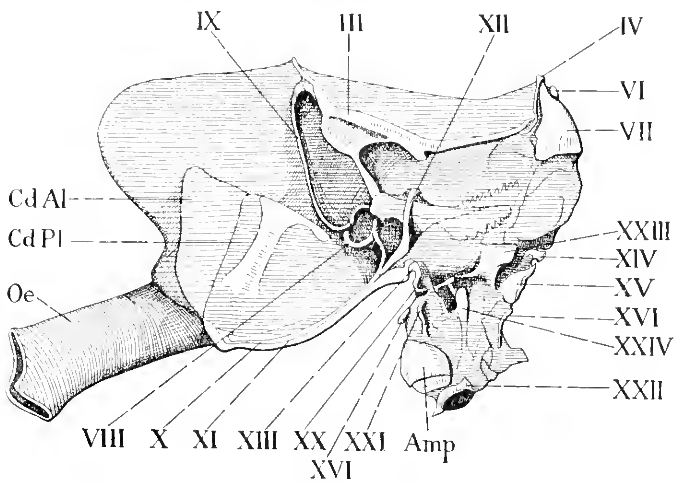


FIG. 26.—Lateral view of stomach showing ossicles after removal of all muscles.

III, zygocardiac ossicle; *IV*, exopyloric ossicle; *VI*, propyloric ossicle; *VII*, pyloric ossicle; *VIII*, pectineal ossicle; *IX*, prepectineal ossicle; *X*, postpectineal ossicle; *XI*, inferolateral cardiac ossicle; *XII*, subdentary ossicle; *XIII*, lateral cardiopyloric ossicle; *XIV*, anterior mesopyloric ossicle; *XV*, posterior mesopyloric ossicle; *XVI*, uropyloric ossicle; *XVIII*, pre-ampullary ossicle; *XX*, anterior supra-ampullary ossicle; *XXI*, middle supra-ampullary ossicle; *XXII*, posterior supra-ampullary ossicle; *XXIII*, anterior pleuropyloric ossicle; *XXIV*, middle pleuropyloric ossicle.

Amp, ampulla; *CdAl*, anterolateral cardiac plate; *CdPl*, posterolateral cardiac plate; *Oe*, esophagus.

downward as an elongate, heavy plate, articulating with the inner termination of the propyloric ossicle. On its ventral (inner) surface it bears the heavy, ridged median tooth which opposes the lateral teeth of the zygocardiac ossicles. (Figs. 25 A, 27, 28.)

VI. Propyloric ossicle. Single.—This appears externally as a small, curved, median ossicle lying in the dorsal wall of the stomach, its outer end just behind the inner terminations of the exopyloric ossicles and articulating closely with them by a short bar of cartilagelike tissue. Upon dissection, the inner part of this ossicle appears triangular in shape, its inner point meeting the uropyloric ossicle at its posterior end and serving to give rigidity to the median tooth. (Figs. 25 A, B, 26, 27.)

VII. Pyloric ossicles. One pair.—These strongly convex, triangular structures lie between the exopyloric ossicles, with which they articulate on either side, and extend behind the propyloric ossicle, entirely on the surface of the stomach. They give attachment to the inner posterior gastric muscles. There is a ligamentous connection

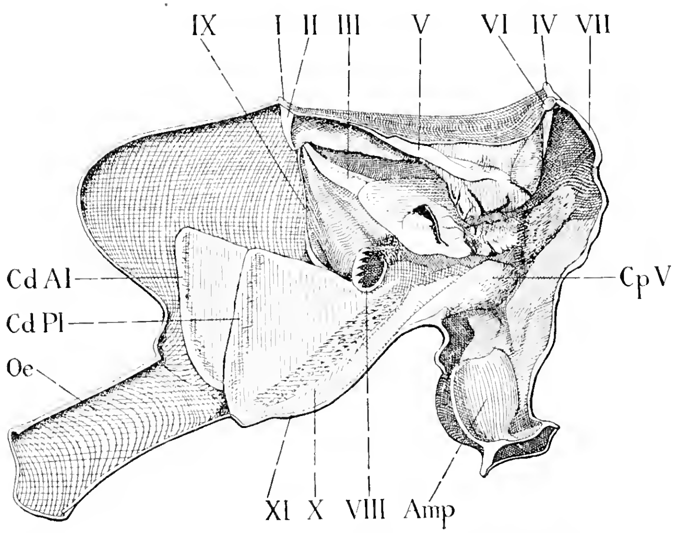


FIG. 27.—Internal view of stomach cut slightly to one side of the median line to show relative positions of the "teeth."

I, mesocardiac ossicle; *II*, pterocardiac ossicle; *III*, zygocardiac ossicle; *IV*, exopyloric ossicle; *V*, urocardiac ossicle; *VI*, propyloric ossicle; *VII*, pyloric ossicle; *VIII*, pectineal ossicle; *IX*, prepectineal ossicle; *X*, postpectineal ossicle; *XI*, inferolateral cardiac ossicle.

Amp, ampulla; *CdAl*, anterolateral cardiac plate; *CdPl*, posterolateral cardiac plate; *CpV*, cardiopyloric valve; *Oe*, esophagus.

between them, but they do not appear to be fused into one structure, as in the case in the European *Cancer pagurus*. (Figs. 25, A. B, 26, 27.)

CARDIAC "SUPPORTING OSSICLES"

VIII. Pectineal ossicles. One pair.—These ossicles lie in the lateral wall of the stomach between the lower posterior end of the prepectineal and the upper posterior end of the postpectineal ossicles. Externally, they appear as relatively small, semicircular structures, but internally, they are seen to bear a distinct brushlike cluster of six or seven long clawlike teeth, which are called the "lateral accessory teeth." (Figs. 26, 27, 28.)

IX. Prepectineal ossicles. One pair.—These slender, curved, rodlike ossicles, lying entirely on the lateral stomach wall, extend upward and forward from the pectineal ossicle to the outer anterior end of the zygocardiac ossicle with which they articulate by a cartilagelike tissue. (Figs. 25 C, 26, 27, 28.)

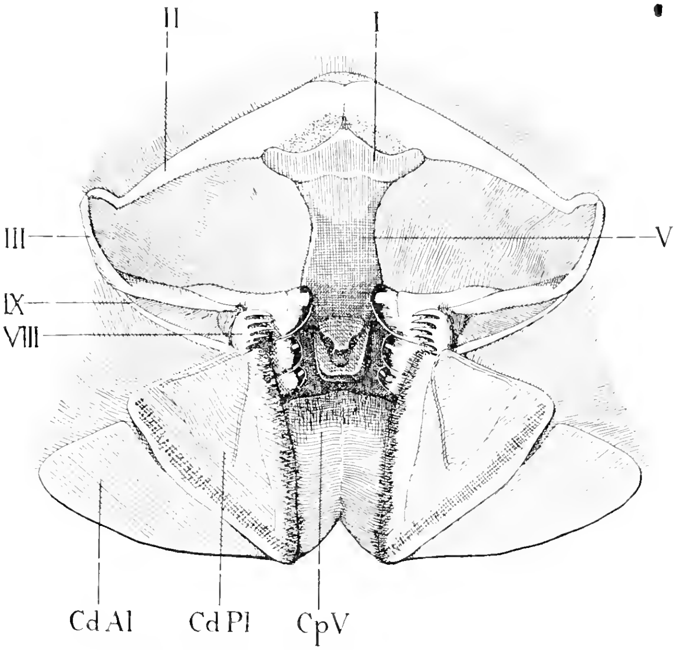


FIG. 28.—Internal view of posterior part of stomach, the anterior parts being dissected away to show the "gastric mill."

I, mesocardiac ossicle; *II*, pterocardiac ossicle; *III*, zygocardiac ossicle; *V*, urocardiac ossicle; *VIII*, pectineal ossicle; *IX*, prepectineal ossicle.

CdAl, anterolateral cardiac plate; *CdPl*, posterolateral cardiac plate; *CpV*, cardiopyloric valve.

X. Postpectineal ossicles. One pair.—Passing downward and forward from the posterior margin of the pectineal ossicle, these ossicles, also slender and rodlike, merge with the ventral wall of the stomach below the posterolateral cardiac plates. For the greater part of their length they lie closely in contact with the inferolateral cardiac ossicles, which can scarcely be distinguished from them at their anteroventral termination. (Figs. 26, 27.)

XI. Inferolateral cardiac ossicles. One pair.—These ossicles are in contact with the subdentary ossicles near their posterior termination, but as they go forward and downward along the ventral wall of the stomach, they soon join the postpectineal ossicles, as noted in the preceding paragraph. Seen from below, these ossicles are found to be wide posteriorly, tapering as they converge anteriorly. (Figs. 25 C, 26, 27.)

XII. Subdentary ossicles. One pair.—Each of these ossicles, somewhat curved and boomerang-shaped externally, is in contact on its upper margin with the zygocardiac ossicle. Ventrally each is attached by a cartilagelike tissue to the inferolateral cardiac ossicle just at its posterior point of attachment to the postpectineal ossicle. (Fig. 26.)

XIII. Lateral cardiopyloric ossicles. One pair.—These extremely small curved ossicles lie behind the inferolateral cardiac ossicles and are attached on their lower posterior border to the anterior supra-ampullary ossicles. (Fig. 26.)

Cd Al. Anterolateral cardiac plates. One pair.—These rhombic membranous plates lie directly in front of the posterolateral cardiac plates but are much less clearly defined. There is no heavy calcification in these plates, but the anterodorsal margin is stiffened into a ridge that is slightly thicker than the remaining membrane of the plate. (Figs. 25 C, 26, 27, 28.)

Cd Pl. Posterolateral cardiac plates. One pair.—These broad plates, nearly triangular in shape, lie above and in front of the postpectineal ossicle. Although most of the surface is membranous, each plate has a hammer-shaped calcification extending along its upper and anterior borders, to give attachment to the lateral cardiac muscles. The inner posterior border of each plate has several rows of bristles, which project into the stomach. (Figs. 25 C, 26, 27, 28.)

Cp V. Cardiopyloric valve.—This valve lies in the ventral posterior part of the stomach, bounded at each side by a posterolateral cardiac plate. It is approximately tongue-shaped, and the thickened posterior end is provided with bristles. It regulates the entrance of triturated material into the intestine. (Figs. 25 C, 27, 28.)

PYLORIC "SUPPORTING OSSICLES"

The three following pairs of ossicles are found in the dorsal wall of the pyloric foregut, which is bent so that it is now directed posteriorly.

XIV. Anterior mesopyloric ossicles. One pair.—These small angular ossicles project sharply from the membrane surrounding them. They are near the median line and below and posterior to the pyloric ossicle (*VII*). (Figs. 25 B, 26.)

XV. Posterior mesopyloric ossicles. One pair.—These ossicles lie directly below the preceding. They are roughly crescentic in shape and are connected by a thin membrane. (Figs. 25 C, 26.)

XVI. Uropyloric ossicles. One pair.—These very slender, angularly-bent ossicles are found behind the posterior mesopyloric ossicles in the roof of the pyloric region, now forming the posterior termination of the stomach. (Figs. 25 B, 26.)

PV. Pyloric valves. One pair.—These valves project posteriorly from the cartilagelike tissue which lies posteriorly behind the uropyloric ossicles (*XVI*) in the dorsal wall of the pyloric region. (Fig. 25, B.)

The ventral wall of the pyloric foregut bears the following ossicles:

XVII. Antero-inferior pyloric ossicle. Single.—This median rhomboid plate is transversely widened and lies immediately in front of the ampullae. Its widest base is anteriorly in contact with the cardiopyloric valve. (Fig. 25 C.)

XVIII. Pre-ampullary ossicles. One pair.—These two very small ossicles project from the region just behind the outer border of the antero-inferior pyloric ossicle and a short distance in front of the pyloric ampullae. (Figs. 25 C, 26.)

XIX. Postero-inferior pyloric ossicle. Single.—This small bowshaped ossicle lies behind the inter-ampullary groove. It is not heavily calcified and therefore is not very apparent at first glance. (Fig. 25 C.)

XX. Anterior supra-ampullary ossicles. One pair.—Each one of this pair of ossicles is a small semicircular, heavily calcified projection, which appears just below and in contact with the lateral cardiopyloric ossicle and behind the supra-ampullary ossicle. (Figs. 25 C, 26.)

XXI. Middle supra-ampullary ossicles. One pair.—Each one of this pair of short, straight ossicles lies in a vertical position below the preceding and above the ampullae. (Fig. 26.)

XXII. Posterior supra-ampullary ossicles. One pair.—These semicircular ossicles lie close together below the ampullae, and terminate the series of ossicles supporting the pyloric region posteriorly. (Fig. 26.)

The following ossicles occur in the pleuropyloric walls:

XXIII. Anterior pleuropyloric ossicles. One pair.—This very heavily calcified, triangular structure projects strongly from the side wall of the stomach in front of the anterior mesopyloric ossicle (*XIV*). It is continued as a long forked calcareous projection leading forward and downward externally along the stomach wall. (Fig. 26.)

XXIV. Middle pleuropyloric ossicles. One pair.—Attached to one of the forks of the calcareous projection of the preceding ossicle is a rounded but equally prominent ossicle, which is arbitrarily called the middle pleuropyloric. The posterior pleuropyloric ossicle seems to be lacking in the blue crab. It is named but not figured by Pearson (1908) in his study of *Cancer pagurus* (p. 103). (Figs. 25 B, 26.)

MUSCLES OF THE ALIMENTARY SYSTEM

For the sake of conformity with the writings of other authors, the muscles of the alimentary system are discussed according to their origin, following the definition of Mocquard,[4] who recognized two sets of muscles—first, the *extrinsic*, in which the points of origin are on some part of the body skeletal system and which are inserted on ossicles lying in the walls of the stomach, and second, the *intrinsic*, which are attached at both ends to stomach ossicles or to thickened parts of the stomach membrane.

EXTRINSIC MUSCLES

The following three sets of muscles help to work the gastric mill:

197. Musculus gastricus anterior. One pair.—Each muscle of this pair has its origin on the cervical membrane and extends backward, gradually convergent toward the midline. They are attached side by side on the inner anterior part of the pterocardiac ossicle (*II*). These muscles are the most readily detected of any of the stomach muscles, as their large size and dorsal position bring them conspicuously to view as soon as the carapace is broken in that region. (Figs. 29, 30.)

198. Musculus gastricus posterior mesalis. One pair.—These muscles arise from two small calcareous projections on the under side of the carapace at the median part of the mesogastric region. There is a distinct transverse indentation or channel on the outside of the carapace, which indicates the position of attachment of these muscles, as well as that of the external posterior gastric muscles and the dorsal pyloric muscles to be mentioned later. The inner posterior gastric muscles extend forward and downward to their attachment on the pyloric ossicle (*VII*). These muscles are not so heavy as the anterior gastric muscles (*197*) just described. (Figs. 29, 30.)

199 a and b. Musculus gastricus posterior lateralis. Two pairs a and b.—These muscles arise from the under side of the mesogastric region in the outer part of the same channel which marks the origin of the inner posterior gastric muscles (*198*) discussed above. They extend downward and forward, converging as they go, and the median

[4] Mocquard, F., Recherches anatomiques sur l'estomac des Crustacés podophthalmaires. Ann. Sci. Nat., 6 ser., Zool., vol. 16, p. 238, 1883.

ones (*199 b*) are inserted just below the inner end of the exopyloric ossicle (*IV*) near the end of the propyloric ossicle (*VI*), while the external pair (*199 a*) are inserted on the outer half of the exopyloric ossicle (*VI*). The outer and inner posterior gastric muscles seen in their natural positions resemble the spokes of an opened fan, being nearly alike in size and length and converging at somewhat similar angles to their respective points of insertion. (Figs. 29, 30.)

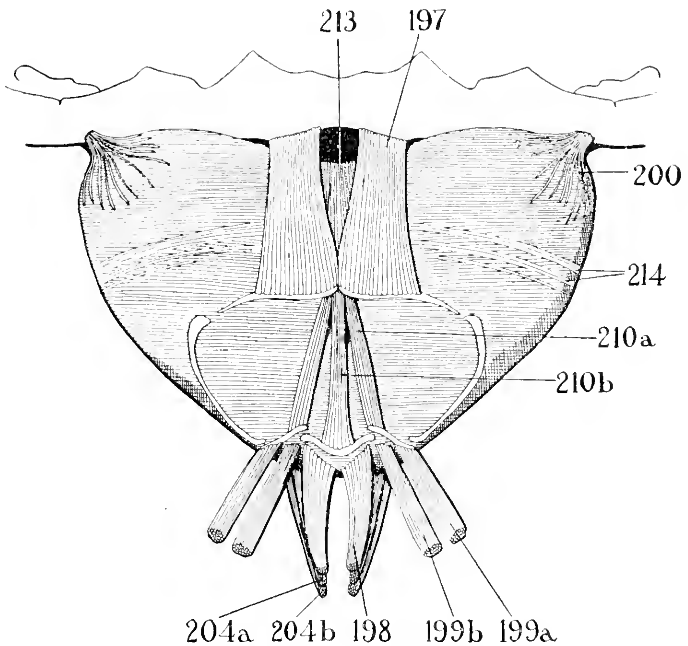


FIG. 29.—Muscles of the stomach viewed from above.

197, musculus gastricus anterior; *198*, musculus gastricus posterior mesalis; *199a* and *b*, musculus gastricus posterior lateralis *a* and *b*; *200*, musculus dilatator anterior superior ventriculi; *204a* and *b*, musculus dilatator dorsalis pylorici anterior *a* and *b*; *210a* and *b*, musculi cardiopylorici *a* and *b*; *213*, musculus cardiacus anterior mesalis; *214*, musculus cardiacus anterior lateralis.

The following muscles dilate the stomach:

200. Musculus dilatator anterior superior ventriculi. One pair.—Each muscle arises from the inner side of the cervical membrane immediately behind the orbit. The body of the muscle extends inward and backward, dividing very soon into a dozen or more slender fibers which diverge widely to their points of insertion at various places on the anterior upper and outer walls of the stomach. These fibers are exceedingly delicate. (Figs. 29, 30.)

201. Musculus dilatator anterior inferior ventriculi. One pair.—The muscles of this pair are extremely attenuate and difficult to separate from the antero-superior dilator muscle of the foregut (*206*) at their common origin on the upper part of the epistome. A careful tracing shows that the former pair is inserted on the lower anterior wall of the ventriculus above and behind the termination of the esophagus. The connectives of the cerebral ganglion pass diagonally across them. (Fig. 30.)

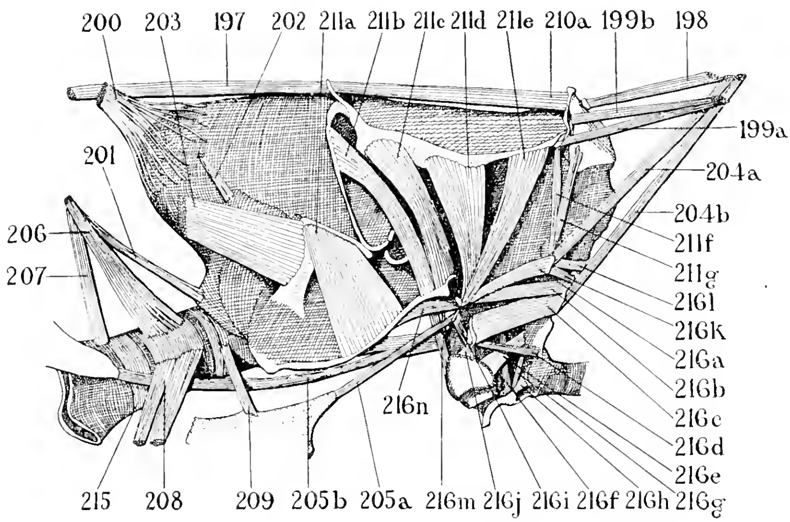


Fig. 30.—Lateral view showing muscles of the stomach.

197, musculus gastricus anterior; *198*, musculus gastricus posterior mesalis; *199a* and *b*, musculus gastricus posterior lateralis *a* and *b*; *200*, musculus dilatator anterior superior ventriculi; *201*, musculus dilatator anterior inferior ventriculi; *202*, musculus dilatator lateralis anterior ventriculi; *203*, musculus dilatator lateralis posterior ventriculi; *204a* and *b*, musculus dilatator dorsalis pylorici anterior *a* and *b*; *205a* and *b*, musculus dilatator pylorici inferior *a* and *b*; *206*, musculus dilatator anterior superior oesophagei; *207*, musculus dilatator anterior inferior oesophagei; *208*, musculus dilatator lateralis oesophagei; *209*, musculus dilatator posterior oesophagei; *210a*, musculus cardiopylorici *a*; *211a-g*, musculi interiores cardiaci laterales *a-g*; *215*, musculi circumoesophagei; *216a-n*, musculi pylorici *a-n*.

202. Musculus dilatator lateralis anterior ventriculi. One pair.—These muscles arise on the roof of the prebranchial chamber and pass inward and downward to their insertion on the upper margin of the anterolateral cardiac plate (*Cd Al*). They are not very firmly knit and may be torn away with the tissues surrounding the stomach. (Fig. 30.)

203. Musculus dilatator lateralis posterior ventriculi. One pair.—Arising on the roof of the prebranchial chamber, these muscles pass inward through the sheetlike sinus tissue, widening somewhat as they approach their insertion along the anterior edge of the hammer-shaped calcification in the posterolateral cardiac plate (*Cd Pl*). (Fig. 30.)

204 a and b. Musculus dilatator dorsalis pylorici anterior a and b. Two pairs.—The two muscles on each side run close together at their origin, so that they are not readily separable. They arise directly below the origin of the inner posterior gastric muscle (*198*), being attached to the lower end of the same calcareous projection of the inner surface of the carapace at the median part of the mesogastric region. Both pairs of dorsal pyloric muscles pass downward and forward as ribbon-like bundles of muscle fibers. The anterior and upper of the two pairs (*204 a*) is inserted on the anterior pleuropyloric ossicle (*XXIII*), while the posterior and lower pair (*204 b*) terminates on the posterior mesopyloric ossicle (*XV*); thus at their insertions they are entirely separate. (Figs. 29, 30.)

205 a and b. Musculus dilatator pylorici inferior a and b. Two pairs.—Each slender muscle of the outer pair (*203 a*) originates on the endopleurite of the first maxillary segment, passing backward and upward to its insertion on the pre-ampullary ossicle (*XVIII*). The muscles of the inner pair (*203 b*), much longer than the outer but equally attenuate, arise near the base of the mandibular apophysis, thence passing close to the sides of the esophagus and the posterior wall of the cardiac region, and are inserted on the antero-inferior pyloric ossicles (*XVII*) in the ventral wall of the pyloric region. For the last half of their course, the muscles of this inner pair lie so near together that the two appear to be one. (Fig. 30.)

The following muscles dilate the esophagus:

206. Musculus dilatator anterior superior oesophagei. One pair.—Each of these muscles arises from the epistome near the midline and just beside the median projection from which spring the basal ocular muscles. Diverging backward and downward, the muscles widen considerably at their insertion on the upper wall of the esophagus. (Fig. 30.)

207. Musculus dilatator anterior inferior oesophagei. One pair.—These muscles are nearly indistinguishable from the preceding at their origin on the epistome, but they pass straight downward to an insertion in a more anterior position on the esophagus. (Fig. 30.)

208. Musculus dilatator lateralis oesophagei. One pair.—This muscle springs from the posterior angle of the epistome, diverging considerably as it approaches the esophagus, on the lateral wall of which the various fibers find their attachments, just below those of the preceding muscle. (Fig. 30.)

209. Musculus dilatator posterior oesophagei. One pair.—This muscle is small and not easily distinguishable, lying as it does within the web of tissues surrounding the stomach. It arises on the endopleurite of the first maxillary segment, passing backward and over the inner ventral pyloric dilator (*205 b*) to its insertion on the lateral wall of the esophagus just posterior to the insertion of the lateral dilator of the esophagus (*208*). (Fig. 30.)

INTRINSIC MUSCLES

210 a and b. Musculi cardiopylorici a and b. A median and two lateral.—The median muscle (*b*) extends from the thickened posterior border of the mesocardiac ossicle (*I*) to the upper central edge of the propyloric ossicle (*VI*). The lateral muscles (*a*) extend from the mesocardiac ossicle (*I*) to the inner end of the exopyloric ossicle (*IV*), diverging slightly posteriorly. These muscles oppose the movements of the extrinsic gastric muscles. (Figs. 29, 30.)

211 a-g. Musculi interiores cardiaci laterales a-g. Seven pairs.—These muscles all run more or less dorsoventrally on the lateral wall of the stomach. (Fig. 30.) In the following list, the dorsal insertion is named first:

a. Hammer-shaped ossicle in the posterolateral cardiac plate (*Cd Pl*) to the inferolateral cardiac ossicle (*XI*).

b. Prepectineal ossicle (*IX*) to inferolateral ossicle (*XI*).

c. Zygocardiac ossicle (*III*) to inferolateral ossicle (*XI*).

d. Zygocardiac ossicle (*III*) to anterior supra-ampullary ossicle (*XX*).

e. Zygocardiac ossicle (*III*) to anterior supra-ampullary ossicle (*XX*); perhaps this and the preceding should be considered as parts of the same muscle because they have their origins and insertions on the same ossicles, although not on the same points of the ossicles.

f. Exopyloric ossicle (*IV*) to anterior pleuropyloric ossicle (*XXIII*).

g. Pyloric ossicle (*VII*) to anterior pleuropyloric ossicle (*XXIII*).

212. Musculus cardiacus posterior inferior. One pair.—This muscle is composed of short fibers attached on the sides to the inferolateral cardiac ossicle (*XI*) and coming almost together at the median line, where they are attached to each side of a projecting ridge running down the center of the cardiopyloric valve. These muscles cannot be seen until the outer and inner lower dilators of the pylorus have been removed, as well as the obscuring branches *m* and *n* of the pyloric muscle. (Not figured.)

213. Musculus cardiacus anterior mesalis. Single.—If one detaches the anterior gastric muscles carefully, the weak and poorly developed strands of the anterior cardiac muscle may be seen. It arises underneath the former, in front of the anterior median part of the mesocardiac ossicle (*I*), passing forward and downward over the anterior wall of the stomach, and dividing into numerous fibers before it reaches its attachment above the esophagus. (Fig. 29.)

214. Musculus cardiacus anterior lateralis. One pair.—The fine strands of this muscle arise on the anterior border of the anterolateral cardiac plate (*Cd Al*) and go upward as a thin sheet of very loosely-knit fibers to their attachment near the median line just above the esophagus, close to that of the preceding muscle. (Fig. 29.)

215. Musculi circumoesophagei. Many.—Taken all together, these numerous muscle fibers go to make up a band surrounding the esophagus. Individually they are very small. (Fig. 30.)

216 a-n. Musculi pylorici a-n. Fourteen pairs.—It is most convenient to list these numerous small muscles controlling the constriction of the pylorus in tabular form, giving the ossicles between which each muscle extends. The numbering of each individual muscle has been purely arbitrary and without other significance than one of identification. (Fig. 30.)

a. Lateral cardiopyloric ossicle (*XIII*) to anterior pleuropyloric ossicle (*XXIII*).

b. Lateral cardiopyloric ossicle (*XIII*) to posterior mesopyloric ossicle (*XV*).

c. Middle supra-ampullary ossicle (*XXI*) to posterior mesopyloric ossicle (*XV*).

d. Middle supra-ampullary ossicle (*XXI*) to uropyloric ossicle (*XVI*).

e. Ampulla (*Amp*) to uropyloric ossicle (*XVI*).

f. Posterior supra-ampullary ossicle (*XXII*) to middle pleuropyloric ossicle (*XXIV*).

g. Posterior supra-ampullary ossicle (*XXII*) to uropyloric ossicle (*XVI*).

h. Posterior supra-ampullary ossicle (*XXII*) to pyloric valve. (*PV*).

i. Pre-ampullary ossicle (*XVIII*) to middle supra-ampullary ossicle (*XXI*).

j. Middle supra-ampullary ossicle (*XXI*) to ampulla (*Amp*).

k. Anterior pleuropyloric ossicle (*XXIII*) to posterior mesopyloric ossicle (*XV*).

l. Anterior pleuropyloric ossicle (*XXIII*) to anterior mesopyloric ossicle (*XIV*).

m. Ampulla (*Amp*) to antero-inferior pyloric ossicle (*XVII*).

n. Lateral cardiopyloric ossicle (*XIII*) to inferolateral cardiac ossicle (*XI*).

ABBREVIATIONS USED ON THE FIGURES

a-b, primitive dorsoventral axis of appendage.
A Cxpd, anterior part of coxopodite.
Add, tendon of adductor of mandible.
Ant, anterior border.
Appd, appendage.
Bnd, endite of basipodite.
Bs-Iscpd, basi-ischiopodite.
Bspd, basipodite.
Ccx, exite of coxopodite.
Cnd, endite of coxopodite.
Crpd, carpopodite.
Cxpd, coxopodite.
Dcpd, dactylopodite.
End, endite.
Endpd, endopodite.
Eppd, epipodite.
Ex, exite.
Expd, exopodite.
Flb, flabellum.
Flg, flagellum.
I, dorsal promotor muscle.
Iscpd, ischiopodite.
J, dorsal remotor.
K, ventral promotor.
L, ventral remotor.
Mrpd, meropodite.
Palp, palp.
P Cxpd, posterior part of coxopodite.
Post, posterior border.
Prpd, propodite.
Prtpd, protopodite.
Ptg, paratergite.
Scg, scaphognathite.
St, statocyst.
Stn, sternum.
T, tergum.
Tn, telson.

REFERENCES

BAUMANN, H.
1919. Das Gefäss-system von *Astacus fluviatilis* (*Potamobius astacus* L.) Ein Beitrag zur Morphologie der Decapoden. Zeitschr. wiss. Zool., vol. 118, pt. 2, pp. 246-312, 35 figs.

BERKELEY, A. A.
1928. The musculature of *Pandalus danae* Stimpson. Trans. Roy. Canadian Inst. Toronto, vol. 16, pp. 181-321, 8 pls.

BINDER, G.
1929. Das Muskelsystem von *Daphnia*. Lotos Prag., vol. 77, pp. 30-32.

BÖRNER, C.
1921. Die Gliedmassen der Arthropoden. *In* A. Lang's Handbuch der Morphologie der Wirbellosen Tiere. Vol. 4. Arthropoda.

BORRADAILE, L. A.
1922. On the mouth-parts of the shore crab. Journ. Linn. Soc., Zool., vol. 35, pp. 115-142, pls. 10-11.
1926. Notes upon crustacean limbs. Ann. Mag. Nat. Hist., ser. 9, vol. 17, pp. 193-213, pls. 7-10.

BROOKS, W. K.
1882. Handbook of invertebrate zoology for laboratories and seaside work, chaps. 18, 20, 21. Cassino, Boston.

CALMAN, W. T.

1896. On the genus *Anaspides* and its affinities with certain fossil Crustacea. Trans. Roy. Soc. Edinburgh, vol. 38, pt. 4, no. 23, pp. 787-802, 2 pls.

1909. Crustacea. Part 7, third fascicle of "A Treatise on Zoology," edited by Sir Ray Lankester. London.

CANNON, H. G. and MANTON, S. M.

1927. On the feeding mechanism of a mysid crustacean, *Hemimysis lamornae*. Trans. Roy. Soc. Edinburgh, vol. 55, pt. 1, no. 10, pp. 219-253, 4 pls.

1929. On the feeding mechanism of the syncarid Crustacea. Trans. Roy. Soc. Edinburgh, vol. 56, pp. 175-189, 8 figs.

CHILTON, C.

1916. Fauna of the Chilka Lake. Some terrestrial Isopoda from the shore of the lake. Mem. Indian Mus., vol. 5, pp. 461-482, 36 figs.

DANIEL, R. J.

1928. The abdominal muscular systems of *Praunus flexuosus*. Proc. Trans. Liverpool Biol. Soc., vol. 42, pp. 5-41.

1929. The abdominal muscular systems of *Meganyctiphanes norvegica*. Proc. Liverpool Biol. Soc., vol. 43, pp. 148-180.

1931. The abdominal muscular systems of *Homarus vulgaris* (L). and *Palinurus vulgaris* (Latr.). Proc. Trans. Liverpool Biol. Soc., vol. 45, pp. 3-49, 2 pls.

1931. The abdominal muscular systems of the shore crab (*Carcaenas maenas*) and of the zoea I and megalopa states. Proc. Trans. Liverpool Biol. Soc., vol. 45, pp. 50-56, 2 figs.

1931. Comparative study of the abdominal musculature in Malacostraca. Pt. I. The main ventral muscles of the typical abdominal segments. Proc. Trans. Liverpool Biol. Soc., vol. 45, pp. 57-71, 2 pls.

1932. Comparative study of the abdominal musculature in Malacostraca. Pt. II. The superficial and main ventral muscles, dorsal muscles and lateral muscles, and their continuations into the thorax. Proc. Trans. Liverpool Biol. Soc., vol. 46, pp. 46-107, 6 pls.

HANSEN, H. J.

1921. Studies on Arthropoda I. 80 pp., 4 pls. Copenhagen.

1925. Studies on Arthropoda. II. On the comparative morphology of the appendages in the Arthropoda. A. Crustacea. pp. 1-176, 8 pls. Copenhagen.

1930. Studies on Arthropoda. III. On the comparative morphology of the appendages in the Arthropoda. B. Crustacea (supplement), Insecta, Myriopoda, and Arachnida. pp. 39-49. Copenhagen.

HUXLEY, T. H.

1880. The crayfish. An introduction to the study of zoology. 371 pp., 80 figs. Appleton, New York.

JACKSON, H. G.

1928. The morphology of the isopod head. Part 2. The terrestrial isopods. Proc. Zool. Soc. London, pp. 561-595.

KEIM, WILHELM.

1915. Das Nervensystem von *Astacus fluviatilis* (*Potamobius astacus* L.). Ein Beitrag zur Morphologie der Dekapoden. Zeitschr. wiss. Zool., vol. 113, pt. 4, pp. 485-545, 28 figs.

NETZ, WILLY
1917. Das Skelett des Flusskrebses (*Potamobius astacus* Leach). Dissertation. 104 pp., 38 figs. Marburg.

PEARSON, J.
1908. *Cancer pagurus*. Mem. Liverpool Marine Biol. Committee, vol. 16, 209 pp., 13 pls.

RATHBUN, M. J.
1930. The cancroid crabs of America, of the families Euryalidae, Portunidae, Atelecyclidae, Cancridae, and Xanthidae. U. S. Nat. Mus. Bull. 152.

RAYMOND, P. E.
1920. The appendages, anatomy, and relationships of trilobites. Mem. Connecticut Acad. Arts and Sci., vol. 7, 169 pp., 11 pls.

SCHMIDT, WALTER
1915. Die Muskulatur von *Astacus fluviatilis* (*Potamobius astacus* L.) Ein Beitrag zur Morphologie der Decapoden. Zeitschr. wiss. Zool., vol. 113, no. 2, pp. 165-251, 26 figs.

SMITH, G., WOODS, H., SHIPLEY, A. E., WARBURTON, C., THOMPSON, D'A. W.
1909. Crustacea and arachnids. The Cambridge Natural History, vol. 4.

SNODGRASS, R. E.
1927. Morphology and mechanism of the insect thorax. Smithsonian Misc. Coll., vol. 80, no. 1, 108 pp., 44 figs.
1928. Morphology and evolution of the insect head and its appendages. Smithsonian Misc. Coll., vol. 81, no. 3, 158 pp., 57 figs.
1929. The thoracic mechanism of a grasshopper and its antecedents. Smithsonian Misc. Coll., vol. 82, no. 2, 111 pp., 54 figs.
1932. Evolution of the insect head and the organs of feeding. Smithsonian Report for 1931, pp. 443-489, 25 figs.

WILLIAMS, LEONARD W.
1907. The stomach of the lobster and the food of larval lobsters. State of Rhode Island and Providence Plantations. 37th Ann. Rep. Comm. Inland Fisheries, pp. 153-180, 10 pls.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 10

RECENT DISCOVERIES OF CAMBRIAN BEDS IN THE NORTHWESTERN UNITED STATES

BY
CHARLES ELMER RESSER
Curator, Division of Invertebrate Paleontology,
U.S. National Museum

(PUBLICATION 3284)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 6, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

RECENT DISCOVERIES OF CAMBRIAN BEDS IN THE NORTHWESTERN UNITED STATES

By CHARLES ELMER RESSER

Curator, Division of Invertebrate Paleontology, U.S. National Museum

The lifelong studies of Dr. Charles D. Walcott on the stratigraphy and paleontology of Cordilleran North America not only made this a classic area for geologic research, but also established here the most complete known sections of Cambrian strata. However, a considerable area in which Cambrian strata seem to be wanting existed between the definitely known outcrops of the Cambrian in Montana and in British Columbia. Dr. Walcott's further plans included field work in the northern United States and southern Canada for the investigation of this problem, but his death prevented the completion of the project.

Recently, several fortunate discoveries of Cambrian beds have been made in northwestern United States which contribute to a better understanding of the fundamental structure of the Rocky Mountain region. To understand fully the significance of these recent discoveries it is necessary to have in mind both the geographic distribution of the concerned Cambrian outcrops, as well as the primary structural regions of the Cordilleras, especially with respect to the location and direction of geosynclines and basins at the beginning of Paleozoic sedimentation.

PREVIOUSLY KNOWN DISTRIBUTION OF THE CAMBRIAN

Hitherto, as a result of Walcott's extensive studies, the Lower Cambrian was known to extend from southern California northward through the Great Basin as far as the Eureka District in central Nevada and the vicinity of Salt Lake City in the Wasatch Range of Utah. From these points northward, beds older than Middle Cambrian seemed to be lacking, not only in northern Utah, Idaho, and Montana, but also for a considerable distance along the southern part of the Canadian Rockies.

The Middle Cambrian, on the other hand, was known to extend beyond the mentioned points in Nevada and Utah, throughout the Wasatch and thence northward into the western side of the Teton Range, in western Wyoming, and to crop out widely about the headwaters of the streams forming the Missouri River in western Montana. North of the Belt Mountains or of the latitude passing through Helena, Mont., no Middle Cambrian was known in the vast expanse of Beltian sediments extending far north into Canada, except that discovered in 1905 by Walcott in a limited area near Ovando, Lewis and Clark County, north of Helena. In the Canadian Rockies Walcott traced similar Middle Cambrian beds southward at least as far as Elk Pass on the Continental Divide. Thus it is evident that the gap between the nearest exposures of Middle Cambrian in the Rockies of the United States and of Canada was much smaller—by the distance between Salt Lake City and the Ovando area—than that between the nearest exposures of the Lower Cambrian.

Finally, the Upper Cambrian was known to extend rather generally throughout the southern Rocky Mountains, as defined below, where it constitutes the sole Cambrian deposition. These strata are at present best designated as the Deadwood series. In Montana the upper portion of Peale's Gallatin limestone series is of about the same age as the Cambrian in the Southern Rockies, and in Canada beds corresponding rather closely to the Gallatin series and younger strata are well developed. However, both in Montana and in Canada the Upper Cambrian has a more restricted distribution than the Middle Cambrian and does not exactly coincide with it. Thus, earlier observations indicated that Cambrian outcrops were confined to the Rocky Mountain system proper—as defined in the following paragraphs—and that in it an extensive area existed in western Montana, northern Idaho, and the southern parts of Alberta and British Columbia, in which Cambrian strata were apparently lacking.

PRIMARY STRUCTURAL UNITS OF THE ROCKY MOUNTAINS

Before the recent discoveries are described, a few words concerning the fundamental structure of this part of the Cordilleran region will be helpful. In the light of early Paleozoic history it is desirable to depart somewhat from the regional classification in vogue, which is based primarily on present topography and is, therefore, a delimitation of physiographic rather than of structural provinces. The structural provinces, as here outlined, take account of the persistently positive and negative elements, and amounts of total and differential movement, or, in short, the geographic conditions during the initiation of the Cambrian or of other initial early Paleozoic periods, in so far as they are determinable.

Southern Rocky Mountains.—According to conditions at the beginning of Paleozoic time, which persisted throughout that era, this structural province is regarded as including the Southern and Middle Rockies as recently defined by Fenneman. This includes the ranges in central Colorado, Wyoming, and south-central Montana, but excludes the Wasatch and western Wyoming ranges.

Although the Southern Rockies are in line of strike with the ranges to the northwest, nevertheless they have a wholly different geologic history and consequent structure, consisting essentially of a Cryptozoic [1] core fringed with belts of Paleozoic rocks. We may take the Big Horn Range as a typical example of the Southern Rockies. This range consists of an elongate dome of peneplaned Cryptozoic rocks, the edges of which are surrounded by a band of early Upper Cambrian overlain by younger strata. It is certain that the overlapping edges of the Upper Cambrian strata have been stripped back along the peneplaned surface on which they rest, but they appear never to have covered altogether the higher, central portions of the dome. Owing to the positive nature of these domes, coupled with their stability throughout long periods of time, it is not surprising that real geosynclines are apparently absent from the Southern Rockies, and that, in consequence, all sediments from Cambrian to Recent times are basin deposits laid down in the same manner as the Tertiary beds of the present Big Horn Basin.

The northern boundary of the Southern Rockies is naturally an irregular line. Along the main strike the province terminates with the Beartooth Mountains, northeast of the Yellowstone National Park. However, the Gallatin and other similar Montana ranges to the west of the Beartooth mass should be excluded, even though in their evident stability and peneplaned cores they retain characteristics of the Southern Rockies. Their Cambrian, or initial Paleozoic, strata clearly belong to the northern subdivision, so that they represent the southern shore line of that province. Eastward of the Beartooth mass the northern boundary of the Southern Rockies extends far northward to include the Little Rockies and Big Snowy Mountains of central Montana, and to the east to embrace the Black Hills in South Dakota.

Applying the same criteria to the delimitation of the western boundary of the Southern Rocky Mountains, it is necessary to exclude the Wasatch, Teton, and intervening ranges from this province and include them with the Great Basin, even though the Tetons and possibly the Salt River ranges partake somewhat of the structural nature of the Southern Rockies. Cambrian and other Paleozoic strata in

---

[1] Term recently used by Schuchert and Dunbar, Textbook of Geology, 3rd ed. John Wiley & Sons, New York, 1933.

these ranges were apparently deposited in a geosyncline, and the contained faunas indicate their deposition in the seas covering the Great Basin. In other words this situation would naturally be expected if these ranges are the eastern margin of the Great Basin geosyncline.

The manner in which Cambrian distribution is related to the structural provinces is well shown in the Beartooth region. On the south and east sides of this dome Upper Cambrian strata of the Deadwood series rest directly on the peneplaned Cryptozoic, but on its northwestern flanks the older Middle Cambrian holds this relationship. This situation extends the Middle Cambrian shore line, described by Peale for the southern margin of the Gallatin Valley, a considerable distance toward the east.

Northern Rocky Mountains.—From the Beartooth Mountains in southern Montana, immediately northeast of the Yellowstone National Park, northward to the Yukon River in northern Canada, all ranges of the eastern Cordilleran element may be grouped as the Northern Rocky Mountains. Again, from the standpoint of Cambrian or early Paleozoic history, this usage departs from that of some physiographers, conforming more closely to that of Daly, who regards the Rockies as confined, in an east-west direction, to the mountains between the Great Plains on the east and the Rocky Mountain Trench on the west.

In contrast to conditions characterizing the Southern Rockies, the northern subdivision consists essentially of great thicknesses of folded and faulted sediments, evidently deposited in geosynclines. These geosynclines were, of course, the result of prevailingly negative movements, which allowed the accumulation of thicker, more continuous sedimentary series than were possible in basins of the Southern Rockies.

In the southern portion of the Northern Rockies, as stated above, the Gallatin, Madison, Jefferson, and McCartney Ranges exhibit Cryptozoic cores, on whose peneplaned surface Middle or Upper Cambrian strata rest without intervening Beltian beds, in which respect they assume characteristics of the Southern Rockies. However, only a few miles north of the mentioned ranges Beltian strata lie beneath the Cambrian, and continuing northward the Beltian at once thickens rapidly, covering most of northwestern Montana and extending into Canada beyond the Watertown Lakes Park. It has been estimated that these Beltian strata total fully 60,000 feet. For a long time it was thought that this enormous thickness of sedimentary deposits constituted the complete sedimentary record of the geosyncline, but the recent discoveries indicate the possible presence of at least Middle Cambrian, as well as the previously known younger Paleozoics.

RECENT DISCOVERIES OF CAMBRIAN BEDS IN THE ROCKY MOUNTAINS

It will be easier to understand the true significance of the following finds if we take them up in the order of their discovery, which also automatically places them in their proper provincial grouping.

Pend Oreille Lake.—The first discovery extending the area of known Cambrian outcrops into the supposed gap across the Beltian area was made about 1920 by Dr. Edward Sampson, at that time a member of the United States Geological Survey. He found a good Cambrian section along the southern shores of Pend Oreille Lake in northern Idaho. Here limestones and shales contain abundant Middle Cambrian fossils, which recall both those of the Ovando region in central Montana and also others in the Canadian Rockies, thus showing that Cambrian seaways extended across the western as well as the eastern portions of the supposedly barren Beltian area, where Walcott's studies in 1905 had shown the existence of Cambrian.

Extension of the Ovando area.—During recent years the Montana State geologists have been studying the sedimentary beds of northwestern Montana, particularly with the view to unraveling the complicated Beltian sedimentary record. This work greatly extended the Cambrian, both geographically and stratigraphically, in the Ovando region about the head of Sun River observed by Walcott in 1905. Study of these data is now under way by Dr. C. F. Deiss of the State University at Missoula, Mont.

South Kootenay Pass.—The third significant discovery was made by Dr. G. S. Hume, of the Canadian Geological Survey, during the field season of 1932, when he collected what appear to be Middle Cambrian fossils north of Red Deer River, in the vicinity of North Kootenay Pass, southern Alberta. Here shales, with layers and lenses of limestone, overlie about 100 feet of quartzites, which in turn rest on the Beltian with an erosional unconformity between. The Middle Cambrian is said to be overlain by Silurian strata in the southernmost locality found, but a little farther north is directly succeeded by Devonian. The Cambrian, as well as the other mentioned Paleozoic beds, vary rather rapidly in thickness. This discovery reduces the gap, as previously outlined, by many miles in a north-south direction, as the Pend Oreille find did in the east-west direction.

Beartooth Mountains.—The recent work of the Princeton University group studying the geology of the Beartooth region has shown the presence of Middle Cambrian on the northwestern quadrant of the Beartooth Mountains. On the eastern and southern sides of this uplift only the Southern Rocky Mountain Upper Cambrian series is present, but west of a gap where Cambrian is lacking, the presence of northern Middle Cambrian apparently determines the southeastern extent of the geosynclinal seas washing the margins of the more stable lands which prevented their continuation southward through Wyoming or the Southern Rockies.

All four new localities mentioned lie within the Rocky Mountains proper, and in every respect their strata resemble those previously determined by Walcott's studies; consequently they serve merely to close the gap between the previously known Cambrian areas in the southern part of the Northern Rockies. In other words, these discoveries were to be expected as long as definite evidence was not at hand that the known Middle Cambrian seaways had detoured around this supposedly barren Beltian area. From our knowledge we may, therefore, infer that a thin, probably discontinuous sheet of Middle Cambrian once covered some of this Beltian area, but no evidence exists pointing to the extension of younger Cambrian beds across the area. Naturally, thin beds, lying on top of great masses folded and faulted into the high ranges such as exist here at present, would suffer severely from erosion, with the result that only patches of Cambrian are left here and there in the bottoms of synclines. Nevertheless, it is the opinion of all who have studied the region that the Middle Cambrian sheet never extended all the way across the gap.

DISCOVERIES WEST OF THE ROCKY MOUNTAINS

In contrast to the four finds described, another group located in northeastern Washington contribute not so much toward closing the gap, but have a much greater significance, since they occur west of the Rocky Mountains in the strike of the Selkirk and Purcell systems.

Metaline Falls.—Recently Washington State geologists searched patiently the hitherto supposedly unfossiliferous metamorphosed rocks in the eastern part of their State and were rewarded by finding fossils which prove the presence of Paleozoic strata as was previously suspected. Last winter, Mr. W. G. Bennett, a student of Washington State College, found a shale containing good Middle Cambrian fossils at Metaline Falls on the Pend Oreille or Clark Fork River in the northeastern corner of the State, a few miles south of the international boundary. This shale occurs in the southward extension of Daly's Pend Oreille group or Summit series. This does not necessarily remove either series from the Beltian, but probably indicates conditions similar to those described for the Rocky Mountain Beltian area north of Helena, Mont. This shale is part of a limestone belt lying between two mountain ranges of quartzite and schist. Besides the shale and limestone, from which other Paleozoic faunas have been collected, graptolitic argillites are present, which are now being studied by Dr. Ruedemann. The Middle Cambrian fossils in the shales are *Elrathia* aff. *cordillerae, Pagetia* cf. *bootes, Kootenia* sp., *Olenoides,* and *Westonia,* all typical of the Stephen formation, very common in the Rockies about Lake Louise, Alberta, and Field, British Columbia.

Localities near Colville.—In 1931 C. C. Branson reported *Kutorgina,* a genus confined to the Lower Cambrian, from the Stevens series on the Colville River, 6 miles north of Chewalah, Wash., a locality about 40 miles southwest of Metaline Falls. The Stevens series formerly was also regarded as Beltian in age, and as stated for the Pend Oreille group, it probably is Beltian but was covered with Cambrian beds, fragments of which remain in the infolded synclines.

A second Lower Cambrian locality was found by Mr. Bennett, who sent in a single piece of limestone from the town of Colville. This limestone contains fragments that appear to represent *Wanneria,* or at least an olenellid trilobite, accompanied by several cups of *Archaeocyathus.* Taken together, these two discoveries unquestionably extend the known range of Lower Cambrian strata far southwest of the most southerly locality previously known in Canada. This was at Cranbrook in southeastern British Columbia, and in or west of the Rocky Mountain Trench, which is the western limiting feature for the Rocky Mountain system. However, it is not clear whether we should regard this occurrence as being in the Purcell or in the Rocky Mountain systems. On the other hand, without doubt, the Washington Lower Cambrian localities are west of the Purcell Trench and, therefore, in the Selkirk system.

Kettle Falls.—Finally, Mr. Bennett secured another piece of fossiliferous rock a few miles east of the Columbia River, at Kettle Falls, 10 miles west of Colville, containing a pocket in which occur silicified fragments of *Nisusia, Hyolithes,* and a small, smooth trilobite suggesting *Agnostus.* This small fauna could be either Lower or Middle Cambrian, but seems to be the latter. This piece of rock is from an argillaceous quartz conglomerate, lying between two masses of schistose greenstone and grit. The conglomerate itself is much metamorphosed and sheared, and since the fossils are not distorted, it is likely that originally they occurred in a limestone pebble forming a part of the conglomerate. This, therefore, raises the question as to whether the conglomerate is of Cambrian age or younger.

PRESENT CAMBRIAN DISTRIBUTION

With the data furnished by these recent discoveries, the general picture of Cambrian distribution has been considerably altered, and several generalizations become possible.

The Lower Cambrian is still unknown both throughout the Southern Rockies and in the northern division as far north as the Bow Valley, near Lake Louise, Alberta. This statement, of course, disregards the possibility that the Cranbrook occurrence in the Rocky Mountain Trench should be included with the Rocky Mountains and not placed in the Selkirk system. On the other hand, the distribution of the Lower Cambrian has been extended in the ranges west of the Rockies a considerable distance farther south than it was formerly known to occur.

Middle Cambrian distribution was expanded to a greater extent. In the Rocky Mountain system it has reduced the Beltian gap to several hundred miles, and to the west its range has been expanded equally with that of the Lower Cambrian.

On the other hand, the Upper Cambrian received no unquestioned additions, so that the Deadwood series still constitutes the sole record in the Southern Rockies and retains approximately its previously known distribution to the north.

DEDUCTIONS REGARDING CAMBRIAN SEAWAYS

When Lower Cambrian seas first penetrated the continent in western North America, it appears to have been along a single great geosyncline, the complete course of which was outlined by Philip King (1933). Judging from Lower Cambrian occurrences, it seems that this geosyncline developed by growing simultaneously from its two extremities. Thus Lower Cambrian waters entered its southern portion, the Great Basin geosyncline, and passed through what is now southern California as far northward as central Nevada and Utah. From the north, marine waters apparently came down from the Arctic to northeastern Washington, leaving an unoccupied gap of several hundred miles, because existing evidence does not indicate removal of Lower Cambrian here prior to deposition of the Middle Cambrian. It will be noted that this interpretation considers the existence of but one geosyncline, which follows the trend of the northern Rockies south from their northern extremity to Montana, where it swings westward around the Southern Rocky Mountain region and thence continues southwestward through the Great Basin, to enter the Pacific in southern California. Or possibly one might consider this as two geosynclines joined by a crossover in Montana; but the faunas in both are the same.

By Middle Cambrian time floods apparently penetrated the entire length of this long negative area. It is not to be understood that all Middle Cambrian formations are thought to have covered the entire width and length of the geosyncline, for they were evidently deposited in relatively narrow, often parallel, and always very shallow troughs, and differential movements within the larger depressed area must have operated everywhere and during all time so that every formation was a discontinuous sheet. (See Walcott, 1927.)

With the beginning of Upper Cambrian time, subsidence appears to have affected the whole continent to such an extent that marine waters were enabled not only to flood portions of this long geosyncline, but also to extend themselves out across the smoothed surfaces of interior portions of North America. Thus in the Southern Rocky Mountains Cambrian seas were able to enter the basins between certain positive elements which were then islands and are now the cores of existing ranges. It seems that possibly all of the Cordilleran geosyncline was drained at the close of Middle Cambrian, because the basal Upper Cambrian beds usually contain salt crystals, ripple marks, and other shallow-water features. On the other hand, relatively soon after the seas reached their maximum extent in lower Upper Cambrian, emergence began west of the Mississippi Valley, so that the younger members of the Cambrian are less and less widely distributed. With no change in dip, the Mons, Garden City, Manitou, or equivalent formations again spread widely both within and without the geosyncline, overlapping the Cambrian beds of various ages but apparently never reaching beyond them to rest directly on the Cryptozoic. In other words, diastrophic movements creating early Paleozoic basins or geosynclines were fully determined by early Upper Cambrian.

REFERENCES

Branson, C. G.

1931. New paleontologic evidence on the age of the metamorphic series of northeastern Washington. Science, n.s., vol. 74, p. 70.

Daly, R. A.

1912. Geology of the North American Cordillera at the Forty-ninth Parallel. Geol. Surv. Canada Mem. 38.

DEISS, CHARLES F.
1933. Paleozoic formations of northwestern Montana. Bur. Mines and Geol., Montana, Mem. no. 6, March.

KING, PHILIP.
1933. An outline of the structural geology of the United States. Internat. Geol. Congr., 16th sess., Guidebook 28, pl. 1.

PEALE, A. C.
1893. The Paleozoic section in the vicinity of Three Forks, Montana. U.S. Geol. Surv. Bull. 110.

SAMPSON, EDWARD.
1928. Geology and silver ore deposits of the Pend Oreille District, Idaho. Idaho Bur. Mines and Geol., Pamphlet no. 31, December. (Mimeographed.)

WALCOTT, D. C.
1927. Pre-Devonian sedimentation in southern Canadian Rocky Mountains. Smithsonian Misc. Coll., vol. 75, no. 4, April 2.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 11

PHOTOTROPIC SENSITIVITY IN RELATION TO WAVE LENGTH

(With Two Plates)

BY
EARL S. JOHNSTON
Division of Radiation and Organisms, Smithsonian Institution

(Publication 3285)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 6, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

PHOTOTROPIC SENSITIVITY IN RELATION TO WAVE LENGTH

By EARL S. JOHNSTON

Division of Radiation and Organisms, Smithsonian Institution

(WITH TWO PLATES)

INTRODUCTION

Asymmetric growth resulting from unilateral stimulus has been designated tropism. Growth curvatures following unilateral illumination are usually classified under the term phototropism. Different plants respond in different degrees to light, but perhaps those most frequently used in phototropic experiments are the sporangiophores of *Phycomyces* and the coleoptiles of *Avena*. In such studies the intensity, the wave length, and the duration of exposure to light each acts as a contributing factor toward the final result. Just as there appears to be a threshold of intensity for a given duration of light exposure, so there are wave lengths which seem to exert no influence on these growth responses, but with exposures to other wave lengths the plants show distinct degrees of sensitivity. Not only do different plants vary in their sensitivity, but separate portions of the same plant respond differently. Recent work on growth substances indicates the presence of factors other than light in this complex plant-response.

In the present paper the subject is limited, in the main, to the influence of radiation of different wave lengths on phototropism as shown by the response of the coleoptiles of *Avena sativa*. The variety used is Culberson, C.I. no. 273, for which the author wishes to thank Mr. T. Ray Stanton, of the United States Department of Agriculture. All the light intensity measurements were made by Dr. E. D. McAlister, to whom credit for that part of this work is given.

HISTORICAL SURVEY

Many of the early experiments on phototropism have been reviewed by Parr (1918) and the data classified under four general theories: 1. The "intensity" theory originating with De Candolle in 1832 and adhered to in a more or less modified form by Wiesner, Darwin, Engleman, Oltmanns, Yerkes, Loeb, and Davenport. 2. The ray-direction theory advanced by Sachs in 1876 and supported by the experiments of Strasburger, Davenport, and Canon. 3. The wave-length theory first investigated by Payer in 1842. 4. The energy theory first mentioned by Müller in 1872 in which the maximum response of cress seedlings shifted in the spectrum for different energy values of the wave lengths studied.

The basis for much of the recent quantitative work on phototropism was laid by Blaauw (1909, 1914, 1915, 1919). His studies were perhaps the first serious attempt made to interpret this growth response in terms of modern physics. Plant responses were studied in different spectral regions of sunlight and of the carbon arc and compared with the energy values calculated from Langley's (1884) tables. Blaauw found the most effective region of the carbon spectrum for phototropic response of *Avena* seedlings to lie between 4660 and 4780 A, while the red and yellow regions were ineffective. According to Blaauw (1914), the curvature of a plant resulting from unilateral illumination is caused by the light-growth responses on the opposite sides which are illuminated differently. The minimum amount of radiation required to produce phototropic response was found to be 20 meter-candle-seconds. It also appears from his work that for equal effects the product of light intensity and time of exposure is a constant.

It is impossible to evaluate the effect of wave length in many of the early phototropic experiments because of the lack of accurate physical data. Some 10 years after the early quantitative studies of Blaauw, Parr (1918) made a study of the responses of *Pilobolus* to different wave lengths and intensities of carefully measured artificial light. The results of these quantitative studies are best summarized in her own words:

(1) *Pilobolus* responds to the light of all the regions of the visible spectrum. (2) The presentation time decreases gradually from red to violet. There is no indication of intermediate maxima or minima. (3) The presentation time does not vary in direct ratio with the measured value of the energy of the light in the different regions of the spectrum. (4) The presentation time varies in inverse ratio to the square roots of the wave frequency. (5) The product of the square root of the frequency times the presentation time, decreases with the decrease in the energy value of the spectral regions, and is an approximate constant for a given light-source. (6) The spectral energy in its relation to the presentation time may be expressed approximately in the Weber-Fechner formula, if the wave-frequencies be made a function of the constant. (7) The relation of the spectral energy to the presentation time may also be approximately expressed in the Tröndle formula, the wave-frequencies being made a function of the constant.

About the same time Hurd (1919) showed wave-length effect on young rhizoids by equalizing the intensity of the light coming through a series of Wratten filters. Only the blue (4700 to 5200 A) and violet (4000 to 4700 A) lights produced phototropism, negative in direction. The other lights at the intensity of 1800 meter-candles had no effect. However, with a greater intensity the green light (5200 to 5600 A) exerted a negative phototropic effect as well as the blue and violet.

For the purpose of investigating the wave-length effects of radiation on phototropic bending of young plants, Johnston (1926) constructed and described a simple plant photometer. The apparatus consisted of a long box divided into three compartments. Each end compartment contained an electric lamp which could be moved toward or away from the light-filter window in the partition separating it from the central or plant compartment. Plants which easily respond in their directional growth to differences in light intensities were employed in place of the adjustable indicator or photometer screen in the ordinary Bunsen photometer.

Sonne (1928-1929) determined the necessary amount of energy of different wave lengths to produce a minimum phototropic response in oats. The young plants were so placed that about 1 cm of their tips were exposed at different distances from the light of a monochromator for different exposure periods. The visible part of the spectrum of a Hefner lamp was used as a standard of comparison. Minimum response was obtained at 0.86 x 10^{-5} g. cal. per cm^2 in 1 second. The energy was measured by a thermo-element. The results are summarized in table 1.

TABLE 1.—*Sonne's Data showing Phototropic Sensitivity Determined from the Amount of Energy Required to Produce a Minimum Response in Oats*

Wave length (A)	Absolute energy	Phototropic effect
5700	588	0.17
5460	371	0.27
4360	0.028	3572
4050	0.06	1667
3660	0.10	1000
3130	0.66	152
3020	0.96	104
2800	2.3	44
2650	32 and 15?	7
2530	19	5
2400	77	1

It will be seen from this table that the amount of energy which barely causes phototropic curvature varies with the wave length. The yellow (5700 A) is about 600 times as intense as is the white light necessary to bring about the same response, while the green (5460 A) is approximately 400 times as intense, and the blue (4360 A) only .03 as strong as the energy of his standard white light. The blue is thus approximately 10,000 times as effective phototropically as the green and 20,000 times that of the yellow. The violet (4050 A) is also very effective but only about half that of the blue.

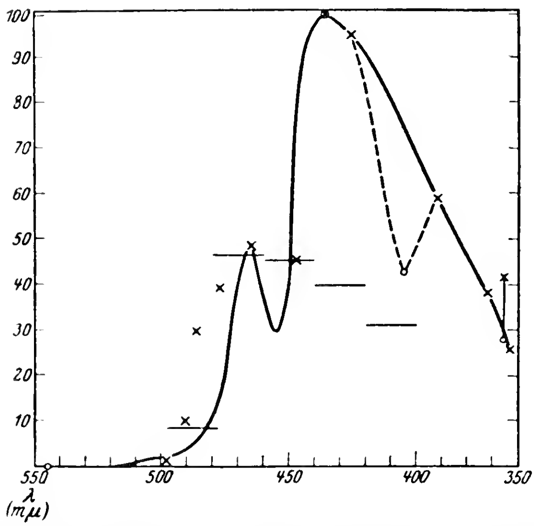


FIG. 1.—Graphs from Bachmann and Bergann showing the sensitivity of *Avena sativa* to wave lengths of light (continuous line) compared with their corrected values of Blaauw (crosses), of Sonne (circles), and of Koningsberger (horizontal lines).

Bergann (1930) made a very careful study of the effects of monochromatic light on the growth and bending of *Avena sativa* as well as the effects produced by a change of intensity and length of exposure. Employing the method of placing the young plant between two opposing lights, he concludes that the regions other than the red and infrared produce corresponding growth reactions for suitable intensities. In unilateral light equal bending is shown for corresponding intensities, first positive, then negative, and finally positive. Light curvatures and light-growth reactions are parallel processes. The stronger the light-growth reaction in a given wave-length region, the greater will be the phototropic response. The seedlings " choice " in the compensation experiments between two wave-length ranges is always that which corresponds to the stronger growth reaction.

Bachmann and Bergann (1930) review the early work of Blaauw and correct the energy values of his data for light absorbed by $CuSO_4$ and water filter, surface reflections, and color filter in order to compare his results with those obtained by Bergann. The results of Sonne and Koningsberger are also corrected and compared. These data are represented graphically in figure 1, in which the continuous line is the sensitivity curve. The data from Blaauw's work are indicated as

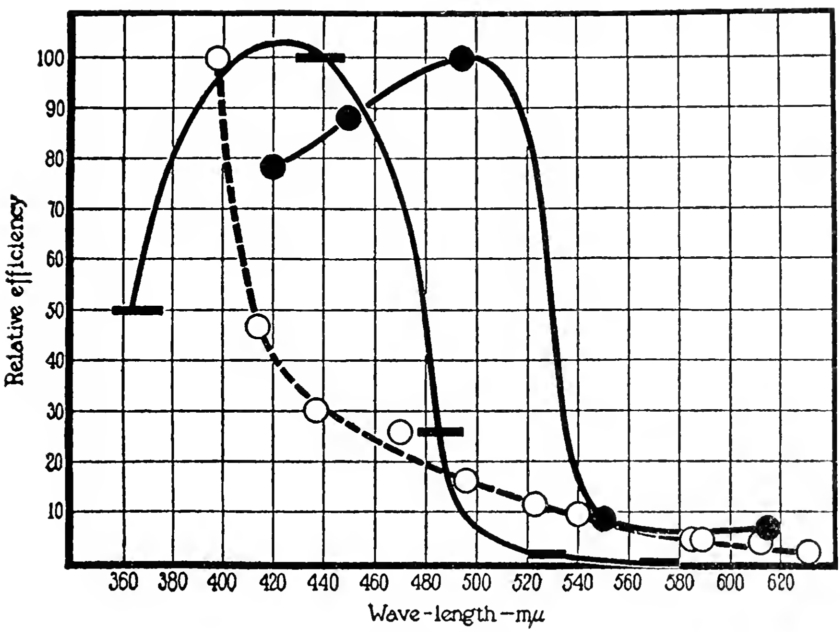


Fig. 2.—Graphs from Castle showing the relative efficiencies of different wave lengths in their stimulation on *Phycomyces blakesleanus* (horizontal lines), on *Phycomyces nitens* from data of Blaauw (solid circles), and on *Pilobolus* calculated from data of Parr (open circles).

small crosses, those of Sonne as circles, and those of Koningsberger as horizontal lines. The multiplier for Blaauw's data in the short-wave-length region is 2.5.

From this work it is concluded that there are two maxima in the phototropic curve and that these correspond in general to the maximum light absorption regions of chromolipoids. It appears that the phototropic curvatures in the different wave-length regions follow the absorption of light by specific substances or their compounds in these same regions.

The sensitivity of the sporangiophores of *Phycomyces* to light of different wave lengths was investigated by Castle (1931). The sporangiophores were placed between two light sources. The intensities were adjusted until the phototropic effects of the different spectral regions were equal. At this point the efficiency of each region was taken as proportional to its relative energy content. Wratten filters were used in conjunction with a copper chloride filter. The most sensitive region proved to be in the violet (4000-4300 A). In figure 2 Castle compares his results with those obtained by Blaauw and Parr. It is pointed out that because of the presence of "accessory" pigments in these sporangiophores care must be taken in correlating these results with those obtained from the absorption spectrum of the photosensitive substance.

PRELIMINARY EXPERIMENTS

The general method of studying the wave-length effects on phototropism as described by Johnston (1926) was used by Johnston, Brackett, and Hoover (1931) with an improved plant photometer for evaluating four spectral regions in terms of plant response. The general procedure was to place an oat seedling between two different and oppositely placed lights, and after an interval observe the growth curvature. If, for example, when the seedling was exposed to blue and to green lights, a distinct bending was noted toward the blue side, the lights were so adjusted as to increase the green or decrease the blue intensity. Another seedling was then used and the process repeated until a balance point was reached where the effect of one light neutralized the effect of the other. When this balance point was determined, a specially constructed thermocouple replaced the plant and the relative light intensities were measured. From these experiments it was found that no measurable phototropic response was found for wave lengths longer than 6000 A (Wratten no. 24—red filter), while a noticeable bending was found with the yellow filter (Corning's heat-resisting yellow—yellow shade), whose cut-off on the short-wave-length side was 5200 A. The threshold for wave-length influence was found to lie somewhere between 5200 and 6000 A. The effects of green and blue light (Wratten filters nos. 61 and 47 respectively) were progressively greater, being in round numbers 1,000 for the green and 30,000 for the blue times that of the yellow.

These results justified a more elaborate and better controlled experiment wherein narrower spectral regions could be investigated. For this purpose Johnston (1931) used the specially constructed monochromator illustrated in plate 1. Care was taken to eliminate scattered light and to keep the conditions surrounding the coleoptile symmetrical, with the exception of the wave-length region being investigated. A double-walled glass cylinder with water between the walls slowly rotated about the axis of the coleoptile. Two strips of paper blackened on the inside and separated 1 cm from each other were wrapped about the cylinder in order to shield all but a restricted region at the tip of the coleoptile from the light. The cylinder was encased in a light-proof box which contained two oppositely placed side windows. Through one window, light was passed from the monochromator, and through the other, light from the standard lamp. The standard used was a 200-watt, 50-volt projection Mazda lamp with the filaments in a plane. The standard lamp was enclosed in an air-cooled brass housing with one small glass window opening toward the plant. The light from the standard was passed through a number 6.0 Corning line filter, a heat-absorbing glass, and a water cell before entering the rotating cylinder surrounding the plant. The number 6.0 Corning line filter transmitted wave lengths from about 4400 A to 5800 A and from 7000 A to 12800 A of the light transmitted by the water filter. The radiation intensity of the standard was 0.37 microwatts/cm^2 at a distance of 25 cm. This value, of course, varied with different lamps and also with the same lamp as it aged. A photographic red lamp was used behind the small rear window of the plant box for properly placing a coleoptile at the beginning of each exposure. Previous experiments showed the coleoptile to be insensitive for all practical purposes to this particular light. The monochromator lamp was located outside the phototropic room, which was a small room with no outside walls located in the west basement of the Smithsonian building. Very little daily temperature fluctuation occurred in this room because of its ideal location.

Coleoptiles of oats, *Avena sativa* Culberson, were used in all these experiments. The seeds were germinated at approximately 25° C. between glass plates covered with moist filter paper. The plates were so placed in moisture chambers that the seedlings grew vertically. A careful selection of the seedlings was made for straightness when they had attained a length of 2 to 4 cm. One was then transferred to a small Erlenmeyer flask fitted with a cork stopper. It was supported by means of a little cotton in a small hole of the stopper. The flask was filled with distilled water so that the roots were entirely immersed. With the cross hairs in a small telescope as a guide, the seedling was adjusted to a vertical position within the glass cylinder located between the two lights.

The general experimental procedure was to illuminate the coleoptile on its two opposite sides, preferably the narrow edges, and after a time interval to note the resulting growth curvature. If the light adjustment was very much out of balance as indicated by the plant, a bending similar to that shown in plate 2 occurred in 20 to 30 minutes. An adjustment was then made in the proper direction and the used seedling discarded for a new one. As the balance point was approached the exposure time necessarily increased. Finally on moving the standard light back and forth through a distance of 1 cm, the plants could be made to curve repeatedly toward one light then toward the other. The balance point was taken to be the midpoint between these two positions. Care was always used not to expose the fresh seedlings to any light but red in the preliminary handling. Priestley (1926) has shown that light affects normal and etiolated shoots very differently. The amount of light required to induce phototropic curvature in normal light-grown shoots is greater, and must be continued longer, than that required to bring a similar curvature in etiolated shoots.

After a balance point had been determined and tested by using several seedlings, a specially constructed thermocouple was inserted into the glass cylinder occupied by the seedlings and the light intensities measured at the balance position. The junction of the thermocouple was made of a short length of fine bismuth wire and one of bismuth-tin alloy, each about 25 microns in diameter. The alloy was made up of 95 percent bismuth and 5 percent tin. Utmost care was needed in measuring the light intensities since the plants were found to be much more sensitive to the light than the best physical instruments available. It should be remembered, however, that the seedling integrates the effect of radiation over a relatively long period, while the thermocouple responds in a few seconds.

The results of this experiment are presented in table 2. The ratio of the intensity of the monochromator light to that of the standard light is given in the third column for corresponding wave-length ranges shown in the first column. Where filters were used in combination with the monochromator they are indicated in the second column. No phototropic responses were obtained in any of the first six wave-length ranges. The first quantitative measurements that could be made were for the range 5040 to 5160 A. In the last column of the table the relative phototropic effectiveness of the different wave-length ranges is given. The ratio 29.10 was arbitrarily taken as unity.

With unilateral illumination through the monochromator and a number 77 Wratten filter in the region 5430 to 5670 A, bending occurred in four hours. This indicated the approximate threshold region of phototropism. In order to determine this point more accurately a mercury arc in pyrex glass was substituted for the Mazda lamp of the monochromator, and by passing this light through a number 77 Wratten filter, a seedling was unilaterally illuminated by the 5461 mercury line. In five such tests, each lasting from two to several hours, two gave positive bending and three no bending. With reasonable certainty it can be concluded that under these particular experimental conditions the threshold wave-length effect is at or very near 5461 A.

TABLE 2.—*Data from the Preliminary Experiment Showing Phototropic Effectiveness of Restricted Regions of the Spectrum. That for Wave-length Region 5040-5160 A is Taken as Unity*

Wave-length range (A)	Filter [a] used with monochromator	Light intensity ratio (Monochromator/standard)	Relative phototropic effectiveness
7250-7700	W 88		
6900-7300	W 88		
6550-6950	CLF 2		
6250-6600	CLF 2		
5940-6270	CLF 3		
5670-5950	TR		
5430-5670	W 22; CLF 5.1		
5200-5430	W 77		
5040-5160	CLF 6.1	29.10	1.0
4940-5070	CLF 6.1	2.49	11.7
4810-4930	CLF 6.1	0.68	42.8
4670-4800	CLF 6.1	0.54	53.9
4550-4670	CLF 7	0.29	100.3
4450-4550		0.27 [b]	107.8
4410-4500		0.34 [b]	85.6
4360-4450		0.36 [b]	80.8
4280-4360		0.41 [b]	71.0
4210-4280		0.47	67.0
4130-4220		0.84	34.6
4070-4135		1.49	19.5

[a] W, Wratten; CLF, Corning line filter; TR, thermometer red.
[b] With the standard lamp at a fixed position from the plant, the intensity of monochromator light was varied by changing the resistance in its lamp circuit until a balance point was obtained.

When the phototropic effectiveness is plotted against wave length, a curve is obtained as shown in figure 3, with its maximum at about wave length 4550 A. The horizontal lines represent the wave-length ranges for which balance points were determined. Points where filters were used in addition to the monochromator are represented as circles.

There is a slight suggestion of two other maxima, one on each side of the peak. It could not be determined from these data whether or not these secondary maxima were real. Furthermore, certain conditions existed during this preliminary experiment which make it impossible to consider this sensitivity curve more than approximately correct. Although an attempt was made to burn the lamps at a constant voltage, there was some fluctuation during the exposure of the seed-

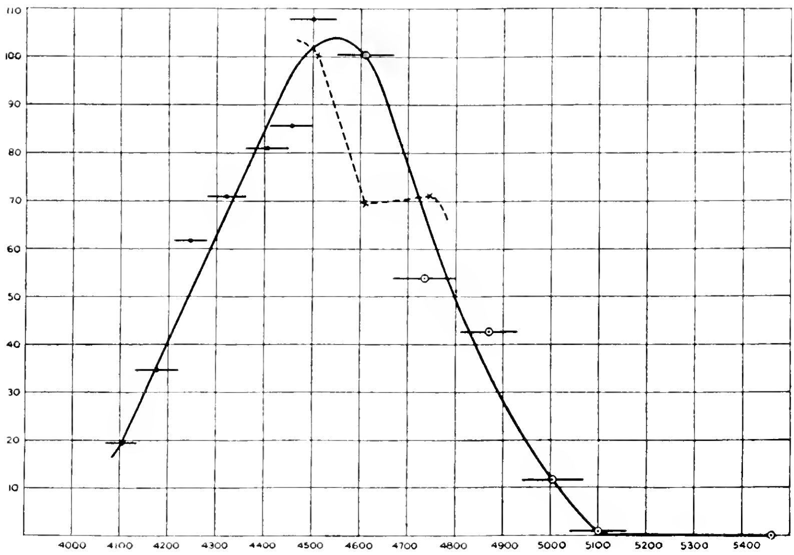


FIG. 3.—Phototropic sensitivity curve of preliminary experiment (continuous line). The ordinates are relative sensitivity values, the abscissae, wave lengths in angstroms, and the horizontal bars indicate the wave-length ranges of the balance points. Circles indicate points obtained with filters combined with the monochromator. Points more accurately determined are indicated by crosses and connected by dash lines.

lings and during the intensity measurements. Also, in some of the work the standard lamp as well as its filter cell was cooled by tap water. This resulted in an accumulation of iron on the glass surfaces during the time required for determining the balance points. These uncontrolled factors undoubtedly modified to some extent the character of light transmitted.

Because of the suggested secondary maximum on the longer-wave-length side, three points on this side were again determined. This time the lamps were connected to a battery of storage cells and the current held more nearly constant. These three wave-length regions with the corresponding phototropic effectiveness are given in table 3 and the midpoint of each band plotted in figure 3. Here a distinct break in ascent of the curve is shown.

Table 3.—*Data from the Second Experiment Showing Phototropic Effectiveness in the Spectral Region Indicating the Presence of a Double Maximum*

Wave-length range (A)	Light intensity ratio (monochromator/standard)	Relative phototropic effectiveness
4460-4560	.29	100.3
4558-4662	.42	69.3
4685-4805	.41	71.0

IMPROVED EXPERIMENTATION AND RESULTS

Another experiment was planned and carried out in which the technic was further improved. A motor generator was installed wherein the current used for the light sources was automatically controlled. Both the monochromator lamp and the standard lamp were connected in series and replaced at the same time when one burned out. These lamps were the Mazda projection type rated at 200 watts, 50 volts, with an average life of 50 hours. They were burned at four amperes. The water jacket around the standard lamp was removed and the filter cooled by a thermosiphon method in which distilled water was used. In the longer-wave-length regions the light from the monochromator was passed through suitable glass filters to reduce the effect of scattered light of shorter wave lengths affecting the seedlings. Unfortunately no filters which transmitted an adequate percentage of light were available for wave lengths of 4500 A or shorter when used in connection with these projection lamps.

The data from this more accurately controlled experiment are presented in table 4 and shown graphically in figure 4. The maximum phototropic effect occurs at 4400 A, a region about 150 A shorter than the maximum found in the earlier experiment. A secondary maximum occurs at approximately wave length 4750 A with the intervening minimum at about 4575 A. From this double maximum the sensitivity of *Avena* falls off rapidly to 5000 A on the long-wave-length side, and to 4100 A on the short-wave-length side. It would be interesting to determine if the limit of sensitivity in the case of *Avena* continues to fall off on the short-wave-length end of the spectrum, as some previous work would indicate. At some future date it may be possible to extend this curve into the violet and ultraviolet regions.

Considerable difficulty was experienced in obtaining a satisfactory balance point in the region of 4800 A. It was necessary to repeat this part of the experiment several times. All other points gave consistent data. It is possible that a slight shift of the seedling, one way or the other from the center of the light beam, in this particular portion of the spectrum was sufficient to account for the difficulty of obtaining entirely satisfactory data. If this were true, then it would indicate a considerable change in sensitivity over a range of only 100 angstroms at about wave length 4800 A.

TABLE 4.—*Data showing the Phototropic Effectiveness of Restricted Regions of the Visible Spectrum. That for the Hg Line 4358 A is taken as Unity*

Wave-length range (A)	Filter [a] used with monochromator	Light intensity ratio (monochromator/standard)	Relative phototropic effectiveness
4945-5055	SG	9.37	.05
4873-4970	NC	1.78	.27
4760-4840	HRN	.54	.89
4650-4750	SG	.51	.94
4530-4620	SG	.58	.83
4470-4545		.49	.98
4360-4440		.42	1.14
4270-4335		.48	1.00
4170-4230		.65	.74
4072-4125		1.18	.41

[a] SG, Sextant green (1.94 mm); NC, Noviol "C" (4.15 mm); HRN, heat resistant Noviol (3.04 mm).

As mentioned above, the light source for this experiment was the Mazda projection lamp. Most of the regions investigated were approximately 100 angstroms wide. For the five points on the short-wave-length side no filters were used. It is believed that the amount of scattered light coming through the optical system of the monochromator in this end of the spectrum did not greatly change the character of the sensitivity curve. It is much more important to eliminate the scattered light at the long-wave points. However, it seemed advisable to determine one or two points on the short-wave-length side by using the lines of the mercury arc that fall in this particular region. A mercury arc in pyrex glass was set up in front of the monochromator, and balance points were determined for lines 4047 A and 4358 A. These points gave ratio values of 1.08 and 0.48 respectively, and phototropic effectiveness values of 0.44 and 1.00. Both points are indicated by crosses on the graph in figure 4. Because of the purity of the 4358 A mercury line its value was taken as unity for all the points given in table 4 and shown in figure 4.

The efficiency value for line 4358 A falls below the curve. This is to be expected if the points on the curve adjacent to wave length 4358 A contained scattered light of more phototropic effectiveness. The value for the 4047 A line is above the curve. It may be noted that this radiation was not exactly monochromatic, since an examination with the spectroscope showed very faintly the presence of lines 4078 A

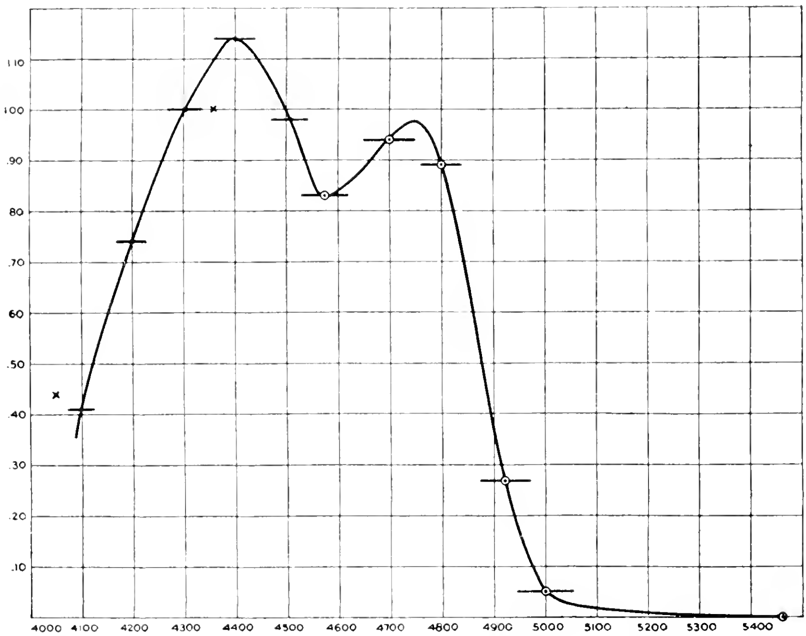


Fig. 4.—Phototropic sensitivity curve. The ordinates are relative sensitivity values, the abscissae, wave lengths in angstroms, and the horizontal bars indicate the wave-length ranges of the balance points. Circles indicate points obtained with filters combined with the monochromator. The crosses show where mercury lines were used.

and 4358 A. This would make the apparent effectiveness of this line (4047 A) greater than its actual effectiveness and hence raise it above the curve. On the other hand, the curve itself is doubtless a little higher than that which would have been obtained had it been possible to use filters in addition to the monochromator for this region. It may be possible that the phototropic sensitivity curve actually begins to rise at this point, although there is no indication of this from the other data obtained in this work. It is to be expected that in the ultraviolet region the curve would rise, owing to injury of cells on the proximal side of the seedling.

DISCUSSION

The use of the plant photometer in determining the sensitivity of seedlings to light has in its favor the elimination of the operator's judgment at many points during the experiment. The plant itself is used as a null point instrument. After a time interval the plant has grown toward or away from the standard light. There is no need for the operator to estimate the angle of curvature or the exact time at which bending begins. Repeated experiments demonstrate that by moving the standard lamp 0.5 cm toward or away from the plant when located at a balance distance of approximately 25 cm, the curvature of seedlings can be changed from one direction to the opposite. It is interesting to note that repetition of balance points seldom differed from each other by more than 5 percent. Very rarely was an unorthodox seedling or an apparently nonsensitive seedling found.

One possible objection to this method might be raised. Each point on the phototropic curve is not strictly comparable to the others. This arises from the fact that the plant was at a fixed distance from the monochromator. The intensity of the various wave lengths used was different. The intensity of the standard light was changed to balance that of the monochromator light. A better method perhaps would be to maintain the standard light at a fixed intensity with respect to the plant and change the monochromator light to balance the standard light.

It is of interest to note that the maximum phototropic response occurs at wave length 4400 A. This point lies midway between the greatest absorption maxima of chlorophyll *a* and chlorophyll *b* recently measured by Zscheile (1934) by an improved method. It is also the position of one of the maxima found by Hoover (1934, data unpublished) for carbon dioxide absorption by young wheat plants. Since phototropic response is an index of growth retardation it would at first appear that photosynthesis progresses best at a point in the spectrum where growth is least. Such is not the case, however, when the other and somewhat greater maximum of carbon dioxide absorption is considered. This occurs in the region of 6400 A. Here there is no phototropic response and no retardation in growth.

The absence of any phototropic effect in the red and infrared, as shown in these experiments as well as by those of other investigators, and the sharp rise in the curve from about 5000 A into the blue, is typical of an electronic photochemical reaction. The photochemical nature of at least some of the underlying processes involved in phototropism is also suggested by the part played by auxins.

Went and his school have shown that small pieces of agar and gelatine impregnated with this growth-promoting substance when placed asymmetrically on decapitated coleoptiles bring about a growth curvature with the small agar or gelatine block above the convex portion of the coleoptile. The amount of bending can be influenced by exposing the tips to light before impregnating the agar or gelatine blocks. It would appear that light either prevents the formation of the auxins or destroys their activity. Furthermore, Kögl (1933) and Kögl, Haagen-Smit, and Erxleben (1933) show this growth-promoting substance to be an unsaturated acid of the formula $C_{18}H_{32}O_5$, which loses its growth-promoting activity on oxidation.

Recently Flint (1934) has called attention to a very interesting relationship between light and the germination of lettuce seed. Certain varieties fail to germinate unless exposed while in a moist condition to a small amount of light. In his preliminary work it is shown that light of wave lengths shorter than about 5200 A inhibits germination, while that longer than about 5200 A brings about changes resulting in germination. Furthermore, he has shown that normal or non-light-sensitive seeds could be made light-sensitive by subjecting them in a moist condition to strong blue light. These seeds would not germinate until exposed to light of wave lengths longer than 5200 A.

All of this work is very suggestive of a common photochemically responsive growth-promoting substance in these lettuce seeds and in the coleoptiles of oats. Light in the visible spectrum of wave length shorter than 5200 A exerts an inhibiting influence on the oat seedling. Likewise this same wave-length region exerts a decided inhibiting action on the germination of these lettuce seeds. However, an exposure to light of longer wave length is necessary for the germination of the light-sensitive seeds, even though the exposure is of as short a duration as one minute. This stimulating effect of the red was not noted in the phototropic experiments. All that can be said is that red light did not exert an inhibiting action. The seedlings were handled in red light, so that if a stimulating action were present, it could not be detected, since no corresponding experiments were tried in total darkness.

SUMMARY

The influence of radiation of different wave lengths on phototropism is briefly reviewed and discussed.

Experiments are described in which the plant photometer was used to determine the sensitivity of the coleoptile of *Avena sativa* to the different wave-length regions of the visible spectrum.

The phototropic sensitivity curve rises sharply from 4100 A to a maximum at 4400 A. It then drops off to a minimum at about 4575 A and again rises to a secondary maximum in the region 4700 to 4800 A. The fall is very rapid from this point to 5000 A, from where it tapers off very gradually to the threshold on the long-wave-length side at about 5461 A.

Phototropism, because of its photochemical nature, its relation to auxins and the fact that it is a specific light-growth reaction, places in the hands of the experimenter an important tool for investigating the fundamental relationship of plant growth processes to light.

LITERATURE CITED

Bachmann, Fr., and Bergann, Fr.

1930. Über die Werkigkeit von Strahlen verschiedener Wellenlänge für die phototropische Reizung von *Avena sativa*. Planta, Arch. wiss. Bot., vol. 10, pp. 744-755.

Bergann, Friedrich.

1930. Untersuchungen über Lichtwachstum, Lichtkrümmug und Lichtabfall bei *Avena sativa* mit Hilfe monochromatischen Lichtes. Planta, Arch. wiss. Bot., vol. 10, pp. 666-743.

Blaauw, A. H.

1909. Die Perzeption des Lichtes. Rec. Trav. bot. neerl., vol. 5, pp. 209-372.

1914. Licht und Wachstum. I. Zeitschr. Bot., vol. 6, pp. 641-703.

1915. Licht und Wachstum. II. Zeitschr. Bot., vol. 7, pp. 465-532.

1919. Licht und Wachstum. III. Die Erklärung des Phototropismus. Med. Landbouwhoogeschool, Wageningen, vol. 15, pp. 89-204.

Castle, E. S.

1931. The phototropic sensitivity of *Phycomyces* as related to wave length. Journ. Gen. Physiol., vol. 14, pp. 701-711.

Flint, Lewis H.

1934. Light in relation to dormancy and germination in lettuce seed. Science, vol. 80, pp. 38-40.

Hurd, Annie May.

1919. Some orienting effects of monochromatic lights of equal intensities on fucus spores and rhizoids. Proc. Nat. Acad. Sci., vol. 5, pp. 201-206.

Johnston, Earl S.

1926. A plant photometer. Plant Physiol., vol. 1, pp. 89-90.

1931. A quantitative determination of phototropic response to wave length. (Paper presented at meeting of the Amer. Soc. Plant Physiol., New Orleans, La., Dec. 29.)

Johnston, Earl S., Brackett, F. S., and Hoover, W. H.

1931. Relation of phototropism to the wave length of light. Plant Physiol., vol. 6, pp. 307-313.

Kögl, Fritz.

1933. On plant growth hormones (*auxin A* and *auxin B*). Rep. British Assoc. Adv. Sci., vol. 1933, pp. 600-609.

KÖGL, F., HAAGEN-SMIT, A. J., and ERXLEBEN, H.
1933. Über ein Phytohormon der Zellstreckung. Reindarstellung des Auxins aus menschlichem Harn. Zeitschr. Physiol. Chem., vol. 214, pp. 241-261.

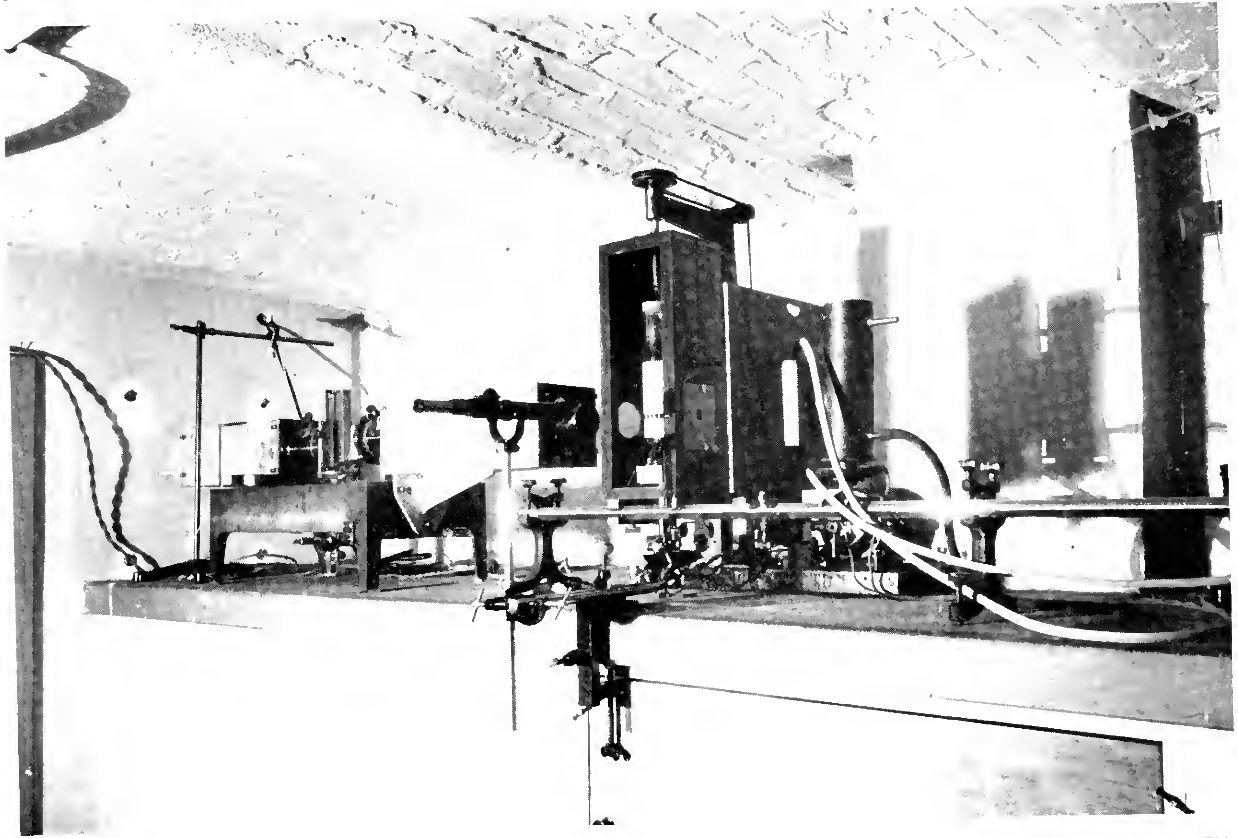
LANGLEY, S. P.
1884. Researches on solar heat and its absorption by the earth's atmosphere. U. S. War Dep., Prof. Papers Signal Service, no. 15, 242 pp. Washington.

PARR, ROSALIE.
1918. The response of *Pilobolus* to light. Ann. Bot., vol. 32, pp. 177-205.

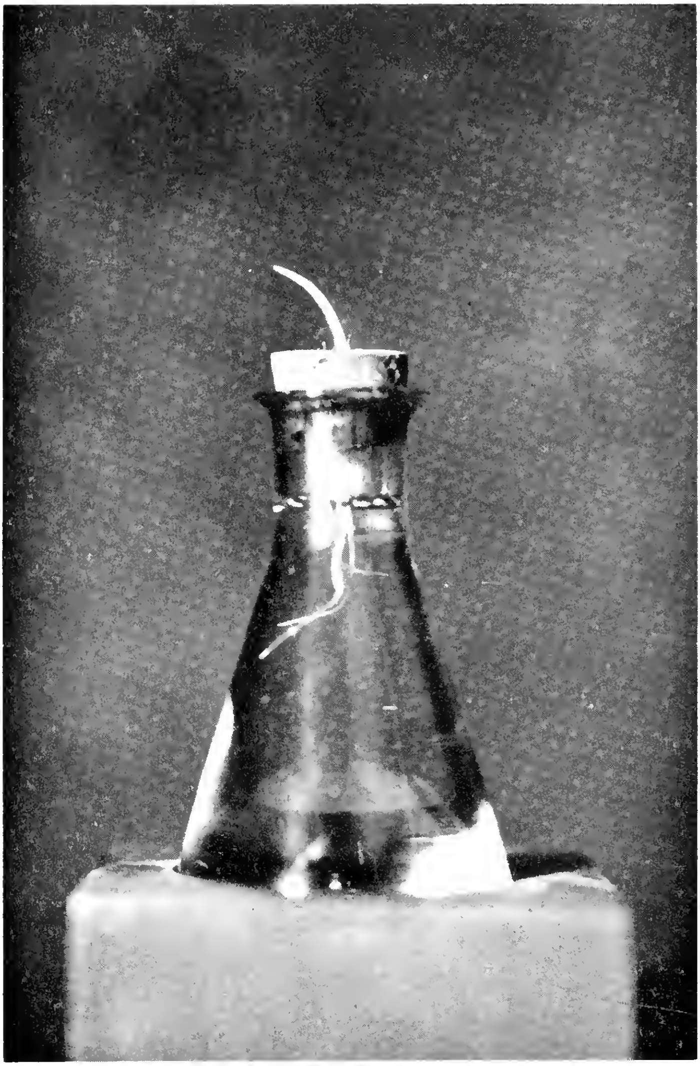
PRIESTLEY, J. H.
1926. Light and growth. III. An interpretation of phototropic growth curvatures. New Phytol., vol. 25, pp. 213-226.

SONNE, CARL.
1928-1929. Weitere Mitteilungen über die Abhängikeit der lichtbiologischen Reactionen von der Wellenlänge des Lichts. Strahlentherapie, vol. 31, pp. 778-785.

ZSCHEILE, F. PAUL, JR.
1934. An impoved method for the purification of chlorophyll *a* and *b;* quantitative measurement of their absorption spectra; evidence for the existence of a third component of chlorophyll. Bot. Gaz., vol. 95, pp. 529-562.



General View of Improved Plant Photometer with Monochromator on Left, the Plant Chamber with Front Removed and Showing Double-Walled Glass Cylinder in Center, and the Sliding Standard Light Housing to Right



PHOTOTROPIC CURVATURE OF AN OAT SEEDLING RESULTING FROM A DIFFERENCE IN WAVE LENGTHS OF LIGHT ILLUMINATING IT FROM OPPOSITE SIDES

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 12

Hodgkins Fund

REMARKABLE LIGHTNING PHOTOGRAPHS

(WITH ONE PLATE)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(PUBLICATION 3287)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 2, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

Hodgkins Fund

REMARKABLE LIGHTNING PHOTOGRAPHS

By C. G. ABBOT

Secretary, Smithsonian Institution

(With One Plate)

About 30 years ago the Institution made grants from the Hodgkins Fund to Alexander Larsen, of Chicago, to promote his studies of lightning flashes, in which he made many photographs of lightning, using a moving camera. Mr. Larsen contributed an illustrated paper on this subject to the Appendix to the Smithsonian Report for 1905.[1] He continued these experiments for several years after 1905, and in the year 1908 sent to this Institution the two extraordinary photographs shown in plate 1, with the following notes:

The print marked no. 4 [pl. 1, fig. 1] is from a plate which was the fourth one exposed on that occasion [May 29, 1908]. The camera at the time was moved with a speed of 1 revolution in 5 seconds. The flash was a very bright one, but it was so sudden and vivid that I did not notice anything peculiar about it. The thunder accompanying it was very sharp and sudden, like the report from a cannon. The interval between lightning and thunder cannot be given accurately; it was less than a second, and probably more than half a second.

The picture of this flash is very remarkable; I have never seen any one resembling it, and would prefer to call it a tubular flash on account of its general shape and large diameter, measuring, as it does, over 3 mm at its widest part, and about 2 mm at its narrowest; this great width cannot be accounted for, to be caused by the movement of the camera; the uniformity of the width, both in the vertical and horizontal portion of it, disproves that idea. It seems to be a practically instantaneous flash, coming from a NW. direction in an almost straight line at an angle of 32°, then bending suddenly, moving upward again, bending in a SW. direction, moving downward, again turning eastward making another bend, moving south slightly upward, then turning downward again.

If we assume that the nearest portion of this flash took place at a distance of 1,000 feet, which in my opinion would be a conservative estimate, we are confronted by the remarkable fact that the diameter of this flash would be over 18 feet. (The angle of the lens is 43°.)

I am absolutely at a loss to account for this remarkable flash; it does not appear to be a ribbon flash, which can be accounted for by the movement of the lightning path, by air currents, so will have to defer my opinion until some future time, and leave it to others who may be able to give a plausible explanation.

---

[1] Ann. Rep. Smithsonian Inst. 1905, pp. 119-127, 6 pls., 1906.

To summarize, will say that the flash was apparently one which took place between two clouds; it has the appearance of a very flexible tube of large diameter, was almost instantaneous, and accompanied with a heavy downpour of rain. The camera when the exposure was made was moved by hand, the camera being placed on the stand described previously and was slanted upward at an angle of 15°; the speed was 1 revolution in 5 seconds.

Temperature was 23° C. Barometer steady at 29.81 inches. Wind S.W. afterwards changing W. and N.W., with intervals of calm.

. . . .

On the same evening [July 17, 1908] a friend of mine, R. J. Spickerman, residing at 2813 Lowe Ave., about 6 miles south from my place, secured a most remarkable photograph of a flash [pl. 1, fig. 2], by means of a small $2\frac{1}{2}$ by $3\frac{1}{2}''$ film camera. A copy from the original photograph is enclosed, marked no. 9, and also an enlargement of the same, marked no. 10. In describing how he obtained the flash he said that he was sitting on the porch watching the beautiful display, and having a camera, he thought that he would try his luck in photographing, having heard me speak of it several times.

He held the camera on his lap, pointing it toward the southeast, where the most flashes were observed. He thought that he held the camera still, at the time that he secured the flash, but the photograph shows that it must have moved. It shows a meandering and very complicated flash, consisting of four distinct and separate rushes,[1] following one another in the same path, opened up by the first discharge. It is almost incomprehensible how such a complicated flash can follow all those curves and bends which the photograph shows. The only reasonable explanation to my mind would be that the path of the flash was a partial vacuum with very low resistance, which the beaded or striated appearance of this flash also would tend to confirm. How this partial vacuum can be accounted for is a difficult problem to solve. It is the first lightning photograph which I have had the fortune of seeing that shows the path in broken lines, or striated. It is this peculiarity which makes it especially interesting. I have only on one occasion observed a vertical flash which showed the path broken up in alternate light and dark divisions (it is about 4 years ago). I did not succeed in getting a photograph of it.

It is possible that those beads or striae are of similar nature as those produced in vacuum tubes, although they differ from them in this respect, that the striae in a vacuum tube are narrow (as the name implies), whereas in the flash they are wide. The word striae is really a poor term to use; beads would be more appropriate, and I shall use it hereafter when speaking of them. On the original photograph some of these beads are 1 mm long but the most of them about $\frac{1}{2}$ mm. The dark spaces between them are on the average about $\frac{1}{5}$ mm wide. Now, saying that the angle of the lens is 36°, and the distance of the flash from the camera was 10,000 feet, which is a conservative estimate, that would mean that the average length of the beads would be 36.5 feet and the average distance between them would be 14.6 feet. Of course these figures are only approximate; they only give an idea for comparison between the striae in a vacuum tube and those in the flash. These divisions seem to have been of a stationary nature,

[1] I think I can see six separate rushes.—C. G. A.

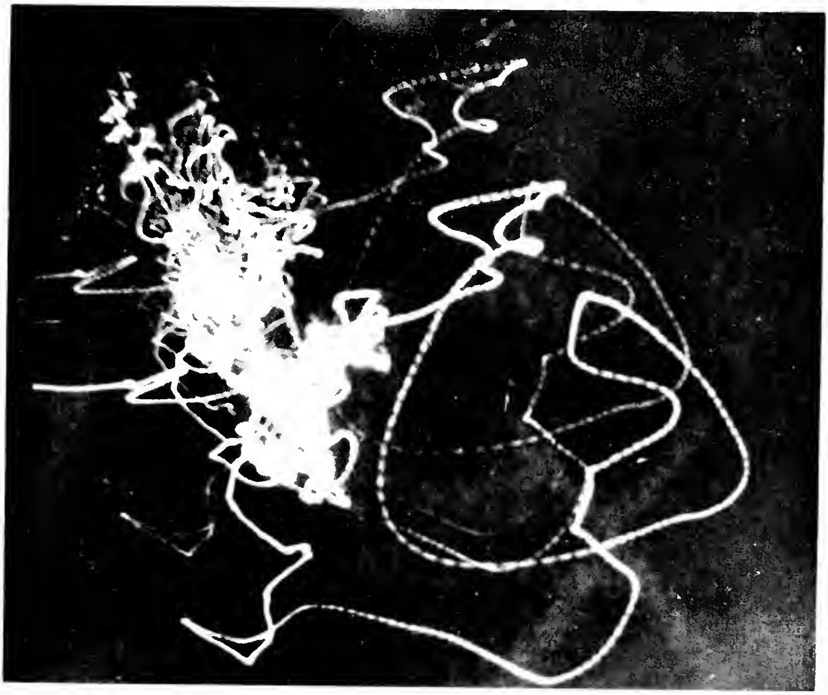
occupying the same relative positions on the different rushes; in that respect they behave somewhat like the striae in a vacuum.

It is possible that these beads in reality were not as wide as they appear, the apparent width being caused by their intense light causing halation to a certain extent. The whole flash seems to be made up of these alternate light and dark spaces; in some places of the picture, where the flash was moving either away from or toward the observer, it shows the beads very close together, forming almost unbroken lines, but judging from the general appearance, it seems that the divisions are of about uniform dimensions. When this picture was taken there was a continual display of meandering flashes, lasting for over an hour. No rain was falling, and Mr. Spickerman judged the lightning to be about ½ mile above the ground. The flash is certainly very interesting, and I think that it deserves to be reproduced in the yearly report of the Institution, if possible, together with the photograph taken by me on May 29, marked no. 4 in my last report.

The barometer reading at 7 p.m. = 758.5 mm. Temperature = 29° C. Relative humidity 80 percent. Wind, west.

B. F. J. Schonland, of the University of Cape Town, Union of South Africa, has lately been making somewhat similar experiments in lightning photography, on which he reported at the meeting of the National Academy of Sciences at Washington, in April, 1934. Mr. Schonland, calling at the Smithsonian Institution, examined Mr. Larsen's photographs and expressed a particular interest in the one here shown as plate 1, figure 1. At his suggestion this publication is made, and it seemed to the writer interesting to include also figure 2.

1. Photograph by A. Larsen of lightning flash between clouds near Chicago on May 29, 1908. Camera moving about a vertical axis. Speed one revolution in 5 seconds.



2. Photograph by R. J. Spickerman of lightning flash between clouds near Chicago on July 17, 1908. Camera held stationary in the lap of the operator.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 13

THE STANDARD SCALE OF SOLAR RADIATION

BY
G. G. ABBOT AND L. B. ALDRICH
Smithsonian Institution

(PUBLICATION 3288)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 2, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE STANDARD SCALE OF SOLAR RADIATION

By C. G. ABBOT and L. B. ALDRICH
Smithsonian Institution

We published about 2 years ago[1] a description of the double-chamber compensation water-flow pyrheliometer No. 5 and the results of comparisons made between it and silver-disk pyrheliometer S.I.5_{bis}. These results indicated that the Smithsonian radiation scale of 1913 was 2.5 percent too high, but on account of certain defects in the sensitive parts of the water-flow pyrheliometer No. 5 we felt that further comparisons were needed before accepting that correction.

The thermoelectric junctions, which were imperfectly soldered in 1932, have been removed and replaced by others securely melted together. Every care was used in reassembling the instrument to guard against all conceivable sources of error. We have employed the instrument on Mount Wilson in July 1934 to restandardize silver-disk pyrheliometer S.I.5_{bis}. Besides the diaphragms within the boxed instrument shown in plate 1, figure 3 of our former publication, we invariably used in addition in 1934 the double polished screen described in lines 34-40, page 4, of our former publication, whereby the water-flow pyrheliometer No. 5 was limited to observe precisely the same sky area as the silver-disk pyrheliometer S.I.5_{bis}. All other arrangements were precisely like the best ones described in our former paper. During most of the days observed in 1934 the sky was of exceptional clearness, and observations were made only at high sun. The temperature of the different days varied so much that on some comparisons silver-disk pyrheliometer S.I.5_{bis} was read at 46° C., while on some other occasions its readings were as low as 26°, with all intermediate temperatures between these extremes represented in the several series. We were unable to detect any differences in results showing any influence of this large range in temperatures.

As stated in our former paper, the entire measurement made with the compensation water-flow instrument consists in a determination of the energy of the compensating electric current. Equivalence between solar and electric heating in the two opposed chambers is indicated by

[1] Smithsonian Misc. Coll., vol. 87, no. 15, 1932.

a null reading of the sensitive galvanometer connected into the thermoelectric circuit whose two sensitive junctions are in the outflowing currents of water issuing from the two chambers. In preparing for a series of readings, both chambers were opened simultaneously to the sun rays, and the adopted zero of the galvanometer was that which subsisted during this preliminary joint exposure. After the conclusion of a series, the zero was again determined in the same way, and sometimes was found to have changed a little. Nevertheless, error from such a drift of zero is approximately eliminated by the device of alternately exposing the two chambers to solar and electrical heat. For if owing to an unknown drift of the real zero the electrical energy is determined too large within one chamber, it will be found for the same reason too small in the other immediately afterward by about an equal amount. To secure complete elimination, we took one more electrical measurement on one side than on the other and made our comparisons as between $\frac{\text{West plus West}}{2}$ and East. Users of the Ångström compensation pyrheliometer will have employed and will appreciate this corrective principle. In fact we found no appreciable difference in the results of the various series as between occasions when the drift of the galvanometer zero was relatively large and relatively small, respectively.

The total deflection for uncompensated solar heating ranged from 3 to 10 centimeters on the scale of the galvanometer, depending on the rate of flow of the water current used on different days. The zero observation could be made to a tenth of a millimeter or better, corresponding to from $\frac{1}{300}$ to $\frac{1}{1000}$ of the total deflection. No systematic difference in results depending on the rate of flow of the water current could be detected.

During the entire campaign of comparisons, the silver-disk pyrheliometer was read by C. G. Abbot, with timing by the eye and ear method, listening to beats electrically sounded from an accurate seconds pendulum. The galvanometer and current measurements were made by L. B. Aldrich.

To determine the electrical energy of compensation, an electric current from storage batteries was passed through slide wire resistances, thence to a milliammeter, and thence to the manganin heating coils within the pyrheliometer chambers. The resistances of these heating coils were repeatedly measured on a standard Wheatstone's bridge. They were found to be identical to within less than $\frac{1}{1000}$ with the resistances of the same coils in 1932. The readings of current on the milliammeter ranged between 50.0 and 63.0 on its scale, and could usually be read to somewhat better than $\frac{1}{600}$, possibly to $\frac{1}{1000}$.

The milliammeter, with its position and surroundings unchanged, was calibrated against two standard cells which were obligingly checked against standards between two of our comparisons by a member of the staff of the California Institute of Technology, and found highly accurate. We believe that we have measured the pyrheliometer currents by these methods to better than $\frac{1}{500}$, possibly to $\frac{1}{1000}$. As the current enters the formula in its square, the error due to inaccuracy of current measurements may reach 0.5 percent but is believed to be less. Accidental errors of the standardization of silver-disk pyrheliometer S.I.5_{bis} against the water-flow pyrheliometer are to a great extent eliminated by the numerous repetitions of the comparisons.

We now give in the following table a summary of the results of the standardization.

Date	No. of comparisons	Temperature range of S.I.5_{bis}	Mean value of constant S.I.5_{bis}
1934		° Centigrade	
July 12	5	35-46	0.3667
" 14	6	31-42	0.3641
" 15	6	30-40	0.3626
" 16	5	33-42	0.3615
" 17	11	29-38	0.3622
" 20	9	26-34	0.3619
Total	42	Mean	0.3629

This mean value is 2.3 percent below the value 0.3715, which, as stated in our former paper, represents the Smithsonian scale of 1913. The defect 2.3 percent is in close agreement with the defect 2.5 percent indicated by our results of 1932. But on account of the numerous observations and highly satisfactory conditions prevailing in 1934, we prefer to attach full weight to the correction 2.3 percent. The causes which may have contributed to the higher scale found in 1913 are fully discussed in our former paper.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 13

THE STANDARD SCALE OF SOLAR RADIATION

BY
C. G. ABBOT AND L. B. ALDRICH
Smithsonian Institution

(PUBLICATION 3288)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
NOVEMBER 2, 1934

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE STANDARD SCALE OF SOLAR RADIATION

By C. G. ABBOT and L. B. ALDRICH
Smithsonian Institution

We published about 2 years ago[1] a description of the double-chamber compensation water-flow pyrheliometer No. 5 and the results of comparisons made between it and silver-disk pyrheliometer S.I.5_{bis}. These results indicated that the Smithsonian radiation scale of 1913 was 2.5 percent too high, but on account of certain defects in the sensitive parts of the water-flow pyrheliometer No. 5 we felt that further comparisons were needed before accepting that correction.

The thermoelectric junctions, which were imperfectly soldered in 1932, have been removed and replaced by others securely melted together. Every care was used in reassembling the instrument to guard against all conceivable sources of error. We have employed the instrument on Mount Wilson in July 1934 to restandardize silver-disk pyrheliometer S.I.5_{bis}. Besides the diaphragms within the boxed instrument shown in plate 1, figure 3 of our former publication, we invariably used in addition in 1934 the double polished screen described in lines 34-40, page 4, of our former publication, whereby the water-flow pyrheliometer No. 5 was limited to observe precisely the same sky area as the silver-disk pyrheliometer S.I.5_{bis}. All other arrangements were precisely like the best ones described in our former paper. During most of the days observed in 1934 the sky was of exceptional clearness, and observations were made only at high sun. The temperature of the different days varied so much that on some comparisons silver-disk pyrheliometer S.I.5_{bis} was read at 46° C., while on some other occasions its readings were as low as 26°, with all intermediate temperatures between these extremes represented in the several series. We were unable to detect any differences in results showing any influence of this large range in temperatures.

As stated in our former paper, the entire measurement made with the compensation water-flow instrument consists in a determination of the energy of the compensating electric current. Equivalence between solar and electric heating in the two opposed chambers is indicated by

[1] Smithsonian Misc. Coll., vol. 87, no. 15, 1932.

a null reading of the sensitive galvanometer connected into the thermoelectric circuit whose two sensitive junctions are in the outflowing currents of water issuing from the two chambers. In preparing for a series of readings, both chambers were opened simultaneously to the sun rays, and the adopted zero of the galvanometer was that which subsisted during this preliminary joint exposure. After the conclusion of a series, the zero was again determined in the same way, and sometimes was found to have changed a little. Nevertheless, error from such a drift of zero is approximately eliminated by the device of alternately exposing the two chambers to solar and electrical heat. For if owing to an unknown drift of the real zero the electrical energy is determined too large within one chamber, it will be found for the same reason too small in the other immediately afterward by about an equal amount. To secure complete elimination, we took one more electrical measurement on one side than on the other and made our comparisons as between $\frac{\text{West plus West}}{2}$ and East. Users of the Ångström compensation pyrheliometer will have employed and will appreciate this corrective principle. In fact we found no appreciable difference in the results of the various series as between occasions when the drift of the galvanometer zero was relatively large and relatively small, respectively.

The total deflection for uncompensated solar heating ranged from 3 to 10 centimeters on the scale of the galvanometer, depending on the rate of flow of the water current used on different days. The zero observation could be made to a tenth of a millimeter or better, corresponding to from $\frac{1}{300}$ to $\frac{1}{1000}$ of the total deflection. No systematic difference in results depending on the rate of flow of the water current could be detected.

During the entire campaign of comparisons, the silver-disk pyrheliometer was read by C. G. Abbot, with timing by the eye and ear method, listening to beats electrically sounded from an accurate seconds pendulum. The galvanometer and current measurements were made by L. B. Aldrich.

To determine the electrical energy of compensation, an electric current from storage batteries was passed through slide wire resistances, thence to a milliammeter, and thence to the manganin heating coils within the pyrheliometer chambers. The resistances of these heating coils were repeatedly measured on a standard Wheatstone's bridge. They were found to be identical to within less than $\frac{1}{1000}$ with the resistances of the same coils in 1932. The readings of current on the milliammeter ranged between 50.0 and 63.0 on its scale, and could usually be read to somewhat better than $\frac{1}{600}$, possibly to $\frac{1}{1000}$.

The milliammeter, with its position and surroundings unchanged, was calibrated against two standard cells which were obligingly checked against standards between two of our comparisons by a member of the staff of the California Institute of Technology, and found highly accurate. We believe that we have measured the pyrheliometer currents by these methods to better than $\frac{1}{500}$, possibly to $\frac{1}{1000}$. As the current enters the formula in its square, the error due to inaccuracy of current measurements may reach 0.5 percent but is believed to be less. Accidental errors of the standardization of silver-disk pyrheliometer S.I.5_{bis} against the water-flow pyrheliometer are to a great extent eliminated by the numerous repetitions of the comparisons.

We now give in the following table a summary of the results of the standardization.

Date	No. of comparisons	Temperature range of S.I.5_{bis}	Mean value of constant S.I.5_{bis}
1934		° Centigrade	
July 12	5	35-46	0.3667
" 14	6	31-42	0.3641
" 15	6	30-40	0.3626
" 16	5	33-42	0.3615
" 17	11	29-38	0.3622
" 20	9	26-34	0.3619
Total	42	Mean	0.3629

This mean value is 2.3 percent below the value 0.3715, which, as stated in our former paper, represents the Smithsonian scale of 1913. The defect 2.3 percent is in close agreement with the defect 2.5 percent indicated by our results of 1932. But on account of the numerous observations and highly satisfactory conditions prevailing in 1934, we prefer to attach full weight to the correction 2.3 percent. The causes which may have contributed to the higher scale found in 1913 are fully discussed in our former paper.

From a painting by E. G. Cassedy.

BAY ISLAND POLYCHROME I VASE WHICH CONTAINED CENTRAL VOTIVE CACHE, DIXON SITE, ROATAN

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 92, NUMBER 14
(End of Volume)

ARCHEOLOGICAL INVESTIGATIONS IN THE BAY ISLANDS, SPANISH HONDURAS

(With 33 Plates)

BY
WILLIAM DUNCAN STRONG
Anthropologist, Bureau of American Ethnology

(Publication 3290)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
FEBRUARY 12, 1935

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

CONTENTS

ILLUSTRATIONS

PLATES

TEXT FIGURES

ARCHEOLOGICAL INVESTIGATIONS IN THE BAY ISLANDS, SPANISH HONDURAS

By WILLIAM DUNCAN STRONG
Anthropologist, Bureau of American Ethnology

(With 33 Plates)

INTRODUCTION

The following report is based primarily on an archeological reconnaissance of the Bay Islands carried out by the Smithsonian Institution during the months of April and May, 1933. In June and July, 1931, the Boekelman Shell Heap Expedition of the American Museum of Natural History had made a similar survey of the islands. Through the courtesy of the latter institution and of Junius Bird, archeologist of the Boekelman Shell Heap Expedition, I have been permitted to include their data with ours—a happy combination, since the results of both expeditions overlap and supplement one another in many ways. Prior to either of the above investigations, in 1930, and again in 1931, Mr. Mitchell-Hedges, working under the auspices of the Museum of the American Indian, Heye Foundation, spent several months on the Bay Islands and gathered together a very large number of fine specimens. Through the courtesy of the Museum of the American Indian, I have briefly studied this collection, which is assigned to the various islands but is without data as to sites or exact provenience. On this account, and because adequate description would require a separate report, I have used the Mitchell-Hedges material mainly for general comparative purposes.

The itinerary of the Boekelman Shell Heap Expedition was as follows: June 30, 1931, the schooner *Clodia* arrived at Utila Island; July 10, left Utila for Roatan Island; July 17, left Roatan for Bonacca Island; and July 22, left Bonacca for the mainland. The Smithsonian Expedition on the motorboat *Amigo* arrived at Roatan Island April 25, 1933; reached Helena Island May 6; left Helena for Barburata Island May 7; visited Morat Island May 11; arrived at Bonacca Island May 12 and left May 17; arrived at Utila Island May 18 and left May 21 for Roatan. From Roatan we returned to the mainland on May 23. Thus, together, the two expeditions spent only 48 days on the islands. Both lack of time and the circumstances of each expedition made exhaustive researches impossible. However, the results attained and the problems defined seem worthy of publication. From the archeological standpoint not only the Bay Islands but also the major portion of the Spanish Honduras mainland form an important and little-known field.

The Bay Island survey of the Smithsonian Institution was an extension of a plan conceived and organized by A. W. Payne, research associate of Johns Hopkins University, to conduct an archeological investigation of the Patuca River region of northeastern Honduras. The work of the expedition was financed throughout by Norman A. Haskell, a student in geology at Harvard University. Mr. Payne, Mr. Haskell, and the writer comprised the expedition, which was in the field from February to July, 1933. I am especially indebted to Mr. Haskell for sketch maps of Bay Island sites used in this paper. Dr. L. S. Rowe and other officials of the Pan American Union furnished maps, advice, and other valuable assistance. To Junius Bird I am indebted for the use of his excellent notes, photographs, and collections now in the American Museum of Natural History. At the latter institution Dr. Clark Wissler, N. C. Nelson, Dr. George Vaillant, and Miss Bella Weitzner were all extremely helpful in my work. For much comparative data, manuscript material, and advice I am especially grateful to both Dr. Vaillant and Dr. Samuel K. Lothrop. At the Museum of the American Indian, Heye Foundation, Charles Turbyfill aided me greatly.

In Honduras the officials of the Government at Tegucigalpa and the Governor of the Bay Islands, Señor Charles Osgood, made our work possible and extended us many courtesies. Similarly the officials of the United Fruit Company, and of the Truxillo Railroad Company at Puerto Castilla, assisted us throughout the entire expedition in every conceivable manner. For this, and for very many personal courtesies we are extremely grateful. Thanks are also due to Captain Boynton, of Oak Ridge, Gerald Borden, Joe Saba, and the other members of the crew of the *Amigo,* who were willing workers and good companions.

At the National Museum E. P. Henderson made numerous mineral identifications, H. A. Rehder identified various molluscan remains, Gerrit S. Miller, Jr., identified mammal remains, and Dr. George S. Myers identified fish and reptile bones. For this assistance I am extremely grateful. Dr. Dale Stewart has examined our small and fragmentary collection of human skeletal remains, but this, as well as Mr. Bird's more extensive collection of crania, will be reported on by

others at a later time. The frontispiece and the text figures in the present report are the work of E. G. Cassedy, artist of the Bureau of American Ethnology. Finally, I am very grateful to my wife, Jean Stevens Strong, for numerous translations and other technical and critical assistance.

ENVIRONMENTAL BACKGROUND

"Las Islas de la Bahia" are a charming and comparatively little-known group of islands 10 to 40 miles north of the northern coast of Spanish Honduras. Located on the Caribbean Sea, not far east of the entrance to the Gulf of Honduras, they are clearly visible from the mountainous mainland (see map, fig. 1). The group is made up of three large islands, Utila (Utilla),[1] Roatan (Roatán, Ruatan, Guayama), and Bonacca (Guanaja, Guanassa), and the smaller islands, or island groups, Helena (Masa, Elena, Helen), Barburata (Borburata, Barbareta, Barbaretta), Morat (Goamoreto, Murat), and, closest to the mainland, the two Hog Islands (Cayos Cochinos). Roatan is the largest with a length of about 30 miles and a maximum width of 9 miles. Helena is really a small eastern extension of Roatan, being separated by a mangrove swamp and a narrow, in part artificial, channel. Bonacca is the second largest and is even more mountainous than Roatan. Utila is third in size and is low, swampy, and heavily forested. Barburata, Morat, and the Hog Islands are all small and rugged. With the exception of low-lying Utila, the islands, covered with dark green forest, rise majestically out of the blue tropical sea in a most alluring fashion.

The island chain is formed by the tops of a great submerged east-to-west mountain range, around which coral reefs have formed and rich soil has accumulated. Bonacca is the highest of the islands, a peak near the center reaching 1,200 feet. Roatan has a mountainous west-to-east backbone which reaches a height of 800 feet at the western end. Utila is the lowest of all, having only one hill 290 feet high at the eastern end. The formations are for the most part limestone, and the islands are surrounded by intricate coral reefs, some above the surface of the sea but most of them marked only by white lines of breaking surf. In the interior valleys a rich alluvial soil occurs, the product of decaying vegetation, and the hills are covered with red clay, which usually supports a dense vegetation. There are no rivers on any of the

[1] I follow the orthography given in the 1925 edition of the U. S. Hydrographic office, "Map of the Western Shore of the Caribbean", except that the names Borburata and Murat are changed to Barburata and Morat to conform to local usage. The following brief ecological account is based on standard works on the region, the majority of which will be cited later, and on personal observation.

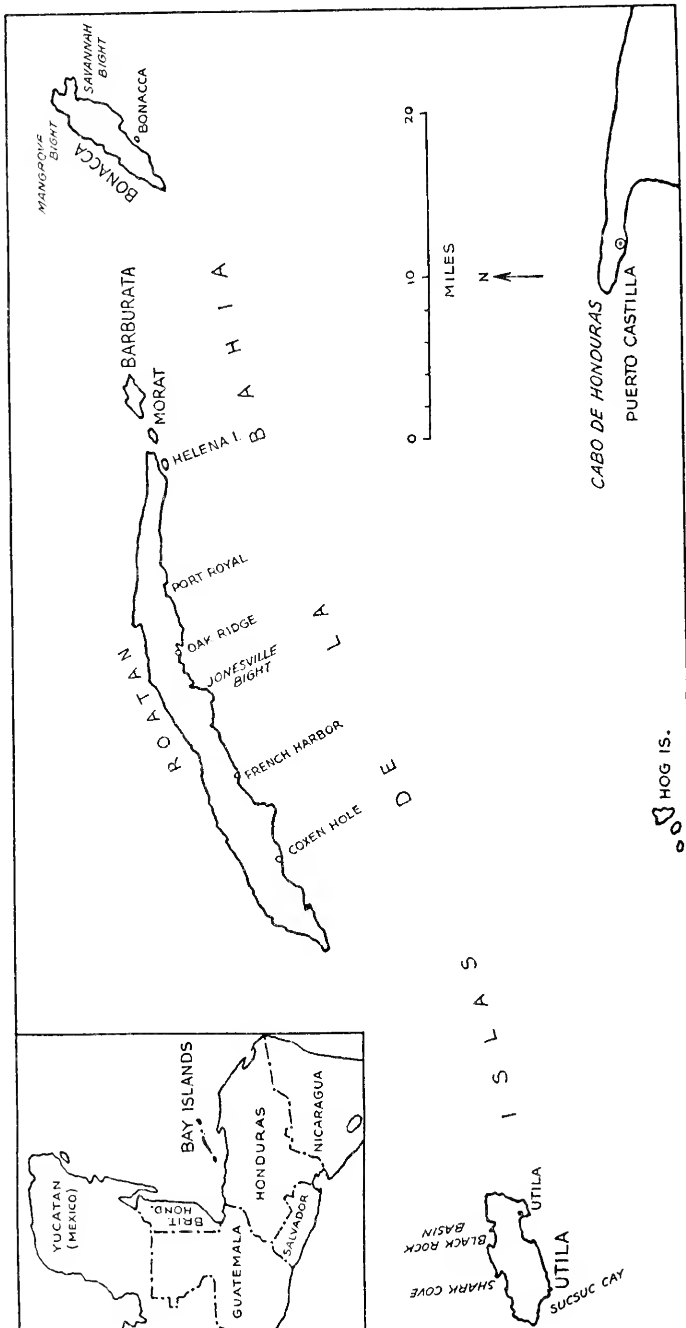


FIG. 1.—Map of the Bay Islands.

islands and only a few small streams, often terminating in the many mangrove swamps. Springs of good water are rather numerous. Roatan is marked by a number of salt-water lagoons or drowned valleys, which form a system of interior waterways on the south side.

All the main harbors are on the protected southern shores away from the prevalent northeast trade winds. From west to east these consist of East Harbor on Utila; Coxen Hole, Dixon Cove, French Harbor, Oak Ridge, and Port Royal (formerly important, but practically deserted at present) on Roatan; and Bonacca Harbor within the reefs on the southwest tip of Bonacca Island. Only a few scattered families of Black Caribs live along the northern shore of Roatan, and on all the islands the population centers on the side toward the mainland. Access from the mainland is simple, and small native craft ply back and forth at all seasons. The period from November to February, however, is dangerous, owing to frequent "northers," which may do much damage. From the middle of June to the middle of August the islands are subject to squalls, and revolving storms or hurricanes occur occasionally at this time of year. However, the Islanders are a maritime people and are not often caught out under such circumstances.

The climate is similar to that of the adjacent mainland of Honduras but is said to be cooler, owing to the surrounding water. The temperature is lowest during the rainy season from September to February, which is a period of heavy showers rather than steady rain. It is not oppressive during the dry season and the nights are usually pleasantly cool. Along the shores the cool sea breeze is pleasant, but the densely forested interior valleys are often stifling. The islands are said to be more healthful than the mainland and have not been subjected to cholera or other epidemics that have ravaged that region. The British colony on the Mosquito Coast prior to 1778 sent malaria patients to Bonacca, where they recovered rapidly.[2] However, malaria does occur to some extent, and there are numerous mosquitoes, sand flies, and bottle flies on the islands, though in April and May they were not nearly so bad as on the mainland. To escape the mosquitoes, and for the sake of coolness, the town of Bonacca has been built on low cays out in the harbor. Rheumatism is reported as having been very prevalent[3] and apparently is still rather widespread. Beyond these superficial observations I dare not go.

---

[2] Young, 1842. Rose, 1904, chap. 12, describes a smallpox epidemic on Utila in 1891.

[3] Mitchell, 1850. Quoted at some length by Squier, 1858, pp. 116-121. This account gives a rather detailed picture of Bay Island conditions in the middle of the nineteenth century.

The island flora is abundant, and, as would be expected, is very similar to that of the mainland.[4] Large numbers of pines grow on some of the higher ridges, especially on Bonacca, which led Columbus to call it the " Isle of Pines ". Other portions exhibit complete rain forest characteristics, with tall hardwood trees, lianas, epiphytic plants, and a dense lower layer of small palms and shrubs. Many of the higher slopes are covered with cohune or corozo palms, some of the lower lands and sand spits support large groves of coconut palms, and gloomy mangrove swamps fringe considerable portions of the shore line. Savannas are rare, but small open areas occur, especially on Bonacca and Utila. The fauna of the islands is also basically that of the mainland minus practically all of the larger mammalian and many of the larger avian species. In regard to flora and fauna it would be of great interest to know what relation the Bay Islands bear to the Antilles, which, though almost 400 miles distant, probably have exerted some influence, since both wind and ocean currents bear from that direction. There are no large mammals in the Bay Islands except the manatee; jaguar, ocelot, tapir, deer, peccary, and monkeys do not occur. The agouti or " watusa ", a rodent the size of a large hare, is the main island game animal. The raccoon is probably also present on the islands. The domestic hog was introduced into the Bay Islands by Cortez in 1525 or 1526 and spread rapidly in a wild state. (Conzemius, 1928, p. 62.) The avifauna of the islands appears to be somewhat limited, especially as regards land birds. The curassow, guans, and macaws are absent. There are two species of parrots, which are still very numerous. Of these, the yellow-headed species (*Chrysotis auripalliata*) has long been highly regarded as a pet on account of the facility with which it learns to talk, and its export from the islands began at a very early date. (Conzemius, 1928, p. 63.) Black vultures, blue pigeons, small woodpeckers, grackles, large brown cuckoos, flycatchers, warblers, and vireos were observed on all the islands. Water birds are numerous; herons, egrets, ibis, pelicans, and frigate birds were particularly noted.

Among the lower orders, snakes are not particularly abundant, and we saw none during our visit. The deadly fer-de-lance and the rattlesnake are said not to occur. The "*tomagoff*" (sp. ?), a smaller form said to be related to the fer-de-lance, does occur, but strange to say is not thought to be dangerous. Other snake species are undoubtedly present, and many iguanas and other smaller lizards abound, especially in the coconut groves. Of larger reptiles, both

[4] For a brief summary of the ecology of the Mosquito Coast, see Conzemius, 1932, pp. 1-8.

the crocodile and the caiman occur, but we saw neither. Fish, as would be expected, are a very abundant source of food; a large number of species occur. Sharks of various species are numerous, but do not seem to be as much feared by the natives as are the many barracuda. Mollusca abound, the various whelk and conch species being an important item of island diet, as are the large crayfish. The teeming insect life is probably similar to that of the mainland; the troublesome mosquitoes, sand flies, and bottle flies of the coast have already been mentioned, and horseflies are annoying in the bush. Wherever domestic stock is abundant, the small red ticks or "garrapatas" are a great source of annoyance to man. So much for the natural setting; the colorful history of the Bay Islands will now be briefly sketched in.

HISTORICAL AND ETHNOLOGICAL BACKGROUND

The question as to what white men first "discovered" the Bay Islands and the adjacent mainland of Honduras is one that an archeologist may justly shy away from. According to Fiske, it was the trio, Vincente Yañez Pinzon, Juan Diaz de Solis, and Americus Vespucius, in the years 1497-1498.[5] This date has been discounted by various other historians, who claim that the evidence of their association and voyage is too tenuous for acceptance. Fortunately, it is a matter of slight importance in the present connection, since neither Pinzon, Solis, nor Vespucius have left any observations that can be referred to the Bay Islands.

One is on safe ground, however, in regard to the fourth and last voyage of Columbus. The great Admiral sighted the island of Bonacca (Guanaja) on July 30, 1502, and it was from this place that he first gazed upon the Central American mainland, searching in vain for the great cities of Asia that, to the day of his death, seemed just beyond his farthest voyaging.

Besides the Admiral's, there are some five eye-witness accounts of this voyage.[6] In addition, the historians, Las Casas, Peter Martyr,

[5] 1892, II, chap. 7. Fiske believes that these three, inspired by the second voyage of Columbus, sailed from Spain to the Bay Islands and the mainland near Cape Gracias á Dios, and thence north up the coast perhaps as far as Chesapeake Bay. This voyage of Pinzon and Solis is usually given the date of 1506, assigned by Herrera (see Conzemius, 1928, p. 59, and Navarrette, 1829, p. 46), but Fiske cites Gomara, Oviedo, and other sources indicating that it was prior to 1500.

[6] The letter of Columbus to the Spanish Sovereigns, written from Jamaica in 1503, Hakluyt Society, 1847, pp. 169-203; the letter of Diego de Porras, Navarette, 1829, I, pp. 283-284; the Testament of Diego Mendez, in 1536, Hakluyt

and Herrera give very complete accounts.[7] Of these the first two are especially valuable. While Las Casas was writing his great work at Valladolid, between 1552 and 1561, he had access to all the invaluable letters and papers collected by Ferdinand Columbus, and in addition he was intimately acquainted with the family of the great explorer. Peter Martyr was also a personal friend of many of the explorers, and owing to his high position in the Council of the Indies, he had ample opportunity to satisfy his intense personal interest in the new lands of which Europe was then just becoming fully aware. Herrera compiled his material at a later date.

Columbus himself, merely mentions Bonacca, which he called the "Isle of Pines". In regard to the mainland to the south and east he mentions that the natives used sails, had elaborate cotton textiles, worked copper with crucibles and forges, and that in Cariay (the Mosquito Coast) he saw an elaborately sculptured sepulcher and heard of others. The people, he says, were fishermen and barbarians speaking many languages and adds that he saw more gold in Veragua (northern Panama) in 2 days than he had seen in the Antilles in 4 years. This letter in its totality is one of the most tragic documents in history.

De Porras says that Bonacca would measure 20 leagues around but that it contained nothing of benefit, presumably gold or treasure. He describes its inhabitants as a warlike people of good stature, who were archers. From Bonacca he states that the adjacent mainland appeared high and near, being only 10 leagues distant. From this island they took an Indian to translate for them, who gave them the names of some of the mainland provinces. De Porras stresses the savage nature of the peoples to the south, who were so cautious that groups living only 20 leagues apart did not understand each other. The testament of Diego Mendez does not mention the Bay Islands.

In the Probanzas of Diego Columbus is the testimony of Pedro de Ledesma, pilot and captain of the warship *Vizcaino*. Ledesma states that "12 leagues before the mainland they found an island that the Indians called Guanaja and the Admiral called 'of Pines' where

Society, 1848, pp. 204-234; the Probanzas of Diego Columbus, in 1515, Navarette, 1825-1829, III, p. 556; the letter written by Bartholomew Columbus, in 1505 or 1506, Harrisse, 1866, p. 473; and the "Historie del S. D. Fernando Colombo; Nelle quali s' ha particolare, & vera relatione della vita, & de' fatti dell' Ammiraglio D. Christoforo Colombo, suo padre . . . . etc. In Venetia, MDLXXI. Appresso Francesco de' Franceschi Sanese." The edition here cited is the reprint of London, 1867, Cap. 88, pp. 288-296. See Columbus, Ferdinand.

[7] Las Casas, 1875, II, chap. 20; Herrera, 1726-1730, Dec. 1, Lib. V, Cap. V; and Peter Martyr, 1812, 4th chap. of 3rd decade, pp. 481-482.

they leapt ashore and talked with a Señor who called himself Imbibe, and from here they crossed over toward the mainland which is called the land of Maya in the language of the Indians and from here to the coast ahead as far as a cape which the Admiral called Gracias á Dios". Bartholomew Columbus states that "The Island of Banassa which they discovered here has very robust people who worship idols. Their food is mostly a certain bleached grain the height of a *cesare* which grows just as it grows in the *ballcare* in clumps, from which they make excellent bread. . . . . In this place they took a ship of theirs (the natives) loaded with merchandise and wares and were told that it came from a certain province called *Maiam* or *Iuncatam*[8] with many garments of silk [sic] of diverse colors."

Ferdinand Columbus was a boy of only fourteen when he accompanied his father on his last voyage. Subsequently he gathered together a great library of books and manuscripts pertaining to the discoveries of the period. This magnificent collection, some 20,000 volumes, furnished the source material for most of the early historians, but about four-fifths of the collection has now disappeared. The "Historie" written by Ferdinand Columbus, survives only in the Italian translation of Alfonso Ulloa. It is thought that the latter may have tampered with the text in places.[9] Las Casas apparently had access to the same manuscript sources and the concurrence of the two accounts, at least regarding this immediate region, is close. Las Casas will be quoted at some length and only additional facts in the "Historie" need be given here, for some of these seem to have the human touch of an eye witness not found elsewhere.

Ferdinand called the island Guanara, and locates it 12 leagues from the mainland near the point his father called "Casine". Later, in 1508, he says, this point was designated as the Cape of Honduras on the voyage of Solis. The island contained nothing of worth save pieces of earth called *calcide*, from which copper is smelted, and some of the sailors, thinking this was gold, kept pieces for a long

---

[8] Lothrop 1924, p. 13, and 1928, pp. 354, 355, points out that the word "Yucatan", a Spanish corruption of the native phrase, did not come into use until 1517, whereas this letter was written in 1505 or 1506. The original document bears out this contention inasmuch as the words "vel Iuncatam" are superscribed over the word "Maiam" and do not belong to the original text. See Brinton, 1882, p. 10. Lothrop concludes that this touched-up passage is doubtless the source of the assertion of later historians (and ethnologists) that the captured canoe came from Yucatan.

[9] Harrisse, 1871, and elsewhere, has attacked the authenticity and value of the "Historie", but Fiske, 1892, I, p. 340, defends it as "of priceless [historical] value".

time. While his half brother, Bartholomew, was ashore, a canoe laden with merchandise arrived from the western parts toward New Spain. Of the flint-edged, wooden swords in the cargo Ferdinand says that they cut naked men like steel, and he remarks on their copper axes which were similar to the stone axes of other Indians. He mentions their maize drink " similar to English beer " and says of the cacao nuts that they were so highly valued that if one fell " everyone bent to seize it, as if it had been their eye ". Columbus released all but " one old man called Giumbe, of good authority and prudence " who served faithfully as guide and interpreter " wherever his language was understood ". When they reached an area where it was not understood, " which was before we arrived at Cape Gracias á Dios on the coast of Orecchia ", he was given presents and sent back to his own country " very contented ".

Columbus, according to Ferdinand, proceeded to Casine from Guanara. Here the people were of the same disposition as those of the other island (Bonacca), who did not have such broad foreheads. There were many languages among them, and the Spaniards had to talk by signs since their interpreter had been with them too short a time to know their language, nor did he know the Indian language of Hispaniola, which many of the sailors had learned.[10] The people who lived near Casine wore the same sort of painted shirts and small squares over their loins as those who were in the trading canoe. Some wore shirts like those of the Spaniards, reaching to the navel and without sleeves. They made breastplates of cotton which turned the blows of their own weapons and even those from some of the Spanish arms. Their arms and bodies were decorated with burned or painted designs of lions, deer, turreted castles, and other diverse figures. The more noble wore small squares of white and red cotton instead of caps, and some had tassels of hair hanging on the forehead. The faces of some were dyed black, others red, and some streaked, while still others blackened their eyes or wore bird beaks, all of which they believed made them beautiful, but to the Spaniards they appeared as devils. They brought several hundred loads of provisions, including excellent chickens of their country, roasted fish, red and white beans similar to kidney beans, and other things

[10] This is a somewhat obscure passage: " Il prefetto allor comandò che fossero lor donati sonagli, e *Ave Marie*, e altre cosette: e dimandò loro per segni delle cose della regione per lo interprete sopraddetto: ancorchè, per esser poco tempo, che era con noi, non intendeva i cristiani, per la distanza, come che poca, della sua terra della Spagnuola, ove molti de'navigli aveano appreso il parlare indiano: nè meno intendeva gl'istessi Indiani; . . . ."

as presents. Having delivered their presents they fell back without saying a word.

Of the people to the east, as far as Cape Gracias á Dios, he says that they were black, of ugly appearance, and very savage. They had nothing of copper and, according to the nearby Indians, they ate human flesh and fish raw as they killed them. Their ears were pierced with so large a hole that one could easily pass a hen's egg through, hence Columbus called that region Orecchia (the coast of ears).

The account of Las Casas is as follows:

Finally, with great difficulties, dangers and indescribable labor, they arrived and discovered a small island that the Indians called Guanaja, and it had for neighbors three or four other islands, smaller than this one, that the Spanish afterwards called Guanajas, all were well populated. At this island the Admiral commanded his brother Doñ Bartolomé Colón, Governor of this island, that he go ashore as captain of a boat and get news; he went, taking two boats full of people, found the natives very peaceful and of the type of those of the other islands [i. e., the Antilles], except that they did not have broad foreheads, and, because there were many pines there, the Admiral named it Isle of Pines. This island is a matter of 12 leagues distant from the cape that they now call Cape of Honduras, where there is or was the Spanish city that they called Trujillo, and which now has five or six residents; . . . . As soon as the Governor had gone ashore at this island of Guanajes or Guanaja, a canoe full of Indians arrived, as long as a galley and 8 feet broad; it came loaded with goods from the west, and must be certainly from the land of Yucatán, because it is near here, a matter of 30 leagues or so [sic]; in the middle of the canoe they had an awning of matting made of palm which they call *petates* in New Spain, inside and under which were their women, children and property and goods, so that neither the water of the sea or of the sky could wet anything. The goods and things that they brought were, many cotton blankets, very gay with many colors and designs, and sleeveless shirts, also colored and designed, and some of the sashes with which the men cover their private parts, of the same colors and designs. Item, wooden swords with some grooves in the blades and there were attached with pitch and fibres certain flint knives, small copper hatchets to cut wood, and bells (*cascabeles*) and some medals, crucibles to melt the copper; many cacao nuts which they use for money in New Spain, and in Yucatan, and in other parts. Their supply of provisions was corn bread and some edible roots, which must have been those which in this Española we call *ajes* and *batates* (sweet potatoes), and in New Spain *camotes* (sweet potatoes). Up to 25 men came in the canoe and they did not dare defend themselves nor flee seeing the ships of the Christians, and so they took them in their canoe to the Admiral's ship; and those from the canoe climbing onto the ship, if it happened that their underclothing was caught, then they put their hands in front of them, and the women covered their faces and bodies with shawls as the Moors of Granada used to do with their scarfs.

The account of Herrera is practically identical, except that he mentions that the sleeveless shirts were without collars and reached to the knee; that the cotton blankets were not only colored but were also decorated with needlework; that the men's sashes were of the type called in New Spain *mastil* (i. e., breeches), and that the Indian boat crew had a wine or beer made of maize. He continues, that the Admiral was impressed with their honesty and modesty, " and treated them very well, and taking from them some of the showy things to take back for a sign he ordered given them things of Spain in recompense, and he permitted all of them to go in their canoe except an old man who seemed a judicious person so that he could give them word of what was in this land; because the first thing of which the Admiral inquired signs, was showing them the gold that they give him news of the land where it was: and because that old man pointed out, that they had it toward the parts of the East, they retained him, and took him until they did not understand his language [just west of Cape Gracias á Dios] before they let him return to his country ". Las Casas' and Herrera's description of the people on the adjacent mainland agrees with that of Ferdinand Columbus.

The account of Peter Martyr contains a few variants. The explorers came to an island,

which the inhabitantes call Guanassa, so florishing and fruitefull, that it might seem an earthly Paradyse. Coasting along by the shores of this Ilande, hee [Columbus] mette two of the Canoas, or boats of those provinces, whiche were drawne with two naked slaves against the streame. In these boates was caryed a ruler of the Ilande, with his wife and children, all naked. The slaves seeing our men alande, made signes to them with proud countenance in their maisters name, to stand out of the way, and threatned them, if they would not give place. Their simpleness is such, that they neyther feared the multitude, or power of our men, or the greatnesse and straungenesse of our shyppes. They thought that our men would have honoured their maister with like reverence as they did. Our menne had intelligence at the length, that this ruler was a great marchant, which came to the marte from other coastes of the Iland: for they exercise buying and selling by exchaunge within their confines. He also had with him a good store of such ware as they stande in neede of, or take pleasure in; as laton belles, rasers, knives, and hatchettes made of a certayne sharpe yellowe bright stone, with handles of a strong kinde of wood: also many other necessarie instruments with kytchen stuffe, and vesselles for all necessary uses: likewise sheetes of Gossampine cotton, wrought of sundry colours.

Columbus then proceeded to a large land " ten myles distant " which the inhabitants called Quiriquetana but which he named Ciamba. When he landed, the inhabitants flocked around without fear and brought the Spaniards gifts of food. In this great land there were two regions, one called Tuia and the other Maia. The country was pleasant and well wooded. Beside " Gossampine " and " date trees ", from which textiles and long, broad swords and darts are made respectively, maize, yucca, potatoes, and various medicinal plants were abundant. The inhabitants "are of hyh and goodly stature, well lymmed and portioned, both men and women covering their privie partes with fyne breeches of gossampine cotton, wrought with divers colours ". The natives, to make themselves beautiful in their own eyes, painted their bodies red and black with " the iuyce of certayne apples which they plant in their gardens for the same purpose ". Plant, flower, and knot designs were employed for such paintings, according to the fancy of the individual. Peter Martyr concludes with the statement that: " Their language differeth utterly from theirs of the Ilandes neere about them [the Greater Antilles?]."

The death of Isabella in 1504 was a sad blow to the Indians of the Caribbean, for she had been much interested in her new subjects and had ordered that they be well treated. The bars having been let down by Ferdinand, enslavement of the natives went on apace and both the Greater and Lesser Antilles were soon depleted of their native population. Since the importation of negro slaves into the Spanish Dominions was forbidden, expeditions were soon sent far afield in search of captives to work the mines. The peaceful inhabitants of the Bay Islands did not escape, and from 1516 to 1526 suffered several raids by Spaniards from Cuba and Jamaica. Since the enslavement of Indians who took up arms against the Spanish or were cannibals was permitted, it was simple enough to justify these expeditions at home. One of the first of these raids occurred in 1516, when two vessels from Cuba rounded up a great number of Indian slaves on the Bay Islands. They were battened below hatches, and the larger vessel sailed to Cuba, leaving the men with the smaller vessel to round up the survivors. Arriving at Santiago, the Spaniards left only a few of their number on guard while the others went ashore. Apprised of their departure by the ensuing silence, the Indians broke out, killed the guards, and hoisting the sails, made their way without compass or chart across more than 650 miles of open sea to their island homes. On their arrival they fell upon the remaining Spaniards and soon drove them away. Unfortunately, this act of poetic justice was soon upset by the arrival of more Spaniards from Cuba, who, after a desperate fight, broke down the Indian resistance and sailed away with some 400 slaves.[11] It is not remarkable that after such happenings as these, Francisco Hernandez de Cordoba with two other leaders, returning from Yucatan in 1517, received such a hot

[11] For more details see Herrera, 1601, Dec. II, Lib. II, Cap. VII; also Squier, 1858, pp. 605-606; and Conzemius, 1928, pp. 59-62.

reception from the Bay Islanders that they "lost the major part [of the attacking force] by the impetus and destruction of their slings and arrows." (Alcedo y Herrera, 1883, pp. VIII-IX.)

It was Hernando Cortez, the iron-handed conqueror of Mexico, who brought to an end the enslavement of the surviving Bay Islanders. During his brief stay at Trujillo (1525-1526) he despatched one or two armed expeditions to drive off slave hunters from the islands. He states that the Indians were peaceably disposed and that he desired by mild treatment to reduce them to the service of the crown. In a letter to Charles V, dated September 3, 1526, he states that owing to these slave-hunting expeditions, some of the Bay Islands had become entirely depopulated.[12] From this time until 1530, when the enslavement of Indians was prohibited throughout the Spanish Dominions, the Bay Islands were not further molested.

Cortez had undoubtedly brought blood and iron to the peoples of the valley of Mexico, but to the harried Bay Islanders he brought peace and comparative safety. Their chiefs sent in their allegiance and received letters of protection and, in return for their abundant fish, Cortez gave them some sows and a boar, whose wild progeny soon overran the islands. From this time on, the Bay Islands were governed from Trujillo, the newly founded capital of Honduras, and the Indians supplied the town with fish, cassava, and maize. They were employed in public works and, besides fishing, transported passengers and freight by sea. The Spaniards regarded them as very ingenious, stating that they made excellent cordage and cables as well as providing pitch, tar, and lime.[13]

Close as the contact between the Islanders and the Spaniards appears to have been during this brief halcyon period, there seems to be very little on record concerning the customs of the Indians. When López de Salcedo was appointed Governor of Honduras in 1527, he attempted to learn what he could concerning the religion and customs of the Indians of that province. Herrera's summary of the results of this inquiry are tantalizingly brief. He states that there were three principal idols near Trujillo which were worshipped in temples. One of these was located on an island about 15 Spanish leagues from Trujillo. Possibly this was at Plan Grande on Bonacca, but at any rate it would seem to have been on the Bay Islands. The idols were all of female shape and of a green marblelike stone. They were attended by a priest with long hair, who was forbidden to marry and

[12] See Conzemius, 1928, pp. 61-62, for references to the original sources.

[13] Conzemius, 1928, pp. 62-63, and D. Francisco de Avila y Lugo, cited by Squier, 1858, p. 610.

who, through the power of the idol, had great influence in the community. In addition, the Indians had other idols and adoratios to which they made sacrifices. The idols served to ward off bad luck and bring good fortune to the farms and towns. The priest was called *Papa* and taught the sons of the upper classes (*caballeros*) at the temple. To challenge the power of the idols, Hernando de Saavedra burned the one nearest to Trujillo, and the priest, who had said that the idol would destroy any who profaned it, thereupon cut off his hair and became a Christian. (Herrera, 1726-30, Dec. IV, Lib. I, Cap. VI.)

The century of quiet, during which Spanish effort had been concentrated in the richer fields of Mexico and Peru, was brought to a close by the rise of the buccaneers in the Caribbean. These marauders found the Bay Islands a favorable and strategic haven, and the Spanish soon began to look askance at the Indian plantations there which offered food and shelter to their enemies. The raid of Van Horne in 1639 brought matters to a crisis, and in that year De Avila, Governor of Honduras, was requested by the President of the Audiencia of Guatemala to investigate conditions on the Bay Islands and to define a policy toward them.[14] De Avila reports that there were then about 400 Indians on the islands living in four towns, Guanaja, Masa, Roata, and Utila. The people of Guanaja, especially the grandson of the cacique, were conspiring with and aiding the buccaneers, but the Indians of the other islands seemed to be loyal to Spain. The town of Guanaja (Bonacca) had 84 tributaries (i. e., adult men); Masa and Roata had barely 14 tributaries, of whom about 9 were *encomienda* to one Gonzalez. Masa was evidently located on Helena Island and Roata about 2 leagues from Barreros (a port on the southern shore of Roatan marked by red *barrancas* visible from the sea). The people of these two towns, it is said, suffered much from mosquitoes, whereby the population had been reduced. Utila had as many as 22 tributaries who were *encomienda* to another Spaniard. The main port seems to have been East Harbor, and the Indians had their cornfields inland. All four towns had been burned by the Dutch in that year.

Although De Avila makes no written recommendation for the removal of the aborigines, this was then being seriously considered. It actually took place in 1650 after the recapture of the islands from the English logwood cutters and illicit traders, who had seized and fortified Port Royal. This affair will be mentioned in another place.

[14] This report is published in translation by Squier, 1858, pp. 608-614.

It is not known how many Indians remained after this fighting and turmoil subsided, but all that did were removed to Guatemala, where they either died out or rapidly disappeared as a distinct people. (Conzemius, 1928, pp. 65-66.) So ends the Indian history of the Bay Islands.

With the ensuing history of the Bay Islands we are less directly concerned. Certain phases of the buccaneer and the following period are mentioned later in connection with Port Royal. The last British claim to the islands was formally established in 1850. This was considered by the United States as being in direct opposition to the Monroe Doctrine and the Clayton-Bulwer treaty of 1850, and a tense diplomatic situation developed. The matter was peacefully settled in 1859 when Great Britain negotiated a treaty by which the islands were returned to Honduras. Since that time they have formed the Department of the Bay Islands under the Republic of Honduras. Although Spanish became the official language in 1872, English is still spoken by the bulk of the somewhat heterogeneous population. Indeed, it was not until 1902 that the majority of the English population realized that their assumed British nationality and claims to British protection were without any basis in fact. (Rose, 1904, chap. 15.)

Considering the early and close contact between the Spanish and the original Bay Islanders, which extended from 1503 until 1650, it is surprising that not enough of the native language survives to place them linguistically. Neither early sources nor recent linguistic research give much direct aid in this regard. The former are obscure, but they do suggest that both the culture and language of the Bay Islands was very close to that of certain major groups on the adjacent mainland.

There has been much discussion concerning the language spoken by the interpreter whom Columbus acquired from the trading canoe at Bonacca. Lothrop denies that there is any evidence of this canoe having come from Yucatan and cites the early writers to prove that the province of Maia, here referred to, was actually on the Honduras mainland.[15] More recently, Blom has stated positively that the traders were Maya, presumably from Yucatan. He bases this conclusion on the term *Maiam*, and the word *suyen*, which he says Bartholomew Columbus gives as the native name for the square cloaks found in the canoe. In the Motul dictionary the Maya word *suyem* is given for

[15] Lothrop, 1924, 1927. In the latter he suggests that the canoe may have been en route *to* Yucatan with chipped stone, etc., but there seems to be no direct evidence for this.

similar cloaks.[16] The latter bit of evidence would go far toward settling this controversial point, since it would indicate that the traders spoke Maya, or at least used a Maya term for such articles of clothing. However, I have been unable to find the word *zuyen* in the Bartholomew Columbus letter as given by Harrisse (1866), or in Las Casas, Oviedo, or other primary sources. If it does occur in an eye-witness account it strengthens the case for the traders being Maya, but I cannot vouch for this.

Two citations from early historians, given by Blom, offer evidence that canoes from Yucatan commonly traded in this region. Oviedo states: "Because along said coast there is an extensive trade in said fruit cacao, which is used as money among the Indians, and which is very useful and precious, and richest and most highly estimated merchandise which they have, canoes go from Yucatán loaded with clothing and other goods, to Ulua, and from there they return loaded with cacao." (Oviedo, III, 1853, p. 253.) Landa writes that "the occupation to which they are most inclined is trading, carrying salt, clothing and slaves to the lands of Ulua and Tabasco, exchanging it for cacao and beads of stone which both were like money and with this money they could buy slaves and other beads, granting that they were fine and good, which the chiefs wore as jewelry during the feasts, and they had other beads made out of certain red shells which were valued as money and personal jewelry, and they brought them in their network bags." (Landa, as cited by Blom, 1932, p. 546.)

It is evident, therefore, that the region around the mouth of the Uloa was an important trade center where much cacao was obtained, and that canoes such as the one encountered by Columbus were common carriers along this coast. This, however, does not mean that only the Maya indulged in the carrying trade. Bartholomew Columbus, speaking of a people south of Cape Gracias á Dios, says: "Following farther as far as a land called Cariai in which live people of good strength who live by industry and trading as they do in the province which is called Maia" (Harrisse, 1866, p. 472.) Hence, there seems good reason to believe that not only Yucatecan Maya, but also Chol or Chorti Maya and Jicaque from the Uloa region, the Bay Islanders themselves, and certain peoples on the Nicaraguan coast, all indulged in coastal trading.

[16] See Blom, 1932, pp. 533-534, 546, and 548. Dr. Blom (letter of August 24, 1934) calls my attention to an error in this paper in regard to footnote 2, which should occur after the fourth instead of the third paragraph. In a later letter (October 1, 1934) Dr. Blom points out that the word *zuyen* is used by Cogolludo (vol. I, p. 8, 1867 edition). Cogolludo, however, cannot be regarded as a primary source in this regard.

Concerning the location of the province of Maia, Lothrop believes it was on the Honduras mainland but that the term was only accidently, not linguistically, cognate with Maya proper. Blom believes that it refers to the Maya regions of Yucatan. The eye witness, Ledesma, and the historian Peter Martyr, are specific in locating the province of Maia on the Honduras mainland. Bartholomew Columbus makes Maia equivalent to Yucatan but, as already pointed out, this equivalence may well have been a later and alien addition to his text. Las Casas, and after him Herrera, assign the canoe to Yucatan, but this may have been based on the touched-up letter, as Lothrop believes.

As the evidence now stands, there is no positive proof regarding either the language spoken by the traders at Bonacca or the location of the region of Maia. Regarding the first, it is clear that " Giumbe " could make himself understood among certain groups on the mainland adjacent to the Bay Islands, but it is equally certain that several different languages were spoken even in the immediate vicinity of the Cape of Honduras. My own interpretation of the evidence is that " Giumbe " and his fellow merchants had come from the western part of Honduras, probably from near the mouth of the Uloa, and that their native tongue, which may have been Chol or Chorti Maya, Jicaque, or even Lenca, was understandable to numerous mainland groups to the west of Cape Gracias á Dios. As to the provenience of the land of " Maia ", I incline toward the testimony of Ledesma and Peter Martyr, that it was on the Honduras mainland. If it were one of the provinces of the culturally advanced Uloa region occupied by Maya, all the bits of evidence concerning these much-discussed traders fall into line. However, there may be difficulties, linguistic or otherwise, of which I am unaware, standing in the way of such a solution. In any case we are no nearer an answer to the original problem concerning the linguistic affiliations of the Bay Islanders.

A compilation of modern linguistic classification leads to no more definite results. Squier states that there are good reasons to believe that the people of the Bay Islands and those of the adjacent mainland pertained to the same stock. He classified both as Lenca, a group in which he also included Jicaque and Paya. (Squier, 1858, pp. 252, 604.) In 1910 Lehmann grouped the Sumu and Miskito as close linguistic affiliates of the Talamancan subdivision of the Chibchan stock, with the Paya, Lenca, and Jicaque as more remote members.[17] In his later work he indicates that the people of the Bay Islands

[17] Lehmann, 1910, pp. 711, 723. This classification is not universally accepted; see Lothrop, I, 1926, pp. 13, 18.

were Paya in speech, on the grounds that in 1622 Spanish missionaries took Bay Island Indians to the Paya to serve as interpreters. His map shows Paya on the mainland to the south and east of Trujillo and on the Bay Islands. (Lehmann, 1920, II, pp. 629, 631, and map.) The Jicaque are indicated on the mainland opposite the islands. A small Nahuatl colony inland from Trujillo, which Cortes mentioned, is also shown on the map.

According to Thomas and Swanton the available sources indicated that the Jicaque occupied the Honduras coast from Puerto Cortez to just beyond Trujillo, taking up a considerable part of the modern province of Yoro. They place the Paya to the east of the Jicaque. Although the Bay Islands are not specifically designated as to speech affiliations, they are directly opposite the bulk of the Jicaque. (Thomas and Swanton, 1911, pp. 73-76, 78-81, and map.) Conzemius favors the last classification inasmuch as he argues that, since the Jicaque occupied the opposite mainland, the Bay Islanders were also of Jicaque speech. He denies Lehmann's assertion that they were Paya on the basis that Columbus acquired a Maya (sic) interpreter at Bonacca who could converse with mainland peoples as far east as Cape Gracias á Dios. Hence he argues that the Maya tongue served as a *lingua franca* along the entire coast and that the Bay Island interpreters taken to the Paya spoke Maya and not their native tongue. (Conzemius, 1928, p. 68.) This last argument seems somewhat tenuous. However, the argument of Lehmann that because the Bay Islanders could communicate with the Paya, therefore the Bay Islanders were Paya, seems to me equally unconvincing. Adjacent peoples, even of totally different linguistic stocks, that have been long in contact are often bilingual. I have used an Eskimo interpreter to make contacts with Algonkian Indians, and when we went up the Patuca River in 1933, we had a Miskito interpreter to talk to the Sumu, and there we found Sumu who could speak Paya.

All of which involved discussion merely demonstrates that we do not know what language was spoken by the aborigines of the Bay Islands. The language is undoubtedly extinct today, but the archives may yet yield a Bay Island vocabulary to solve the difficulty. In the more remote portions of the Department of Yoro several groups of Jicaque still live in isolation, up the Patuca and in Nicaragua are the remnants of the Sumu, while in the interior of Honduras the Paya are still numerous. When their languages and surviving cultures have been analyzed by linguist and ethnologist, more light will be thrown on these problems than is now available.

EXPLORATIONS

Utila Island

The Boekelman Shell Heap Expedition while at the Bay Islands did their most extensive work on Utila, whereas we spent only our last 4 days there. As a result the following section is based primarily on the excavations of Bird and his companions, supplemented by our own brief reconnaissance. We visited and sampled all the main sites where they worked, and in addition each party visited certain sites not investigated by the other. William Waterhouse, of East Harbor, who justly bears the reputation of being the best guide on the island, was employed by both parties. The town of East Harbor is a very attractive place, and the officials and other residents were pleasant and hospitable. From Utila one gets a magnificent view of the mainland, and the great blue mountains of Honduras loom impressively in the distance. The island itself, while flatter and probably better for agriculture, is less picturesque than the others of the group.

BLACK ROCK BASIN

Site 1, Urn and Skull Burials

The Boekelman Expedition was the first to do scientific work at these important sites, working, as we did, from a vessel anchored in Black Rock Basin, which is one of the very few island harbors on the north shore. Both parties rather arbitrarily distinguished two sites (see map, fig. 2) to the west of Black Rock Basin, although for a mile or so along this low coral and sand shore there are a series of aboriginal occupation and burial sites. These have been considerably dug over by local treasure hunters, but there is undoubtedly still a great deal of undisturbed evidence to be secured.

To reach site 1 from the vessel (map, fig. 2) we rowed in a small boat to the west end of the basin. Landing here at a small native plantation, we walked west about half a mile along the low shore line, which consists of rough coral rock interspersed with occasional bits of sandy beach. The entire shore line is heavily grown up with large coconut palms. Within half a mile of the west end of the basin potsherds, conch shells, and other traces of aboriginal occupation appear, and these extend to the west with varying intensity for at least half a mile and perhaps farther. Bird, in his notes, refers to a small shell heap about 600 feet inland from the beach, near site 1, and states that two former shell heaps in this vicinity had been burned for lime. The only sites we saw during our brief visit were on, or just back from, the beach.

The ground at site 1 is about 6 to 8 feet above sea-level at the highest point. Beginning toward the water, Bird and his party ran a trench (trench 1, fig. 3) through the main section of the deposit. This revealed first about 12 to 18 inches of light wind-blown sand. Below

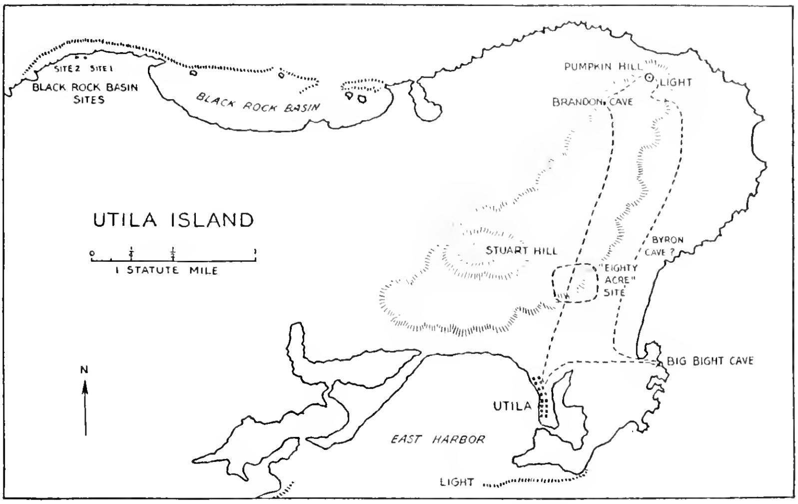


FIG. 2.—Map of east end of Utila Island.

this was a layer of black earth, mixed with sherds and other cultural debris, of varying depth (see fig. 3), and below this was white, unmixed, beach sand. The layers were not always clear-cut or of equal thickness throughout, as the diagram indicates. I may add that digging here was extremely difficult, owing to innumerable palm roots

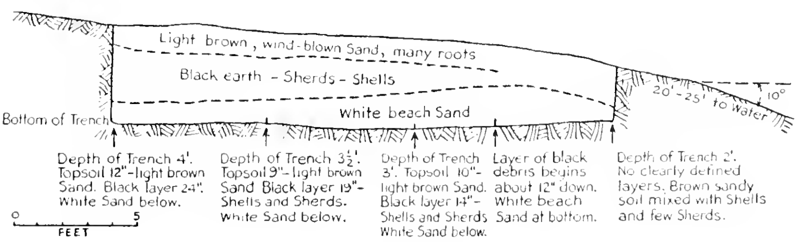


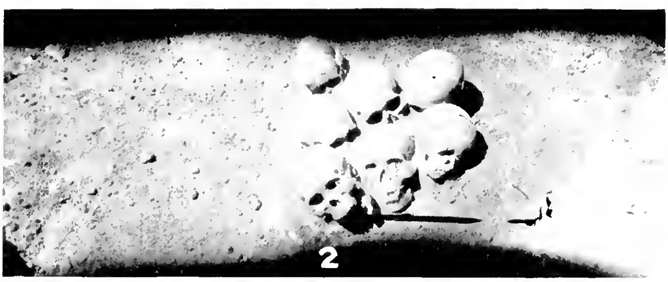
FIG. 3.—Cross-section diagram of trench 1, Black Rock Basin, site 1, Utila.

heavily interlaced in the top levels. The trench indicates that the shore at this point had been occupied for a considerable period, during which a layer from 1 to 2½ feet thick, full of broken pottery, fish and animal bones, and broken shells, had accumulated.

Over this some 18 inches of wind-blown sand had been deposited, in the main by natural agencies. The burials here are intrusive into these deposits (see fig. 5).

The burials at site 1 were located by test pitting in the vicinity of trench 1. The rims of burial urns 1 and 2 were struck 18 inches below the surface. They were in the black mixed layer, but were surrounded by white beach sand (pl. 2, fig. 1). Burial urn 1 (pl. 3, fig. 1) is of monochrome red ware without any slip. It is 45 cm high, 26 cm outside diameter at mouth, and .5 cm thick in the middle portion. The vessel is not highly polished and is sand-tempered. It contained two skulls. The only attempt at decoration is a narrow line of punctate marks around the neck. Burial urn 2 (pl. 2, fig. 1) was similar to the last in both size and type. It contained one small stone mortar and a number of human bones, including three slightly worn molars, one scapula, one clavicle, three skull fragments, and a few ribs and leg bones, some of the last being charred. The rim of burial urn 3 was within 5 inches of the surface. Both rim and neck were broken off, and the remainder of the pot was cracked (pl. 2, fig. 1). The vessel was not preserved but in general type seems to have been very similar to urns 1 and 2. The earth over this urn was loose, and it appeared to have been disturbed within recent times, as all the human bones were freshly broken and very much mussed up. It contained fragments of skull and other human bones and the broken leg from another pottery vessel.

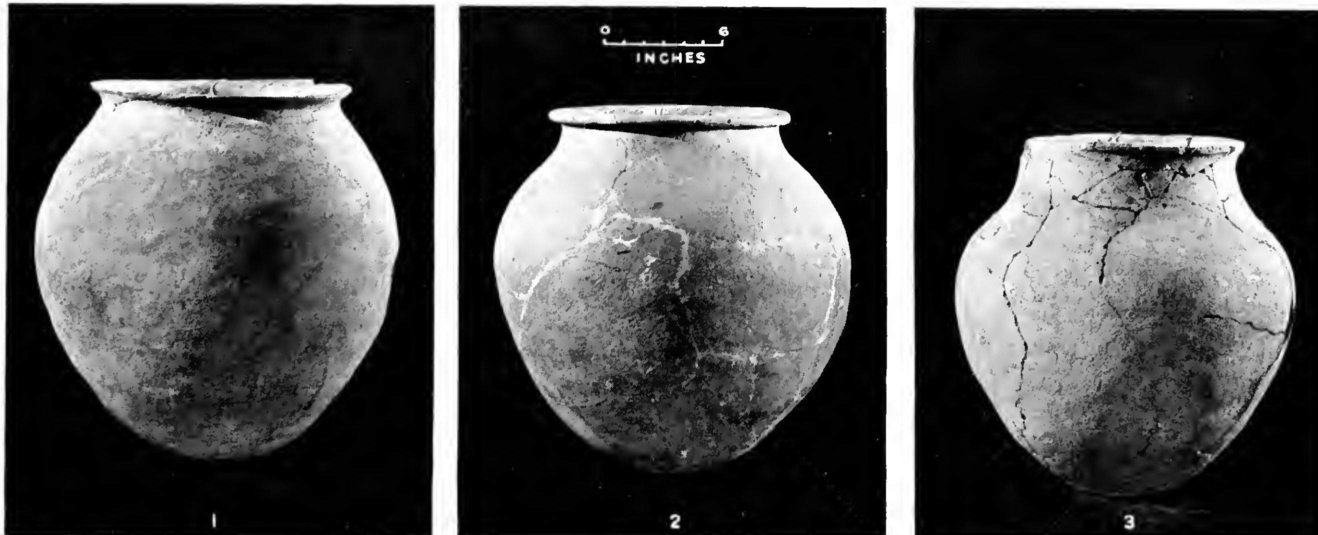
The arrangement of these urns (1-3) and the adjacent skull and bundle burials is shown in the photographs (pl. 2) and Bird's diagram (fig. 4). Just south of urns 1 and 2, about 18 inches below the surface, was a group of seven skulls closely packed together, all facing south. The mandible accompanied each crania in its normal position, and these were the only skulls found in that condition at the site. Skull 1, broken while in the earth, was that of a child with primary teeth still in position but secondary teeth formed in bone; skull 2 had peculiar pockets in the bone; skull 3 had the third upper molar just formed in bone (discarded); skull 4 had no teeth in the upper jaw and the secondary first molar, left side, lower jaw, just emerging; skull 5 was that of an adult male with worn molars; skull 6, no data; skull 7, a child, same state of development as skull 1. A short distance east of this group, and at the same depth, were five other skulls, all facing south. These were 2 feet west of burial urn 3 (see pl. 2, fig. 1; fig. 4). The three skulls to the north had two femora in front of their facial portions. Behind the two skulls to the south were six or seven femora laid roughly north and south (fig. 4).



Photographs by Junius Bird.

BLACK ROCK BASIN, UTILA

1. Burial urns 1-3 and skulls.
2. Skull burial.
3. Burial urns 7-8 and skulls around burial urn 6.



Photographs courtesy of American Museum of Natural History.

BLACK ROCK BASIN, UTILA

1. Burial urn 1.
2. Burial urn 7.
3. Burial urn 8.

Another group of urn, skull, and bundle burials occurred close by. The rim of burial urn 4 was within 6 inches of the surface (fig. 5). It was protected on three sides by vertically placed pieces of coral rock, the ends of which projected slightly above the ground, and on

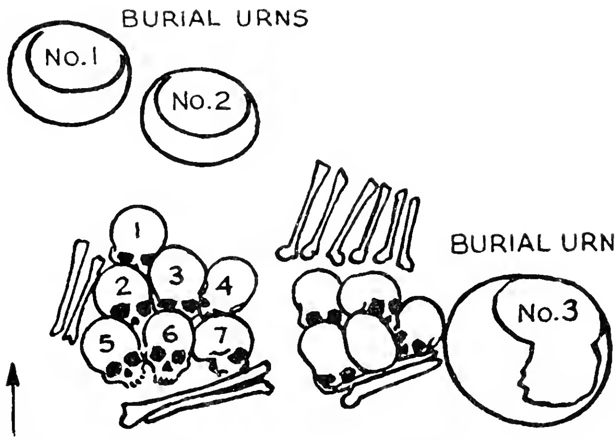


FIG. 4.—Diagram of skull and urn burials 1-3, Black Rock Basin, site 1.

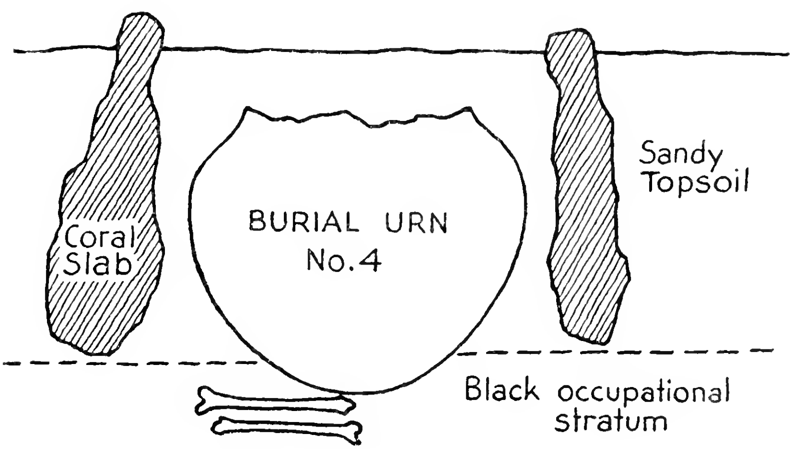


FIG. 5.—Cross-section diagram of burial urn 4, Black Rock Basin, site 1.

the fourth side by several large fragments of other pots nested together. The bottom of urn 4 was 22 inches deep, in the black occupational stratum. The rim, neck, and shoulders were broken away, and a piece 6 inches in diameter was missing from the bottom of the vessel. This urn, generally similar in type to the others, was not saved. The vessel was filled with sand from the surface and contained only a few fragmentary human bones, six or seven vertebrae, lower leg bones and a section of femur. Beneath the urn was a partial bundle burial.

Burial urn 5 was close to 4 and of the same type. The protecting coral slabs projected above the surface, and a rectangular grinding stone with rounded edges was to one side. The bottom of the urn, which was not saved, was 24 inches below the surface and had a small, perfectly round hole made from the inside in the bottom. It contained two adult skulls, a complete skeleton, and a few fragments of a child's cranium and jaw.

The disposal of skulls around burial urn 6 was particularly striking (pl. 2, fig. 3; figs. 6, 7). The urn, which was not saved, was

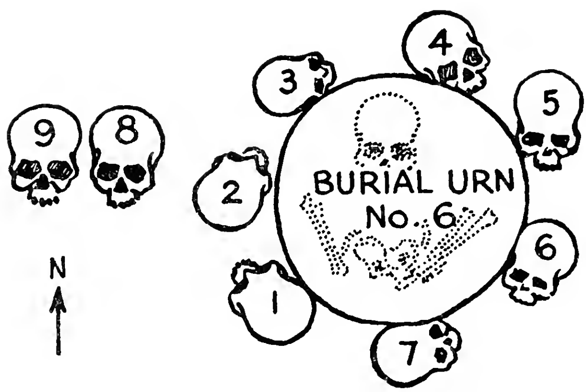


FIG. 6.—Horizontal diagram of skulls and burial urn 6, Black Rock Basin, site 1.

badly broken in its upper portions and was mixed with numerous other sherds in the top soil. The rim must have been within 6 inches of the surface. Beach sand had sifted about the pot and skulls, and the original pit had evidently been filled with it. The bottom of the urn rested in the black occupational stratum 28 inches below the surface (fig. 7). Coconut palm roots were growing through the urn and the skulls. The burial urn itself contained the skull and disarticulated bones of one individual, evidently an old man. Around the urn were seven skulls, all apparently adolescents of about the same age. With one exception (fig. 6, skull 7), all were facing clockwise. The tops of the skulls were 10 to 13 inches below the surface. There were two other skulls (8, 9), with slightly heavier supraorbital ridges, to the west of the burial urn (pl. 2, fig. 3); these faced south. All the skulls were filled with beach sand composed largely of minute shell fragments. Underneath burial urn 6 was a mass of closely packed human bones in a pocket of white beach sand (fig. 6); (these are not indicated in Bird's original vertical diagram, but I have added them in accord with his description). As far as could be determined, this mass included 14 femora, 14 lower leg bones, 14 upper arm bones, 7 jaws, 7 pelvic portions, and a disproportionately small collection of ribs and vertebrae. Slightly above the burial urn and to the north was a bundle of long bones, apparently from the same adolescent individuals whose skulls were placed around the burial urn.

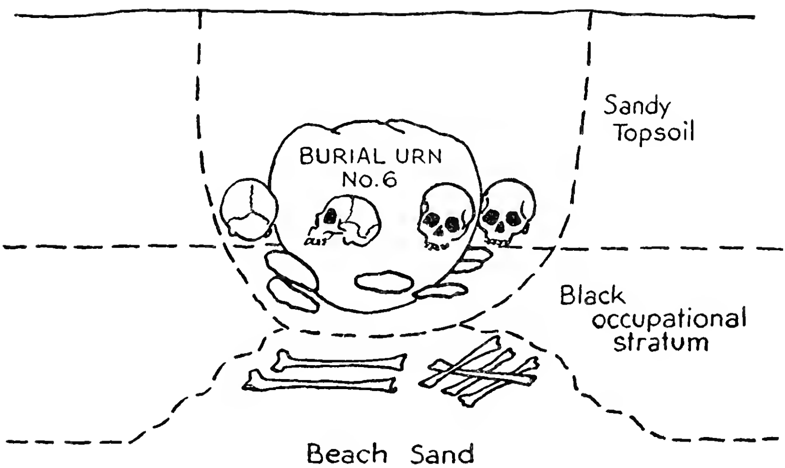


FIG. 7.—Cross-section diagram of skulls around burial urn 6, Black Rock Basin, site 1.

Burial urn 7 (pl. 3, fig. 2) was 3½ feet northeast of urn 6 (pl. 2, fig. 3). Like all the others, it is of monochrome, red-brown ware, with sand tempering. The vessel is 42 cm in height, with an outer mouth diameter of 27 cm; in thickness it varies between 1 and .5 cm. It has more of a neck than urn 1 (pl. 3, fig. 1) and an obliquely everted lip. The rim was 10 inches below the surface with the bottom resting in the black occupational stratum. The upper half was full of sand, then occurred a single layer of potsherds, and below this were two skulls, one adolescent, the other more mature, both very poorly preserved. In addition, there were three vertebrae, two fragments of pelvis, and a small mandible, apparently that of the adolescent skull.

Burial urn 8 (pl. 2, fig. 3, and pl. 3, fig. 3) was 1 foot north of urn 7 on the same level. This vessel has a pleasing shape with considerable neck but a small everted rim. It is 34 cm in height, 28 cm in outside mouth diameter, and .8 cm thick at the neck. Half of a similar urn had been placed over the aperture of urn 8 but had broken into small fragments. Urn 8 contained two adult skulls (only one of which was saved) and a child's skull with holes in the forehead. No long bones were present, but there were numerous vertebrae and ribs; two vertebrae, fused together, were preserved. One of the adult skulls was that of an old person and lacked any teeth in the maxillary.

Bird's material from site 1 is segregated according to depth. Since the specimens preserved include only about 40 potsherds and 2 other artifacts, the results thus obtained, although valuable, are not striking. The ceramic material, with the exception of the burial urns previously described, is all broken and of a monochrome, red to buff, sand-tempered type. The upper layer extends from the surface to a depth of 18 inches. This very roughly coincides with the wind-blown sand stratum, although, as figure 3 indicates, the respective depths of the strata were variable. From this upper layer there are at hand some 17 sherds, including 10 rim sherds. One of the latter is from a thin, highly polished, red bowl, with one perforation for "crack lacing". Three are decorated with incised, punctate, and relief adornment, and one has a raised and notched horizontal band on the neck. Two large sherds come from big vertical jars with slightly flaring necks. One of them is decorated by an incised panel, 6.3 cm wide, below the neck, having a St. Andrew cross with punctate marks where the lines cross; the other has incised double scrolls with four punctate marks diagonally through their centers (compare pl. 24, *a*). Two sherds from simple open bowls are both incised, one with an elongated double scroll, the other with irregular crisscross lines. One rim sherd is identical with the burial urn rim type (pl. 3, fig. 2). There are two thin (.5 cm) body sherds with linear and curved ornamentation by incision and relief. One basal fragment with a bored hole 2.5 cm in diameter is similar to the burial urns. There are two hollow conical feet, one plain with three irregular perforations and the other decorated by incisions, punctate marks, and raised vertical strips, on which are other punctate marks. Two rim sherds have vertical loop handles; one is plain and the other has crudely incised lines extending its length. The latter handle is from a vessel with two raised scalloped bands extending around the neck where the handle is attached. The only nonceramic artifact from this stratum is a much battered celt (8.5 cm long, 3.6 cm thick) of hard gray stone.

Some 25 sherds are listed as coming from a depth of 18 to 28 inches, a layer roughly corresponding with the black occupational stratum. Of these, four are rim fragments of small, plain, open bowls; eight are rim fragments from wide-mouthed, plain vessels with a short neck and flaring lip; and two are rim sherds from straight-walled, probably annular-based vessels without decoration. Only two sherds are decorated: one well-polished fragment is from a straight-walled vase and has a step design between double incised lines around the neck; the other is from the same type of vessel but of coarse red ware with incised square and scroll designs. There are two vertical loop handles, one of which has ridged edges. Three hollow conical feet are cylindrical down to a sharply tapering point, they are deeply incised and punctured, suggesting some sort of a conventionalized head. One conical foot is long and slender (7.5 cm in length), and one is a hollow hemisphere without decoration. All the feet come from medium-sized vessels. The only other artifacts are a saddle-shaped piece of pottery, possibly a burnisher; a notched pottery net sinker (?) 2.5 cm in length; and a perforated cowrie shell from the interior of burial urn 1. There are also a considerable number of shark and other fish vertebrae and unworked shells in Bird's collection, but it was not possible to have these identified in the time available for study.

Our own collection from this site is a mere sample of 20 sherds, all of the red to buff monochrome ware and very similar to the above. They were obtained from test pits in a previously disturbed area and hence have no stratigraphic value. Three sherds have the raised band with scallops or points around the neck where it joins the body. There is one entire rim of a small urn 23 cm in outside mouth diameter, with a probable diameter of some 25 cm for the entire vessel. It has a somewhat constricted orifice and a low, flaring rim. There are two other rim sherds from similar vessels. Two cylindrical pointed feet and one conical foot, as well as one loop handle, are similar to the above. About half the sherds have rather simple incised designs. The remainder are plain and, as a rule, coarse in texture. Besides the potsherds we obtained a flat pendant of dark green talc (3.5 cm in greatest width), which has a conventionalized jaguar face incised on one surface (pl. 11, *h*). A round disk (9.5 cm in diameter and 2.5 cm thick) of rhyolite porphyry with rounded edges and a biconodont perforation 2 cm in diameter suggests a mace head, but the shaft hole is very small for such usage. A section of a prismatic flake knife of obsidian (7 cm long) and two smaller fragments were also found (fig. 15, *a*, *b*). One section of a polished cylindrical roller pestle 12.5 cm in diameter was noted.

Bird states that the decorated sherds came from the upper levels and that all the sherds from the lowest level were plain. The foregoing anlysis of the collection bears out, in the main, his own observations made at the site. Some decorated ware does come from below the 18-inch level, but it is markedly more abundant above than below this line. Next to the nature of the urn burials, this is apparently the most significant result of the excavations at this site.

Site 2

This concentration of cultural detritus, apparently part of the same general deposit, is located 400 feet west of site 1. Guided by Mr. Waterhouse, we visited the site the same day we examined site 1. The deposit is made up of broken pottery, shells, fish remains, etc. Fragments of human bone were noted, but no complete urns or burials were encountered by either party. Bird dug a cross trench here (trench 2) and also a test pit. There are no diagrams of these excavations. This trench apparently reached a depth of between 4 and 5 feet, the upper 18 inches or so consisting of somewhat intermixed wind-blown sand, the next 3 feet of black occupational debris, and below this the unmixed beach sand. Bird states that potsherds were very abundant, all being plain, unpainted ware, usually red but sometimes black at the center with red surfaces. He also observes that the sherds in the upper refuse had ornamented knobs and legs with some raised decoration, whereas the sherds from the lowest level lacked decoration.

As at site 1, the material from this site that was saved is in large part allocated as to depth. The largest amount of material, however, comes from the surface down to a depth of 20 inches, the material preserved from below this depth being almost negligible. Probably the collection saved was definitely selected to show the more complex pieces. From the surface down to 20 inches come 20 fragments of hard, well-polished bowls or jars, all more or less smoke-blackened. A few have loop handles, and several are decorated with designs made in relief or by incision. Some 25 sherds come from small to medium, plain jars with constricted necks and low to medium flaring rims. One or two have straight necks, and one open bowl has concave vertical walls and a rounded bottom. Another group of highly polished, thin, brown sherds come from a vessel with a concave " dimple " in the bottom. One solid, vertical loop handle, and several broad loop handles decorated with raised and sometimes notched ridges, are present. There are several decorated feet, two of which are hemispherical with holes suggesting eyes and with "noses" in relief, and one represents the head of a snouted animal, possibly the tapir.

From 28 to 36 inches come five sherds of dull brown ware; a large fragment (7.5 cm high and something over 30 cm in diameter) of an open-mouthed bowl; and four other rim sherds with low flaring rims. One of the latter is of the urn type. None of these pieces is decorated.

The nonceramic material from trench 2 includes two very shallow, ovoid "dishes" of pumice, of which the longest is 17 cm in length. The exact depth and the purpose of these pieces is uncertain. There is also one rectangular "burnisher" of pumice, 7 cm in length. One leg of a hard, gray, long metate (upper layer, surface to 18 inches), and sections of two "roller" stones, one of polished granite (upper layer, surface to 18 inches) and one of white coral (depth uncertain), were recovered. One small fragment of an obsidian flake knife (from a depth of 10 to 20 inches) is present. Of shell artifacts, a much worn celt with a sharp edge, manufactured from the ridged portion of a conch, comes from a depth of 36 inches. There are nine smoothly worn fragments of cowrie and conch shells from various depths, which suggest tools, but they also occur in the unmixed, underlying sand, and their form probably results from wave action.

The test pit also yielded considerable broken pottery. From the upper layer, surface to 12 inches, there are 12 rim sherds from medium to small vessels with constricted necks and low flaring lips. Two of these have incised designs around the neck, and two of the larger rims approach the urn type. Two large fragments are from thick, open bowls; one fragment from a flat, slightly concave plate; two vertical loop handles; and three decorated legs are from this level. One of the last is a long, hollow cone (10.5 cm in length) with a compressed tip and seven perforations of various sizes; one is similar but shorter with a flattened tip; and the last is hemispherical with four perforations (one at the tip) and is decorated with two small "adornos" in relief. From a depth of 12 to 15 inches come four coarse, dark red rim sherds, two being from small open bowls and two from jars with slightly flaring rims. From a depth of 21 to 27 inches come two rim sherds, both plain, one from a small open bowl with a slight contraction around the neck, the other from a globular vessel with a low, sharply everted rim. One other plain red potsherd comes from this level. The only nonceramic artifacts from this test pit were a few bored shells and shark vertebrae.

In addition to the material just described, Bird's collection from site 2 contains a certain amount of pottery from uncertain depths.

This can be described in conjunction with the small collection that we made at the site. Fragments of large, thick, open-mouthed bowls are fairly common, as are those of medium-sized jars often with vertical loop handles. The handles are both thin and flat, and round and solid, in type. A number of sherds of polished brown ware also occur. Several snouted lugs suggest tapir or peccary heads, and one is too conventionalized to permit even a guess as to the animal represented. On the whole, however, elaborate lugs are not particularly characteristic of any of the Black Rock Basin sites. About 20 pieces are feet from tripod vessels. The majority of these are long (10.5 cm being the greatest length) and conical, with six perforations into the hollow interior, and usually with circling incised designs and little "adornos" in relief. The tip is usually compressed but sometimes modeled to suggest two legs or some other form. One is a hollow, round ball with two perforations; and four more are of the same type but are decorated wth "adornos", more perforations, and incisions. The hollow legs nearly all have, or did have, gravel rattles in them. Two feet are solid and much conventionalized; one of these is of the short cylindrical type with punctate decoration. the other suggests an animal head with two punctate eyes, three punctate teeth, and a buttonlike nose. More or less elaborate tripod feet, it may be added, are apparently more usual here than are lugs.

Amidst the occupational debris were many conch, whelk, and other shells, both large and small. The conch shells usually have been broken on the side in removing the meat. Mammal bones include the manatee and probably others not identified. Turtle and iguana remains are rather common. Fish bones are numerous, especially many varieties of shark vertebrae, many of which have been perforated. Bird has a considerable amount of such material (A.M.N.H. collections) that has not been analyzed. Our much smaller collection yielded the following: several fish vertebrae, probably those of the jew fish (*Promicrops*); the jaw of a puffer fish (perhaps *Diodon*), and two jaw fragments of the parrot fish (*Scarus*).

BRANDON HILL CAVE

On a rocky ridge not far to the southwest of Pumpkin Hill (see map, fig. 2) is a deep cave of which one hears as soon as "relics" are mentioned to anyone from the islands. According to stories from many sources this remarkable cave penetrates down to salt water, or according to another version extends all the way to the southeast shore of Utila. A golden cup, a rusty sword, and a crucifix, as well as a cache of rifles, are among the finds reported from here, and the gold cup incident at least is apparently true. (See Rose, 1904, p. 147.) Incredible tales of magic and buried treasure float from mouth to mouth around the islands, and a folklorist would have a rich field for investigation among both whites and negroes. While no "treasure" finds other than this one gold cup (apparently looted from some church) ring true, the rumors have their inevitable concomitant in a senseless destruction of Indian sites in the fruitless search for gold.

Brandon Hill Cave is a beautiful place, and wherever its winding limestone passages may actually lead, they are extensive enough to satisfy the most ardent cave explorer. The mouth of the cave is difficult to reach, but having once attained it, one may sit at ease in the cool entry chamber. There is about a foot of dust on the floor, which has been much turned over, but we were able to find two pieces of what appeared to be white rock painted bright red on one face. These on analysis proved to be thick pieces of pottery. A few plain brown sherds were also recovered as well as fragments of green glass bottles. A fish line extends down the steep, narrow crevice leading into the deeper passages of the cave. Mr. Haskell and Mr. Payne crawled down and along these winding, bat-infested cracks for about half an hour but returned without having reached the end or having seen any likely places for excavation.

Bird explored this cave until the descending crevices became too small to permit passage. The material which he obtained indicates that at least the main chamber was occupied by the aborigines. This collection includes some 21 sherds from the shallow dirt floor just inside the entrance, all of which had been turned over by treasure hunters. The majority of these are of the plain monochrome, red or brown ware, but there are a few sherds that are highly polished and one that is incised. Several are from small open bowls and one from a small jar with a short vertical neck. One sherd is part of an annular base, and one is a loop handle. The pottery ranges from 1.2 cm to .3 cm in thickness. The thin sherds are of light brown ware and may be Polychrome I in type, but if so, all traces of paint have disappeared. The two most interesting sherds, however, are covered with a chalky white lime slip on the inside and a bright red paint on the outer surface. This paint has worn off in places, the white showing through. The sherds are .7 cm in thickness and are probably from the same vessel as those which we found. Seventy-five feet inside the entrance Bird found four sherds on the rock floor; all are dark brown, and two are rather elaborately incised with curved lines, scrolls, and dashes.

The other finds include a fragment of a stone bowl (2.5 cm thick) made from a hard conglomerate highly polished on the inside, and a portion of a hemispherical hammerstone with one polished surface. Particularly interesting is a complete, sharp-edged celt (8.8 cm in length), ovoid in form, which is made of conch shell. A fragment of an obsidian knife, several large land snails with perforations, various other fragmentary and whole bivalve shells, and five pieces of a dark glass bottle are also present. There are several fragments of animal bone and a number of small human skull and other bone fragments which are highly mineralized. The latter are of considerable interest but unfortunately no likely places for more complete burials could be found in the cave.

BYRON CAVE

This cave, the approximate location of which is given on the map (fig. 2), is some distance inland in a wooded area and was rather difficult to locate. It was explored by Bird but not visited by our party. Bird reports that the small cave opening leads back into the rock from the bottom of a craterlike formation. For about 60 feet it is low and narrow, opening into a fair-sized room with a deep pool of fresh water at one side. Bird secured several lime incrusted sherds in the passageway and, by diving, brought up one vessel from a depth of about 18 feet in the pool. This was located with a flashlight, the deep dive being made even more hazardous by the low roof over a portion of the pool. This bowl is about 30 cm in diameter with a globular body, a slightly contracted neck and a low, swollen, everted rim. The only decoration is an incised line around the neck. The sherds from the chamber and passageway include a small section of an undecorated globular pot (perhaps 25 cm in diameter) which has a constricted orifice but no rim; a portion of a short-necked bottle or water jar (perhaps 20 cm in diameter); and half of a globular bowl with a slightly constricted orifice and a low, slightly flaring rim. The latter has a small vertical loop handle and an estimated diameter of 15 cm. The small sherds from the passageway have a calcareous incrustation about 1.5 mm in thickness on their surface. All the pottery from this site is of plain red ware, fairly well polished, and the majority of the pieces are somewhat smoke-blackened. They are obviously utilitarian types.

Bird states that the inner cave is poorly adapted for habitation and, as there is a good fresh-water pool in the outside crater, believes that the inner cave served as a hiding place. Such places must have been at a premium when the Spanish slave hunters were harrying the Islanders.

BIG BIGHT CAVE

This interesting site is close to East Harbor (see map, fig. 2) and has been rather thoroughly cleaned out by other visitors. It is locally known as " Big Bight Cave " and consists of a rough, basinlike area of rough rock or coral perhaps 25 yards in diameter, in which there are a number of cracks, pits and caves full of fresh water. According to Bird the formation here is volcanic in origin while my own hasty impression was that it was tumbled coral rock. The pools are surrounded by great irregular masses of needle-sharp rocks, and the holes have from 1 to 6 feet of water in them, many being inaccessible. Flat, smooth pieces of coral are laid as stepping stones from the inland edge of the basin to the main water hole. The site is only about 30 or 40 feet from the sea.

By stripping and diving, I secured a representative collection of potsherds. I presume Bird obtained his in the same manner for the only pieces noticed by us were in the water. Bird mentions it as " a water hole used by Indians " and states that " the surface of all sherds show the effect of lying in water; in nearly all cases the sand tempering is exposed on the surface ". His collection includes 2 small complete vessels and some 13 sherds. All the pottery is of the monochrome red or brown type without any visible slip. One complete bowl is 6 cm in height with a slightly contracting neck, plain rim, and a wide mouth. The other is 5.5 cm in height, it is a small plain jar with globular body, a restricted orifice and a slightly flaring, medium high rim. A half portion of a large open bowl with an annular base is rather striking (fig. 34, *b*). It is 11 cm in height, of coarse, brown, sand-tempered pottery, and has two solid, vertical loop handles and a double line of bosses around the body. There are five fragments of medium-sized jars with slightly flaring rims ranging from 2 to 4.5 cm in height. Three of these have rather crude incised, applique, and punctate decorations. The most elaborate sherd is from a shallow open bowl with flaring lips and a tall tripod base. The legs are cylindrical with round swollen tips and raised upper portions with punctate decorations. Around the body, below the rim, is an incised series of panels, each containing two opposed step designs. There are two separate feet from similar vessels which, like the above, form rattles; one of these may be from the same bowl, but the other is of mammiform or cascabel shape. There is one small, solid, rectangular lug and a much worn sherd with a rather elaborate incised design consisting of a repeated double spiral ending in two dots.

Our sample collection consists of half an open bowl and some 16 other sherds. These are all monochrome, ranging from brown to red, grit-tempered and coarse in texture. Most of them are coated with coral, which is almost a centimeter thick on some sherds, and many other sherds at the site had been fastened into the rocks by coral growth. The largest fragment is from an open bowl (18 cm in diameter) with a round bottom and a low concave neck which flares out slightly at the top. There are rim fragments of several round pots of medium size with low, slightly flaring rims, and several others from small round bowls with no necks but thickened rims. No other artifacts were noted at the site.

Although the water in the accessible caves is fresh, there may be some that is brackish. That this was a water hole used by the Indians seems the most logical explanation. The whole site, however, gives the impression of having once been a great cave that has fallen in, and it is tempting to explain the presence of numerous broken pots in inaccessible places in this way. Our own examination of the site was too hurried to check this hypothesis.

"EIGHTY ACRE" AND OTHER SITES

This site was evidently not worked by the Boekelman Expedition, but on Bird's composite photograph of the east end of the island he locates a "mound with potsherds" in the vicinity. Mr. Waterhouse took us to the place and is responsible for the statement that it covers 80 acres. It is certainly a large and important site and, being close to Stuart Hill, is probably one of the main habitation places connected with the stone causeways and other ceremonial features there which are mentioned by Rose (1904).

We examined an area of several acres on the edge of some low hills (see map, fig. 2), all of which is covered with broken pottery and kitchen refuse. There are a large number of low, irregular mounds here which seem to be composed in considerable part of refuse. They also contain human burials. We dug shallow pits into two of these mounds, but although we found some scattered human bones and teeth, along with sherds and other refuse, we did not strike any definite burials. Mr. Waterhouse stated that both extended and flexed burials, with the bones in rather firm condition, had been dug up here.

Our sample collection from here includes 24 sherds. These, like all other pottery noted at the site, are monochrome, ranging from brown to red in color. They are tempered with white (coral) grit and are rather well polished, although they lack any but the simplest attempts at decoration. Three fragments are from thick, round-bottomed, open bowls, one of which has a small ovoid lug with "coffee bean" eyes. Six sherds are from smaller open bowls, one of which has a perfectly flat rim. Nine are from small bowls with restricted orifices and low slightly flaring necks. Only one of these has a lug and irregular vertical incisions near the neck. A crudely modeled, solid conical leg and a thick body sherd (1 cm in thickness) are the only other pottery pieces. Other detached feet and lugs, some of which were modeled, were noted at the site.

There are six fragments of prismatic flake knives of black obsidian and many similar pieces were found in the mounds. Fish bones are very abundant, our sample containing four shark vertebrae (species indeterminable), the jaw of a hog fish (*Lachnolaimus maximus*), and others of indeterminable species. Shells did not seem to be very abundant, but a few mammal bones were noted. The fragments of the latter which were saved are too incomplete for identification. Irregular calcined stones and charcoal were observed in the mounds. Our examination of the site was extremely brief but sufficient to indicate that it was a definite habitation site, containing much material and apparently of considerable extent. Taken in conjunction with the stone causeways reported as converging on Stuart Hill, of which we were unaware at the time of our visit, the "Eighty Acre" site seems highly important.

As a whole, the island of Utila is obviously an extremely promising place for extensive archeological research. Habitation, ceremonial, and burial sites are all present, and of these only one or two have been even seriously sampled. The island as a whole has not yet been examined even for surface indications, and this is especially true of the western end. Here on the surface of the ground near the small settlement of Sucsac Cay (see map, fig. 1) Bird obtained a small collection of sherds. These include two fragments of open bowls; two rims of large urnlike vessels with sharply everted lips; several rims from medium to large jars with low necks and flaring lips; one loop handle, and several body sherds. All are of course red ware without slip or decoration. We heard of other burial grounds in this part of the island which evidently resemble that at Black Rock Basin, but we had no time to visit them.

Roatan Island

Roatan, the largest island of the group, appears to have been the least exploited archeologically. The Mitchell-Hedges collection from Roatan is small and seems to have been acquired mainly by gift or purchase. The Boekelman Shell Heap Expedition worked one site in Jonesville Bight, visited Port Royal, and purchased a small collection from the vicinity of Coxen Hole. We visited the same places and, in addition, excavated a hitherto untouched offertory site near French Harbor. In the present discussion these sites will be described, commencing with Port Royal near the eastern end of the island, and proceeding west to the vicinity of Coxen Hole.

PORT ROYAL

If the buccaneer period in the Caribbean ever becomes the subject of direct archeological investigation, Port Royal will not be neglected. Once the most important harbor in the islands, Port Royal in 1933 had a population of one American and a scant handful of native Hondurans. Here is a setting that for beauty and romance rivals Stevenson's "Treasure Island". Backed by steep, jungle-covered hills, the great empty harbor is defended by encircling coral reefs, through which only two narrow deep-water entrances penetrate. Old stone forts guard the channels, the ruins of a buccaneer town are hidden in the dense bush on the mainland, and, as a final touch, there is even a "pirate's cave" located on a small creek, whose bed is full of old broken rum bottles (see map, fig. 8). Since no aboriginal remains could be found at Port Royal we spent only one day here. However, with adequate time for exploration, native sites could probably be located, and the colonial remains in themselves merit a much more extensive examination than we were able to give them.

With the beginning of the seventeenth century, Spanish domination of the Bay Islands began to be disputed by a horde of freebooters of English, French, and Dutch nationality, and in the ensuing struggle Port Royal, as the most easily defended harbor, became the scene of repeated violent struggles. The first important raid on the islands came in 1639, when a party of Dutch buccaneers under Van Horne ravaged Utila and Bonacca. It was at this time that the Spanish began seriously considering the removal of the Indian population from the Bay Islands, which was finally effected in 1650. (Conzemius, 1928, pp. 64, 65.) Meanwhile, in 1642, Port Royal was occupied by a considerable number of English logwood cutters and illicit traders from the region that is now British Honduras, and the harbor was strongly fortified. Piratical raids from here so annoyed the Spanish that they sent Francisco Villalva y Toledo with four men-of-war to drive out the invaders, but so forbidding were the defenses that he returned to the mainland for reinforcements. In March 1650 he returned and, after some hard fighting, drove the freebooters from the island. The struggle and the subsequent removal of the few remaining natives depleted the isands, and for some years they lay waste, only feebly occupied by Spain. (Conzemius, 1928, p. 65, and Squier, 1858, p. 615.)

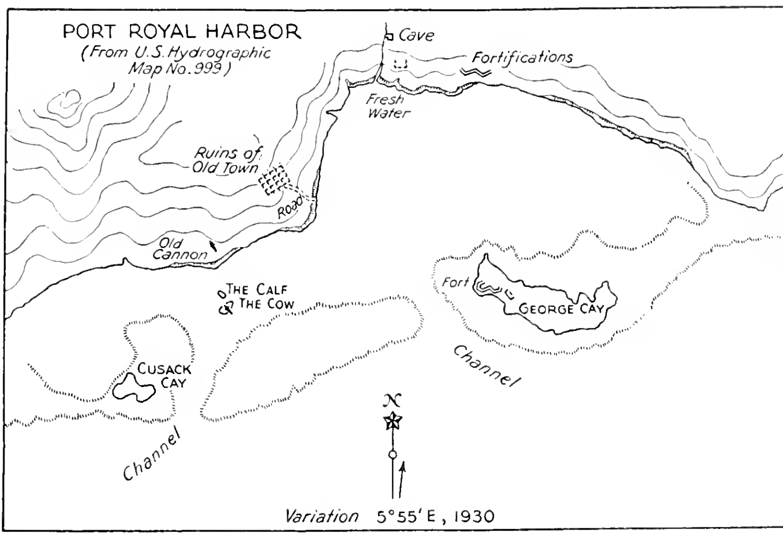


FIG. 8.—Map of Port Royal harbor showing buccaneer remains, Roatan.

In 1742 the British made an attempt to obtain possession of most of the Atlantic Coast of Central America. As part of this plan they occupied Roatan and fortified Port Royal with materials brought from the mainland. (Squier, 1858, pp. 615, 616.) Several English visitors at a somewhat later date mention this and give some interesting details. Strangeways states that there is a "Careening Kay" (for beaching and scraping vessels) at the northeast end of Port Royal Harbor, and quotes the following passage from the Columbian Navigator: "In Port Royal Harbor British ships formerly obtained wood; and they procured water from a rivulet in the NW. part of the harbor. The harbor is capacious enough to contain 20 or 25 sail of the line. Formerly there were two batteries here; one on the west end of George's Isle, and the other on a high point of land on the SW. part of the harbour. The heights of Roatan command such an extensive prospect, that no vessel can pass to the Bay of Honduras without being seen from them." He adds that the English took possession of Roatan in 1742 and built a fort in which they put 250 men commanded by Pitts, a logwood cutter. (Strangeways, 1822, pp. 40-42.) About 1827 Roberts visited the islands. In regard to Port Royal he says: "This beautiful island has an excellent harbor, easily defended; it was once in the possession of the English, who erected batteries completely commanding this harbor, and marked out a space at its end for the erection of a town." At the time of Roberts' visit none of the islands were occupied, owing, he states, to danger of Indian attacks. (Roberts, 1827, p. 276.) Although England specifically gave up her claims to this region in the treaty of 1763, she nevertheless retained her hold on Roatan, the piratical inhabitants of which caused so much trouble to Spain that, in 1780, she once more declared war.

The events which followed are described by the Bishop Pelaez (quoted by Squier, 1858, pp. 616, 617):

On the 24th of September, 1781, advices reached Truxillo, which were immediately communicated to the government at Comayagua, that certain negroes and others, to the number of about 300 men, had constructed three forts at the entrance of the principal port [Port Royal] of the island of Roatan, armed with 50 guns, and that three armed vessels cruised in the neighborhood, the object of the whole being to intercept the ships plying between the kingdom of Guatemala and Cuba. It was reported that these freebooters had 3,000 barrels of provisions for their support, and that their object in holding the port was to make it a refuge for their vessels, which were no longer allowed to go to Jamaica.

When this information reached Guatemala, the President Galvez made arrangements to expel the intruders. He called out the militia of Amatitlan, Zacatapeque, Chiquimulu, Santa Ana, San Salvador, Nueva Segovia, Leon, Olancho, Tegucigalpa, and Comayagua. The company from Leon numbered 200 men, under the command of Colonel Don Josef de Navas; San Salvador sent 300 men, and Santa Ana 200; and Don Miguel Machado, of Gracias, headed 200 men, equipped at his own cost.

In the meantime, two Spanish vessels of war, the Santa Matilda and Santa Cecilia, of the royal navy, with a sufficient number of *piraguas* from Bacalar, arrived at Omua, and the forces above mentioned, under the command of Galvez himself and his Lieutenant Estacheria, embarked on the 2nd of March, 1782. They steered direct for Roatan, and at once attacked the forts erected to command the principal harbor [Port Royal]. After a heavy cannonade, detachments of the troops landed and opened regular trenches against the forts, which were so closely invested and hotly pressed that on the 16th of the month they surrendered at discretion. The lives of the defenders were spared, but all their dwellings, to the number of 500, were destroyed.

The British also had settlements on the islands of Bonacca and Morat, all of which were captured by Galvez. The prisoners were ex-changed at Havana and only a few Negroes who fled to the swamps of Roatan escaped.

Things were evidently quiet around Port Royal for almost 15 years; then in 1796 the British forcibly deported some 5,000 Black Caribs (a mixture of Carib Indian and African Negro) from St. Vincent on the Windward Islands to Roatan. (Squier, 1858, pp. 618, 619, and Conzemius, 1928, p. 58.) These people, who had been attached to French interests, were giving the British much trouble, hence they were deported en masse and landed at Port Royal. It is not clear whether the British intended to reserve their dominion over the Caribs or were simply getting rid of them. In any event, the Captain General of Guatemala justly regarded it in the light of an invasion and sent armed forces to Roatan where the Caribs gladly surrendered without resistance. Most of them quickly accepted the invitation of the Honduras Government to come to the mainland, though a small number preferred to stay on the then deserted island of Roatan. For the remainder of the eighteenth century the Bay Islands were undisputedly held by Spain, and a small garrison was maintained on Roatan (Henderson, 1811, p. 204), probably at Port Royal.

Not until the middle of the nineteenth century did Great Britain again assert her claims to the Bay Islands, and again it was Port Royal that was the scene of action. (Squier, 1858, p. 620; Young, 1842, p. 147.) In 1838 a group of liberated slaves came to Roatan from the Grand Cayman Islands, desiring to settle. The commandant at Port Royal informed them that they must first obtain permission from the Honduras Government. Certain of the immigrants did so, but others appealed to the British Superintendent at Belize. This officer shortly thereafter appeared off Port Royal in the sloop of war *Rover*, landed forcibly and, running down the flag of Central America, hoisted the British flag. Young thus describes the affair: "A British sloop of war appeared off the port; a boat full of men was dispatched to the shore, the Central American flag hauled down, and that of Old England planted in its place. Shortly after the vessel set sail the commandant pulled down the English colors and hoisted his own, which was no sooner observed than the vessel was put back, and landed a party of seamen and marines. The Central American flag was lowered, and two or three of the middies amused themselves by dancing on it. The commandant and his soldiers, notwithstanding his vociferous protestations, were put on board of the vessel, and had the mortification of seeing, on their departure, the meteor flag of Old England waving in the breeze. They were landed on the beach at Truxillo with a few gentle hints as to their future behavior." Since the ensuing British occupation and later relinquishment of the Bay Islands have been mentioned elsewhere, we may conclude this brief historical sketch of Port Royal with the above somewhat anticlimactic affair.

We spent the day of May 5, 1934, in exploring Port Royal Harbor. It was a clear, windy day, and the guardian reefs were lines of high, white breakers, but inside the blue waters of the harbor were placid. We came in the west channel (see map, fig. 8) and passed the two rocks, the Cow and the Calf, on the former of which there is said to have been a cannon, but only the emplacement now remains. Bird's map of the harbor shows another old cannon on the mainland opposite, but we did not see this. These guns, with others on Cusack Cay, would have made entry to this channel extremely hazardous. We anchored at the head of the bay, where the small stream comes in, and visited an American by the name of Painter, who was the only occupant of the bay we encountered. He had several complete rum or sack bottles which he had found near his house (pl. 4, fig. 2). In type they closely resemble English sack bottles of the seventeenth century.[18] Under his guidance we proceeded about 100 yards up the small creek, the bed of which was littered with fragments and basal portions of irregularly blown, heavy green bottles of the sort illustrated. Here, cut out of a crumbly limestone cliff, is a rectangular cave about 35 by 15 feet in floor dimensions and about 5 feet high (fig. 9). The square walls and columns clearly indicate an artificial origin. The floor is composed of soft dust and dirt, but an apparent lack of artifacts, combined with the none too safe appearance of the cave walls, discouraged extensive digging. To the east of the creek Mr. Payne discovered some stone house foundations about 80 feet long and 20 feet wide. These were in dense bush and their total extent was not determined. They may or may not be the same as the "fortifications" indicated on Bird's sketch map (see map, fig. 8). Mr. Painter stated that there were stone foundations of what appeared to be a town, with a stone paved road leading to the shore, on the point west of his house (see map, fig. 8), but our time was too short to permit us to visit the place. This is probably the English or buccaneer town which the Spanish destroyed in 1782.

Leaving the creek mouth, we returned across the harbor to George, or, as it is locally known, Fort Cay. After considerable wandering through almost impenetrable low bushes we reached the battery that

---

[18] Compare the type shown in the Illustrated London News, p. 902, fig. 3 *c*, Dec. 3, 1932.

extends along the northwest face. Here are emplacements for some six or eight cannon (pl. 4, fig. 1), protected by low walls about 5 feet thick of closely cemented slabs of limestone, brick, and coral. The cannon themselves had all disappeared. About 50 yards southeast of the main battery is a stone structure of massive masonry, locally known as "the powder magazine". It is a little distance from the shore and consists of a heavy wall facing the sea and two short end walls, with a separate and less massive rear wall that is unattached. The structure is some 8 feet high and the front wall is pierced by several loop holes. These have a single aperture on the inside and a double aperture on the outside so arranged that they can-

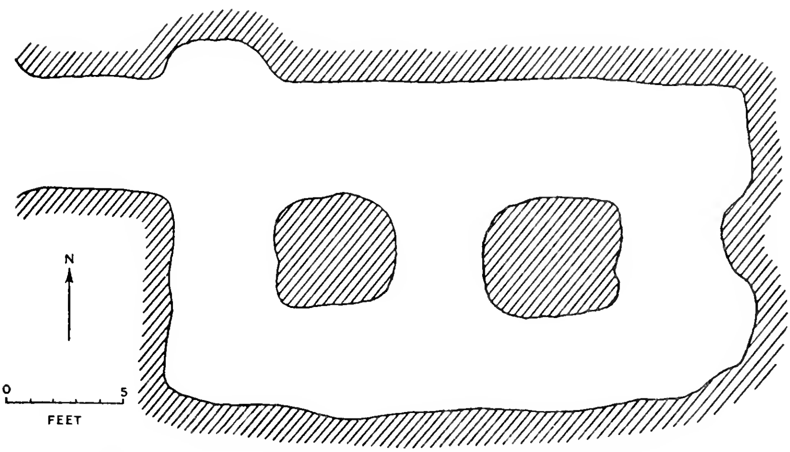


FIG. 9.—Floor plan of "buccaneer" cave, Port Royal harbor.

not be penetrated by direct fire. The inner sides of the stone walls have neat socket holes about a foot off the ground, probably for the insertion of floor beams. Near to this structure we noted several very large holes that had been dug in recent years, perhaps by treasure hunters. Captain Boynton pointed out one of these which he had seen soon after it was dug some years ago. A heavy, square object had evidently been removed from the hole and, at that time, the barked logs used as a skidway to roll the object to the beach were still in evidence. We saw nothing more romantic, however, than a few bits of iron and some old fireplaces near the battery, unless the omnipresent broken bottles on the beach be so considered. From its exposed position I rather doubt that the main structure here was the magazine; more probably it was the central "keep", fire-control or lookout station.

After a night during which a strong southeast breeze forced us to shift anchorage several times, we left Port Royal in the early morning. We had neither seen nor heard of any Indian remains in the vicinity, but it was with deep regret that we passed out between the silent, crumbling batteries, once the pride of "the brethren of the coast".

JONESVILLE BIGHT

This small lagoon or series of drowned valleys is located about 1 mile west of the beautiful little town of Oak Ridge (see map, fig. 1). Samuel Cooper, a long-time resident of Oak Ridge, told us of the finding many years before of painted pottery on the densely wooded

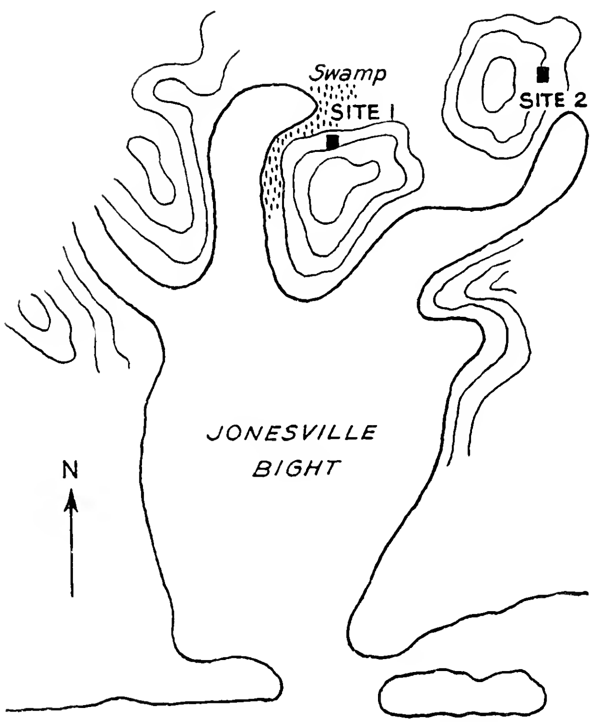


FIG. 10.—Sketch map of Jonesville Bight, Roatan. (Made by Junius Bird.)

ridges behind the town. We made a morning's expedition in search of this or similar sites but failed to locate any archeological evidence, although the ridges behind the lagoons would seem to be promising sites for offertories. That afternoon, April 29, 1934, the *Amigo* took us around to the head of Jonesville Bight (see map, fig. 10) to a site (site 1) which had been visted by the Boekelman Shell Heap Expedition in July 1931. Since Mr. Bird worked this site rather thoroughly and obtained a considerable collection here, the following account is primarily based on his notes and collections, supplemented with such additional material and information as we were able to gather.

Site 1

Jonesville Bight has three arms, and site 1 is located east of the central arm (see sketch map, fig. 10). The eastern shore here is fringed by a mangrove swamp, and to reach the site one enters the first opening in the dark wall of mangroves after the lagoon turns to the east. This is a shallow tidewater stream about 6 feet wide, which will float a dinghy drawing 14 inches. One follows this stream about an eighth of a mile through the mangroves until it is possible to step out on the low sand and mud shore. Here the land is level as far as the foot of the hill to the south, which can be seen through the scanty vegetation. Following the foot of the hill to the east, one comes to a triangular rock about 14 feet high, which juts out from the hill. Directly up the hill from this rock is a cliff about 75 feet high with a slight overhang. This affords a dry shelter for a strip 33 feet long but with an average width of only 2 feet. Near the center, however, the width of the shelter is about 8 feet. Below this the ground dips sharply to the north at an angle of about 40°, and a talus slope of large blocks of stone forms the bottom of a small gorge, which extends some 200 feet to the level bottom land. On either side of the small sheltered area great rocks jut out, and it is difficult to follow along the face of the cliff.

Digging showed the sherds and other artifacts to be entirely on the surface except at the very foot of the cliff, where they were buried to a depth of 10 to 12 inches. Sherds occurred over the entire area, which measured 8 by 33 feet. No charcoal or other evidences of fire were noted, and kitchen debris was lacking. The bones and teeth of a domestic hog were found on the surface, but these were probably later additions. A few human teeth and skull fragments were found in the deposit. Other objects present were large numbers of queen and horse conch shells. Nearly all the queen conch shells had a smooth round hole at the center. These were the most weathered, apparently owing to the perforation, which had been made so that they could be used as trumpets. Examinations of the vicinity, made by Bird and by our party, revealed no other signs of human occupation. The cliff beyond the site extends vertically upward for about 30 feet and then ascends very steeply to the top of the hill, which is entirely covered by irregular blocks of stone. From the nature of the site, which is difficult of access and poorly suited for habitation, and from the nature of the artifacts recovered, site 1 was in all probability an offertory shrine and burial place rather than a dwelling site. In the following discussion of artifacts the collections of both parties have been merged. Bird's collection, which is the most extensive, is in the American Museum of Natural History and ours in the United States National Museum.

CERAMICS

No complete vessels were found at this site; Bird's collection includes 250 sherds and ours 50 sherds. In both collections these were selected, and a large number of sherds, especially undecorated pieces, were left at the site. However, although undecorated, plain red sherds were more common at site 1 than the following tabulation indicates, the proportion of decorated ware at this site was very high. The combined sherd collection falls into the following main types:

No. of sherds	Type
10	Thin polychrome (Polychrome I)
20	Medium polychrome (Polychrome II)
270	Red, unslipped ware. (Of these, 53 are more or less elaborate lugs, 132 are elaborately incised sherds, and 85 are plain sherds.)

The thin polychrome pottery from this site is very limited in amount but very definite in type. It is characterized by an orange slip and elaborate line decoration in black and red-purple. All 10 sherds are from the Bird collection, as I found no sherds of this ware at the site; hence its rarity in the collection reflects its actual rarity at the site. The body sherds show complex design motifs; two rim sherds have a typical, double black line above and a red line below, and the other sherds are from the lower portion of vessels and are marked by heavier black, red-purple, or dark orange lines. One rim sherd (fig. 11, *k*), perhaps transitional between this and the next type, has a geometric design in red-purple and black on both surfaces. The sherds are small, the largest being 6.5 cm in length, and they range from 5 to 7 mm in thickness. There are two lugs that, owing to erosion, lack any slip. One of these is of the applique rider type (fig. 22, *b*), the other a slight variant of the iguana type (fig. 22, *c*). The temper in most of the sherds is too fine to be visible, but in one or two, gray grit can be distinguished. Since this type of ware (Polychrome I) will be analyzed in detail later in relation to other sites where it was more abundant, further discussion can be deferred.

The Bird collection contains 16 sherds of polychrome pottery that do not fall into the above type. I collected four sherds of this ware at site 1, Jonesville Bight, but did not encounter it commonly in the islands, nor does the Bird collection contain much from other island sites. This ware, which I have designated Polychrome II, suggests

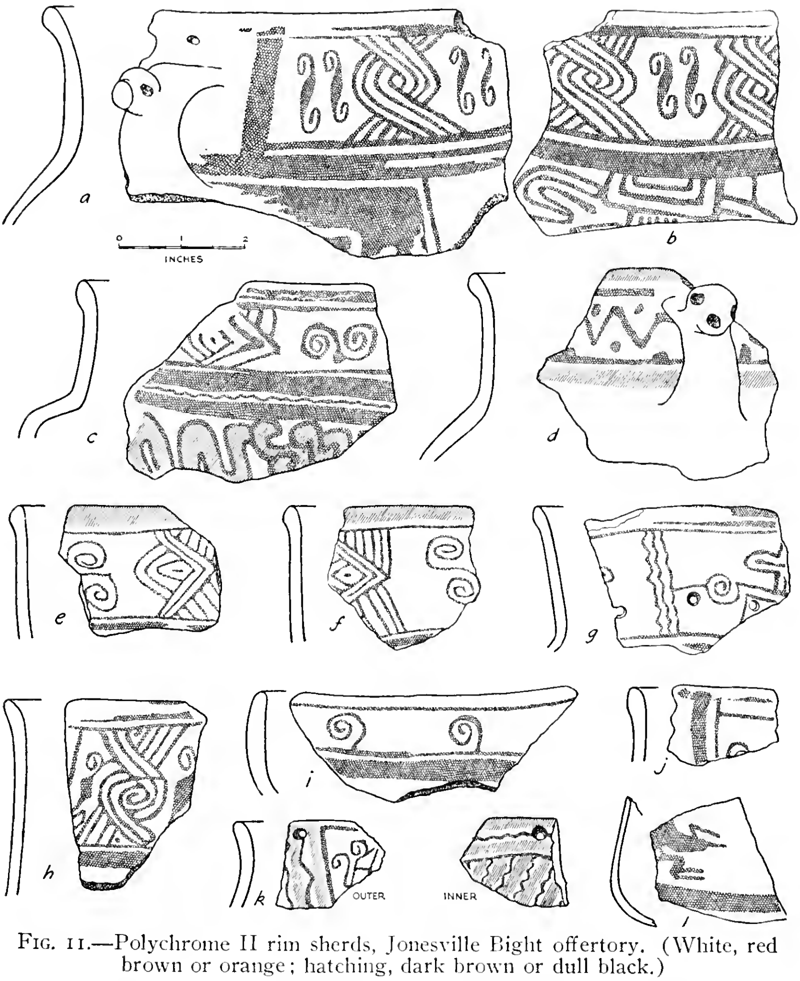


FIG. 11.—Polychrome II rim sherds, Jonesville Bight offertory. (White, red brown or orange; hatching, dark brown or dull black.)

a conventionalized and somewhat simplified development of Polychrome I. It is characterized by a high polish on a red-brown or dull orange slip, with designs in dark brown or dull black (fig. 11). It has a fine gray-grit temper and is fairly thin (3 to 8 mm thick, average 5 mm). The designs are rather well applied but tend to be somewhat isolated and rather simple (fig. 11). The most striking single element is a unit "twined or braided" decoration (fig. 11, *a, b, c*). The single and multiple scroll is common (fig. 11, *a, b, c, e, f, g, h*) and the "twined or braided" element above referred to (fig. 11, *h*) may be derived from this simpler motif. Concentric diamonds with a central dot (fig. 11, *e, f*); angular lines with dots in the angles, occurring between black borders (fig. 11, *d*); wavy black, vertical lines and half scrolls are also used (fig. 11, *f, g*). The above are mainly neck decorations. Below the neck heavy geometric or curvilinear designs occur (fig. 11, *a, b, c, l*) and, in one case (fig. 11, *c*), this dark design has a darker border. One sherd (fig. 11, *k*) has linear designs in black and red-purple on an orange slip occurring both inside and outside of the lip, but, as previously stated, this sherd may be either of Polychrome I type or transitional between I and II.

Since no complete vessels were recovered, shapes must be determined from the available fragments (fig. 11, see rim outlines). Jars with a restricted orifice, a slightly contracting neck, slightly flaring lips, and large vertical loop handles (the latter in two cases with a conventionalized manatee head adornment) are evidently common (fig. 11, *a-d, g*). To judge from the rim fragments, these vessels were rather large, perhaps 30 cm in height. Cylindrical vases with slightly contracting necks and swollen lips occur (fig. 11, *e, f, h, j*). Small open bowls with a rounded bottom (fig. 11, *i*) or with a definite break between wall and bottom (fig. 11, *l*) are also present. The cylindrical jars (fig. 11, *h, j, k*) rather strongly suggest Polychrome I shapes. The occurrence of a number of borings in rim sherds for "crack lacing" (fig. 11, *a, g, k*) suggests that ware of this type was highly valued and carefully mended when not irretrievably broken. The rarity of Polychrome I and II sherds is likewise significant in this regard.

The third type of ware at this site may be termed monochrome, although painted decoration occasionally occurs. The monochrome ware falls roughly into two classes, an elaborately incised type and a plain or very poorly decorated type. At this site, however, the elaborately incised ware is predominant. Monochrome ware of these two classes will be analyzed in considerable detail later in connection with two sites on Barburata Island; hence for the present a rather brief description will suffice.

The elaborately incised ware at site 1 is particularly characterized by fragments of tall cylindrical jars with elaborate lugs and annular bases. Large and small bowl fragments with elaborately modeled tripod legs also occur. The sherds from this site, however, are so badly broken up that shapes and sizes are hard to determine. Rim fragments fall into three main types: those of more or less vertical jars; contracted necks with low slightly flaring rims (much like fig. 11, *a-d*); and contracted mouths, with no neck, but with swollen lips. One of the latter is unique in having a broad, flat, horizontal groove running around the rim, separating it into a lower inner and a higher outer portion. The paste of this ware is well made and well fired, attaining a hardness of 5 in some cases. It ranges in color from light buff to dark red, with a red-brown the prevailing tone. No slip is visible on the great majority of pieces. The surface is well polished in most cases, burnished in others, and in four cases the sherds are fired to a slaty consistency showing gray blue on the inner surface and in cross-section, but polished brown on the outer surface. These are the pieces that attain to a hardness of 5.

Two large fragments are rather unique. The first of these is a small jar (7.5 cm in diameter at the mouth) with a constricted neck and flaring spout. Only the neck and rim are present. The color is a dark brown. It has dark grit tempering, is well polished, and is unique in having vertical fluting down the neck at 4-cm intervals, the square spaces between being decorated with small, even punctate marks. The second unique fragment has a similar constricted neck and three incised lines around the shoulders, below which is a vertical incised pattern. The latter design is obscure, because the lower portions of the vessel are missing.

Decoration in this ware is achieved by incision, applique, elaborate lugs and feet, as well as by form and polish. There are some 15 fragments of tiny jars with delicate incision and punctate design plus applique work (pl. 5, *c*, *f*). These are very thin (2 mm in thickness in several cases). Two of these small fragments have incised grotesque faces, with " coffee bean " eyes and peaked noses in relief. The heavier ware ranges from very hard, beautifully incised sherds to coarser, crudely incised pieces. In thickness this type of pottery ranges from 2 to 10 mm. Step, fret, cross-hatched designs or combinations of these with dots, double scroll and dot, and curvilinear human or monstrous faces (pl. 5, *d*) all occur (similar to pls. 24, *a*, *b*; 26, and 30, *a*, *b*, *c*, *e*). Only three sherds of this monochrome type of ware have a visible slip. Two of these are rim fragments of straight-walled vessels, with a dark red slip and an incised step design reinforced with black paint (similar to pl. 18, fig. 1, *e*). The third is a highly polished fragment with a flat, projecting rim. It has a dark red slip, and there are traces of a black design on the flat rim.

Some 53 lugs were recovered. These are very similar to lugs from site 1, Barburata Island (figs. 24-27). Seven lugs are of the vertical type (*c*) with the constricted center at the point of attachment (compare fig. 26, *a-c*). Some are extremely grotesque, others very plain. Two rather unique face lugs are figured (pl. 5, *a*, *c*) but of these, one (pl. 5, *a*) may come from a figurine. The 17 detached feet recovered at this site are similar to those from site 1 on Barburata Island (compare fig. 28). One conical modeled foot represents a human being (pl. 5, *g*); two cylindrical feet, one hollow and one solid, suggest a manatee head; one hollow cylindrical foot is like figure 28, *d;* and three solid, thin, rectangular feet are like figure 18, but lack the incisions. Fragments of annular bases are rather common, and one of these has the reversed L perforation characteristic of various marble vases from the Uloa River.

The plain or crudely decorated monochrome ware was scantily represented at site 1 and is even more poorly represented in our collections. To judge from the sherds of this type, the plain vessels ranged from heavy jars, slightly less than 1 meter in height, to smaller open bowls and flat saucers only 4.5 cm in diameter. The majority of the plain rim sherds are from medium-sized vessels with restricted orifices and low, more or less flaring rims. No clear distinction can be made between the plain and the elaborately incised monochrome ware at this site, since many of the plain sherds are more highly polished and thinner than some of those that are incised. The distinction is made, however, owing to the fact that it seems to have significance elsewhere and that the low proportion of plain as opposed to incised sherds at this site is very striking.

No complete figurines were recovered, but several fragments were found. One grotesque hollow head (pl. 5, *b*) of brown pottery is similar to those from site 1, Barburata Island (pl. 28, fig. 1, *a-c*) except that the hands on the face are unique. There were five fragments from similar figurines. In addition, there are two five-fingered hands and a number of rolls of fired clay that probably came from figurines. An object of unknown use was a concave oval disk of brown pottery with a perforation at each end (compare fig. 29, *b*).

OTHER ARTIFACTS

Ground-stone artifacts were not numerous but included a small mace head (3.7 cm high) of white marble with vertical incisions down the sides (pl. 17, *i*); a thick, sharp-edged little celt (3.5 cm wide) of gneiss (pl. 16, fig. 1, *j*); a beautiful little celt of dark green jade, or jadeite, with a very sharp edge (pl. 17, *k*); a bulletlike pendant of gray steatite, and a handful of green talc and diopside beads of disk, cylindrical, and round shapes (similar to pls. 14 and 17, *a*). Only one artifact of chipped stone was recovered, an oval knife (8 cm long) of white stone fairly well retouched.

Bird found a number of unworked rock crystals in the deposit, but we found none. Shell artifacts were rather numerous. There were 11 disk shell beads (1.2 to .5 cm in diameter); 58 perforated *Margenelis* shells, each with a rough hole punched through the back; two dozen perforated snail shells (*Cerithium muscarum* Say); a dozen perforated "bleeding teeth" shells (*Nerita versicolor* Linné), and a number of unperforated snail shells. Two disks (3 cm in diameter) of pink shell; two small triangular pendants, each with a horizontal hole through the tip; seven olive shell ornaments, each with one end ground down and a hole through the back; a ground-down cone shell; a thick, ovoid, shell disk with a hole through the center and a rounded groove around the sides; and two unworked clam shells,[19] the only ones found at the site, complete the list. We found two barbs from a sting ray at the site.

The most numerous animal remains were 65 canine teeth of the raccoon, each perforated at the root end. In addition, there were 39 of these broken teeth evidently from the same necklace. A portion of a bone tube 8.5 cm in length had been cut off and rounded at one end. The bone cannot be identified as to type. As previously mentioned, two portions of the jaw, one ground-down tusk, and several loose teeth of a domestic hog were found by Mr. Bird at this site. They were on the surface and probably had no connection with the site beyond the fact that a pig, gone wild, had used it as a shelter and died here. Could it be proved that the bones were left by the Indians, however, it would date their latest use of the place as after the time of Cortez. Bird found two human mastoid bones, one human lower jaw, and a fragment of a second human jaw; we found a few human teeth, including several markedly spatulate incisors, and two small human skull fragments. All these fragmentary human remains were scattered at random through the deposit. Possibly they were once in urns, with the smaller offerings, but if so, earlier visitors at

[19] The above shell identifications are those of Bird. It did not prove feasible to have all Bird's molluscan material in the American Museum of Natural History examined by experts.

the site had broken them and scattered their contents. In this regard it is significant that in 1927 or 1928 Sr. Luis R. Diaz, of Oak Ridge, found a small carved head of green talc at this site. This turbaned head is practically identical with one found by us in an offertory vessel near French Harbor (see pl. 11, *f*). Mr. Bird obtained a photograph of this specimen, which was in the finder's possession. Since one party at least had removed material from site 1, it is probable that it had been disturbed several times before either Bird or our party visited it. That it was an offertory rather than a dwelling site, however, seems well borne out by an analysis of the remaining material.

Site 2

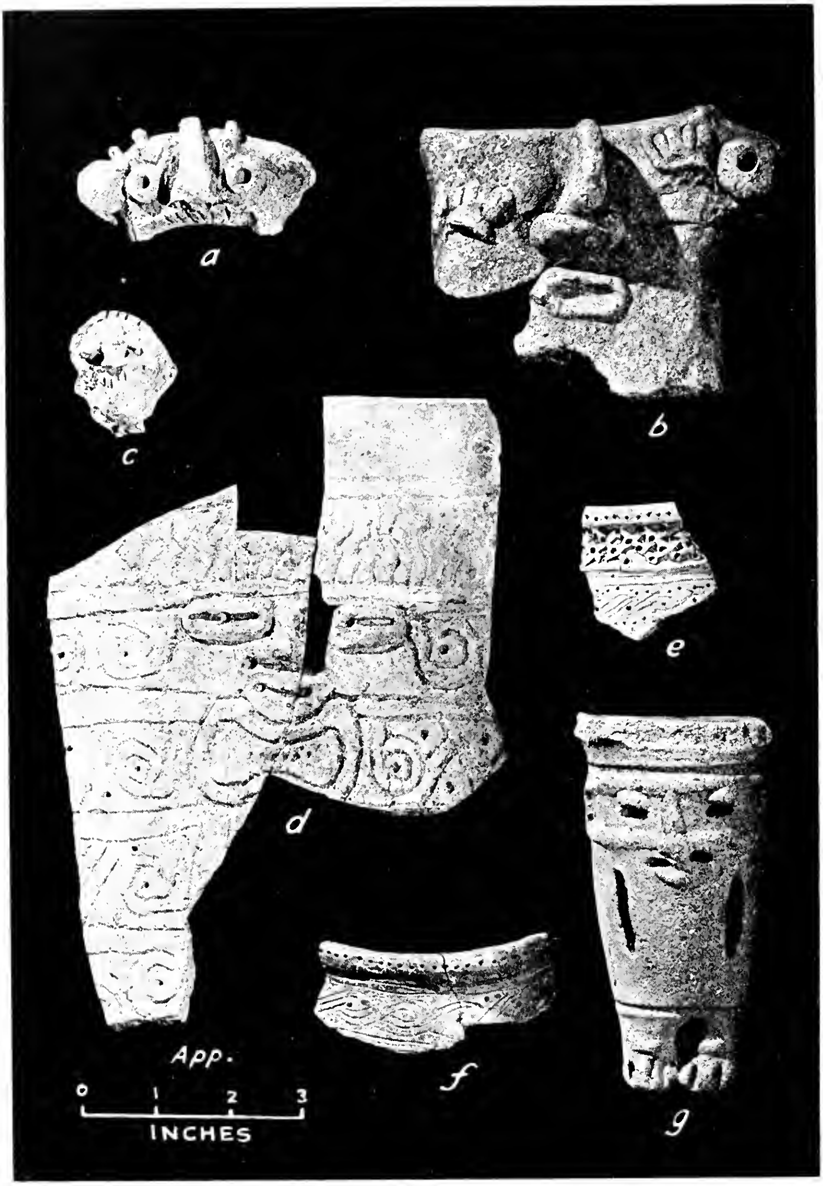
Having completed our examination of the main site we accompanied our guides to some caves on the west shore of the eastern arm of Jonesville Bight (see site 2, map, fig. 10). These are located about half a mile northeast of the landing place, up on the side of the hill. They consist of a series of clefts in the face of a vertical cliff. Fallen slabs have wedged into these splits, and one can crawl beneath these, in one place for about 50 feet. Several crevices converge at one point into what might properly be called a cave, but evidences of human occupation were of the slightest. We found one sherd of coarse red pottery near the entrance but nothing else. The floor was covered by a layer of sandy dust, in places perhaps 4 feet deep. We sank a pit to a depth of 3 feet in one corner and encountered animal bones at about 2 feet but no ashes, artifacts, or other evidences of occupation. It is possible that complete excavations here might be rewarded, but our superficial examination was not promising. Bird examined this site in 1931 but found nothing. Local people report that on top of this hill, locally known as Marble Hill, is a large cave 30 feet deep that must be reached by the use of ropes. No human evidence was reported from here and we did not examine it.

FRENCH HARBOR

Our discoveries in this vicinity, although entirely accidental, were perhaps the most important on the entire trip. No sites had been reported at French Harbor (see map, fig. 1) and we called there primarily to obtain gasoline and mail from the mainland. While we were waiting for the arrival of the schooner bringing these supplies, an acquaintance was formed with Ogilvy G. Dixon, a long-time resident

PORT ROYAL, ROATAN

1. Old buccaneer fort.
2. Old rum bottles.



Photograph courtesy of American Museum of Natural History.

ELABORATE MONOCHROME SHERDS AND FIGURINE FRAGMENTS, JONESVILLE BIGHT OFFERTORY, ROATAN

2

DIXON SITE, ROATAN

1. Central offertory vase *in situ*.
2. Offertory vase (Polychrome I) after removal.

a 1 b

e 4 f

DIXON SITE, ROATAN

1. Monochrome vessels.
2. Monochrome vessels *in situ*.
3. Slab metate and roller pestle.
4. Monochrome vessels.

of French Harbor. Mr. Dixon reported having seen pieces of broken pottery some 20 years earlier while prospecting for new plantation land on the high ridge behind the settlement. Lacking more promising leads, Haskell and I, with Jerry Borden and Joe Saba, accompanied him on a search for this place.

The Dixon Site

Heading northeast from the settlement, we climbed a series of steep ridges until we reached the central, east-to-west ridge that forms the backbone of the island. Cutting our way through dense brush, we climbed this ridge, which reaches an altitude of some 750 feet. Here our guide appeared at somewhat of a loss, as well he might after so long a time, but began a diligent search for two " Adam's Needle " trees which marked the spot. According to Dixon, these rather small, thorny palms (probably a species of *Bactris*) nearly always occur near pottery deposits on the ridges. After considerable vain searching, Haskell and I sat down to appreciate the view which, from here, takes in both sides of the island. To the north the ridge breaks off almost precipitously down to a coastal strip around Big Bight, the plantations of a few Black Caribs, who are the sole occupants of the north shore, coming close up to the steep central ridge. On the south an equally extensive view is likewise revealed, but the mountainous mainland was shrouded in the smoke of plantation-clearing fires, which at this time of year darken both the islands and the mainland.

Rather to our surprise, one of the boys returned to say that they had found the site. It proved to be on the highest part of the ridge in this vicinity, which formed a knob some 40 feet wide and about 90 feet long from east to west. To the north this space was edged by limestone rocks, which dropped off precipitously over the rim; to the south the slope was more gradual but still rather steep. As is the case along the entire ridge there was dense vegetation over all, including the steep northern face. Through the bush, however, limited glimpses of both sides of the island could be obtained. The site is located about 2 miles from French Harbor in a northeast direction, but the " trail " to the site is about three times that distance. The knob is some 20 to 30 feet higher than the rest of the ridge but is not visible as a distinctly higher area from any great distance.

There were no artificial constructions marking the place. The two small " Adam's Needle " trees, remembered by Dixon, and a few plain sherds unearthed in soil-testing many years before were the only distinctive land marks. Later work demonstrated that the central portion of the knob was covered by a roughly circular artifact area approximately 35 feet in diameter. The predominant material here was an immense amount of broken pottery, mostly of a coarse, red, unpainted ware. The entire deposit was thinly covered with soil and humus, and the artifact layer itself was not thick, ranging from 6 inches in total depth (including top soil) on the edges to 2 feet at the center. Within this roughly lenticular deposit potsherds of variegated sizes were extremely abundant and other artifacts in lesser proportions. Clearing and excavation revealed no particular order in the deposit except that the main offering occurred in the central part of the artifact area. About 10 feet northwest of this was a group of small, rudely incised pots (pl. 7, fig. 2), and a few feet to the northeast of the central offering were several broken metates, figurines, and flaked stone knives. The latter occurred scattered throughout the deposit. There was a small pile of conch shells 10 feet south of the central cache. The majority of these were perforated, apparently for use as trumpets. Excavation revealed some charcoal but no ash deposits, camp debris, nor human or animal bone. There were no traceable living or house floor levels, and the presence of numerous complete artifacts and models of complete artifacts amidst the mass of broken pottery indicated that the site had served as an offertory rather than as a place of habitation. This conclusion was strengthened by the nature of the central deposit or offering.

The votive cache was encountered on the second of the two days which it was possible to devote to the site. It appeared first as a mass of nested potsherds extending from a few inches below the surface to a depth of 2 feet (pl. 6, fig. 1). The majority were large sherds of a plain red ware, though a few were polychrome in type. They were tightly packed, forming a complete covering for the enclosed offering. Complete pots did not appear to be represented—rather a collection of large sherds so arranged as to suggest a thick deposit of forcibly nested pots. It was impossible to preserve all these sherds for laboratory study; hence it is not known whether any restorable pots were present. The protective covering averaged 10 sherds in thickness above and below the votive offering. The latter consisted of a perfectly preserved polychrome pot (pl. 6, fig. 2). On the lip of the pot was a medium-sized, much-worn stone celt. The vessel itself proved to be full of sifted-in black earth and smaller offerings. A number of green stone beads, the most numerous type of offering, appear in the photograph (pl. 6, fig. 2). In all, there were 487 objects in the vessel, as follows:

1 large copper ring.
1 small copper ring.
2 shell tubes.
30 variegated copper bells.
1 rounded piece of copper.
5 small, notched *Oliva* shells.
1 six-pointed star of shell.
7 shell labrets.
3 triangular shell pendants.
6 pieces of cut shell.
1 fragment of stone bead.
18 fragmentary shell beads.
6 carved stone faces (excellent).
4 carved stone faces (cruder).
2 carved stone human figures.
5 incised pieces of stone.
2 bird figures of stone.
1 spindle whorl of stone (maze design).
1 small stone gorget (rectangular).
2 incised stone disks (small).
3 rounded pebble pendants (crudely incised).
4 T-shaped stone pendants (small).
1 incised ring.
23 small stone pendants.
2 partially perforated pebble pendants.
1 small, unworked pebble.
26 incised stone beads (various shapes).
3 cruciform stone beads.
164 cylindrical stone beads.
68 round stone beads.
88 disk stone beads.
2 triangular stone beads.
1 highly polished, small stone celt.

Near the central cache was a small worn celt, a broken lava metate, two small tumblerlike clay vessels, a crude canoe-shaped pottery vessel, and a larger troughlike object of pottery. All of these can be seen in the photograph (pl. 6, fig. 1). In addition, a considerable number of quartz crystals, a curved plain metate and muller (pl. 7, fig. 3), and two celts were found close by. As discussion of the artifacts will show, many of the objects were broken when found, but the presence of a number of perfectly preserved pieces, as well as the indubitable offertory nature of the central cache, suggests ceremonial deposition of all the material rather than refuse accumulation on a habitation site.

CERAMICS

The ceramics from the Dixon site fall into two main types, a numerically preponderant monochrome ware and a small amount of polychrome pottery.

The polychrome ware (Polychrome I) is best represented by the complete vessel (pl. 1), which contained the central votive offerings. This is a well-made but slightly asymmetrical vase, 20.3 cm high. The mouth of the vessel is slightly ovoid in form, measuring 11.8 cm in width parallel to the two lugs and 12.2 cm at right angles to them. The body of the vessel averages 3 mm in thickness. The lugs serve as rattles through the inclusion of small pieces of gravel, and each represents a human face with uptilted nose, punctate eyes, and raised ear plugs. The face projects from the body of the lug in a manner suggesting inclusion within the mouth of a shark or serpent (fig. 12). However, as later discussion of lugs on this ware will show, this may be illusory. Like the lugs, the tripod feet, which are perforated on the inner side, also serve as rattles. The painted design is considerably weathered, but owing to its duplication on both sides of the vessel it has been possible to restore it with complete accuracy (compare pl. 1 and pl. 6, fig. 2). This design is executed with black and purplish-red lines on a uniform orange-red slip, which covers the entire pot.

FIG. 12.—Detail of lug, central offertory vessel (Polychrome I, pl. 1), Dixon site, Roatan. (White, orange-red; black, black; hatching, purplish red.)

The central black and purplish-red design in the main panel is a variant of the widespread plumed serpent motif. It consists of a grotesque head with eye, nose, and mouth indicated and decorated with nose ornaments, ear plugs, and an elaborate plumed headdress (pl. 1). The body is a conventionalized serpent form with a short writhing midsection decorated with plumes and ear plugs. The body terminates in a conventional tail tip formed by a square crossed by three vertical lines. The small design in the panel above is the same motif, done solely in purplish-red and considerably simplified. Likewise, the small panel above each lug is the same design even more condensed (fig. 12). Inside the rim is a broad, purplish-red line and below this, forming a band about 3 inches in width, are traces of what may have been a black design. This last is too faint and obscure for delineation or even for certainty. These design elements in their totality are best indicated by the illustrations (pl. 1, pl. 6, fig. 2; fig. 12).

In addition to the complete vessel less than a dozen sherds of the thin polychrome ware (Polychrome I) were noted and preserved. A few others of this type were undoubtedly present in the deposit, but they were very rare. Discussion of this pottery, which is a distinct type, will be deferred until the more abundant Polychrome I ware from site 1, Indian Hill, on Barburata Island has been analyzed. Anticipating, however, it may be stated that among these sherds from the Dixon site there is one lug representing an aberrant applique rider type (pl. 23, *d*). Four feet represent two types, one is spurred (like fig. 22, *i*), the other three are of a simian type (like pl. 23, *e*). The other sherds of this ware are tiny and nondescript. Besides the thin ware sherds, there is one thick sherd (6 mm in thickness) from an open bowl with a dark red slip and a wavy black line design on the outer surface. This last is not in the same tradition as the Polychrome I pieces and probably represents a variant of the better class of monochrome ware.

As has been previously indicated, monochrome, unslipped ware made up the major portion of the artificial deposit. Since the paints employed on the island wares generally seem to have been rather fugitive in quality, it is dangerous to lay too much stress on this last factor. However, the prevalence of incising and the greater thickness of the apparently unslipped ware is rather distinctive. By far the larger portion of the pottery at this site showed no sign of having been painted. Although most of the ceramics were broken, we collected 16 whole or restorable vessels of the unpainted type. The groupings of five small, incised vessels just northwest of the central cache suggests that they too served as special offerings (pl. 7, fig. 2, shows two of these). Most of the vessels recovered entire were rather small and rude in execution, and it is probable that they were merely models of larger and better utilitarian pieces. Their crudity, plus the fact that an attempt has been made to suggest ornate decoration, bears out this supposition.

The plain ware from this site is rather uniform as to color, being a reddish buff on the outer surface and a brick-red below the surface. Whenever pieces have been chipped or rubbed, this brick-red coloring is apparent. The ware is predominantly crumbling in texture, with coarse, white gravel employed as tempering. The inner surfaces of several pieces indicate that they were built up by the coiling process. The size of the vessels is highly variable; they range from small pieces (presumably models of larger forms) to very large vessels which, to judge from fragments, were at least 1 meter in diameter with a thickness of from 2 to 5 cm. Some of the small pieces are relatively thin (5 mm in thickness), but this is rather exceptional.

A variety of shapes are represented (pls. 7, 8). One common type, unfortunately represented at this site in complete form only by miniature pieces, is a cylindrical vase with an annular foot, incised designs on the body, and two vertical lugs on the sides. These range from an almost vertical form with flaring lips to a type markedly constricted just above the base and lacking any flare to the rim (pl. 8, fig. 1). One small vase (pl. 8, fig. 1, *i*) was once elaborately decorated with incised lines and punctate impressions, but weathering has left only a faint indication of this former complexity. The others have simple geometric line and punctate ornamentation (pl. 8, fig. 1). Both the shapes and the decoration of these smaller vessels, as well as the ornate but crudely modeled lugs, suggest a somewhat careless copying of better models. As will become evident when the pottery from similar island sites is discussed, these small crude vases should probably be regarded merely as models of larger vases in daily use, the latter being offered for the most part only in a broken condition, whereas the small, crude, but complete models were made primarily for offertory purposes. Unfortunately, only one incomplete larger vessel of this type was recovered at this site. Unlike its smaller imitations, it is composed of thin, well-finished pottery (3 mm in thickness) with fine grit tempering. The annular base is decorated with broad, horizontally incised lines and heavy punctate marks. The upper body being absent, the main design is but scantily represented by appliqued strips of clay and punctate impressions. This applique design probably represents one version of the " manatee " motif (for more complete examples see pl. 18, fig. 2, *a*, *b*; and fig. 18). Fragments of these well-finished vessels were found at several other sites (pl. 24).

A pottery object of this general cylindrical type with a flare at one end is unique as to the extreme thickness (16 mm) and coarseness of the ware, the absence of lugs or decoration, and the lack of any bottom (pl. 8, fig. 1, *h*). From its present condition it is impossible to tell whether a crude vessel or an open tubular artifact was intended, but the slight rounding at the smaller end suggests the former.

Another type, represented by five pieces, is a rounded bowl or cup-shaped vessel with one or two vertical loop handles on the sides (pl. 7, fig. 4, left, and pl. 8, fig. 2, *a*, *f*). Of the five vessels of this form, only one (pl. 8, fig. 2, *f*) is smooth and polished, the others being coarse and irregular in form and decoration. This well-finished piece is unfortunately too badly broken for accurate reconstruction as to its rim portion. The body is globular with a flattened, markedly convex bottom. The small loop handle (only one is present) is ridged on the edges with a line of raised notches in the center, and occurs on the portion of the pot where the sharp slope toward the apparently constricted mouth begins. The vessel walls are rather thin (5 mm thick). This fragment is probably part of a once utilitarian vessel. The other four vessels are round-bottomed and are so crude as to suggest their hasty manufacture solely as offertory pieces. One is complete (pl. 7, fig. 4, *c*) with two incised vertical loop handles. The same type of crude incision extends in a band around the upper body. Like the other complete vessels of this type, the vessel has a slightly flaring rim. It is crudely and irregularly modeled but is not as thick as the gross handles and rim suggest, being only 6 mm in lower body thickness. A small vessel (pl. 8, fig. 2, *a*) is rather similar but differs in its decoration, which consists of small, vertical lines incised on the body, loop handle, and just inside the rim. The modeling of this piece is also very irregular. Better modeled is a similar vessel (pl. 7, fig. 4, *f*) decorated with two rows of short vertical lines separated by horizontal incisions. Only one vertical loop handle was formerly present. The last bowl of this type is extremely crude (pl. 7, fig. 1, *b*) and appears to have been punched out of a lump of clay. It formerly had two vertical loop handles and the upper body is ornamented by uncertainly executed, short, vertical incisions. Its thickness is extremely variable (6 to 11 mm).

Two globular vessels with constricted necks are present (pl. 7, fig. 1, *a*, and pl. 25, *a*). The largest of these is better modeled and polished than the majority of the small vessels previously described. Its rim is formed by an attached ribbon of clay and its decoration, consisting of incised and indented lines, is irregular (pl. 7, fig. 1, *a*). The smaller vessel (pl. 25, *a*) is likewise fairly well modeled and polished, with two tiny lugs at the base of the short neck. Fine grit tempering has been employed in forming the paste of both. A round-bottomed pot with a slightly flaring lip and wide mouth (pl. 8, fig. 2, *g*) is somewhat cruder in manufacture than the former. This vessel appears to have been made without handles or lugs and is rather thin (5 mm thick). The tempering is white grit somewhat coarser than in the last two vessels. Its form is unique in the present collection. All three of the above vessels have a buff surface patination with the underlying brick-red color showing through wherever they are worn or broken.

Four small saucerlike vessels come from this site (pl. 8, fig. 2, *b*, *c*). Three of these are shallow with round bottoms. They average 7.5 cm in diameter. The fourth (pl. 8, fig. 2, *b*) has a flattened bottom and a raised rim. All are crude in modeling and are various tones of brown, red, and buff. Their purpose, whether utilitarian or for offertory models, is problematical.

An interesting canoe-shaped type is represented by two vessels (pl. 8, fig. 2, *d*, *e*). The larger of these was found close to the central offering. It was apparently broken when deposited but has been restored from the nearly complete portion recovered (pl. 8, fig. 2, *e*). The modeling, although rather crude, definitely suggests a "pitpan" or river canoe in form. The piece is of the brick-red pottery with gray-buff patination. It has been poorly fired, being black in midsection with rather coarse sand for tempering. The second vessel of this type (pl. 8, fig. 2, *d*) is rather different, having depressed, rounded, and incised ends. One end of the upper edge is notched. Its color, tempering, and modeling are similar to those of the vessel just described. A boat form is suggested, but this is far less definite than in the former case, and a bird or animal form may have been intended. Unfortunately, the larger troughlike pottery object behind the central offering (see pl. 6, fig. 1) was not preserved. Its general form faintly suggests a canoe, but it lacked any definite bow or stern extension. It was of the same type of pottery as the two pieces just described but was considerably larger than either.

Owing to the difficulty of removing material from this inaccessible site in the short time at our disposal, only a small sample of the abundant broken pottery could be brought out. This small sherd collection adds some details missing in our discussion of the more complete pieces. It shows that large, well-made vases with intricate and highly conventional vertical lugs were represented. These large lugs, well represented in the Indian Hill collection (see pl. 24, *b*), are obviously the original types from which the small crude miniature vessels (pl. 8, fig. 1) were modeled. There are also two small horizontal lugs, with punctate or incised decoration, that are especially characterized by projections or "horns" at each end and a depressed center. A heavy, red rim sherd with deep, firm incisions and punctate marks represents a fragment of one of the large, utilitarian, cylindrical vases. Three brick-red pottery fragments, very heavy and coarse, are covered with incised circles each about 1 cm in diameter. Although the three pieces are evidently from the same object, they do not fit together, and the nature of the object remains obscure. The design suggests the warts on a toad or possibly the scutes on an alligator's hide. Numerous vertical strap handles decorated with heavy incised lines, crude punctures, and in one case two raised " coffee bean " eyes are also present. One broken-off, rounded, tripod base is especially noteworthy on account of its size (5.6 cm in upper diameter), since it indicates that very large tripod vessels of plain ware were in use. The remaining sherds are from types already described or else without any particularly noteworthy characteristics.

Two almost complete pottery figurines (pl. 28, fig. 1, *e, f*), two unique pottery heads (pl. 28, fig. 2, *c*; fig. 13), and three detached arms from such pottery figures were recovered. The complete figure (pl. 28, fig. 1, *e*) is an unusual type. The projecting jaw, broad nose, wide mouth, perforated ear, and incised necklace are noteworthy. The arms extend down the body, and the fingers touch just above the crotch. No sex is indicated, but a male is suggested by the form and features. It is made of coarse red pottery, is 16.5 cm in height, and is solid throughout. The second figurine (pl. 28, fig. 1, *f*) is very crude, and the arms are missing. It is of the same material as the last, solid, and 12 cm in height. A crude attempt to indicate costume, or perhaps merely to decorate, is indicated by the roughly rectangular incised lines on the front of the body. The features are amazingly crude, but the punctate eyes and broad nostrils suggest the better-made figure already described. However, the prognathous jaw, projecting snout, and hump-backed appearance are unique. The tempering in this figurine is coarse gravel, whereas in the former it is much finer.

The two pottery heads are likewise of different types, although both are modeled from the same coarse red pottery. The first of these (fig. 13) is crudely realistic. It is solid and stands 15 cm in height. Particularly noteworthy are the " coffee bean " eyes, raised mouth with the tongue showing, flat incised ears, and the peculiar broken handle for attachment or for holding. The realistically modeled neck is broken off at the base. The second head is less realistic (pl. 28, fig. 2, *c*) and has a small hollow inside, which opens into the basal concavity through a small opening (2 cm in width) with a raised rim. The aquiline nose, punctate mouth, perforated ears, and the large punctate eyes with slightly raised rims, of this head are noteworthy. The uses to which those two objects may have been put is uncertain.

Three solid detached upper limbs from crude pottery figures are also present. They range from a large, three-fingered piece (2.5 cm in diameter), which may have come from a reptilian form, to a small, curved, fingerless limb 8 mm in diameter. The intermediate-sized piece, a forearm and hand, is the best modeled, having five fingers

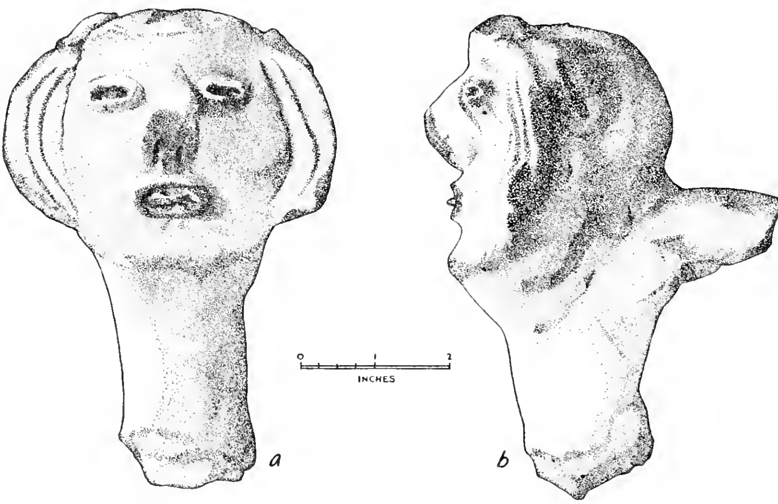


Fig. 13.—Modeled pottery head, Dixon site.

and a series of incised circles with punctured centers around the wrist, apparently depicting a bracelet (pl. 27, fig. 2, *f*). The smallest pottery limb probably came from figurines such as are shown from Indian Hill (pl. 28, fig. 1, *a-c*); the types to which the others were affixed is unknown.

METAL

A considerable number of copper artifacts were found at this site. The majority of these pieces came from the central votive offering, the polychrome vase containing 30 copper bells of various sizes, two copper rings or ear spools, and a hammered disk of copper. In addition, about half a dozen identical small copper bells were found in the soil near this central offering. The bells range in length from 1.8 cm (pl. 10, *c*) to 7 cm (pl. 9, *d*), and several types are represented. The largest bell (pl. 9, *a*) is broken, and one flange has been crumpled up to hold the clapper, which, as in all the other bells, consists of a piece of gravel or a small pebble. The top of this bell is flat and, like the neck, has fine incisions or lines suggesting the use of wire in the building process, although actual wire does not seem to have been used. The loop is round and solid. There is one smaller bell of similar type (pl. 9, *h*). The most common type has a more marked pseudo-wire technique around the neck and has a round wire loop for suspension as shown in the illustration (pl. 9). A few specimens lack this neck (pl. 9, *b*), and some pass directly from the pear-shaped body to the wire loop (pl. 9, *g*). Seven small bells have animal faces in good relief (pl. 10, *a, b, d, f*), one has a complex wire scroll in quadruplicate at the top (pl. 10, *e*) and one bell, the smallest, is globular (pl. 10, *c*). A considerable number of all types have been broken and bent up to retain the clapper. This, in conjunction with the broken and worn appearance of the majority, suggests that they had been used for a long time prior to their deposition as an offering. As to their original source, all that can be said at present is that they closely resemble certain of the copper bells found in a large cave deposit on the Uloa River, which were described by Blackeston (1910 b). Presumably, the bells had been cast in molds, but I do not pretend to understand the exact techniques employed. Aside from the bells the two rings are the only definite copper artifacts. The larger of these (pl. 9, *c*) is 4 cm in diameter and has two holes for fastening in a central disk, which has disappeared. The small ring (pl. 9, *f*) has only a slightly concave edge and lacks perforations. It is not welded together as in the first case, and the two edges overlap. Its use is uncertain, but it may be a broken or unfinished ear spool. The flat disk of copper (pl. 9, *e*) is hammered all over its surfaces, and the edges are smooth. Whether it is an unfinished piece or once served as a pendant is uncertain.

Through the courtesy of the Bureau of Standards, a spectrochemical analysis was made of (a) the copper disk (pl. 9, *e*), (b) a bell with a definite neck and a face in relief (like pl. 10, *f*) and (c) a pear-shaped bell (like pl. 9, *g*). For these data I am grateful to Dr. Lyman J. Briggs, Director of the Bureau of Standards, and to B. F. Scribner, who made the analyses. Aside from their future value in any comprehensive study of aboriginal copper bells, the analyses indicate that (a) and (b) are similar in composition, but that (c) differs rather markedly. It seems probable, therefore, that the ultimate source of the pear-shaped bells (pl. 9, *g*) was different from that of the majority, which have definite necks and in some cases decoration in relief.

The analyses were made as follows:

The arc spectra of cleaned portions of the three specimens burned on pure copper electrodes as a base were photographed (Spectrogram No. R 613 ab) and the spectra were examined for the sensitive lines of Ag, Al, As, Au, Ba, Be, Bi, Ca, Cb, Cd, Co, Cr, Fe, Ga, Ge, Hf, Hg, In, Ir, K, Li, Mg, Mn, Mo, Na, Ni, Os, Pb, Pd, Pt, Re, Rh, Ru, Sb, Si, Sn, Sr, Ta, Th, Ti, U, V, W, Zn, and Zr.

The elements found present and the comparative estimates of the amounts of each are given in the following table. The qualitative scale used in designating the amounts of the elements present, ranges from very small to large concentrations as follows: faint trace, trace, very weak, weak, moderate, strong, very strong.

Analyses of Three Copper Pieces from Votive Cache, Dixon Site

Element	Cu (a)	Cu (b)	Cu (c)
Ag	Moderate	Moderate	Moderate
Al	Faint trace	Faint trace	Trace
As	None	None	Strong
Au	None	None	Trace
Bi	None	None	Trace
Ca	Very weak	Trace	Very weak
Co	None	None	Faint trace
Fe	Moderate	Moderate	Moderate
Ga	Trace	Very weak	Weak
In	None	None	Faint trace
Mg	None ?	None ?	Faint trace
Mn	Weak	Weak	Weak
Ni	Trace	Trace	Moderate
Pb	Very weak	Very weak	Weak
Sb	None	None	Very weak
Si	Trace	Faint trace	Faint trace
Sn	None	None	Moderate

GROUND STONE

In this class the numerous small stone objects found in the complete offertory vessel will be considered first. Nearly all of these are skillfully worked, and many of them by their green color and polished condition suggest jade or jadeite. As a matter of fact no artifacts from this site proved to be of these materials. The majority of the small offertory pieces are of talc, including all the best carvings. This material has a wide range of color, though green is the dominating tone in the present collection. Apple-green is perhaps the most common color, though olive-green, jade-green, apple-green with dark flecks, turquoise-blue (rare), buff (often with a rusty brown patination), grayish white, and gray-black artifacts of talc are present. Talc is relatively soft and can be easily scratched. Beside talc, diopside is the most common mineral represented. In outward appearance the two minerals are very similar, but the latter is much the harder of the two. Certain artifacts of both these materials are considerably eroded, and a small portion of both are covered with a rusty brown patination. Ten artifacts, mostly large round beads, are of marble. They are gray-white in color with considerable green flecking, this last probably due to copper contacts. Two small and badly eroded beads are of calcite. Ten artifacts are of serpentine, including the only unworked pebble in the cache, which is of indurated serpentine. Several of the serpentine artifacts are merely perforated pebbles, and in two cases the perforations do not go through the object. The lack of finish on most of the very resistant pieces is in contrast to the delicate workmanship manifested on many of the more easily worked pieces of talc.

Three small heads surmounted with elaborate headdresses are the most striking pieces (pl. 11, *d, e, f*). They are of apple-green talc with single perforations extending horizontally near the top. In two of the pieces (pl. 11, *d, e*), a small face is represented at the bottom by oval incised eyes and a nose, and the headdress, presumably of quetzal or other plumes, takes up the greater portion of the artifact. The central one of these heads (pl. 11, *e*) is the most artistic in finish, especially as regards the exquisite representation of feathers in stone. The third piece (pl. 11, *f*) differs in having a larger, well-modeled face with slanting oval eyes and large nose. The headdress is also different and may represent some sort of a cloth turban held in front with a round brooch. It is a well-executed and beautifully symmetrical piece. Three other faces are not so well finished, and two of them appear to be merely simplified versions of the first two (pl. 11, *a, b, c*) with different types of headdresses. One of these is bluish gray (pl. 11, *a*), another (pl. 11, *c*) a light green. The third (pl. 11, *b*) is turquoise-blue and has a unique type of square-cut face. All these heads (pl. 11, *a-f*) have the same sort of horizontal perforation through the headdress portion and were probably strung with beads. The perforations average about 3 mm in diameter and are slightly biconodont, meeting near the center. In two pieces each end of the perforation is considerably larger close to the openings, giving a marked funnel-shaped ending to the boring.

Besides the plumed heads, there are a number of other small human or anthropomorphic carvings (pl. 11, *j-r*). One of these of very dark olive-green talc (pl. 11, *k*) bears considerable resemblance to the piece with a square-cut face previously described. The rich, dark color and the clearly delineated features, which include a very prominent nose, are its most noteworthy characteristics. Next to it is a very interesting carving suggesting a death's head or perhaps a tattooed face (pl. 11, *j*). The treatment of the nose and mouth especially suggest a skull, whereas the incised circle on the cheeks, square on the chin, and scroll on the forehead may indicate either painted decoration or tattooing. There is only one ear or, more probably, ear ornament. Another piece (pl. 11, *l*) may have served as the tip for an atlatl or spear thrower, but if so it must have been more ornamental than useful. The slanting upper portion of the piece has a smoothly worn plane surface with a very small perforation near the top bored in from both sides. The actual aperture itself is only 1 mm, but the cone-shaped openings on each side are twice that diameter. Such a small hole for lashing would probably not permit hard usage unless some strong adhesive, of which no traces remain, were used as well. The piece is carved in the form of a human face with prominent eyes and thick protuberant lips. Viewed horizontally, instead of vertically as in the illustration (pl. 11, *l*), the entire piece suggests the head of a serpent or that of the condor or king vulture. Whether this is intentional or not remains uncertain, as does the original use to which the object was put. The material is a very dark green talc, containing numerous imperfections. It is highly polished.

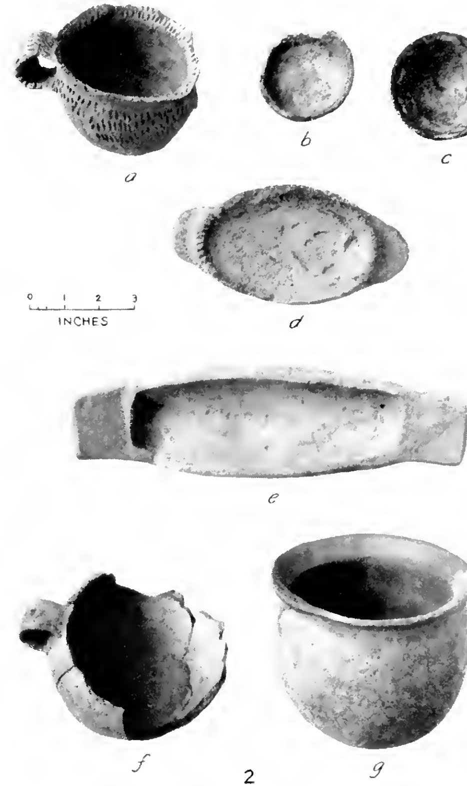
Another piece (pl. 11, *o*) represents a small face surmounted by a large headdress. The material is a dark green talc and the perforation occurs behind the face. The crudest object in the plate (pl. 11, *m*) is of gray-white talc with brown incrustations. A simple geometric face is incised on one surface. Next to this is a unique piece, the rear surface of which is shown in the illustration (pl. 11, *n*). The front surface has only three incisions, suggesting the eyes and nose of a human face. Taken in conjunction with the face just mentioned (pl. 11, *m*), this last marks the extreme of a series of simplifications beginning with the elaborate faces with headdresses (pl. 11, *d, e, f*) and ending with this piece, on which the three dots alone suggest its anthropomorphic character. More interesting, perhaps, is its hollow back with three large perforations (5 mm in diameter) at sides and bottom. The object probably served as a bead from which pendants were suspended. It is made of dark green talc. Another object of similar color and material probably represents a broad, conventionalized face with a narrow and unusual type of feather headdress (pl. 11, *q*). The perforation (2 mm in diameter) in this specimen is likewise behind the face and has exceptionally large biconodont openings (9 mm in diameter). The next specimen (pl. 11, *p*) is somewhat similar in being highly conventionalized and also has a similar perforation, though this is in the upper rather than the lower portion. The last object on the plate (pl. 11, *r*) is of light green talc and appears to be a highly conventionalized human figure with three dots, as in the case previously mentioned, suggesting the face.

The largest human representation in the offertory vessel was an ornamental celt of apple-green talc 7 cm in length (pl. 12, *e*). Incised decoration consists of large circle and dot eyes, a linear mouth, a suggestion of arms and headdress, and vertical and horizontal lines on front and back. The butt end of the celt where the carvings occur is larger than the blade, perhaps representing some sort of socket. A perforation about 9 mm in diameter extends horizontally from shoulder to shoulder. A purely ornamental or ceremonial purpose of this artifact is indicated by its relatively soft material, the absence of any sign of usage, and its perforation and decoration. Another small celt (pl. 13, *c*) of diopside is beautifully worked. It is of a hard material with a sharp cutting edge but shows no signs of use. In color it is a mottled brown and light bluish green. Its length is 4.6 cm.

One spindle whorl of gray-green talc is incised on the upper and larger face with a unilinear maze design of considerable complexity (pl. 12, *b*). The perforation for the spindle has been vertically gouged out, leaving irregular vertical ridges which are lacking in the majority of other perforated pieces. A unique carving of very light green talc represents some sort of bird with a horizontal perforation through the head (pl. 12, *a*). A globular pendant (pl. 12, *c*) of green-blue talc is so weathered that, aside from the suggestion of square incised eyes at the top, the remainder of the design is obscure. Two buttonlike objects of dark green talc are of unknown use (pl. 12, *d*, *g*). The complete specimen, in addition to the larger center perforation, has a small hole at the top. A circularly incised ring, carefully carved from light green talc with two purple streaks down one side, is too small (1 cm in inner diameter) for a finger ring (pl. 12, *f*). Both edges are raised and three incised lines run around the outer circumference between the raised ridges. A fragment of what may have been a plain, polished ring without incisions was also found with this cache. The five objects at the bottom of the plate (pl. 12, *i-m*) are all of various shades of green talc. They served as pendants, as all are carefully perforated. In addition, three other simple objects of this general type are not illustrated. One simple pendant (pl. 12, *h*) is unique in lacking any perforation, an incised line around the smaller end probably serving as an attachment for the suspension cord.

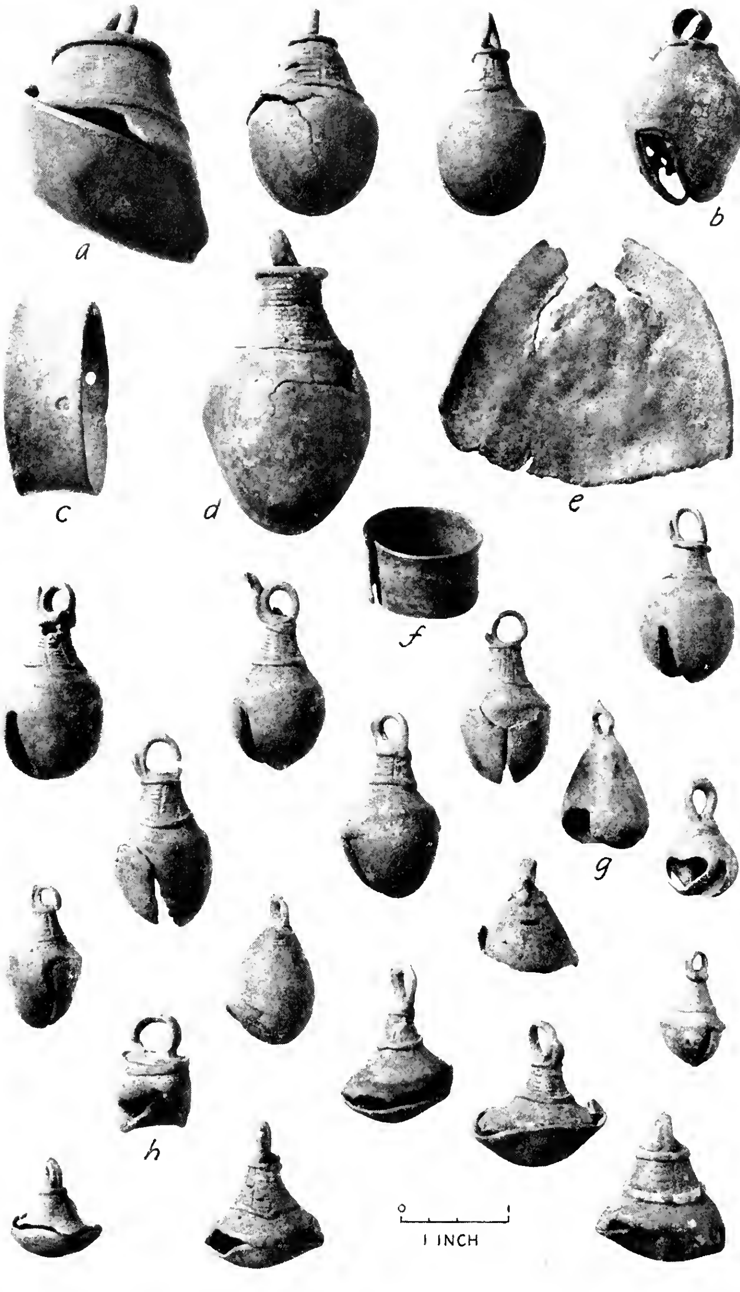
This cache contained one rectangular stone gorget and 32 small stone pendants. The largest and best of these is of serpentine and, having two perforations, may be classed as a gorget rather than a pendant (pl. 13, *a*). It is greenish black in color, and its polished surface is decorated with three groups of vertical lines. The other pendants of serpentine (pl. 13, *m-p*) are much simpler, consisting primarily of flat, polished pebbles perforated at the small end. Two of these have incomplete perforations (pl. 13, *p*, is an example). Besides those figured, there are two similar serpentine pebble pendants, in one of which the perforations, commenced from both sides, are incomplete. In addition there is an unworked pebble of indurated serpentine, 3.6 cm long, which was also in the same pot. Three beautifully colored pendants with single perforations are of diopside (pl. 13, *b, d, g*). Two of these are round and were originally apple-green in color, though this is more or less streaked with brown (pl. 13, *b, d*), and the third is a well-made rectangle of apple-green flecked with black specks and some brown patination (pl. 13, *g*). Pendants of talc are most abundant, numbering 14 in all. Good examples of these are illustrated (pl. 13, *c, h, j, k, l*). Besides the thin, round, and subrectangular pendants of talc, there are several perforated pebbles of this material which resemble similar serpentine pieces (pl. 13, *i*). All these artifacts were probably worn as additions to bead necklaces or else as ear and nose ornaments.

In all, 372 beads were found in this one vessel. Of these, 18 were of shell, in a more or less fragmentary condition. Two much-eroded beads, one small and cylindrical and one cruciform (pl. 14, *d*), are of calcite. Nine large to medium, round beads are of gray-white marble. These are for the most part flecked with green due to copper contacts and are somewhat rough on the surface, showing their crystalline nature. One long, cylindrical incised bead is also of marble. There are 80 beads of diopside, of which 49 are cylindrical of various sizes, 29 are round and of all sizes represented in the entire collection, 1 is square in cross-section, and 1 is triangular. One beautifully polished black bead of cruciform shape is of serpentine (pl. 14, *c*). The remaining 261 beads, comprising all the above mentioned types, are of varicolored talc. All the incised beads (pl. 14, *e*) are of talc except the one cylindrical marble bead with incisions on one end (pl. 14, *e*, top center). The other marble beads are of the round type. The fact that incised beads are predominantly of talc is probably due to the greater ease with which that material may be worked. With the above exceptions, there seems to be little correlation between form and material in the present collection of beads.

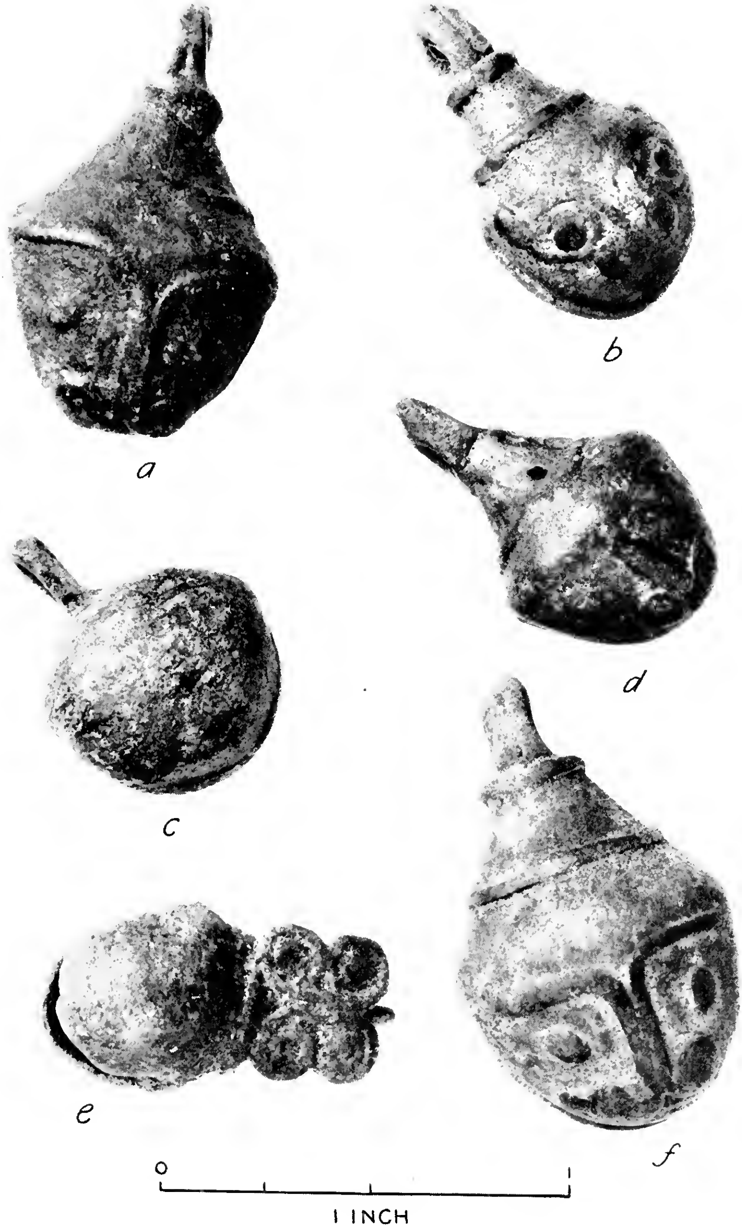


DIXON SITE, ROATAN

1. Cylindrical model vases.
2. Canoe-shaped and other monochrome vessels.



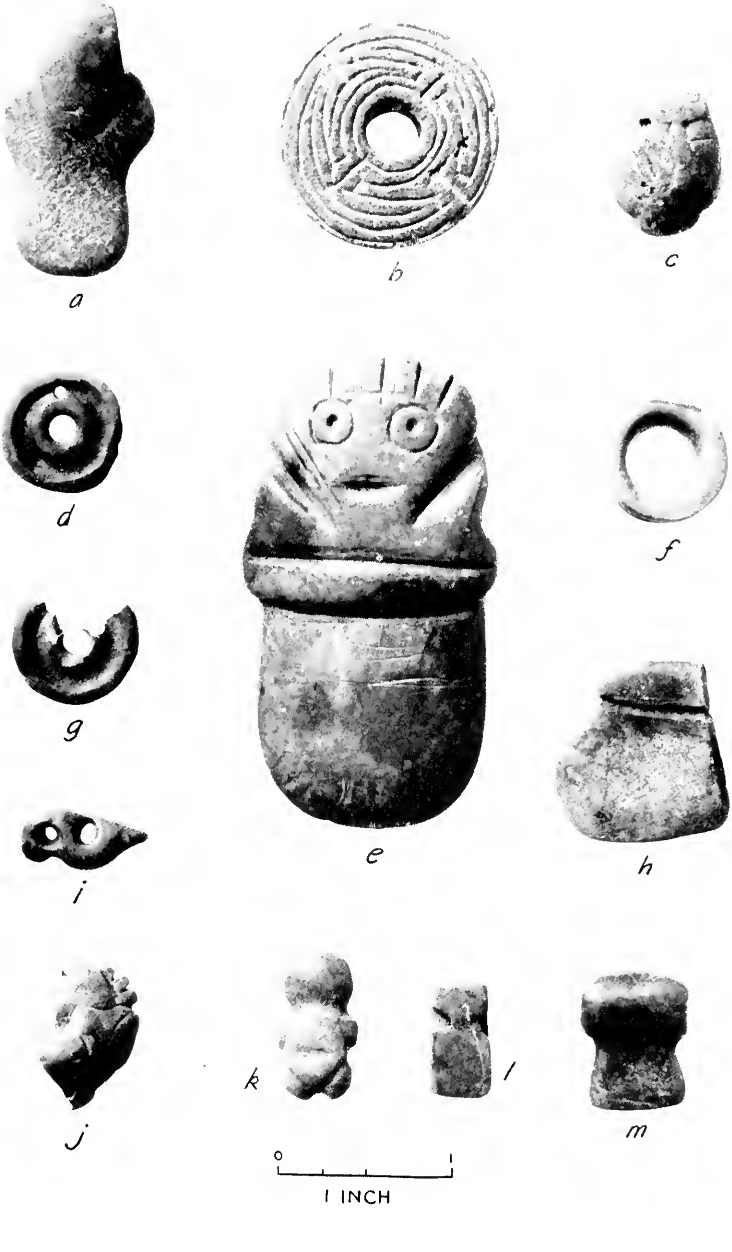
COPPER BELLS AND ARTIFACTS FROM CENTRAL VOTIVE CACHE, DIXON SITE, ROATAN



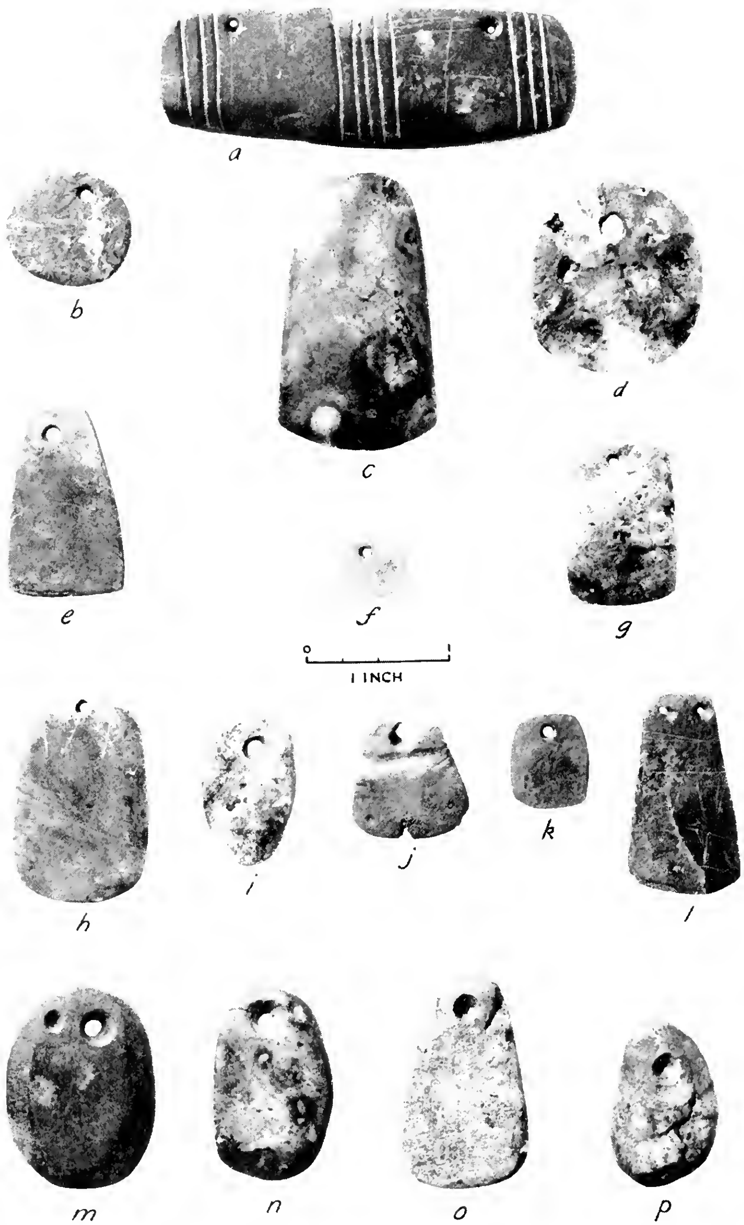
MODELED OR UNIQUE TYPES OF COPPER BELLS FROM CENTRAL VOTIVE CACHE, DIXON SITE, ROATAN

SMALL ANTHROPOMORPHIC CARVINGS OF GREEN STONE

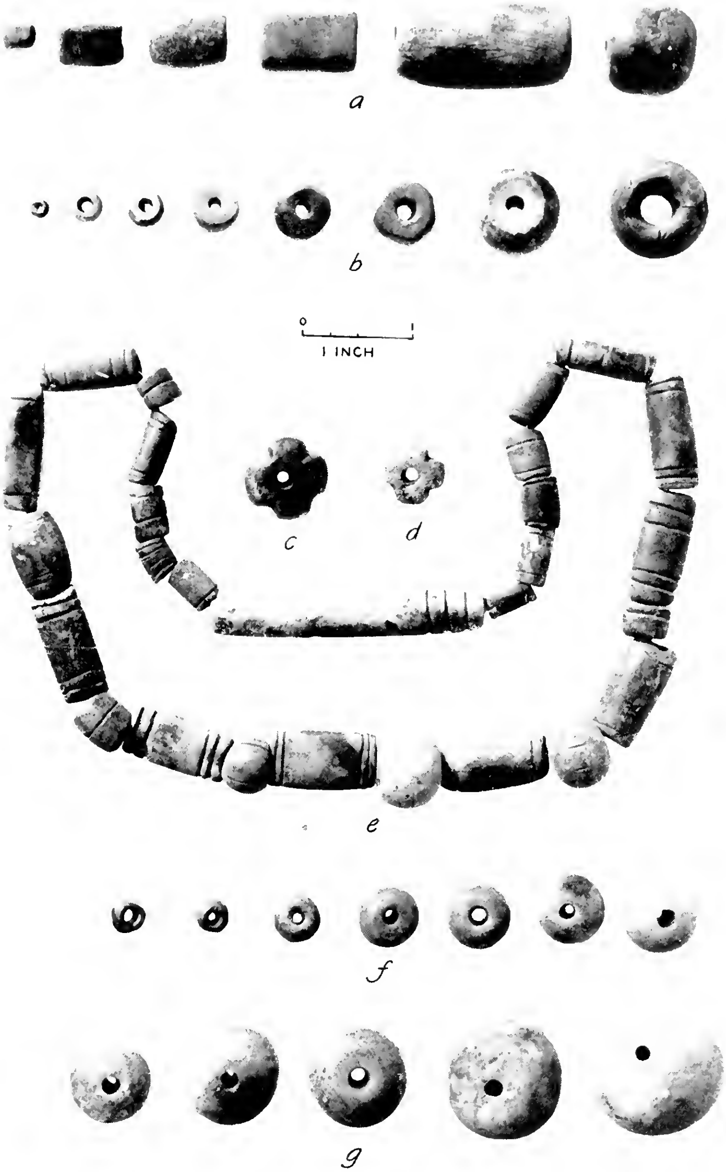
g, i, from site 1, Barburata; *h,* from Black Rock Basin, Utila; all others from central votive cache, Dixon site, Roatan.



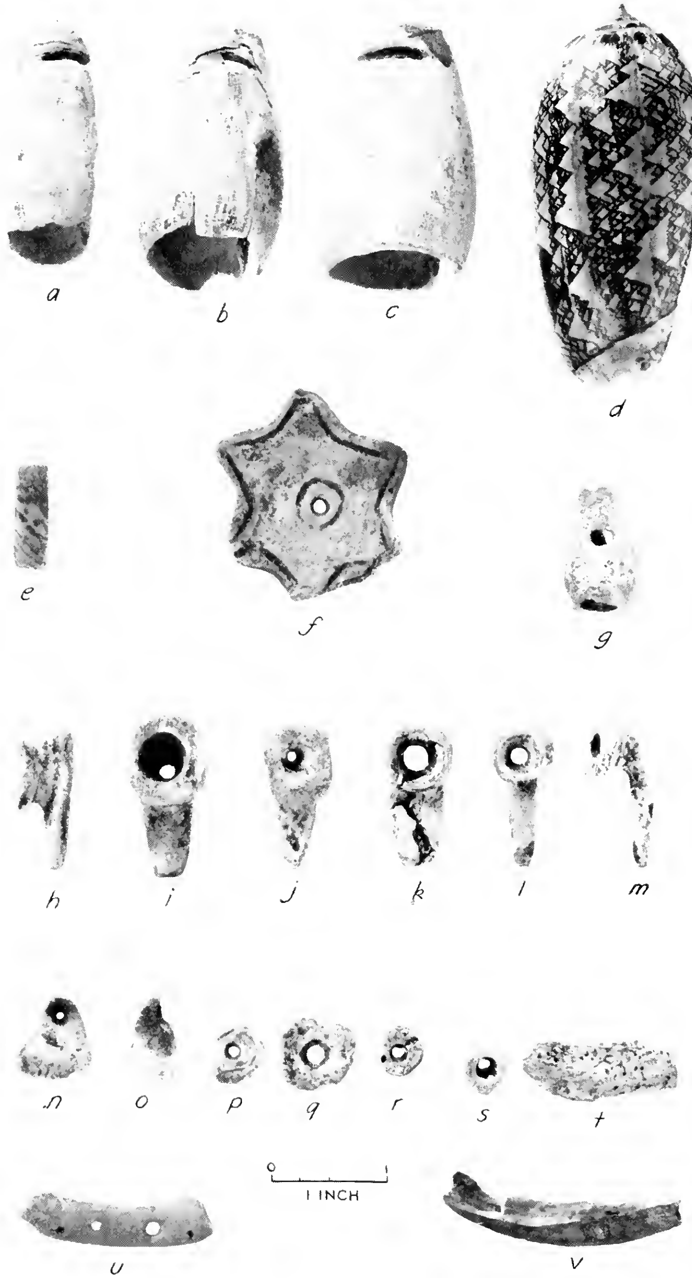
SMALL STONE CARVINGS AND VOTIVE CELT FROM CENTRAL CACHE, DIXON SITE, ROATAN



STONE PENDANTS AND SMALL CELT (*C*) FROM CENTRAL VOTIVE CACHE, DIXON SITE, ROATAN



TYPES OF STONE BEADS, CENTRAL VOTIVE CACHE, DIXON SITE, ROATAN



SHELL ORNAMENTS

c, e, from Helena; *d,* modern specimen (*Oliva porphyria* Linné); all others from central votive cache, Dixon site, Roatan.

The main types of beads in this cache are shown in the illustrations (pl. 14). The great individual and size differences suggest that each piece was worked out and ground down separately from the others. The majority of perforations are smoothly bored, presumably with some sort of a drill, sand, and water. Boring was done from both ends and frequently the holes meet at somewhat of an angle. The holes are very even throughout their length, and an idea of the average size of perforation can best be gained by noting those illustrated (pl. 14). In only a very few cases do the holes fail to extend entirely through the object. Three main types predominate: (a) cylindrical or rectangular (pl. 14, *a*), (b) round (pl. 14, *g*), (c) disk or round

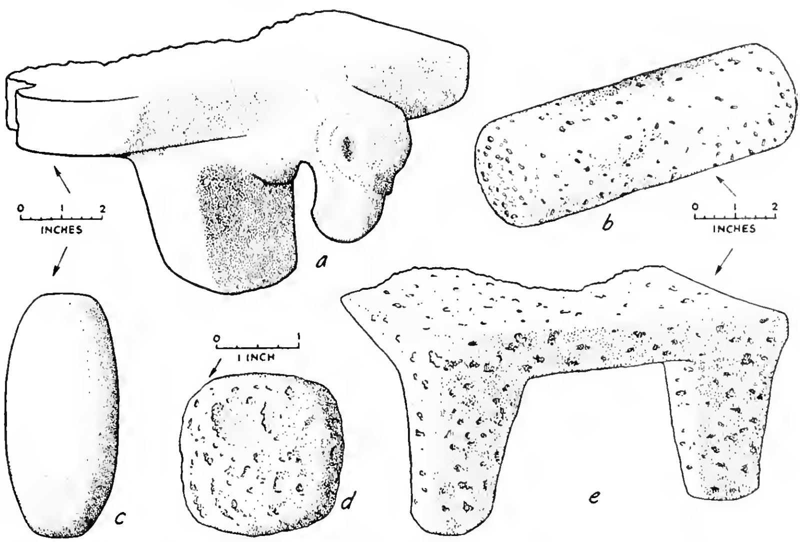


FIG. 14.—Broken metates, mullers and hammerstones: *a*, Indian Hill, site 1, Barburata; *b-e*, Dixon site, Roatan.

with flattened top (pl. 14, *b*); but there is so much individual variation between and within all these major forms that a more exact classification would lead to hair splitting. The incised decoration that occurs on a small percentage of the beads (pl. 14, *e*) is simple, consisting of lines around the ends of cylindrical beads and simple geometric patterns on some of the round beads. The high polish and surface patination of many of the beads suggest that they have been worn and handled over a considerable period of time. These factors combined with the intrinsically pleasing nature of the materials employed gives them a very attractive appearance, often lacking in beads of more uniform manufacture. This completes the list of small ground stone objects found within the complete offertory vessel at this site.

Besides the small artifacts of polished stone from the central offertory vessel, fragmentary metates, manos, celts, hammerstones, and one ornate club or mace head were found in the larger deposit. Only one complete metate was found here (pl. 7, fig. 3); it consisted of a smooth-surfaced but curved granite slab, 35 cm long, 28 cm wide, and 7.5 cm in thickness. The grinding face had been worn smooth, but it was otherwise unworked. A cylindrical roller pestle (31 cm long) of the same material was found nearby (pl. 7, fig. 3). A corner fragment of another polished granite metate with a squared leg was also noted. Owing to difficulties of transport, these were not carried away. Near the central offering was the end portion of a rectangular gray lava metate (pl. 6, fig. 1; fig. 14, *e*), which in its original condition probably had three legs. Two other manos were recovered, one (fig. 14, *b*) a cylindrical, well-worked piece of gray volcanic rock 18.5 cm in length, the other a subrectangular piece of polished granite 15 cm in length with squared ends that had been used for hammering (fig. 14, *c*). A small, rounded cube of granite from this site has all four sides deeply pitted apparently from use as a hammerstone (fig. 14, *d*).

Six complete and three broken celts of polished stone were recovered. The largest of these is of quartz diorite and is 17 cm long. Another celt is similar but smaller (pl. 16, fig. 1, *a, b*). Both these pieces are highly polished and excellently shaped, and the sharp blades of both show evidence of considerable use as chopping tools. Three smaller celts of dacite are shorter and less gracefully shaped. Two of these are shown (pl. 16, fig. 1, *c, d*). The larger was placed just over the lip of the central offertory vessel (pl. 6, fig. 1, and pl. 16, fig. 1, *c*). The cutting edges of all three are much chipped from extensive usage. A small celt of andesite has a very smooth, sharp edge but has been split or ground down along one side of the long axis. A very small celt (pl. 16, fig. 1, *f*) of quartz diorite is well polished but very thick (1.3 cm in thickness) for its length (3.2 cm). Two small broken celts are of diopside, one being of the short, thick type, whereas the other (pl. 16, fig. 1, *e*), which is black in color and excellently polished, is very thin (1 cm in thickness). Both of these blade fragments have a sharp, smooth cutting edge. If we consider all nine polished celts or celt fragments from this site (pl. 16, fig. 1, *a-f*), both the general excellence of workmanship and the extreme variation in size are noteworthy. The fact that the large and medium-sized blades show signs of considerable usage, whereas the smaller ones do not, probably indicates that the latter had other than utilitarian value.

An elaborately worked mace head of diorite constitutes an interesting find (pl. 19, fig. 1, *c*). The object is 4.4 cm in height and has a smoothly worked perforation 3.1 cm in diameter. Although rather regular, this circular perforation tapers very slightly from each end to the middle. Decoration is attained by four large mammiform projections of excellent and uniform workmanship. The tips of two adjoining projections show old breaks apparently from usage.

CHIPPED STONE

The largest object of chipped stone is a crudely worked, **T**-shaped ax of hard indurated shale (pl. 19, fig. 2, *c*). The rounded cutting edge shows evidence of prolonged usage. Several other artifacts of this type were noted at the Dixon site but were not taken away.

Four complete and two broken long oval or elongated diamond-shaped knives of chalcedony were found at the Dixon site. The retouching technique applied to three of these pieces is excellent. Two pieces of translucent gray-buff chalcedony are especially delicate both in form and in retouching. The first of these (pl. 16, fig. 2, *b*) is 18.7 cm in length and only 8 mm in central thickness. Besides the very regular and small retouching on the extreme edge, there are a number of larger nicks suggesting usage. The artifact is complete except for the extreme tip on one end. The second of these pieces (pl. 16, fig. 2, *a*) is perfect but tapers more rapidly to one end than do the other knives. It is 17.4 cm in length and 8 mm in central thickness. Since the smaller, sharper point of this artifact is of lighter color, apparently owing to less patination, and is thicker than the other end, I am inclined to believe that this portion was formerly within a perishable handle of some sort. The knife first described has a very similar outline but shows no color or patination difference between the two ends. In each of the two blades, however, it is the longer points which have nicks apparently resulting from use as a cutting implement. There is, therefore, not only a logical presumption, but also some definite evidence, indicating that these artifacts were originally supplied with handles. A third knife, only two-thirds of which was recovered, is of the same type as the above (pl. 16, fig. 2, *c*). It is slightly heavier than the former, being 1 cm in central thickness. The three remaining pieces are only partly translucent, are oval rather than diamond-shaped, and are of somewhat cruder manufacture. The largest of these is 18 cm in length and 1 cm in central thickness (pl. 16, fig. 2, *e*); the other specimen figured (pl. 16, fig. 2, *d*) is the thickest of all, being 1.4 cm thick in the center. The third piece, of mottled yellow-brown chalcedony, has one end broken off. It is similar to the last two and is not figured. Whether any, or all, of these three artifacts had handles is not indicated by the specimens themselves. There seems to be no positive way of telling whether these knives were primarily of ceremonial or of utilitarian significance. It is tempting to regard the finer specimens, at least, as knives of sacrifice, but although this may well have been true, it is not demonstrable from the evidence at hand.

Besides the above large specimens, two smaller chipped points were recovered. The larger of these (fig. 15, *d*) is of black obsidian and is 10 cm in length. The tip is broken, and the edges show evidence of considerable usage and are much blunted. It was probably employed as a knife. The smaller point is of felsite (fig. 15, *c*). It has a broken

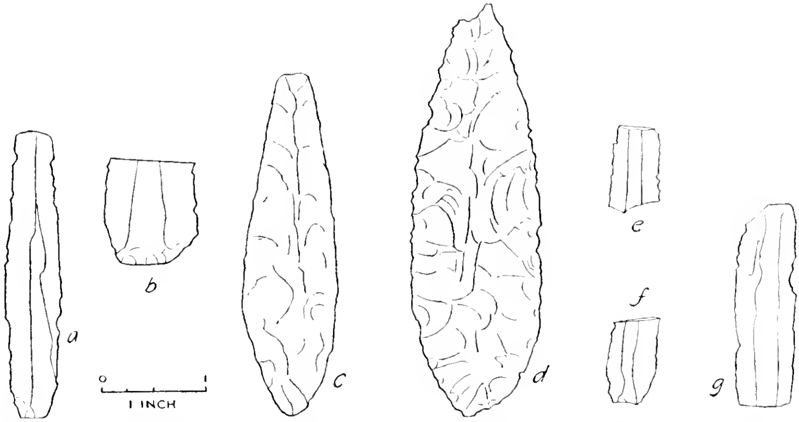


FIG. 15.—Chipped stone artifacts: *a*, *b*, Black Rock Basin, site 1, Utila; *c*, *d*, Dixon site, Roatan; *e*, *f*, Indian Hill, site 1; *g*, Indian Hill, site 2, Barburata.

point, but the edges are fairly sharp and show little or no signs of usage. This suggests that the artifact, which is 7 cm long, may have been a dart or javelin point.

Aside from definite artifacts, the most noticeable stone objects at the site were large numbers of quartz crystals, ranging in length from some 14 cm to very small pieces. None of these showed signs of workmanship, but all had definitely been placed at the site as offerings. A double handful was found in close proximity to the central offering. As it proved very difficult to convince our guide that these were not precious stones, possibly diamonds, he was presented with a considerable number of them. In addition to the one artifact already described, only one small fragment of obsidian was recovered. There were some irregular boulders in the deposit, but these were from the limestone ledges close at hand.

SHELL

Besides large conch shells with perforations, the only other shell artifacts from this site were found in the central offertory vase. These small artifacts include 1 six-pointed star, 5 shell danglers, 7 labrets, 3 triangular pendants, 18 more or less fragmentary beads, and several irregularly cut or ground shell fragments.

The six-pointed star (pl. 15, *f*) is considerably battered and both surfaces are somewhat eroded. It is probably made from a bivalve (*Laevicardium elatum* Sby.) found only on the Pacific coast from Mexico northward. The identification is based on unique wavy ridges or laminations that show on the reverse side of the star and are characteristic of this species. The specimen is 4.5 cm in greatest width and is decorated on one side by a broad, deep incision outlining the star. There is a small perforation in the center surrounded by an incised line. Its use is unknown. The shell danglers (pl. 15, *a*, *b*) are likewise interesting in regard to their source, which is mainly the Gulf of California, though the species (*Oliva porphyria* Linné) may occur further south in the Pacific. The present specimens are chalky white, in marked contrast to the rich natural coloration of the shell, which consists of an intricate and beautiful series of fine, zigzag brown lines on a shell-pink background (pl. 15, *d*). Such exquisite shells must have had high trade value, and their occurrence here on the Atlantic side of the Isthmus, far from their natural range, is interesting. In manufacturing the danglers, one tip has been removed. A notched hole made for suspension, and a considerable portion of the opposite end has been ground down. Their use is unknown, but their shape and method of perforation suggest that they may have been used as a decorative and musical fringe for ceremonial garments. Two of the danglers from the vase are nearly complete (pl, 15, *a*, *b*); the other three are badly broken but of the same type. A small *Oliva* (sp.?) shell (pl. 15, *g*) has a more central perforation but is cut in the same manner.

The shell labrets (pl. 15, *h*-*m*) have been ground down from some thick shell, but the species is not identifiable from the worked pieces. Presumably, these were worn as lip ornaments with the button inside the lip and the elongated oval portion outside. With one exception (pl. 15, *h*), all are perforated, with the external opening large and the inner opening small. The purpose of these unequal biconodont perforations, whether for an inset of some sort or for some other reason, is unknown. The largest specimen (pl. 13, *i*) is 3.8 cm in length and 1.4 cm high. Besides those figured, there are two broken fragments of labrets. There are three small triangular pendants, two with a vertical (pl. 15, *n*) and one with a horizontal perforation (pl. 15, *o*) at the small end. In addition, there are three unperforated shell triangles of about the same size. The shell beads are much disintegrated and form a rather heterogeneous group (pl. 15, *p-t*). Several are thin and roughly circular with biconodont perforations (pl. 15, *p-r*), 11 (for the most part badly broken) are cylindrical (pl. 15, *s*), and, finally, one flat, thin section of ground shell (pl. 15, *t*) has a curved perforation through its entire length (3.4 cm). Besides the above shell artifacts, the offertory vase also contained one small unworked pelecypod shell and three fragments of the same material.

Two unusual artifacts were included in the contents of the offertory vase (pl. 15, *u, v*). They are ground-down shell and have a brown patination and green copper stains. Each has a hole (averaging 4 mm in diameter) drilled longitudinally and on a gradual curve. The unbroken piece has one large and one small hole drilled latitudinally near one end. They evidently were used as beads.

VICINITY OF COXEN HOLE

Neither the Boekelman Expedition nor our party made any excavations near Coxen Hole, but several local collections were examined, and some of these were purchased by the former expedition.[20] At the store of Sr. Charles Osgood, Governor of the Islands, we examined a small collection of monochrome pottery consisting mainly of ornate but crude models of larger vessels. They were very similar to the smaller pieces already described from the Dixon site and had been found on one of the ridges behind the town. Bird took notes and photographs of a small collection owned by Doña Carmine e Yorgas, of Coxen Hole, which had been found in the interior of the island directly inland from the town. The collection includes five unslipped, red to brown vessels (monochrome), of which two crudely incised, small, egg-cup-shaped vessels (like pl. 8, fig. 1, *a-g*) were obviously offertory models. The other three had round bodies and constricted openings. One had a low, everted lip, and two had taller cylindrical necks with slightly flaring lips. One of the latter had an interlocking double scroll design with recurving punctate marks at the ends of the lines, and two lugs shaped like apes' heads. There was also a three-legged metate (28 cm long, 18 cm wide, and 12.5 cm high at one end,

[20] A.M.N.H. nos. 1596-1605.

9 cm high at the other) of volcanic rock. The two short legs were at the low end. It was accompanied by a roller pestle of hard gray rock.

A collection purchased by the Boekelman Expedition includes a small vessel of polished red ware found by a farmer on the north shore of the island opposite Coxen Hole. Another group of specimens purchased, obviously part of an offertory deposit, were said to have come from " a grave " in the middle of the island northeast of Coxen Hole. This collection includes 144 beads of green talc, marble, jadeite and diopside (pl. 17, *a*) ; a plumed head of green talc covered with a brown patina (pl. 17, *c*) ; a thin disk pendant of dark green jadeite (pl. 17, *e*) ; three copper bells, of which the two larger specimens have a basal portion of the pseudo-wire technique type (pl. 17, *f, g*) and the two smaller specimens (pl. 17, *b, d*) have obscure designs in relief. The two larger bells are of heavy, dark metal, suggesting bronze or hardened copper, and both contain rough pebbles as clappers, whereas the clappers are missing from the two smaller, thinner specimens. In addition to the pieces illustrated, this collection contains four ornate (monochrome) pot lugs, one of which is unique in having a tenon, as though made separately to be inserted into the wall of a vessel prior to firing; a torpedo-shaped pendant (4.5 cm long) of gray steatite; a small triangular shell pendant; six flat, cylindrical shell beads; and a small piece of metal, which analysis proved to be copper plated with gold. The last is the only specimen containing a large portion of gold in either of our Bay Island collections.

Bird also made a sketch of a unique soft sandstone " mortar ", which has a squared top (50 cm in width), a flange which extends down from the top about 10 cm, and a tapering rounded base. It stands about 50 cm high, and when found, is said to have had a cover of sandstone. The interior forms a truncated cone 42.5 cm deep with the widest portion at the rim. A small irregular hole has been broken all the way through the base. According to local report it was found by a young American in some sort of a mound about a quarter of a mile inland from Coxen Hole. Like all finds in this region, it is said to have had " money " in it, which the finder took. During our stay we were told of several sites near Coxen Hole where pottery occurred but were unable to visit them. Several people also told us of sites near Dixon Cove that had been more or less dug over by local men. It is probable that the west end of Roatan contains much interesting archeological evidence, but we had no time to investigate, nor, so far as I know, was that part of the island examined by Mitchell-Hedges or the Boekelman Expedition.

HELENA ISLAND

This small island is to all intents and purposes an eastern extension of Roatan, being separated from the latter only by a very narrow winding lagoon which traverses a dense mangrove swamp. It is a deep little channel but is said to be in part artificial. (Conzemius, 1928, p. 65.) We arrived at the southeast corner of Helena, having run down outside the cays from Port Royal. Guided by a local colored man called Sam, we paddled in two small canoes about half a mile up the picturesque channel just referred to. The black water of this swamp passage is edged abruptly by myriads of twisting man-

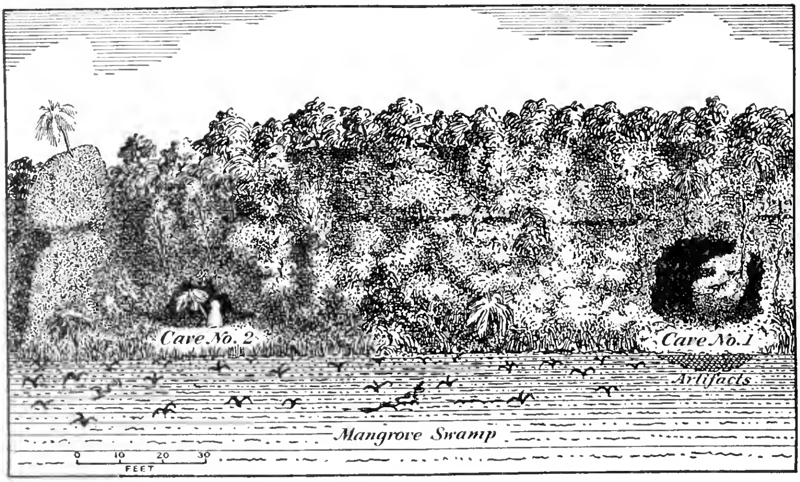


FIG. 16.—Sketch of caves on Helena Island.

grove roots. It is shut in by these trees, interspersed with coconut palms, and the air was dense and hot. White ibis and a number of species of herons added to the tropical effect. Making a landing on the tree buttresses and muddy banks of the eastern side, we walked over the dried surface of the swamp for about 150 yards to a line of steep coral cliffs that border Helena Island on the west. This abrupt escarpment varies from about 40 to 60 feet in height (see map, fig. 1, and sketch, fig. 16) and is wooded. Behind the cliffs the island is high and more open, with tall grass and low bush. Descending abruptly into the dismal swamp, the cliff with its weirdly eroded surface, trailing vines, and crowning trees is picturesque in the extreme (fig. 16).

CAVES 1 AND 2

The site where artifacts had been found proved to be a cave (cave 1, fig. 17) and a rock-ledge shelter (cave 2, fig. 16). The two are about 90 feet apart and just above the level of the swamp. Sam had found this site in gathering coconuts and had previously guided Mr. Mitchell-Hedges to the place. Cave 1 (fig. 17) had a steep approach and two entrances, only one of which was large enough for a man to enter easily. The walls were considerably blackened by smoke. There were no signs of any recent fires. No floor deposit of any extent was present, and aside from the smoke-stained walls the only evidence of aboriginal occupation were a few unslipped red potsherds in the crevices and on the abrupt slope before the cave. Excavations in the black, evil-smelling muck below the cave, however,

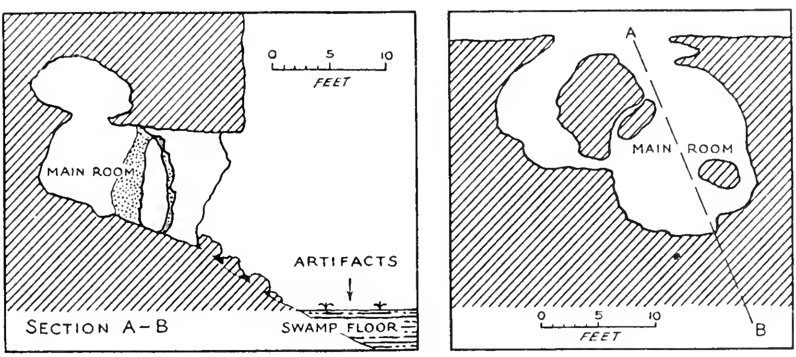


FIG. 17.—Diagram of cave 1, Helena.

yielded a considerable number of artifacts. The artifact-bearing area appeared to be roughly semicircular, with about a 10-foot radius, directly in front of the cave. In the muck and ooze no deposition lines were visible, and no artifacts were found below 2 feet in depth. They occurred irregularly from the surface to this depth. Broken and unbroken conch and whelk shells were abundant, and the miscellaneous artifacts recovered suggested that the place had been a temporary living site. Our excavations were limited by the short time available, and it is probable that more extensive work, especially with some sort of screen and washing technique, would yield a goodly number of specimens in addition to those obtained by Hedges and by our own party. However, the deposit next to the cave seemed to be exhausted when our work ceased, and I am inclined to believe that the entire site is one of very limited extent. Grubbing in the black, oily mud and water was extremely unpleasant, and the omnipresent flies and mosquitoes did not help. An amusing though at times painful aspect of the work was furnished by the numerous land crabs lurking in the muck, which felt like highly desirable artifacts but pinched like demons.

The rock shelter (cave 2) was much smaller than the above and consisted of a niche or ledge 24 feet long and 6 to 7 feet above the level of the swamp (fig. 16). The ledge tapered in width toward both ends, being about 4 feet wide in the center. The roof was formed by the overhanging cliff, and the floor was concave with a niche or shelf some 3 feet higher at the south end. In the concavity was about a foot of brown dust and scaled-off fragments from the walls containing potsherds and a few artifacts. Sam had previously obtained here two or three complete pots, which he had sold.

Particularly striking was a stalagmitic formation, 5 feet in height, which stood in the center and on the outer edge of the main shelf (fig. 16). This definitely suggested a life-size human form having a rounded head and blocklike body. It was natural in origin, although the smooth, almost polished condition of the head may have been the result of human activity. Mounted well above the level of the swamp against such a striking natural background, the object at once suggested some sort of a fetish. Owing to the density of the mangroves at this place, some of our photographs did not come out; however, the field sketch gives a good idea of the object and its situation (fig. 16). Aside from the few artifacts, there were no other signs of human occupation, nor were the walls of the shelter smoke-stained.

We searched along the cliffs for a considerable distance in both directions and climbed to the top in several places without discovering any further human evidence. Several other clefts or small shelters, as well as the foot of the cliff, were carefully examined with similar negative results. On the basis of our examination and excavation, which occupied considerable parts of two days, the site consisted of only the one habitation cave and the rock shelter, or more probably shrine, nearby. The following artifacts were recovered or noted at this place.

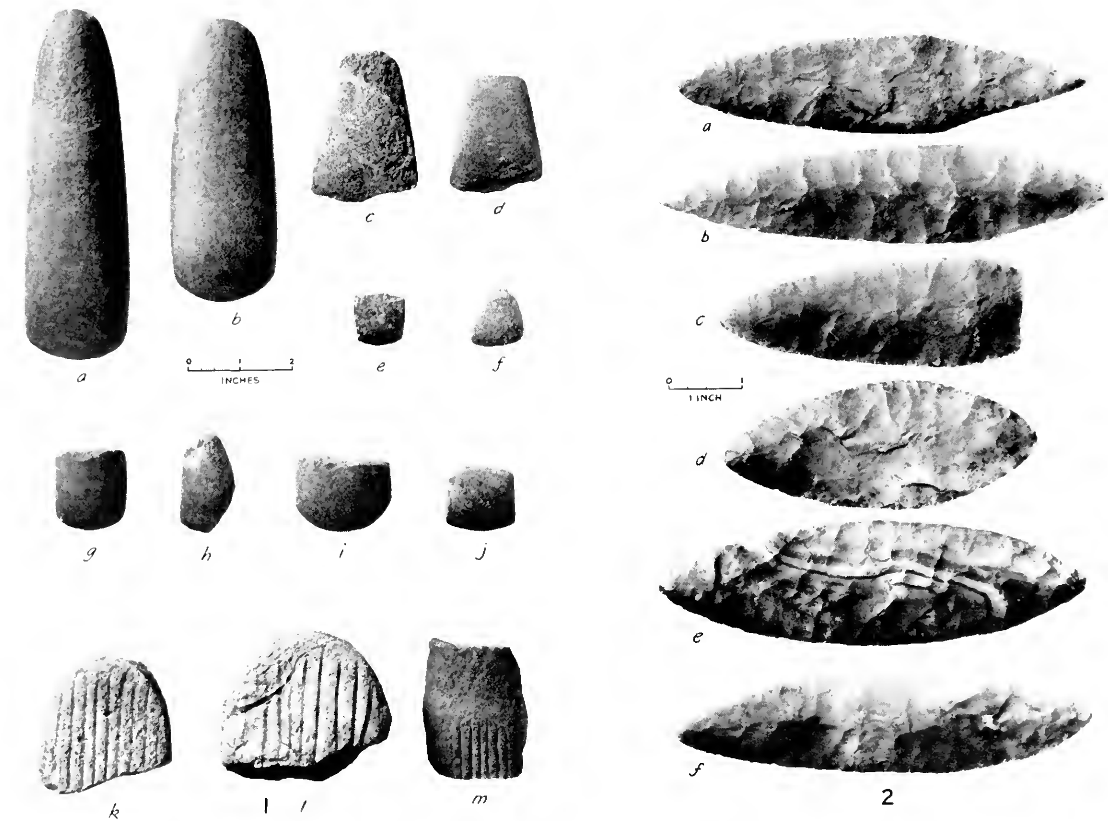
CERAMICS

From cave 1, or rather from the muck at the foot of its steep approach, one complete pot and a large number of sherds were recovered. This pottery was covered with oily black muck and in many cases by a lime incrustation. All sherds were taken to the lagoon and washed, and an attempt was made to fit as many pieces together as possible, since we could not take the entire collection. In this we had no great success, as the sherds had evidently been deposited through sweeping or washing from the cave and were not parts of pots crushed *in situ*. The great majority of the sherds were unslipped red ware (monochrome), of which seemingly representative samples were preserved, along with all sherds decorated in any manner. In the following description it must be remembered that unslipped and undecorated red ware was greatly preponderant at the site. Owing to the greater space required to discuss the more elaborate types, it might appear that these decorated pieces were predominate, whereas actually they represent only about 10 per cent of the total.

The complete pot (pl. 31, *d*) from cave 1 has a badly eroded surface on which the rather heavy white grit tempering is visible. It is globular and without handles, decoration, or traces of any slip. The sherd collection is a mixed lot and certain types occurred here, as is true of the Mitchell-Hedges collection, which were not found elsewhere. Polychrome I is represented by four sherds of a dull brown-orange which are very thin (3 mm in thickness) and highly polished. They have at present no traces of painted designs. Three are from a rounded bowl with contracting mouth and slightly swollen lips without any flare. The fourth sherd is from a flat-bottomed vessel with one hollow foot, of truncated cone form, containing a pottery ball. Polychrome II is represented by two eroded sherds, one of which has traces of design. The latter is a curved fragment from a large bowl (6 mm average thickness) of dull orange color with traces of a rather wavy linear design in dull black. The other sherd is part of a broad, vertical strap handle with a conventionalized manatee head lug on the upper bend (like fig. 11, *a*, *d*). These type identifications are very probable but not positive.

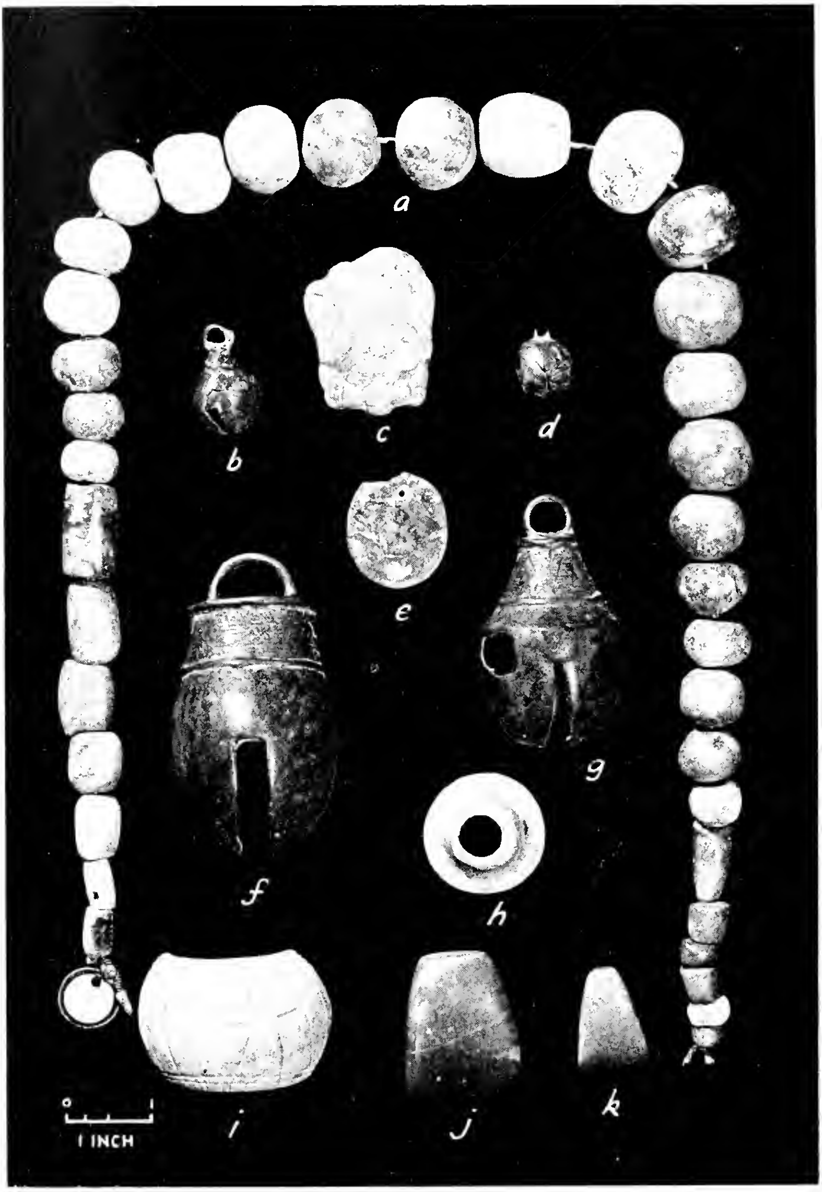
There is another small group of sherds that do not fit into any Bay Island ceramic class yet distinguished. One striking rim sherd (pl. 18, fig. 1, *c*) is highly polished and decorated by paint and incision. It is a dark red with a dull white band below the rim. On the white is a weathered design in black divided into panels; one of these has a single fret design, the other a complex arrangement of lines and dots suggesting the skeuomorphic glyph designs which occur on early Uloa Polychrome ceramics. Below this white and black border is a portion of a skillfully incised design suggesting a conventional animal or monster. A second very striking vase with a slight neck contraction is represented by three sherds, one from cave 1 and two from cave 2. The former (pl. 18, fig. 1, *e*) shows the design. It has a red slip with a panel around the neck of solid black and darker red steps separated by strips of body color. These and the panel borders are outlined by incision. From the two upper black borders peculiar linear designs extend to the lip. There are traces of a black body design, but these are entirely obscure. It is somewhat paradoxical that the paint on this sherd from the muck in front of cave 1 is better preserved than that on two other fragments of the same vessel from cave 2, which was bone dry. The sherds from cave 2 were covered with a brown incrustation which can be only partially removed. A basal sherd from cave 2 may have come from this same vase, though this is problematical. It is of similar ware and thickness with traces of black paint over the exterior. The piece is a portion of a flat bottom with one thin, solid rectilinear foot 5.5 cm in breadth. Three other sherds from cave 1 are from a poorer-grade vessel with a dark red slip and irregular black linear design. The rim sherd (pl. 19, fig. 1, *a*) may be from this last vessel. These sherds do not fit into any of the present Bay Island classifications, but two of them (pl. 18, fig. 1, *c*, *c*) are similar to pieces obtained on Helena by Mitchell-Hedges and may be related to early Uloa Polychrome wares. One rim sherd from a large straight-walled vase (pl. 18, fig. 1, *b*) was covered with a brown calcareous deposit, but where this can be removed, traces of a white slip and black design can be seen. Below this faintly preserved, painted-design panel is another of incised frets. A rim sherd, from a smaller vessel, is so heavily coated with this same incrustation that only bare traces of a similar incised design can be seen. These two sherds are similar to the elaborately incised monochrome pottery, but the presence of a shiny white slip on one of them seems unusual.

Elaborate monochrome sherds are fairly abundant in the present collection. One-third of a large vessel of this type was recovered (fig. 18). The panels of incised design, the monstrous human or simian faces, and the "snakes" in applique are interesting. Two of the heads appear to be extreme conventionalizations of the manatee head motif though they resemble the duck-bill platypus as much as anything else. The vessel had a tripod base, and the incised foot is solid. There are three basal portions of medium-large jars with annular bases showing incised, and in one case applique, decoration. The largest has an outside basal diameter of 17 cm. Two have slightly concave bottoms, but the largest has a convex bottom with a marked "dimple" in the center. This broken vessel has external design panels of opposed step elements, each pair enclosing a dot. In the others, panels with short line and dot designs occur. In addition,



Stone Artifacts, Various Sites

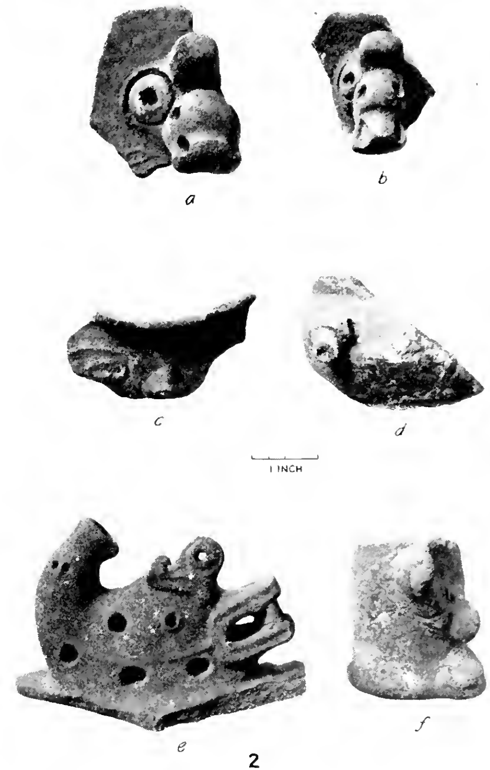
1. Ground stone celts and bark beaters: *a-f*, Dixon site, Roatan; *g*, *k*, Marble Hill Fort, Bonacca; *h*, *i*, Indian Hill, site 1; *l*, Indian Hill, site 2, Barburata; *j*, Jonesville Bight, Roatan; *m*, Morat Island.
2. Chipped stone knife blades: *a-e*, Dixon site; *f*, Helena.



Photograph courtesy of the American Museum of Natural History.

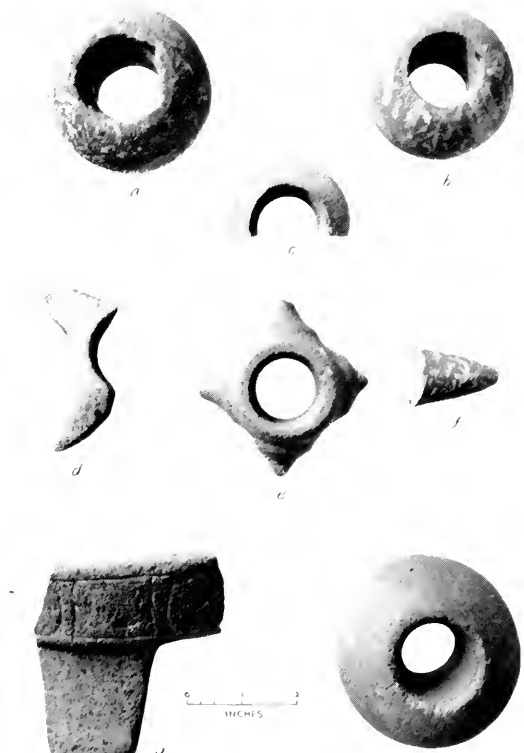
COPPER BELLS AND SMALL STONE CARVINGS

a-g, vicinity of Coxen Hole, Bonacca; *h*, Kelly Hill, Bonacca; *i*, *k*, Jonesville Bight, Roatan; *j*, Marble Hill Fort, Bonacca.

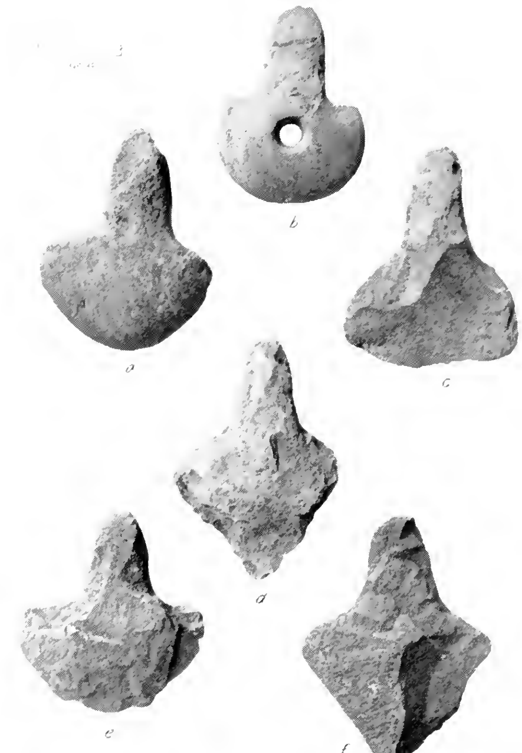


HELENA ISLAND

1. Painted and incised sherds (*a*, *c*, *e* retouched to bring out design).
2. Modeled monochrome sherds.



1



2

STONE ARTIFACTS, VARIOUS SITES

1. Ground stone mace heads and potstand fragment: *a-c*, Helena; *d*, *f*, *g*, *h*, Indian Hill, site 1, Barburata; *e*, Dixon site, Roatan.

2. Ground and chipped T-shaped axes: *a-c*, *f*, Helena; *d*, Indian Hill, site 1, Barburata; *e*, Dixon site, Roatan.

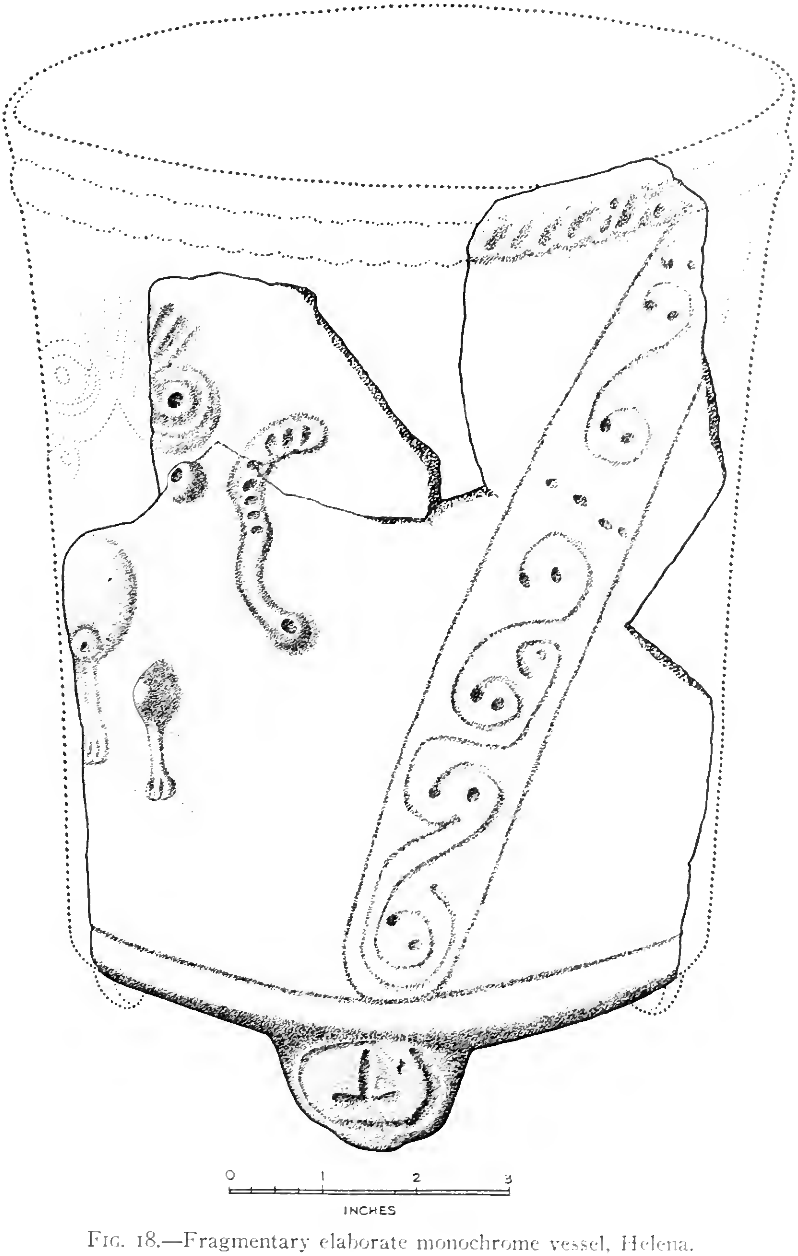


Fig. 18.—Fragmentary elaborate monochrome vessel, Helena.

there are three rim or basal flange fragments from similar vessels; two of these have the opposed step and dot design, and the third has angular lines and dots. Two rim sherds from a highly polished red vase have an outside bevel below the rim. A small portion of body ornamentation on these pieces shows a rectangle of lines in relief containing incised square and curvilinear motifs. Of the three detached feet in the cave 1 collection, two are hollow cylinders flaring toward the top and decorated with punctate markings, and the third is of the thin, solid rectilinear type.

In the cave 1 collection are about a dozen rim sherds of rather coarse, brick-red pottery. All but two of these plain monochrome sherds are from large to medium pots with more or less constricted necks and low flaring lips (similar to pl. 30, *h-l*). The two sherds are from small open bowls, one has a direct, the other a definitely incurved rim. The largest of the sherds with low, flaring rims are similar in type to the small burial urns from Black Rock Basin, Utila. The others appear to have been smaller utilitarian vessels. Aside from simple incised line and dot, or small, rough applique tabs on a few of these, they are undecorated. This sample seems fairly typical of a large amount of the discarded sherds at cave 1.

Cave 2 contained a small amount of broken pottery and one shell bead, but nothing else. As previously stated, a number of complete vessels and considerable other material had been removed by Mitchell-Hedges and the man who discovered the site. All the sherds from this rock shelter were thickly coated with a pinkish incrustation, similar to the powdered debris in the hollow, and in some cases, a whitish, calcareous deposit had been added to this. Conditions for preservation seemed better here than in the perpetually damp mangrove swamp muck, yet in one case, at least, deterioration was more marked. I refer to the red and black painted sherd (pl. 18, fig. 1, *c*) from cave 1, which had retained its color, whereas a fragment from the same vessel in cave 2 bore only the faintest traces of paint. A smaller rim fragment of the same vessel however, under a whitish calcareous coating retains the black collar design almost as well as the larger sherds from cave 1.

In addition, there were three other fragments of slipped ware. One of these is the thick basal fragment (9 mm in thickness) with a solid, rectangular lug, which bears traces of a highly polished black slip. The two remaining painted pieces are obviously from thin Polychrome I vessels and consist of a typical nose-tilted face lug and a hollow flattened, conical foot. Both bear faint traces of characteristic polychrome designs. The foot contains a piece of gravel as a rattle.

Six sherds, at present without traces of any slip, are rather elaborately modeled. The most elaborate of these is a lug representing a plumed alligator or possibly serpent (pl. 18, fig. 2, *e*) with the short tail curving outward and upward and open at the end. The tip of the animal's jaws just reaches the rim of the almost straight-walled vessel from which this fragment was broken. A round, perforated secondary lug on top of the figure's head and a space formed between the jaws and behind the solid teeth may have served for the attachment of carrying cords or decoration. The figure is hollow, and a passage extends from a round perforation in the center of the mouth, through the entire body and out at the top of the tail. There are seven punctate decorations on each side of the lug; of these, the three nearest the body of the pot and the large perforation below the eye actually penetrate to the hollow interior, but the others are not complete. The round tail tip rather suggests the end of a whistle or ocarina, but the lug cannot be made to whistle; hence the perforations are probably for decoration rather than use. A fragment modeled as a human face represents an interesting type of jar (pl. 18, fig. 2 *c*). A complete vessel of this type, which was found by Mr. Boekelman at Marble Hill Fort (fig. 34, *a*), will be referred to later. Another anomalous fragment, probably a figurine, has appendages modeled in high relief and a definite rounded rim on what appears to be the base (pl. 18, fig. 2, *f*). Two lugs are of the manatee type, one definitely suggesting this animal (pl. 18, fig. 2, *a*), as do the majority of such pieces, whereas the second (pl. 18, fig. 2, *b*) is conventionalized with the nasal portion unnaturally drawn out. The extreme of this type of conventionalization appears in the "duck-bill platypus" type of manatee design on a large sherd from cave 1 (fig. 18). Another small bowl fragment has a rather common type of lug (pl. 18, fig. 2, *d*) that may also be derived from the manatee motif.

Three sherds are decorated with deep incisions. One of these has a rather complex design (pl. 18, fig. 1, *d*). Only a few undecorated pottery fragments occurred in cave 2. One of these, a considerable portion of a small jar, has a flaring mouth. Another plain fragment of similar thickness (5 mm) has a broad, vertical loop handle. The four remaining plain ware sherds are too fragmentary to merit discussion.

Considering the ceramics from both these nearby sites, two points seem especially noteworthy. First, cave 2, apparently a shrine, had a majority of decorated pottery and only a small amount of plain ware, whereas the reverse was true in cave 1, which was a living site. Second, the occurrence of fragments of the same especially fine painted pot (pl. 18, fig. 1, *c*) in the muck below cave 1, and also in the hollow below the stalagmitic "image" at cave 2, suggests that broken fragments, especially those from fine vessels, were regarded as suitable offerings.

GROUND STONE

No metal or metal work was recovered at this site. Ground stone artifacts were limited to six pieces. The most striking are two large mace heads of attractively mottled felspar porphyry (pl. 19, fig. 1, *a, b*). The largest of these is 5 cm in height and 7.7 cm in diameter and has a perforation 4 cm in diameter. A smaller mace head of diabase has been broken in half (pl. 19, fig. 1, *c*). Particularly noteworthy is a T-shaped ax of felsite (pl. 19, fig. 2, *b*). Its chipped surface has been ground to a sharp edge, and there is a perforation where the narrow butt runs into the blade. Another specimen of diabase porphyry lacks this central perforation but is otherwise similar (pl. 19, fig. 2, *a*). These axes were probably hafted, as the central perforation in the one strongly suggests, but could have been used in the hand as well. The ground T-shaped ax is merely a refinement of the more numerous chipped axes of this type (pl. 19, fig. 2, *c-f*). Only one stone bead was recovered, a small, round, light green bead of diopside. It has already been noted that, aside from one shell bead and some pottery fragments, all artifacts came from the muck below cave 1.

CHIPPED STONE

Two chipped, T-shaped axes of diabase were preserved (pl. 19, fig. 2, *c, f*) and a number of others were found. The variety of forms that these common artifacts assume is shown in the illustration (pl. 19, fig. 2). One oval knife blade of chalcedony was recovered (pl. 16, fig. 2, *f*). It is well worked and almost complete, but is not as thin (11 cm in thickness) as the best from the Dixon site.

SHELL AND WOOD

Three shell artifacts were recovered: two large shell (*Oliva porphyria* Linné) "bells" or danglers from cave 1 and a rectangular shell bead (pl. 15, *c*) from cave 2. The "bells" consist of medium-sized shells, cut off at one end and perforated at the other (pl. 15, *c*). It is of interest that this species is found on the west coast, but not on the east coast, of Central America. They came from the muck below the cave and are hard and in good condition. The rectangular shell bead from cave 2 has a coral-pink surface on one side and is white on the other (*Spondylus* sp. ?). Numerous large conch shells were found, the majority of which had been broken open to extract the meat. A few examples, however, were complete and had a small, roughly picked hole opposite the natural opening. These last were probably used as signaling trumpets.

From the muck in front of cave 1 came a small fragment of wood 6 cm in length, which shows signs of cutting on one end. It is too fragmentary to suggest any type of artifact but has a certain importance as a hint that mangrove swamps in this region may be found to contain valuable perishable material of this sort.

In conclusion, it seems significant that the great majority of the utilitarian artifacts came from cave 1, furthering the probability that cave 2 had importance mainly as a shrine. Probably the sporadic occupation of cave 1 which, owing to its location, could hardly have been a year-round residence site, was primarily due to its proximity to the striking natural formation in cave 2.

An examination of that part of the Mitchell-Hedges material in the storage collections of the Museum of the American Indian which is allocated to Helena Island reveals many types not represented in our much less extensive collection. Since the sites already mentioned are as far as I know the only ones worked by Mitchell-Hedges, the material probably comes from these. There is a large amount of broken Polychrome I pottery of the thin type with an orange slip and black and red-purple designs, already described. In addition, there are a number of light buff sherds, apparently of the same ware, that have brown designs, often representing rather crude and conventionalized plumed serpents. All the usual Polychrome I lug types are represented, with the addition of (a) a fairly numerous bird head type, which may or may not have incised eyes and a knob or spur on the crown; and (b) an ovoid lug with a perforation on each side and a small knob or ridge on the top. Both types of lug have the usual black and red-purple rings around the base and, occasionally, painted bands over the upper portion. One unusually interesting vase strongly suggests late Copan or Uloa wares. It is straight-walled with a white slip, on which are very crude warrior figures in red. Around the neck is a band of skeuomorphic glyphs. This vessel is unlike any other that I have seen from the islands. There are also a number of Polychrome II sherds and a number of pieces that appear to be transitional between the two polychrome wares.

The collection contains a large amount of the elaborately incised monochrome pottery. In addition to most of the types already described, there are a number of variants of the partly incised and partly applique anthropomorphic and monstrous figures. Elaborate and grotesque lugs and some restored vessels with round tripod feet are represented. There are several complete ocarinas or whistles (like pl. 27, fig. 2, *a-c*) of this elaborately incised monochrome type. The undecorated monochrome ware is represented by a considerable number of simple red vessels and sherds, usually round-bodied with low, flaring lips. To judge from this collection, all of the pottery types described in the present paper were originally represented on Helena Island.

Ground stone artifacts are well represented. There are several crude, low bowls of white marble, one cylindrical pestle of lava, and a beautiful petaloid celt (18 cm in length) of black stone, which has been chipped into shape and subsequently polished to a lustrous finish. There are several ordinary celts of gray stone and a star-shaped mace head of coarse brown lava. The collection contains a number of small green talc heads, but none that is very well finished; there are also square pendants and beads of similar materials. There is one chipped stone knife and one small-stemmed projectile point of brown chert, as well as several of the crudely chipped T-shaped axes. Evidently this Helena site contained much more abundant and varied material than Captain Boynton and the Negro Sam, who were both with Mitchell-Hedges, remembered. As a cross-section of nearly all Bay Island types it is rather remarkable.

Barburata Island

On leaving the Helena site the *Amigo* proceeded to Barburata Island and anchored near Pelican Point (fig. 19). Barburata is an exquisite little island about 2½ miles long. Around the island are coral reefs, some of which are large enough for habitation, supporting a heavy growth of coconut palms and unbelievable numbers of land crabs. Owing to the protecting reefs, the lagoon on the south side of the island is a favorable anchorage, though in certain winds it is hard to find a holding ground. An east wind was sweeping the lagoon during our first night and we were forced to shift anchorage several times. During most of our visit to the islands this strong wind was extremely annoying, though it was never dangerous as are the " northers " which come later in the season.

The first morning after our arrival we rowed to the mouth of a little stream that comes down to the southeastern shore. This valley was a veritable paradise; first one passed through a fringe of cocoa palms laden with nuts, where dragonlike iguanas were numerous, then on into a marvelous grove of wild fig trees with great buttressed trunks and stately branches (pl. 20, fig. 1). The little stream of brown, rippling water, the pervading scent of lime and orange blossoms, and the chatter of flocks of parrots, mingled with the cooing of wild blue pigeons, gave the final touches to the exquisite setting. Following up the stream, we began to climb onto the rolling hills until we came out

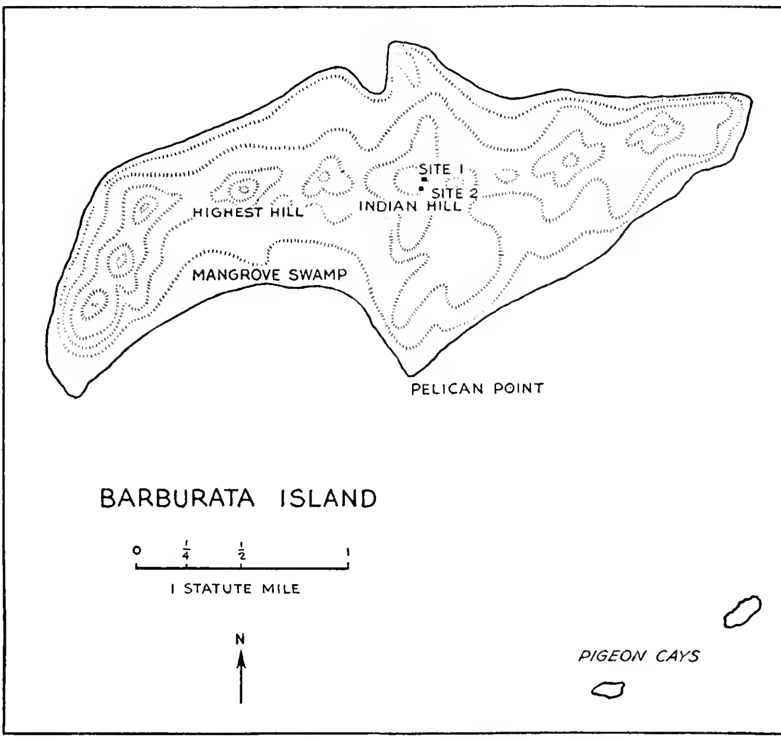


FIG. 19.—Sketch map of Barburata Island. (Made by Norman A. Haskell.)

on a bald spur below Indian Hill. From here the western end of the island can be seen with its rolling surface dotted with open cattle pastures and thick clumps of trees. On this knob several unslipped, red potsherds were picked up, along with one red pottery bead. Continuing on to the northeast, we passed on through thickets of corozo palms covered with nuts, into the dense forest that covers the top of Indian Hill (map, fig. 19; pl. 20, fig. 2). Here two offertory sites are located.

INDIAN HILL

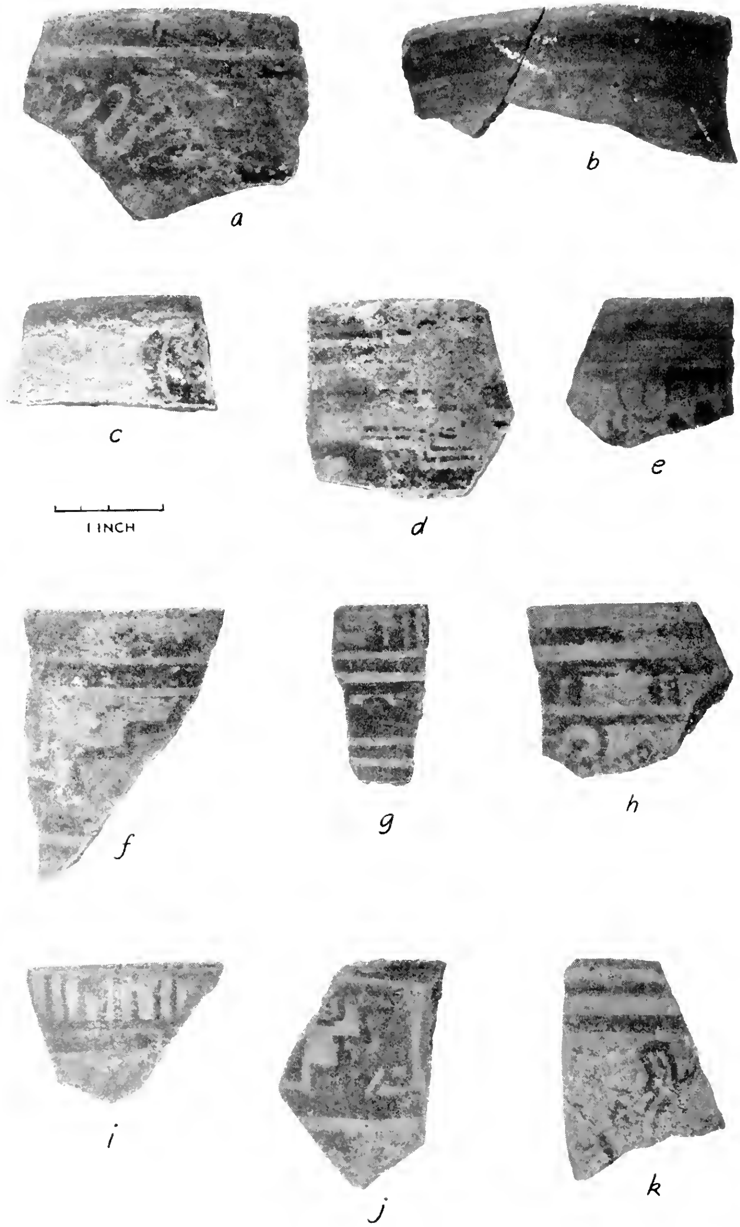
Site 1

The first of these offertories that we investigated is just below the crest of Indian Hill to the northeast. Indian Hill is approximately in the center of the island and its summit is about three-fourths of a mile from the southern and somewhat closer to the northern shore (see map, fig. 19). We estimated its altitude at about 300 feet. Site 1 is marked by two great wild fig trees, one living and one dead, around which, over a space approximately 75 feet from east to west and 60 feet from north to south, is a mass of broken pottery and other artifacts. This deposit is covered by only a few inches of earth in those places where it has not been disturbed. Much of the site had been dug over in a haphazard fashion by earlier visitors. These include the workers of Mr. Mitchell-Hedges' party and a number of local treasure hunters. A tree of considerable size had been cut down to get at the artifact deposits under its roots, and there was a large amount of broken material left on the surface and around this tree (pl. 20, fig. 2). Since it was not possible to remove all this material for detailed study, I made sketches and notes concerning the types represented, which will be incorporated with the following account of artifacts recovered from this site. Owing to lack of time, workmen, and adequate tools, our own excavations were hardly more systematic. Since the central portion of the deposit had been completely pitted, we dug mainly in the northwest corner, taking out a wedge-shaped section, and on the northeast where we came from the edge into the center of the deposit. On the edges the artifact layer was very shallow but became thicker as the center was approached, until it reached a depth of something over 3 feet. This was the thickest portion of the deposit that I observed, but it is possible that in the much-disturbed center it is somewhat deeper. Although the above-mentioned factors, as well as the brevity of our visit, precluded a systematic stratigraphic study, an attempt was made to record the relative depths of various types of artifacts. The most notable result that appeared in this regard was that the bulk of the thin, polychrome pottery (Polychrome I) and a few green stone carvings recovered came from the upper portions of the deposit, usually within a foot of the surface. For the above reasons and others shortly to be discussed this must be taken as a probable rather than a positive indication of their relative age.

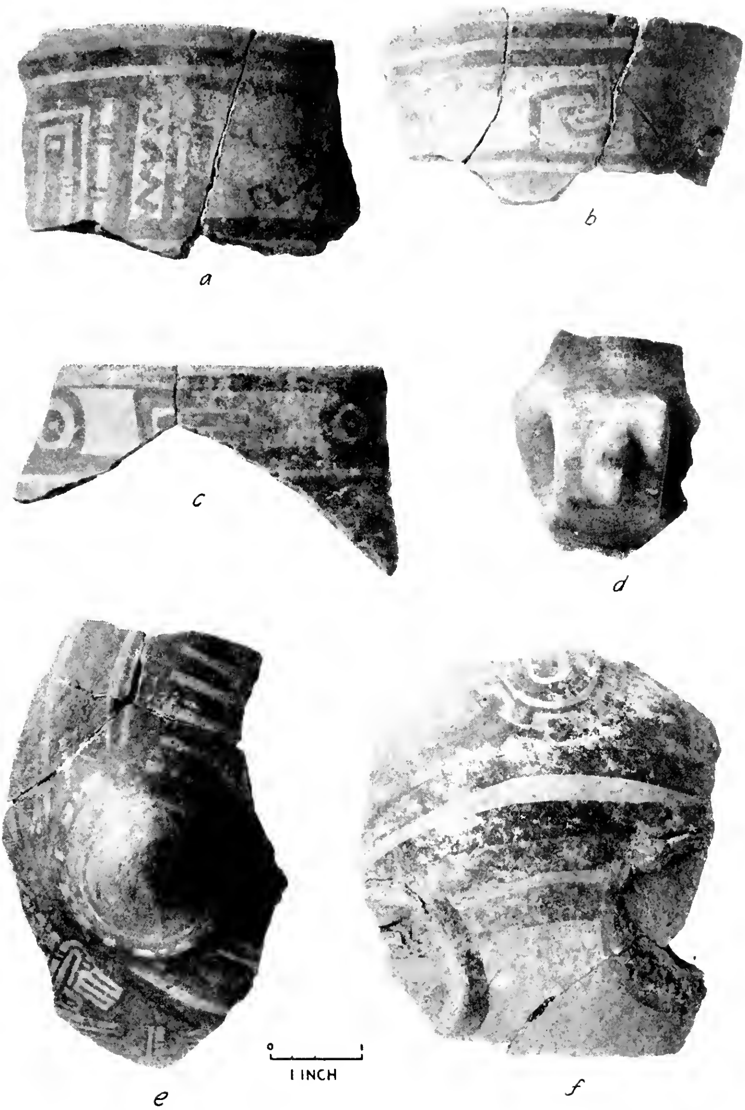
In general nature, the deposit was similar to that at the Dixon site but more extensive. Most striking was the enormous amount of broken pottery. Entire pots were rare, but enough whole and re-

INDIAN HILL, BARBURATA

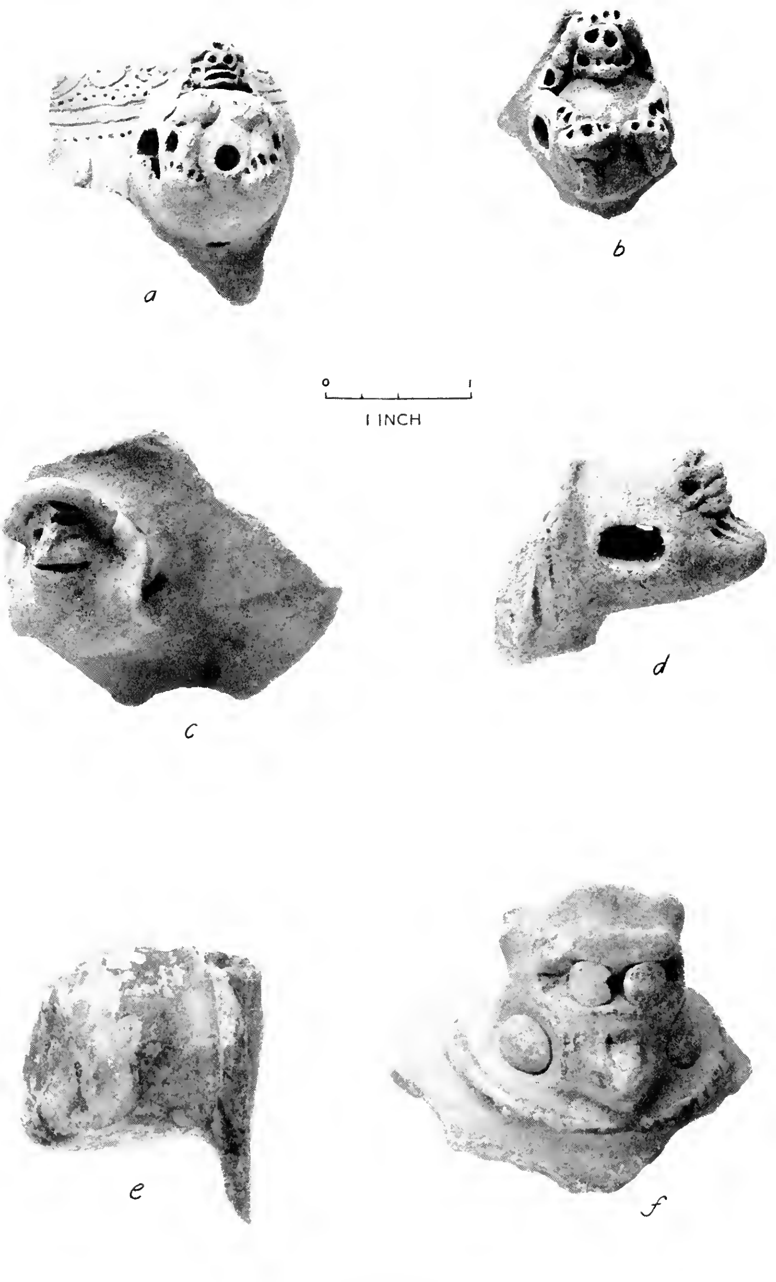
1. Wild fig grove below Indian Hill, Barburata Island.
2. Broken artifacts left at site 1, Indian Hill, Barburata.



POLYCHROME I RIM SHERDS, INDIAN HILL, SITE 1



POLYCHROME I SHERDS, INDIAN HILL, SITE 1



DETACHED LUGS

a, b, monochrome; *c-f*, Polychrome I. *d*, Dixon site; others Indian Hill, site 1.

storable pieces were obtained to give some idea of the various forms represented (pls. 24, 25; figs. 29, 30). Plain and decorated metates, the latter type all broken, were fairly abundant (pl. 20, fig. 2). In addition to the numerous artifact types, a considerable number of conch and whelk shells, rough rocks, a little charcoal, and a few animal bones were noted. A few fragments of human bone and some teeth were likewise recovered. No evidence of definite burials, fireplaces, or house floors was observed. At least 90 per cent of the artificial deposit consisted of closely packed broken pottery.

Unlike the Dixon site no view could be obtained from this place, owing to the dense growth of corozo and other small palms which surrounded it. If these were removed, however, a good vista of at least the northern shore could be obtained. As at the Dixon site, there were no surface structures of any kind.

CERAMICS

Site 1 yielded a large amount of pottery, as well as interesting data on the classification and relationship of the two major wares previously noted at the Dixon site on Roatan Island. In addition to a large collection of sherds, 11 complete or restorable vessels and 15 miniature pots were obtained and about 15 whole or restorable vessels (mostly duplicates) had to be sketched and left at the site, owing to our very limited transportation and storage facilities.

Two distinct ceramic types were noted, a thin, polychrome ware (Polychrome I) and the monochrome ware. No Polychrome II sherds were found at this site. All the whole or restorable vessels and 99 per cent (estimated) of the broken pottery pertained to the monochrome type. After careful study it has been possible to demonstrate a definite relationship between the two types, a matter which will be brought out as each ware is analyzed in detail. This fact, in conjunction with the more superficial occurrence of the thin polychrome ware, will be discussed when sites 1 and 2 on Indian Hill are compared.

The thin, polychrome ware will be discussed first. All sherds of this type encountered were preserved, giving a total of 203. However, owing to the occasional disappearance of painted decoration through weathering, many such pieces were probably not recognized in the field. After thorough cleaning and analysis in the laboratory, certain lug types thought to pertain exclusively to the monochrome red ware were also found to belong to the thin, polychrome ware. It appears, therefore, that our collection of the latter ware might have been somewhat increased had washing facilities been at hand. Nevertheless, including all Polychrome I types, this ware made up a very small percentage of the total pottery deposit in the offertory.

As at the Dixon site, the Polychrome I ware is very hard with a fine paste. It varies from 5 to 9 mm in thickness, averaging around 7 mm. It has been thoroughly and evenly fired and highly polished prior to applying the slip and painted decoration. Tempering, often invisible to the naked eye, is of fine white grit. Sherds are mostly of small size, resulting from the breakage of small to medium-sized vessels. The majority have an orange slip ranging from dark orange to light buff, the latter color being rare. Most of these sherds bear portions of painted designs in black and purplish red. Six sherds have a cream-white slip with black and red designs. A considerable number have only traces of slip and painted design, and a few, indubitably of this type, are so eroded that both slip and design have entirely disappeared.

Since no complete or restorable vessels of this ware were recovered, shapes and designs must be reconstructed from fragments. There are 67 rim sherds; only one of these retains part of a lug, and none has handles. Separate lugs are common. They were placed below the rim and have broken off, usually where they joined the body of the vessel. Rim cross-sections are remarkably uniform and are either slightly swollen or of the same thickness as the body of the vessel. Three rim types can be distinguished: (a) with mouth slightly contracting (fig. 22, *f*), (b) intermediate (fig. 22, *c*), and (c) with mouth strongly contracting (fig. 22, *d*). Practically all rim sherds have an outside design on the neck, usually of purplish red and black (pls. 21, 22). Owing to differential weathering, this design is more or less eroded. Sixteen of the rims have designs on the inside as well as on the outside (fig. 20). These differ in no essentials from outer neck designs. They will be discussed shortly in relation to polychrome design as a whole.

The more numerous body sherds appear to be from small rounded pots or semicylindrical vases. Apparently the larger portion of the body surface was covered with painted design. To judge from fragments, and from the complete vessel at the Dixon site, lugs were usually attached close to the angle between body and neck. Both lugs and feet apparently were modeled on the body at the same time that the pot itself was shaped. Both are hollow and contain pottery balls or gravel, demonstrating their use as rattles. The majority of the lugs are modeled and fall into three main types: (a) nose-tilted (fig. 22, *a*), (b) applique rider (fig. 22, *b*), and (c) iguana head (fig. 22, *c*). Of the 28 painted lugs, 7 are of type (a), 11 of type (b), and 5 of type (c). The remainder represent human or simian forms (pl. 23, *e, f*), animal (fig. 23, *b*), or unusual or intermediate forms (pl. 23, *c*). One lug (pl. 23, *e*), which might be either human, simian, or a conventional jaguar, is almost identical with a lug figured by Gordon (1898, pl. 1, fig. 12) from the Uloa river.

Of the three main lug types, those with the nose-tilted face (a) are best preserved, all retaining both slip and design. Type (b) lugs are more eroded than (a), and type (c) lugs are without either slip or design except in two cases. Presuming that weathering conditions have been equal for all, as would seem to have been the case at least

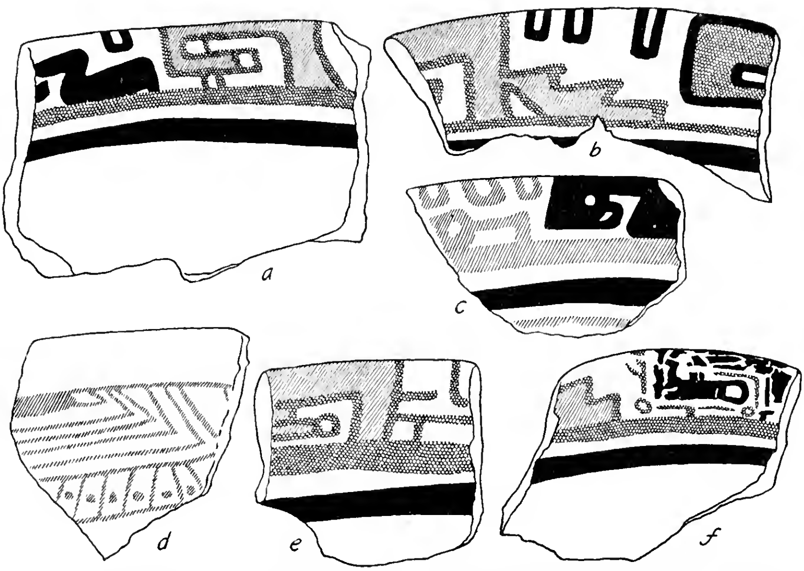


Fig. 20.—Polychrome I rim sherds (inner surface), Indian Hill, site 1. (White, orange-red; black, black; hatching, purplish red; cross hatching, darker red.)

since their deposition in the offertory, this may indicate the older and the later types in vogue. Such a sequence is likewise suggested by the fact that type (a) seems to have developed from type (b) through the "applique rider" face being dropped from the top to the tip of the lug, with the encircling arms thus forming a ridge around the face, thereby giving type (a) lugs the appearance of a face projecting from a fish or reptile mouth. Three rather aberrant lugs (pl. 23, *a, c*) further this suggestion of a developmental transition between types (a) and (b). It should also be noted that both lug types (b) and (c) occur in the monochrome ware as well as in the thin, polychrome (pls. 23, *a, b;* fig. 24, *d, f;* pl. 27, fig. 1, *a*). In many cases it is

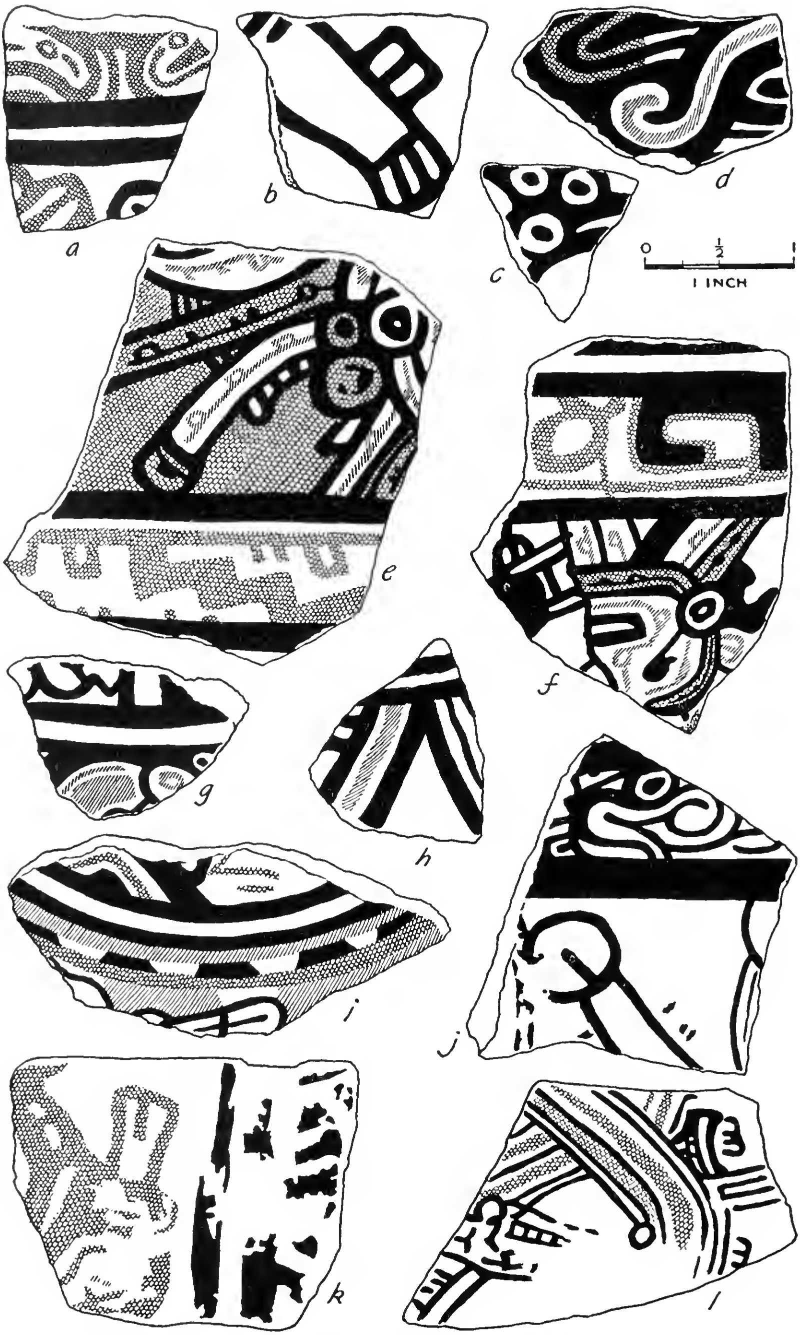


FIG. 21.—Polychrome I sherds, Indian Hill, site 1. (White, orange-red; black, black; hatching, purplish red; cross hatching, darker red.)

impossible to be certain to which ware the badly weathered lugs actually belong (fig. 24, *f*). Type (a) lugs, however, seem to be definitely limited to the thin, polychrome ware (Polychrome I).

To judge from the present collection, handles were exceedingly rare in this thin, polychrome ware. One vertical handle with characteristic painted decoration was recovered at this site (pl. 22, *d*). Basal portions and foot fragments of this ware are rather uniform, a round-bottomed vessel with three conical feet predominating (pl. 22, *c*, *f*; pl. 1). Bottoms are either flattened between the tripod feet or marked by a flattened curve that expands rapidly above the feet.

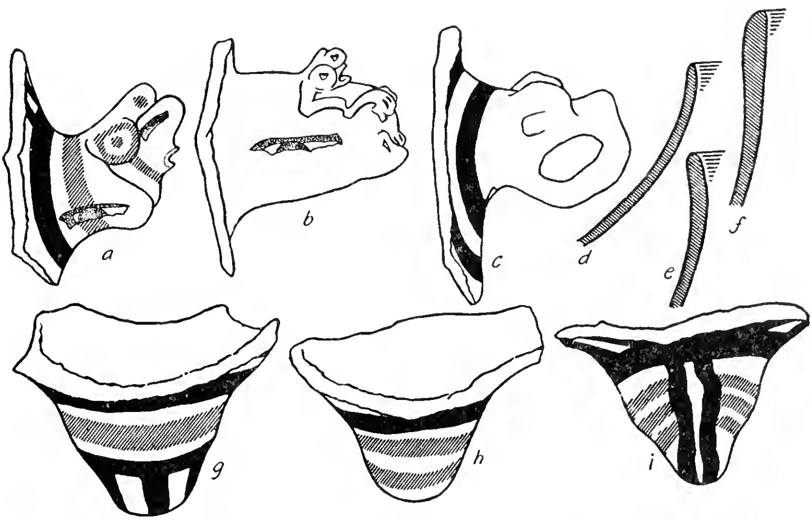


FIG. 22.—Polychrome I rim, lug and foot types, Indian Hill, site 1. (White, orange red; black, black; hatching, purplish red.)

In the present collection all basal fragments come from vessels with three coniform feet. Some 25 sherds with attached feet were recovered. They fall into three main types: (a) humped (fig. 22, *g*), (b) conical (fig. 22, *h*), and (c) spurred (fig. 22, *i*). One example, already described as a lug (pl. 23, *f*), has a worn surface on the back of the figure's head and may have served as a foot. From the complete vessel obtained at the Dixon site (pl. 1) it can be seen that the type (a) lug and the type (a) foot are associated on the same vase. Owing to excessive breakage prior to deposition, the correlation between other lug and foot types is uncertain. In general, the lugs and feet are among the most numerous and best-preserved thin, polychrome sherds from this site.

Originally, the major portion of the outer surface of this thin, polychrome ware was covered, first with a slip and then with a painted design. Around the outside of practically all rim sherds occur purplish-red and black, linear designs. There is nearly always one encircling heavy black or red line and often more. A solid black or a red step design is very common, and decoration in general tends toward the geometric (pls. 21, 22; fig. 20). Some 16 rim sherds have an inside border of design (fig. 20), which is generally the same as that on the outside of the rim. The use of heavy black lines or, more rarely, red lines to set apart the combined red and black rim design is typical (pls. 1, 21, 22).

In all, 98 body sherds were recovered. From these it appears that a large proportion of the body was covered with painted designs—purplish-red and black lines on an orange slip predominating. Recognizable design units include concentric rectangles (rare), concentric circles (common), single frets, interlocking frets, hatched irregular triangles (rare), and plumed serpents or monsters (10 sherds). Of the latter only details such as plumes, ear plugs, eyes, and tail tips can be distinguished (pl. 21; fig. 21). These suggest a close similarity to the more complete "plumed serpents" on the Dixon site offertory vase (pl. 1). Designs on lugs, exclusive of modeling, are for the most part circles or simple geometric designs in black and purplish-red (pl. 1; figs. 12, 22). From the 37 basal sherds recovered, these designs appear to be very similar to that on the complete pot (pl. 1; compare pl. 22, *e*, *f*). Broad, purplish-red bands with black bands above are common (pl. 22, *f*). Designs on feet are generally simple circles or geometric patterns in red and black (fig. 22). The modeling and incising on lugs and feet have been mentioned and can be seen from the illustrations. Summing up, it can be said that the Polychrome I sherds from this site present a rather uniform and distinctive appearance as a ceramic type. Furthermore, analysis of the Indian Hill (site 1) sherds indicates that the complete vessel of this ware from the Dixon site is typical.

Compared to the quantity of thin, polychrome ware, the amount of monochrome, red to brown ware at this site was enormous. Only a very limited selection of this latter type could be transported. Besides the 11 complete or restorable vessels, and the 15 miniature vessels, some 200 monochrome sherds were saved. Some 15 more or less crude vessels of this ware were sketched and measured, being left at the site along with a great mass of fragmentary pottery. Since all types of complete and model vessels of this ware were preserved, or sketched in the field, these can be regarded as a representative sample comparable to the collection of all thin, polychrome sherds encountered. The sherd collection of monochrome pottery, however, cannot be regarded as a random sample, since the majority of those saved were decorated with incising or modeling. It must be borne in mind then, that although the following discussion of complete and restored vessels is fairly typical of the monochrome ware as a whole, the sherds figured represent a very decided minority as compared with the less ornate fragments left at the site.

Two restored vessels are outstanding examples of the most ornate and finest type of red (to buff) ware (pl. 24, *a*, *b*). The sherds from which these two vessels were restored were found rather widely scattered at a depth of about 1½ feet in the sherd deposit. They had evidently been deposited in a broken condition; hence the collection of sufficient pieces to make an accurate reconstruction was very tedious. A considerable number of sherds from vessels of this advanced type were found and samples preserved (pl. 26), but these were not in sufficient quantities to permit accurate restoration.

The cylindrical vessel (pl. 24, *b*) is 23.5 cm high and 17.5 cm across the mouth. It is light buff in color, inside and out, and the pottery is extremely hard. The paste is very smooth, and no tempering is visible. A high polish has been given to both inner and outer surfaces. As is true of most of the monochrome ware, no slip is visible. The bottom is slightly concave with a raised " dimple ", 6 cm in diameter, in the center. The bottom is raised 3.5 cm on the perforated annular base. The two conventional modeled lugs, the scroll design between incised panels, and the incised and perforated annular base, indicate that this type of pottery is a simplified version of the art style which finds its best expression in the famous carved marble vases of the Uloa River valley of the Honduras mainland. (Gordon, 1898a, pl. 12, figs. *e*, *f*; Steinmayer, 1932, fig. 18, p. 20.) The vessel is also of interest as being the apparent prototype of the small model offertory vases from the Dixon site (pl. 8, fig. 1) and elsewhere in the Bay Islands. The conclusion that this striking and excellent type of large vessel was used as a model seems logical when the larger and smaller vessels are closely compared. The reasons for regarding the small offertory vessels as models have previously been discussed.

The second of these striking vessels (pl. 24, *b*) is similar to the last in color and technique except that its polished inner surface is a slate-blue, apparently the result of differential firing. It is the same height as the last but has a central diameter of 21.4 cm. The swollen body is unique. The reconstruction is accurate, inasmuch as the entire base and one entire profile, including a section of rim and one conventionalized alligator head lug, are present. However, the asymmetry of the reconstruction is probably due to the fact that complete rim and central diameters could not be accurately determined from the fragments secured. The simpler unit of incised design is a double scroll with two perforations at each end. The larger unit is a grotesque monster with an aquiline nose in relief, a round, tooth-fringed mouth, a panelled body, and scrolls around the head suggesting the tentacles of an octopus or the legs of a centipede.

The remaining complete or restored vessels from the site are less striking. One well-made, small vessel (11 cm high, 10.5 cm diameter at the mouth) is rather ornate (pl. 25, *d*). Decoration is achieved by incised lines and panels enclosing punctate markings. It has a tripod base, the feet being of the spurred type (fig. 22, *i*) more characteristic of the Polychrome I ware. The vessel is buff in color, hard, and well modeled. Two jars, one medium-sized (pl. 25, *f*) and the other small (pl. 25, *e*), can be considered together. Both are globular, the larger 18 cm in greatest diameter, and both have the same type of decoration. This consists of a series of incised, double line curves, with a punctate mark in the center of each, which encircle the neck. On each side of the neck is a linear anthropomorphic figure in low relief with extended limbs, having head and eyes formed by a small raised lug. The small vessel has a restricted orifice but a surprisingly large, flaring spout. The larger vessel likewise has a restricted orifice but the spout is missing. There is a color difference, inasmuch as the larger vessel is brick-red and the smaller vessel light buff. Both came from a depth of about 3 feet near the central part of the deposit. A small globular vessel (pl. 25, *b*) has a short neck and incised concentric loops on the body. A medium-sized vessel (9 cm high), partially restored, has a definite ring base and resembles a salad bowl in shape (pl. 25, *c*). It is reddish buff in color.

Fifteen tiny clay vessels were preserved (fig. 29). These are probably offertory models of larger vessels and for the most part are of extremely crude workmanship. They appear to have been carelessly modeled from lumps of sand-tempered clay and then hastily fired. All are red-brown in color with two exceptions, which are buff-colored and better polished (fig. 29, *h*, *i*). Common forms are represented in all cases but one, a double-spouted, tripod jar, which is unique in our collections (fig. 29, *c*). These tiny vessels occurred at various depths throughout the deposit. The 15 complete or restorable vessels, unavoidably left at the site, represent common island types. They were all small, unslipped, and range from buff to brick-red in color. Their forms are shown in the illustration (fig. 30, *b-i* and *n*). Taken in conjunction with the larger complete vessels and the tiny models, this entire series would seem to offer a fairly representative collection of ceramic forms so far as the monochrome ware is concerned.

The elaboration that frequently characterizes part of this ware is best demonstrated by the intricate incising on certain vessels (pls. 24, 26, 27) and the multiplicity of modeled forms taken by lugs and feet (figs. 23-28). It is undoubtedly significant that the most elaborate vessels were completely shattered and the sherds widely scattered in the deposit. This suggests that they were carried to the site in a broken condition and not ceremonially killed *in situ*. It should be noted that although elaborate incised work is characteristic of much of the ware, this incising ranges from the pleasing and intricate to the crudest sort of linear and punctate markings. Moreover, some complete vessels have no incising of any sort. It should be remembered that most of the sherds in the deposit were without incised decoration. However, bearing this fact in mind, it is justifiable to concentrate attention on the more ornate vessels and portions of vessels, since these show the artistic skill and conventions of the native artisans in a manner best suited for cultural comparisons.

In order to visualize the art styles represented by incising and the modeling of handles, lugs, and feet, in the monochrome ware, each of these features may be considered in order. Handles are not abundant, but 11 vertical loop handles occur in the sherd collection. One of two joined cylindrical clay rolls is surmounted by a grotesque human face (fig. 25, *a*). Another has an anthropomorphic figure (pl. 27, fig. 1, *a*) of the applique rider type more common on lugs of both the monochrome and the thin polychrome ware. A third very ornate handle consists of a roll of clay indented to suggest a double twisted cord and surmounted by raised punctate decorations (pl. 27, fig. 1, *b*). In addition, one loop handle has a modeled bird (fig. 23, *f*), two have simplified manatee heads modeled on the upper portion, two are long and narrow bands with three vertical grooves extending their length, one is a simple band with two punctate marks at each end, and two are simple bands with a central vertical ridge surmounted by spurs.

The monochrome ware reaches its greatest complexity in the wide variety of extremely elaborate, but for the most part very grotesque, lugs. These adornments were evidently portions of medium-large, intricately incised vessels, which were usually offered in a broken condition. They range in color from brick-red to light buff and are all from carefully modeled vessels of good technique. Their manner

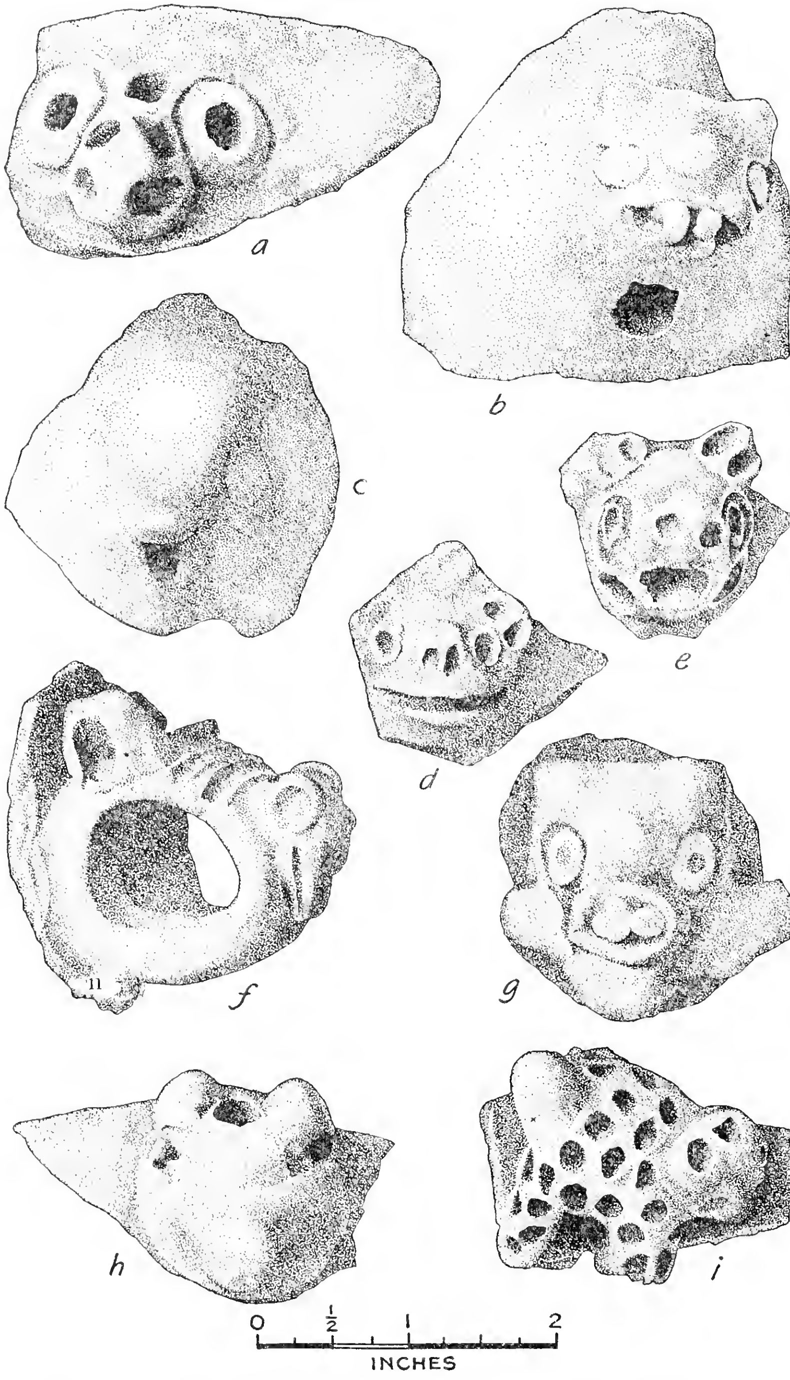


FIG. 23.—Polychrome and elaborate monochrome lugs and handles, Indian Hill, site 1. *b, c, g,* Polychrome I, but paint eroded; remainder, monochrome.

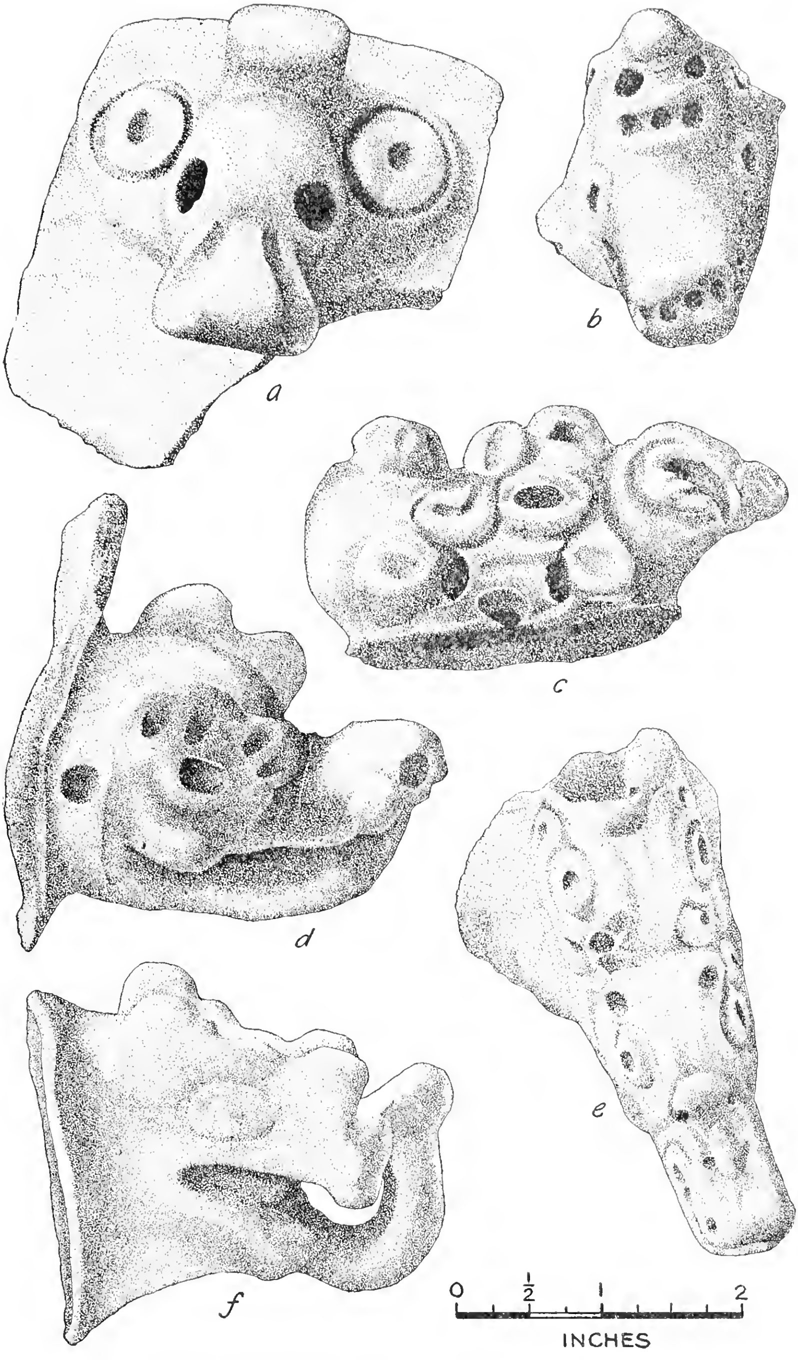


Fig. 24.—Elaborate monochrome lugs, Indian Hill, site 1. *f*, probably eroded Polychrome I.

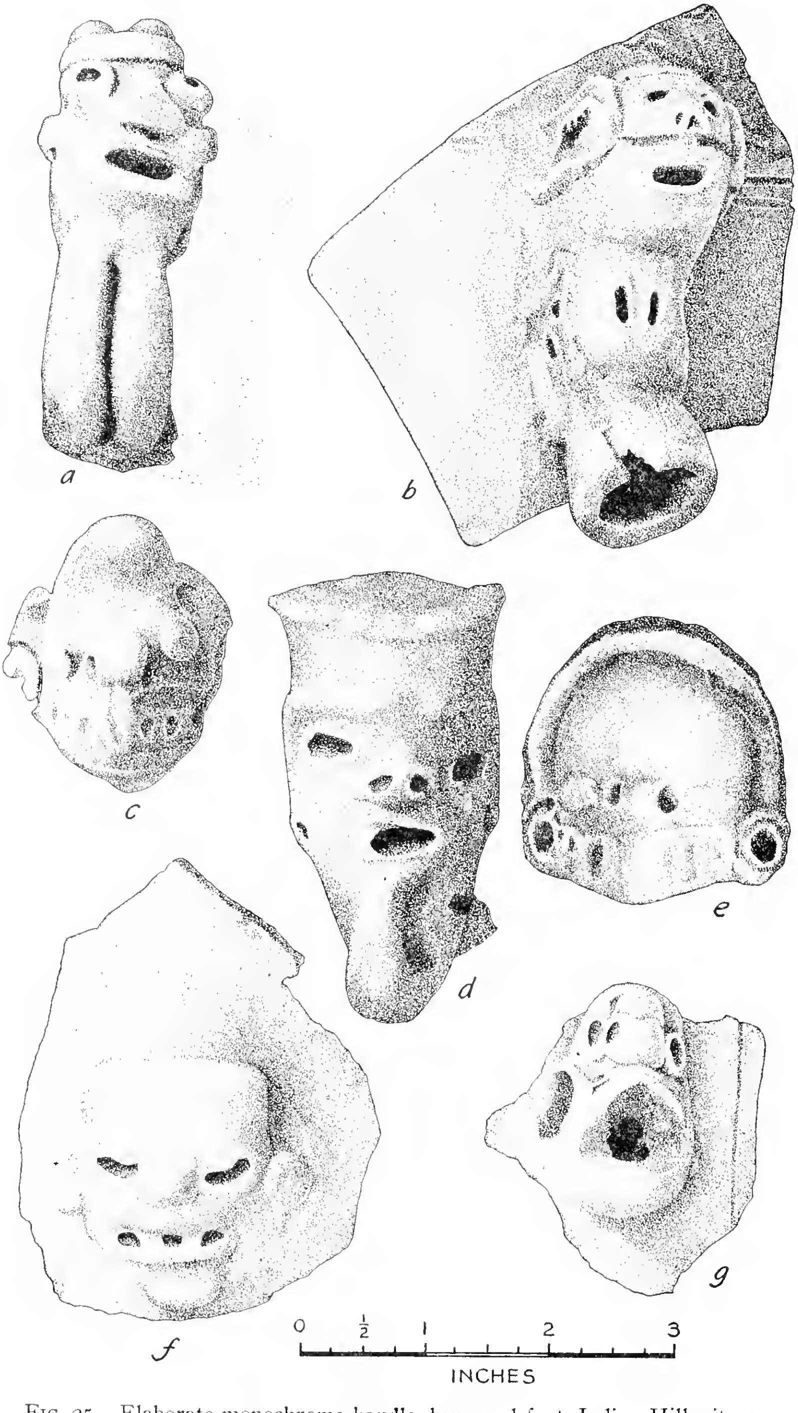


FIG. 25.—Elaborate monochrome handle, lugs, and foot, Indian Hill, site 1.

of attachment can be seen, not only in the two large restored vessels (pl. 24, *a, b*), but also in the smaller, cruder, but complete models of these vessels from the Dixon offertory (pl. 8, fig. 1). The lugs appear to have commonly been molded on the vessel as part of the original coiling process. They are extremely difficult to classify, owing to their extreme conventionalization and to the fact that the various forms blend into one another. The 65 unattached lugs in the present collection were definitely selected from the large number uncovered at the site, but in making this selection an effort was made not only to represent the range of types but also to represent roughly the numerical proportions of each type as noted in the excavation.

The largest class of lugs (d) comprise attached heads, and in a few cases complete bodies, of anthropomorphic, monstrous, or animal forms. There are a wide range of motifs. The animal forms include six manatee heads, which range from the naturalistic (fig. 24, *a*) to the very conventional (fig. 23, *a*). It may be noted that this manatee motif with the two concentric circles on each side (fig. 24, *a;* pl. 18, fig. 2, *a, b*) is very widespread both on the Bay Islands and on the Honduras mainland. There are five cat heads or figures (fig. 23, *d, e, i*), one raccoon or coatimundi (fig. 23, *h*), one peccary (fig. 24, *b*), one alligator (fig. 24, *c*), one bat (?) (fig. 25, *c*), one currasow (pl. 27, fig. 1, *d*), one hammerhead shark (pl. 27, fig. 1, *c*), and two iguana heads (fig. 24, *d*; pl. 27, fig. 1, *e*). Of this list it is interesting to note that only the bat, raccoon, manatee, iguana, alligator, and hammerhead shark are found in the Bay Islands. The jaguar, ocelot (probable sources of the cat motif), peccary, or currasow do not occur on the islands, though all are abundant on the adjacent mainland. In regard to the fundamental relationship between the two main ceramic types noted at island sites, it is significant that practically identical iguana head lugs (fig. 22, *c;* fig. 24, *f*) and very similar cat head lugs (fig. 23, *b, g*) occur in the thin, Polychrome I ware. To return to the monochrome ware, five more or less grotesque human head lugs are at hand (fig. 25, *c, f*). Two of these, evidently representing human skulls (fig. 25, *e*), are identical and from the same pot. In addition to the above, 10 lugs are too conventionalized for classification (fig. 27, *d, f*). Of these, three are ovoid, thin in vertical section, and perforated at the lower part of the tip, thus rather suggesting a tapir's snout. Three are short, rounded lugs with mouth, nose, and eye perforations possibly derived from the manatee motif (compare fig. 23, *a*). Three are rather cylindrical with raised "coffee bean" eyes and, in two cases, with punctate decoration suggesting stripes or spots (fig. 27, *f*). One is merely a small pottery knob. The purpose of all these lugs may well have been for the attachment of suspension cords, but their extreme elaboration suggests that the idea of adornment rather than utility had become dominant in the minds of their makers.

The second most numerous class (e) is a double-ended, vertical lug constricted in the center and attached at this point to the body of the vessel (fig. 26; pl. 24, *b*). There are 22 of the broken-off lugs; of these, 15 have a definite perforation in the lower end of the lug, whereas 7 others lack this hollow or perforation. These are the most elaborately conventionalized of all the lug types; they occur on the

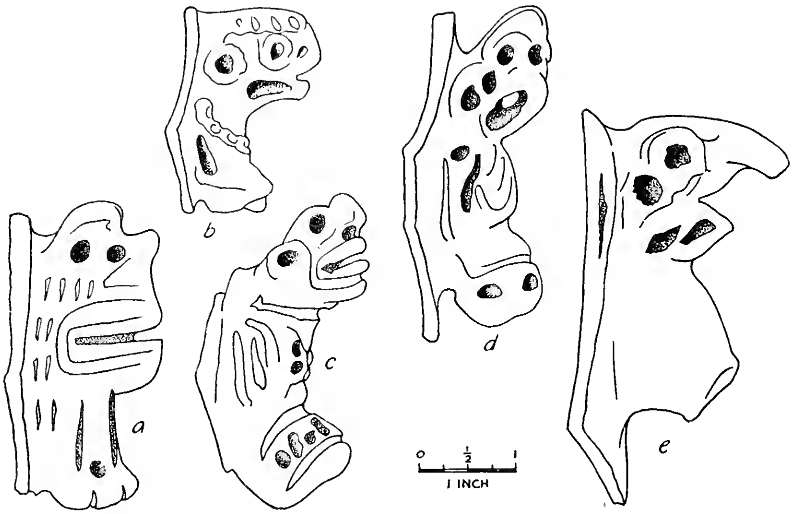


FIG. 26.—Vertical, elaborate monochrome lugs, Indian Hill, site 1.

finest monochrome ware vessels (pl. 24, *b*) and are obviously closely related to the lugs on the splendid marble vases from the Uloa River valley. One of the hollow-ended lugs is definitely human (fig. 25, *b*), and another is very similar to this piece but lacks the head, having a hollow tube at each end. One, a very small example, suggests a jaguar, and two are variants of the manatee motif. A large example suggests the tapir (fig. 26, *c*). There are nine elaborately modeled and incised lugs with punctate decoration (fig. 24, *c*; fig. 27, *c*, *e*; fig. 25, *g*). All of these have a grotesque, humanoid quality of the gargoyle variety. They may be seen in profile on the complete vessels and models (pl. 24, *b;* pl. 8, fig. 1) and in the drawing (fig. 26). Of the seven lugs lacking the perforation at the lower end, one is definitely human

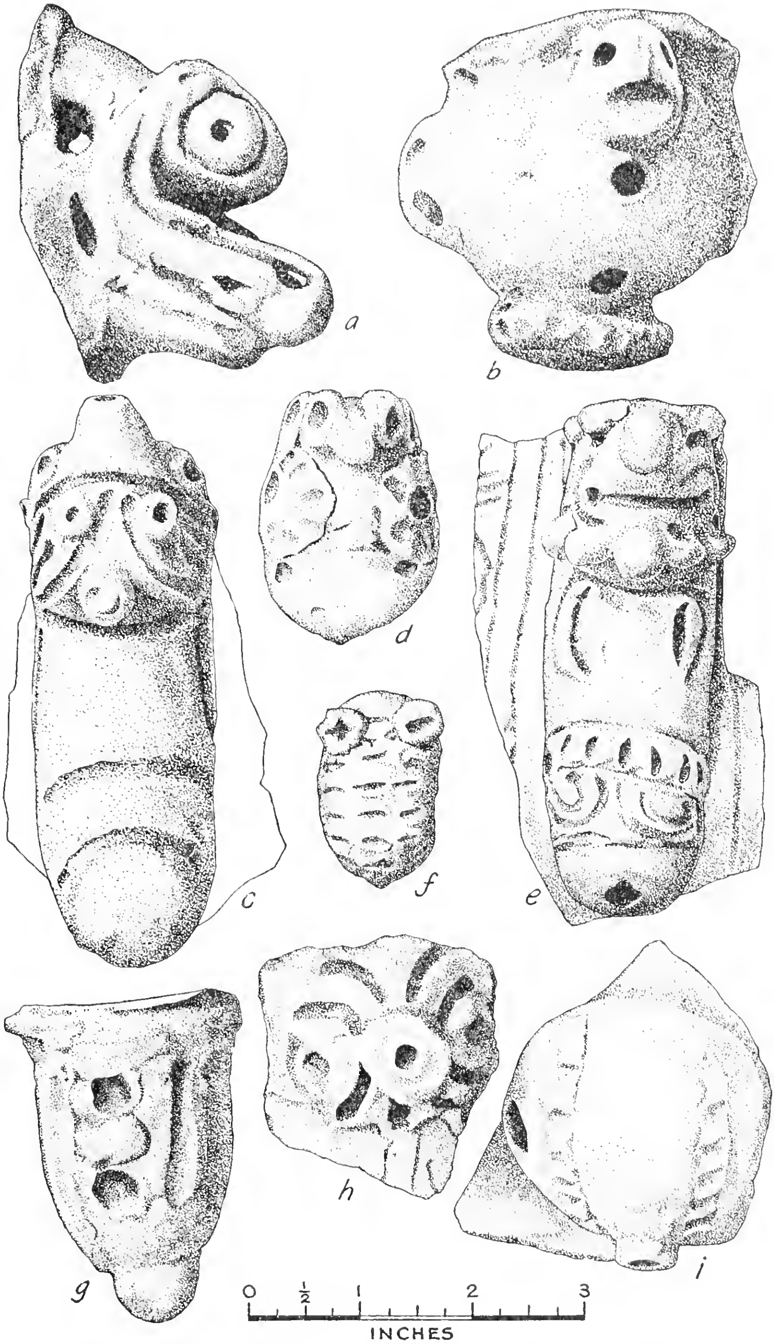


FIG. 27.—Elaborate monochrome lugs and feet, Indian Hill, site 1.

(fig. 26, *c*), one is a jaguar (fig. 26, *d*),[21] two are grotesque humanoid faces (fig. 26, *a*, *b*), and three are too conventional for determination (fig. 27, *d*).

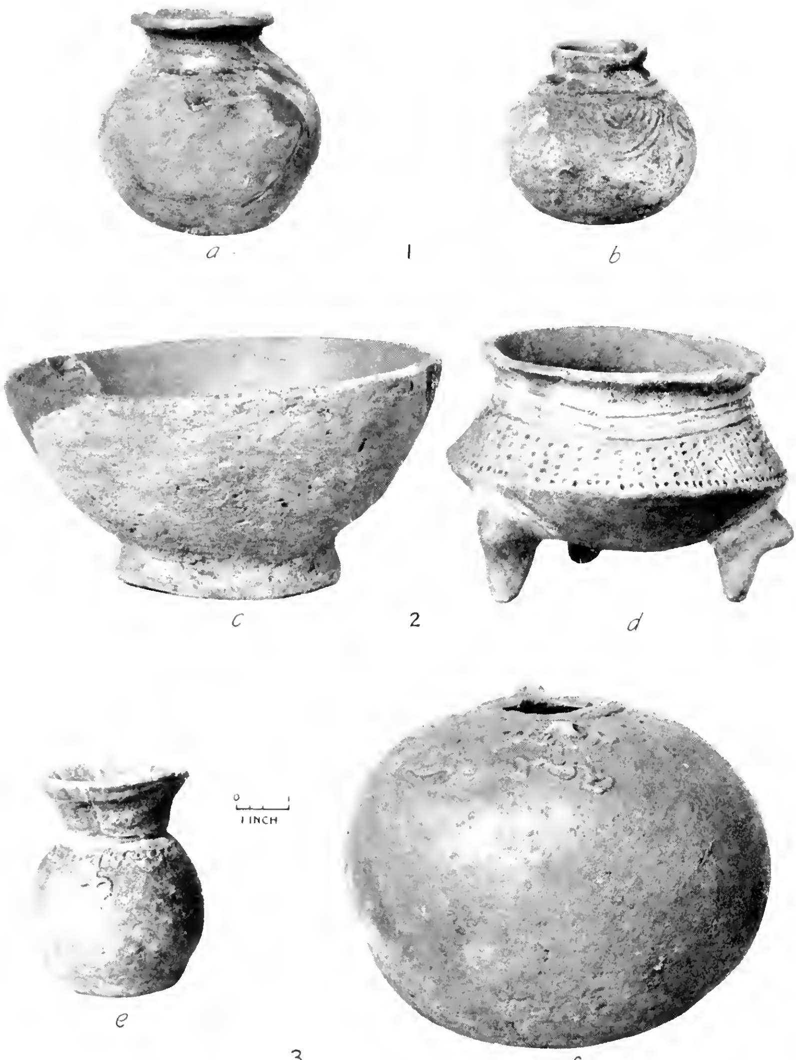
The third type of lug is simply the "applique rider" (fig. 22, *b*) previously mentioned when the Polychrome I ware was discussed. Of the 11 lugs of this type, 2 have traces of slip and design and 1 is incised (pl. 23, *a*), incising being characteristic of the monochrome ware. The remainder may have belonged to either pottery type, depending on whether their present unpainted condition is original or due to erosion. Since certain of these applique rider lugs clearly belong to one or other of the two types of pottery, while the others are uncertain, it can be seen that here is another strong link between the two ceramic wares. It has already been suggested that the unique, Polychrome I lug, type (a), developed from this applique rider type (b), and it is undoubtedly significant in this regard that type (a) is limited to Polychrome I ware, whereas type (b) not only occurs in both wares but, to judge from the present collection, is most characteristic of the monochrome ware.

It is often impossible to distinguish feet from lugs in the latter ware (fig. 27, *h*, *i*). Certain fragments described as lugs may actually have been feet, and vice versa. Where rims or definite basal portions are present, or where wear indicates usage, the distinction is clear, but these criteria are often lacking. However, since the native artisans seem to have regarded both feet and lugs more as adornments than as utilitarian features, and as similar motifs occur on both, a strict distinction is not vital. The annular foot is particularly characteristic of the finer, incised vessels of the monochrome (red to buff) ware and of the models of this type of vessel (pl. 24, *b*; pl. 8, fig. 1). There are no indications that it occurs often on Polychrome I vessels. Other characteristic types of feet are shown in the illustrations (fig. 27, *b*, *g*, *h*, *i*; fig. 25, *d*; fig. 28). The very large foot with elaborate incising (fig. 28, *a*) is apparently from a large and ornate vessel. Two of these feet from different vessels were saved, and a number of others were left at this site (pl. 20, fig. 2). The excellent modeling of negroid-like human features on another cylindrical foot is striking (fig. 28, *c*). A shorter, cylindrical foot with characteristic punctate decoration is also noteworthy (fig. 28, *d*). All three of these latter types are very common on the adjacent mainland. The simpler feet are either mere knobs (fig. 28, *e*) or hollow ovoid projections with slits and applique

[21] This is remarkably similar to those on the Uloa River marble jar figured by Gordon, 1898a, pl. 1, fig. 12.

a *b*

ELABORATE MONOCHROME VESSELS, ULOA MARBLE VASE TYPE OF DECORATION, INDIAN HILL, SITE 1



Monochrome Vessels

a, Dixon site, Roatan; *b-f*, Indian Hill, site 1.

ELABORATE MONOCHROME SHERDS, INDIAN HILL, SITE 1

1 2

DIXON SITE, ROATAN; INDIAN HILL, SITE 1, BARBURATA

1. Elaborate monochrome sherds; *g*, handle of incensario, Indian Hill, site 1.
2. Pottery whistles, figurine and figurine stool fragments; *f*, Dixon site, Roatan; remainder, Indian Hill, site 1, Barburata.

decorations (fig. 28, *g*, *h*). Like those on the Polychrome I ware the hollow feet usually contain pottery balls or gravel rattles. The two wares as a whole have distinct types of feet, the annular base, for example, being confined to the monochrome ware in the present collection. One monochrome vessel with spurred feet of Polychrome I

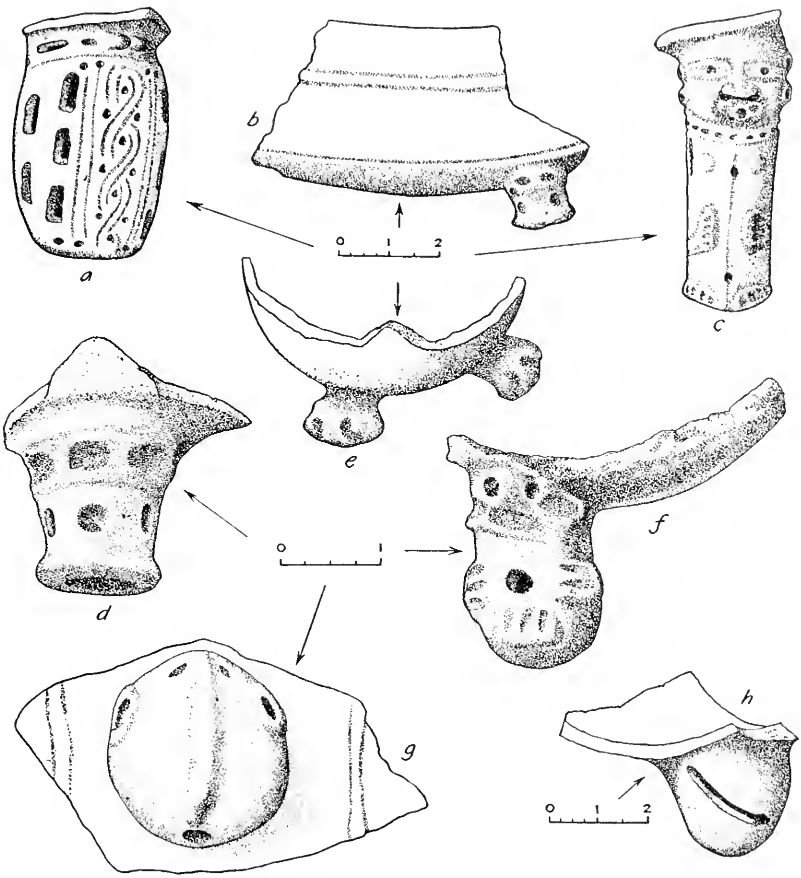


FIG. 28.—Basal portions and feet from elaborate monochrome vessels, Indian Hill, site 1.

type (pl. 25, *d*) is an exception in this regard. Perhaps the most outstanding characteristic of both these wares is the prevalence of the tripod base in every case where feet are present.

This site was exceptional in regard to the uniformity of its ceramics for, with the exception of eight sherds, all the pottery collected pertains to the two main styles just discussed. The most interesting of these exceptions is one small sherd of Plumbate ware [22] found in the upper foot of the deposit. The sherd is thin (3 mm in thickness), is dull greenish gray in color, and has a definitely glazed appearance on both sides. It is lighter on the inner surface and is dull brown in cross-section. The tempering material is too fine to be distinguished. Another sherd is smoked black and polished on the outer surface and red-brown on the inner. Five small rim sherds suggest the usual monochrome ware except that they show traces of red and black geometric designs. Two of these are also incised. These suggest the medium-thick, painted, and incised sherds already noted at the Dixon and Helena Island sites. One thin body sherd has a uniform, light red slip, plus a delicately incised, double line design.

The figurines from this site are of unslipped red to brown pottery. Three almost complete figurines, two broken bodies, four detached heads, and four detached arms were recovered. They came from various depths in the deposit, but no stratification of types was noted. The three nearly complete figurines (pl. 28, fig. 1, *a-c*) are of an exceptionally grotesque type. The very ornate but rather crude decoration in appliqué and punctate techniques is striking. Two have raised, grotesque faces, or noses, suggesting skulls, and all have raised "coffee bean" eyes and elaborate headdresses. Breasts and navels are accentuated, and one (pl. 28, fig. 1, *b*) has a suggestion of male genitalia. One figure (pl. 28, fig. 1, *c*) has an incised fillet around the bottom, and all have rounded bases. There is no clear indication that any of these figures were originally seated on stools or pedestals, but from the abrupt break where the body ends, this is possible. All have solid heads and hollow bodies. Except for punctate marks on upper body and head, their backs are undecorated.

A simpler type of figurine (pl. 28, fig. 1, *d*) has a hollow body and crudely modeled, solid head. Its base is broken and missing. Three of the separate heads suggest this type of figurine (pl. 28, fig. 2, *a, b, e*) except that they are hollow. They were apparently made separately from the missing bodies and have broken off at the point of juncture. Like the other figurines, they have been built up by the coiling method. These four pieces comprise a very simple, crudely modeled figurine type, which lacks ornate adornment and headdress. The portion of body recovered (pl. 27, fig. 2, *h*) has "coffee bean" breasts and navel but lacks the elaborate decoration of the other figurines having these same features. The stumps of an arm and,

[22] For the characteristics, temporal and spatial range, and probable point of origin of this ware, see Lothrop, 1927, pp. 204-208.

especially, of a leg, suggest a similar fragment from cave 1 on Helena (pl. 18, fig. 2, *f*). The fourth detached head (pl. 28, fig. 2, *d*) is unique in being thin and rectangular. It is solid and has a fillet around the top, raised eyes and nose, and a vertically incised mouth. Its purpose and the type of object to which it was formerly attached are uncertain. The four detached arms (pl. 27, fig. 2, *d*, *e*) are simple pottery cylinders with flattened hands and fingers, which were formerly attached to figurines.

The three figurine "stools", or pedestals, (pl. 27, fig. 2, *i*, *j* and fig. 1, *f*) constitute an interesting feature. One of these is definitely a stool, having the remains of four legs underneath plus a knob in the center at one end (pl. 27, fig. 2, *i*). The round body of the figurine has been broken off the upper surface. It is made of hard, well-polished, buff pottery, and the edges are notched. A small, circular ring of brown pottery, which sits evenly on four small legs, has the upper portion broken off (pl. 27, fig. 2, *j*). Its purpose is unknown, but it may have been a figurine base. Similarly an unusual piece of coarse red-brown pottery, one side of which is decorated with a double coil of clay, raised circles, and indentations (pl. 27, fig. 1, *f*), has had some sort of round body broken off the reverse side. None of these fragments fits any of the bottomless figurines previously mentioned, and only one of them (pl. 27, fig. 2, *i*) can be positively identified as a stool.

Four whistles or ocarinas were recovered, of which only one is perfect (pl. 27, fig. 2, *b*). This specimen, with four stops, and a tubular mouth piece at one end, whistles clearly. Besides the four upper stops there is a hole on the lower surface where the mouth-piece joins the body. It strongly suggests a manatee in form, and the two upper flippers are perforated for suspension. Its upper surface is decorated with an incised and punctate design. Two others are similar, but in each case a small break just below the lip prevents whistling. The larger one (pl. 27, fig. 2, *a*) is an even closer replica of a manatee, especially in head form. It is composed of coarse brick-red pottery with white grit temper. The third and smallest one (pl. 27, fig. 2, *c*) has a birdlike face with "coffee bean" eyes and a projecting nose just below the neck. Like the perfect specimen, this last is of well-polished, light brown pottery. A fragment of a fourth whistle (pl. 27, fig. 2, *g*) is of similar ware but represents a stocky conventionalized human figure. A number of complete ocarinas of this anthropomorphic form were seen in private collections on the islands; hence the type is much more abundant than the present collection indicates.

Among the objects of unknown use are six slightly concave disks of coarse red pottery ranging from 4 to 8 cm in diameter. Three have two holes near one edge (fig. 29, *b*), one has two holes close together near one edge, and two fragments have only one perforation on the edge.

One heavy, roughly modeled handle of red-brown pottery (pl. 27, fig. 1, *g*) has a longitudinal perforation from end to end, and a similar perforation (1 cm in diameter) from side to side near the rounded

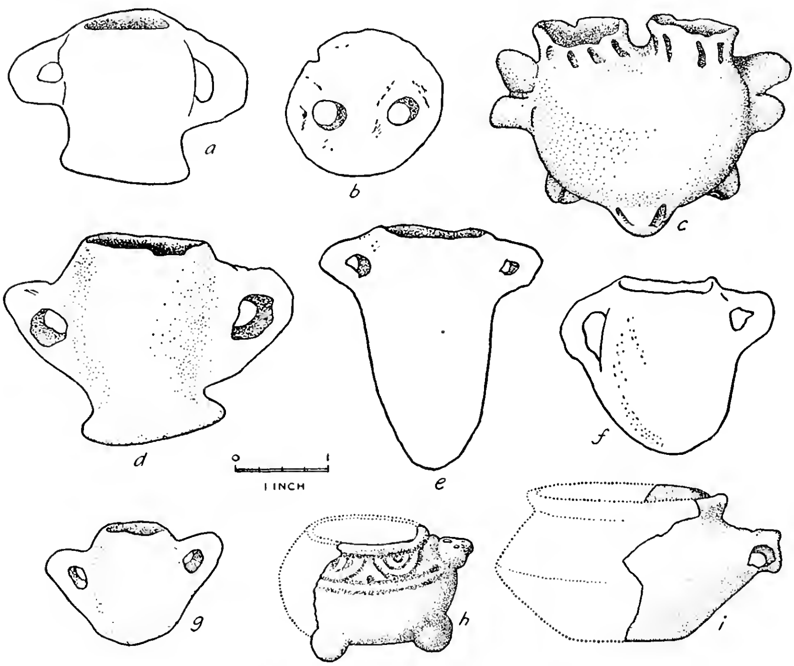


FIG. 29.—Model vessels from Indian Hill, site 1.

tip. A bowl or basinlike extension has been broken off the other end. The piece strongly suggests the handle of an incense burner. This completes the description of ceramics from this site except for pottery beads, which will be discussed under the latter classification.

METAL

With one small exception, no metal work of any sort was recovered by us from Indian Hill offertories. The exception, from site 1, is a very thin piece of hammered-out copper (pl. 29, *i*), which is 2.2 cm in length and has two tiny perforations. It is brown on the outer faces, green where the edges have crumbled away, and was probably worn as a small pendant.

GROUND STONE

Although no cache of small stone carvings was found by us at this site, four interesting green talc ornaments were recovered. They were scattered in the deposit at depths of about 1 foot. Two of these (pl. 11, *g*, *i*) are very similar to carvings from the Dixon site on Roatan Island (pl. 11, *d-f*), and one of them (pl. 11, *i*), with slight variation of headdress, is almost identical with one from the Dixon offertory vessel (pl. 11, *f*). The other (pl. 11, *g*) falls into the same general class but is not so well modeled. In regard to material, technique, and perforations, these two pieces are identical with those previously described from the Dixon site. The third carving is unique (pl. 29, *c*) in size, shape, and design. Of dull apple-green talc, it is 6.5 cm in length by 3 cm in basic diameter. An animal with prominent teeth, probably a highly conventionalized jaguar (although it most resembles a "laughing" horse), is shown in relief. The artifact has a longitudinal perforation 1 cm in diameter extending from end to end. It is well worn and smooth and was recovered at a depth of about 1 foot on the northern edge of the deposit. The fourth piece referred to is of dull gray-green talc and suggests some sort of mnemonic device (pl. 29, *a*). However, no such purpose has been determined, and the designs seem to be too irregular in application to make such an explanation feasible. A biconodont perforation marks the top, and two tips made by three vertical notches on each side mark the bottom. The back is unmarked except for the two incised lines around the neck. It is 8 cm in length and was found near and at practically the same depth as the third carving described above.

A considerable number of beads of various types were recovered, and these were also scattered at random throughout the area which we dug. About half of these closely resemble beads from the Dixon site. There are 14 round beads of diopside (the largest 2.2 cm in diameter), which are identical with those from the Dixon site (see pl. 14, *f*, *g*), and of these 7 are very badly eroded. Only 14 green talc beads were recovered; 9 are cylindrical, 2 are similar but incised, and 3 are small disk beads. Most of these are broken. One blank, of gray-green talc, is cylindrical, 3.7 cm long, and has the beginning of a small hole at each end. Half of the beads recovered are of crude brown pottery, a type not hitherto noticed. The majority of these are either ovoid in form (14) or globular (22) (pl. 29, *e*). All are perforated and roughly modeled. They range from 7 mm to 3.3 cm in greatest dimension. One thin disk bead of pottery has circular ridges (pl. 29, *g*). In addition, four solid balls of hard brown pottery, probably the rattles from broken feet or lugs were recovered. A large bead (2.7 cm in diameter) of polished red pottery was found on the surface of the bare hill about 100 yards southwest of site 1. The finest bead, however, is of clear quartz crystal (pl. 29, *f*) and came from a depth of 8 inches in site 1. It is a beautiful specimen and has a biconodont perforation with a tiny aperture where the two borings meet.

A considerable number of large specimens of ground stone were noted at site 1 (pl. 20, fig. 2), but only a few samples could be taken away. The majority of these had been exposed by earlier excavations, but a considerable number of broken fragments and one or two complete pieces were encountered in our work. Portions of at least six large polished granite metates, originally with three legs, were encountered (pl. 20, fig. 2). The best example, which was preserved (fig. 14, *a*), is of hard gray granite and has a king vulture or condor head on one end. Several of the legs on the fragmentary metates were carved in a simple maze or a fret design (pl. 20, fig. 2). One complete granite metate without legs was encountered. It was 45 cm long by 36 cm wide, of an even thickness (about 5 cm) throughout, and evenly curved with raised ends. Four fragments of three-legged lava metates (similar to fig. 14, *e*) were noted. There was also one complete specimen of this type, its surface measuring 28 cm by 20 cm, which had two legs at one end (10 cm high) and one at the other (15 cm high). All complete and broken metates showed signs of long-continued use.

Numerous roller pestles were present. Two were of granite, about 23 cm long and originally rounded, but worn somewhat smaller at the ends and rectangular through use (similar to fig. 14, *c*). There were a large number of broken cylindrical manos of smooth, polished granite. All were highly polished and of even diameter (the largest was about 15 cm in diameter). The type is well shown in the illustration (pl. 7, fig. 3; pl. 20, fig. 2). In addition, there were several cylindrical and round manos of the porous gray lava (like fig. 14, *b*).

Two fragments of polished diabase pot rests were encountered. One of these (pl. 19, fig. 1, *g*) is 9 cm high and has an estimated diameter of about 30 cm. The other (pl. 20, fig. 2, lower center), about the same size, was accidentally left at the site. Each fragment had one foot (probably part of a tripod base) supporting a smoothly polished ring, which sloped down inwardly from the edge to form a rest for a pot. The complete artifact was evidently a concave ring supported on three (or more) legs. The outer surface of the specimen preserved is marked by incised squares enclosing faint circles, which may have been faces (pl. 19, fig. 1, *g*), and the outer surface of the other piece (pl. 20, fig. 2, lower center) is marked by a joined series of incised ovals. This is an interesting artifact type and was not elsewhere encountered by us either on the islands or on the mainland.

Another interesting group of artifacts comprises several crude marble bowls (fig. 30, *j-m*). Seven of these were found at various depths, and in the litter left by earlier diggers, but only two were preserved. All are of white marble, and all have been considerably eroded, or etched, since they were originally shaped, indicating some antiquity,

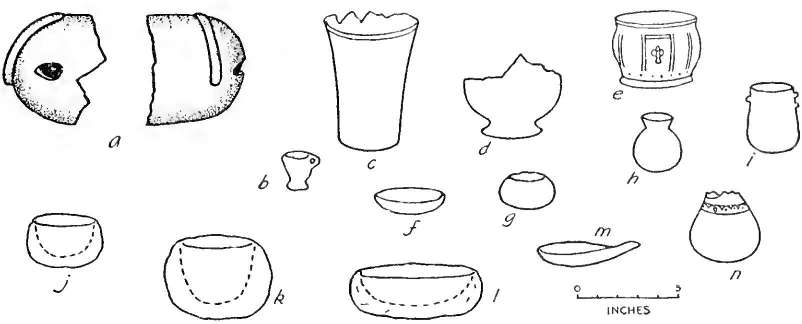


FIG. 30.—Outline sketches of vessels left at Indian Hill, site 1. *a*, small pottery mask; *j-m*, small marble vessels.

though the material is rather friable at best. The surface of each was granular and crumbly with flakes of graphite and other harder minerals composing the marble projecting. The best example (similar to fig. 34, *c*) measures 12 cm across the mouth and is 8 cm in height. It has three knobs for legs and is badly weathered and cracked, with broken edges. This piece was found at a depth of about 2 feet near the northern edge of the deposit. Three other pieces are similar (fig. 30, *j-l*) but lack legs and are even cruder. Three are only slightly concave and one has an end projection like a handle (fig. 30, *m*). The use to which these objects were put is unknown. Taken in conjunction with the fine, unslipped but incised pottery from this site strongly suggesting the exquisite marble vases of the Uloa River, these very crude vessels of marble seem paradoxical. Possibly the marble available to the island people was of too inferior a grade to permit elaborate incising, and the mainland technique was therefore applied in a somewhat simplified form to pottery. Whatever the explanation, the occurrence of such closely similar designs, shapes, and lugs, as well as marble bowls, here and along the Uloa River is too striking to be fortuitous.

Only two broken celts were found at site 1. One (pl. 16, *i*) of quartz diorite, consists of a sharp, rounded blade portion. The other (pl. 16, *h*) is of dark, polished, green diopside and is also very sharp. One corner of its irregularly shaped blade is broken off. Both blades show signs of usage.

One complete and two fragmentary polished stone mace heads were found. The first of these (pl. 19, fig. 1, *h*) is very large (8.6 cm in diameter) and heavy. The material is a gabbro. A large central perforation (4 cm in diameter) is only very slightly smaller at the center than at the two apertures. One fragment, of considerably etched white marble (pl. 19, fig. 1, *d*), is from a star-headed mace or club head. Two points are present, though originally there were five or six. It is 3.3 cm in thickness through the socket hole. This material is not very durable, and the weapon may have had ceremonial or other value. There is one point (pl. 19, fig. 1, *f*) from a similar mace head of the same attractively mottled felspar porphyry material noted in mace heads from cave 1, Helena Island. This is a hard mineral, and such a star-headed club would have had practical value as well as esthetic appeal. The piece is 4.2 cm in length and has been cleanly broken off where it joined the central disk of the club head. The occurrence of star-headed clubs here is of interest from the standpoint of distribution.

CHIPPED STONE

A number of T-shaped, chipped axes or choppers of diabase were found at various depths in the deposit (pl. 19, fig. 2, *d*). These are common artifacts throughout the islands and assume a considerable number of shapes (pl. 19, fig. 2). At site 1 the majority were of the typical T-shape, but one with a single side blade and another coarse, oval blade of diabase without a stem were also found. No ground T-shaped axes were found here. No retouched projectile points or knife blades were found, but two small fragments of obsidian prismatic flake knives were noted. Each broken section is about 2 cm long (fig. 15, *e*, *f*).

SHELL

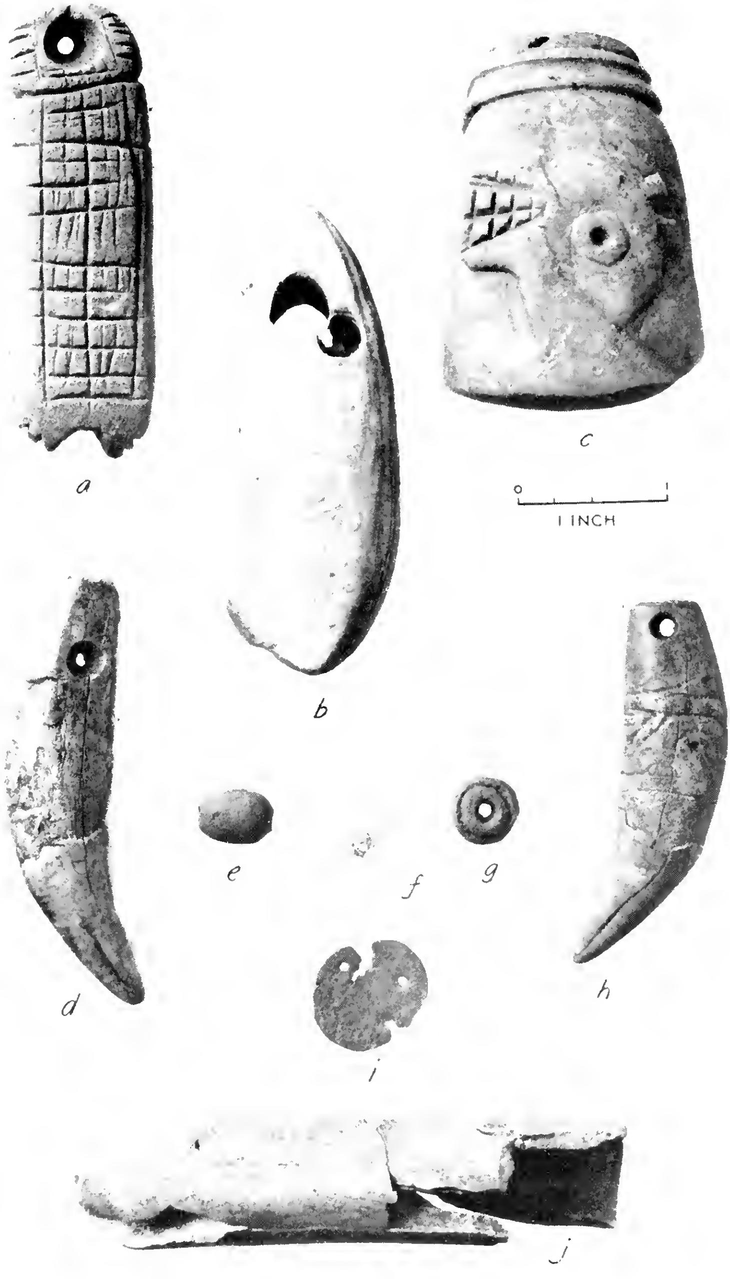
Besides the occasional conch shells with perforations, which probably served as trumpets, very few pieces of worked shell were found. One thick section of the outer lip of a heavy Pacific coast shell

1

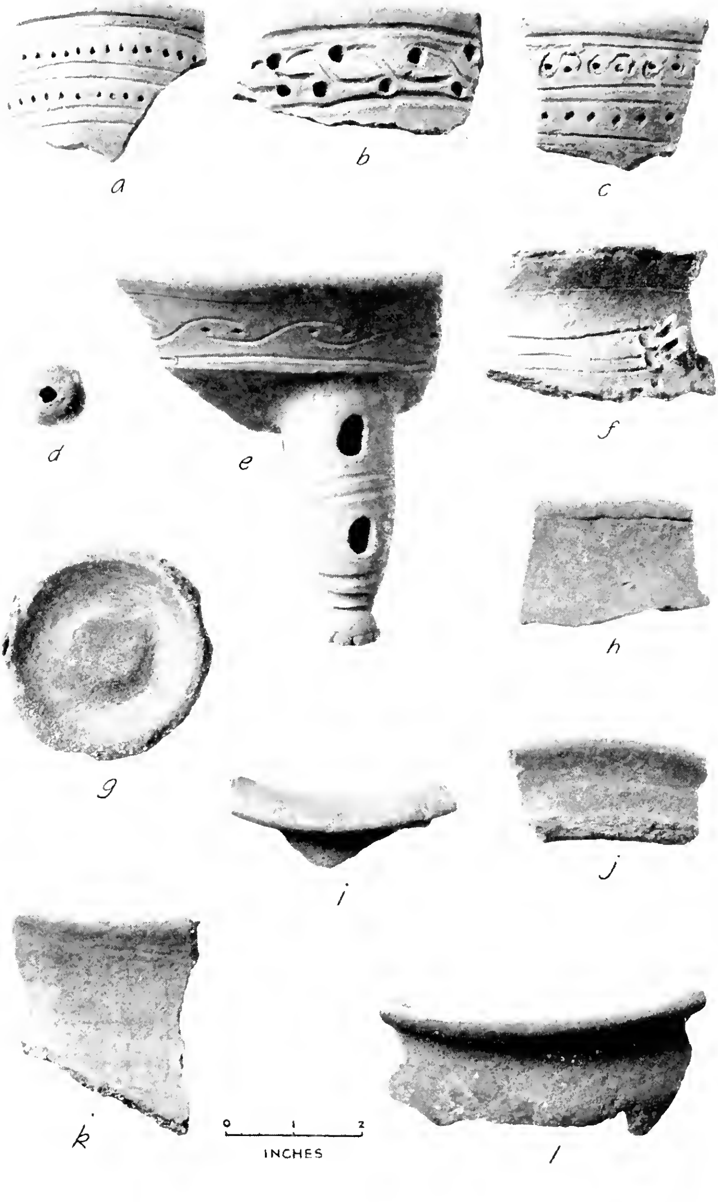
2

COMPLETE AND BROKEN FIGURINES

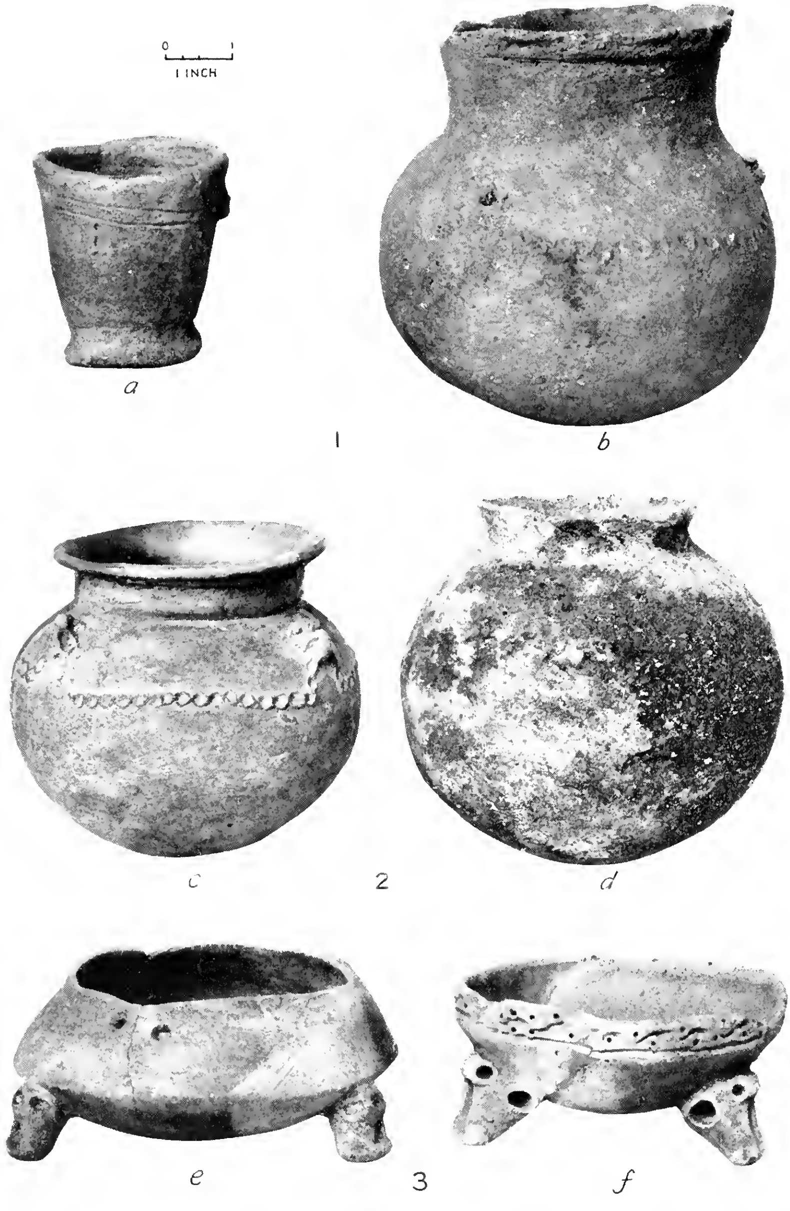
1. *a-d*, Indian Hill, site 1; *e, f*, Dixon site, Roatan.
2. *c*, Dixon site, Roatan; remainder, Indian Hill, site 1, Barburata.



VARIOUS SMALL ARTIFACTS, INDIAN HILL, SITE 1



MONOCHROME SHERDS, INDIAN HILL, SITE 2



MONOCHROME VESSELS, VARIOUS SITES

1. Indian Hill, site 2.
2. *c*, Plan Grande, Bonacca; *d*, Helena.
3. *e*, Sacrificial Spring, Bonacca; *f*, Michael Rock, Bonacca.

(*Strombus accipitrinus*, Lam.) (pl. 29, *b*) is ground down in a curved oval form and has a complete perforation (1 cm in diameter) and a partial one in juxtaposition at one end. There are also two flat, much-weathered triangles of heavy shell ground down at the edges. They are 5.2 cm in length and average 8 mm in thickness. The use of these objects is unknown, though they rather suggest small, incomplete shell celts.

BONE

One bone artifact of unknown use was recovered at this site (pl. 29, *j*). The only other artifacts of this general type were two large perforated canine teeth of the jaguar found in the upper part of deposit. One has been cut down like a wedge toward the base and has a biconodont perforation but is not otherwise worked (pl. 29, *d*). The other has been cut off squarely at the base, is perforated both vertically and horizontally, and is neatly incised with double scroll line and dot patterns above the enamel (pl. 29, *h*). This incised portion is stained green on one side through copper contacts and may at one time have been copper coated. It has already been noted that the jaguar is not included in the Bay Island fauna though abundant on the mainland.

HUMAN, ANIMAL, AND OTHER REMAINS

No human burials nor signs of cremation were encountered, but several human teeth, both adult and juvenile, were found amidst the pottery and other cultural detritus. Some sort of interments, therefore, were made at the spot, but their nature could not be determined. A very few animal bones and fish vertebrae in addition to some unworked whelk and conch shells were found, but their scarcity suggests that they were remnants of feasts or food offerings rather than ordinary kitchen refuse. Similarly, a little charcoal, numerous pebbles, and a number of rough quartzite and coral rocks occurred in the deposit, but there were no fireplaces or markedly burned places. House floors or signs of any definite habitations were totally lacking. A few small quartz crystals were encountered, but they were not at all abundant as was the case at the Dixon site.

SITE 2

This second offertory is located on the tip of a descending ridge about 125 yards southeast of site 1 and about 40 to 50 feet lower down. It is situated in the midst of dense jungle; its exact limits were not determined but it appears to cover an area about 40 feet in diameter.

There were no surface indications other than several irregular pits, each about 6 feet square; elsewhere the deposit was covered by several inches of soil. The depth of the deposit is close to 2 feet at the center, thinning out toward the edges. A number of large wild fig and other great trees grow around the site, and dense thickets of corozo palms and other shrubs hem it in. Since no view is obtainable from here and it has no marked topographic features, the reason for its selection as an offertory is obscure.

This site was visited by the party of Mitchell-Hedges, and the various pits were made at that time and later by Joe Saba. The latter, who accompanied Hedges, stated that over 100 more or less complete crude pottery vessels had been removed from the site and that there had been many nested pots of which all but one or two inner vessels were broken. These inner vessels were of plain ware and contained nothing but fish bones and small shells. Joe stated that in all his work here he had never encountered a painted vessel or sherd, and my rather brief excavations at the site corroborated his observation. Unslipped pottery, however, is present in enormous quantities, though we found only two complete vessels (pl. 31, *a, b*). Joe also stated that he had found human bones and teeth at this site but no regular burials. In our brief examination a few small fragments of human bone were encountered scattered at random amidst the sherds.

The predominant feature of the site is the enormous quantity of undecorated monochrome pot sherds and the comparative rarity of other artifacts. No metates were seen, but several subrectangular manos about 20 cm long and one cylindrical, polished granite fragment 12.5 cm in diameter were found. There were numerous rough pestles or hammerstones, often merely conveniently shaped pebbles or boulders. The most interesting ground stone artifact was a fragmentary, ridged and grooved oval bark beater of calcite (cave onyx) (pl. 16, fig. 1, *l*). The specimen had evidently received long and hard usage. There were numerous large pieces of unworked rock in the deposit, and several of these had been subjected to great heat. Their crumbling texture was the same as that employed for tempering in the coarser pottery. Fragments of schist, green serpentine, and pumice, one piece of the latter being used as a rattle in a pottery foot, were preserved. One fragment, 5 cm in length, of a black obsidian prismatic flake knife, its edges blunted with much use, was found (fig. 15, *g*) but no other chipped stone artifacts were seen. On the whole, stone artifacts of any sort were remarkably scarce, and the larger forms such as metates with legs were lacking. Conch and whelk shells were present, but no shell or bone artifacts were noted.

CERAMICS

In general, the foregoing description of the red monochrome pottery at site 1 would apply equally well to the mass of pottery at site 2, with the exception that highly polished, incised and modeled types are much more abundant at the former site. At both sites occur very large sherds of coarse red ware from pots, possibly burial urns, which must have been at least 1 meter in height and nearly as much in diameter. These are tempered with broken-up coral rock. The two complete pots present little that is new; one is a small offertory model of a larger pear-shaped vessel with a thick annular base (pl. 31, *a*), and the other is a crudely modeled and incised cooking pot with smoke stains on the outer surface (pl. 31, *b*). Both these pieces and the majority of the sherds show definite traces of having been built up by the coiling method. In the case of the cooking pot the neck has been made separately and attached to the body, and the same is true of another detached neck in the present collection. A very small model pot with a broken rim is extremely thick and crudely modeled and incised. A particularly fine vessel is represented by a fragment with one attached leg (pl. 30, *e*). The leg terminates in a heavy foot suggesting that of a tapir, and the graceful bowl is highly polished and pleasingly incised. Other well-polished and neatly incised rim sherds (pl. 30, *a-c*) are apparently from open bowls or from pots with vertical necks. Pottery with crude incisions and small modeled lugs (pl. 30, *f*) is also rather abundant. Separate lugs at site 2 are not as abundant as at site 1, nor do they seem to be as elaborate in modeling and decoration. The most elaborate in the present collection is a large but typical applique rider lug, similar to those from site 1 (compare pl. 23, *b*). It shows no trace of a slip and is gritty in texture and buff in color. Since this form of lug occurs on Polychrome I pottery, this one specimen is the only approach to that ware noted at site 2. However, it will be remembered, that at site 1 the applique rider lug type occurs more commonly on the monochrome ware than it does on the polychrome type. The three other lugs at hand, and those noted at the site, offer no radical departure from the more simple monochrome lugs described at site 1. The very characteristic, double-ended vertical lugs with grotesque modeling (fig. 26) seem to be lacking at site 2, and even the simpler, attached head or body lugs are not at all common. Decorated feet for monochrome ware vessels, although not abundant at site 2, are present and in type and elaboration are similar to those at site 1. In the collection selected at site 2 are six feet. The one illustrated (pl. 30, *e*) is excellent, and a smaller version of the intricately incised, hollow, ovoid foot (fig. 28, *a*) is also present; two others are similar to figure 28, *h*, and two are similar to those on a bowl from Michael Rock (pl. 31, *f*). Thus, although a few excellent examples occur, the wealth of intricately incised and modeled lugs and feet noted at site 1 is lacking at site 2. Two fragments of annular bases were noted; one of these is decorated with short, curved lines ending in dots, the other is well polished but lacks incisions or other decoration. One sherd with a gray-blue inner surface suggests the elaborate, cylindrical type of vessel (pl. 24), and a small model (pl. 31, *a*) represents a simpler version of this type. The scarcity of this type of sherd, however, agrees with the lack of elaborate vertical lugs already noted. The intricately incised, solid pedestal of a small red ware pot (pl. 30, *g*) is a rather unique specimen.

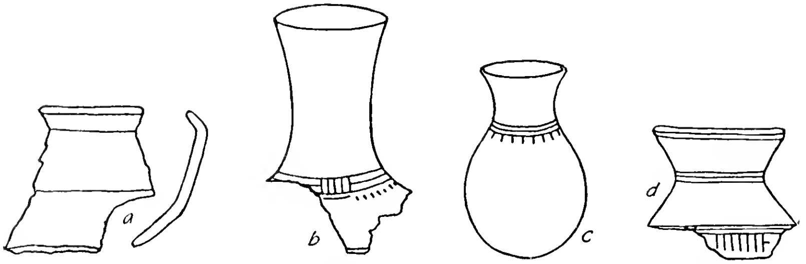


FIG. 31.—Outline sketches of characteristic plain monochrome pottery, Indian Hill, site 2.

To judge from our own small excavations and from the mass of sherds exposed by earlier digging, plain red monochrome pots with swollen bodies, contracted necks, and flaring lips (pl. 30, *h-l;* fig. 31) are strikingly predominant among the complete and broken ceramics at site 2. The more elaborate types just described do occur, but they represent a very small proportion of the deposit as compared to this large to medium type with swollen body, contracted neck, and low flaring lips. Many of these are extremely thick, the sherd figured (pl. 30, *k*) being 1.5 cm through at the neck, and the thicker the vessel, the more coarse is the ground-up coral tempering. Other sherds of this type noted at site 2 were 2.5 cm in thickness. Another type (pl. 30, *i*), with a low, much-everted rim, is thinner (.5 cm thick at the neck) and comes from a vessel with an estimated height and mouth diameter of about 25 cm. Identical rim sherds were noted at cave 1, Helena Island, and at Black Rock Basin on Utila Island, where they served as urns for partial burials. Although the "urn" type was not specifically noted elsewhere, this general type of pot with contracted neck and flaring lips was also abundant at site 1 and at nearly all the island sites we visited.

This concludes the general description of the cultural material present at site 2. The absence of certain types of objects common at other sites is striking. The lack of metates with legs, celts, mace heads, and other ground or chipped stone artifacts as well as certain types of pottery has already been mentioned. Carved heads and pendants of talc or other stone were not seen, and no stone beads were noted. One pottery bead of coarse red ware (pl. 30, *d*) was the only type found. No shell, bone, or metal work was encountered in our excavations. In regard to all these items it should be remembered that such conclusions are based on a mere sampling of the deposit, the examination of the abundant material left by earlier diggers, and the statements of one of the most assiduous of the latter individuals. On the other hand, many other sites, no more exhaustively worked, yielded not only the majority of site 2 types but many of the others as well.

Comparison of Sites 1 and 2

It has already been mentioned that the Polychrome I pottery and the green stone carvings were found in the upper 1 foot of the deposit at site 1, whereas the usually unslipped monochrome ware occurred both with and below these types. It is impossible to demonstrate this statistically for a number of reasons. We were working desperately against time, with two untrained workers and without adequate equipment for carrying on a thorough stratigraphic study. Although care was taken to note the depth of the polychrome sherds and the carvings, there may have been errors, and the present conclusion must be checked by more careful work before it can be unreservedly accepted. Nevertheless, my own observations at site 1 convinced me that this was the case. It is striking, therefore, that at site 2 no polychrome pottery was found and that the great bulk of the monochrome pottery was of the simplest type. The absence of green stone carvings and the rarity of sherds suggesting ornately incised jars are also significant facts in this regard. All of these features were present at the Dixon offertory, Helena Island, and at site 1, Indian Hill. The limited sample available from site 2 may account for the observed absence there of certain less-abundant types of ground and chipped stone as well as bone artifacts, but it can hardly account for the lack of definite pottery types, for pottery was present in great abundance. On this account I am inclined to believe that site 2 may represent a somewhat earlier period than site 1, and that the polychrome and elaborately incised pottery, plus the green stone carvings, all characteristic of the upper layers at site 1, had not yet come into vogue on the islands when the site 2 offertory was in use.

This conclusion leans rather heavily on the observed stratification of types at site 1, and it is freely admitted that this support is not beyond question. Nevertheless, there is no doubt that the site 2 monochrome pottery is identical with the same type of ware from site 1, with the exception that certain more or less elaborate types are missing; nor that the Polychrome I pottery of site 1 is absent from site 2. It is hardly conceivable that social stratification in the same group at the same period could account for these differences, since nearly all of the ceramics were deposited in a broken condition, and had the two accumulations been simultaneous, some of the polychrome and more elaborate monochrome ware would almost certainly have found its way into site 2. It is tentatively concluded, therefore, that site 1 is later than site 2. Since the connection between the superficially unlike Polychrome I and the monochrome wares has been demonstrated, it would thus appear that the influences leading to the development of the Polychrome I (and probably, the definite Uloa River type of incised decoration) were not active on Barburata Island at the time when the site 2 offertory was in use.

Considering the divergent nature of the two offertories on Indian Hill, it is extremely unfortunate that the Mitchell-Hedges collection, assigned to Barburata Island, is not segregated according to sites, since his men worked in both offertories. The storage collection from this island in the Museum of the American Indian is very extensive and contains a large number of complete pottery vessels. Most striking is a tremendous number of simple monochrome (red to buff) vessels, predominantly with round or ovoid bodies and low to medium flaring spouts. A few, of the same general form, have markedly constricted necks and medium to long, bottlelike spouts. The uniformity and nature of this pottery makes it highly probable that this is the collection from site 2 referred to by Joe Saba. With this probable exception the remainder of the material must be discussed as a unit, although our own investigations, coupled with the observations of Joe Saba, indicate that the polychrome pottery and more elaborate artifact types came from site 1 rather than site 2. Polychrome I pottery is represented by a large collection of sherds. This accords very closely with the material we obtained from site 1, which has just been described. I did not see any Polychrome II sherds in the collection. There is a large amount of the elaborately incised monochrome ware, including the usual variety of lugs and strap handles, but the only unique form noticed was a lug suggesting the head of a vulture in profile. A complete flat-handled, shallow-bowled, incense burner demonstrates that this type occurs in the monochrome ware, as was suggested by the round handle from site 1, previously described (pl. 27, fig. 1, *g*). There are also a large number of small monochrome model pots, which are extremely crude. Especially interesting are three large sherds of Plumbate ware identical with the one sherd we obtained at site 1. The largest of these includes a considerable portion of upper body, neck and rim. The form is bottlelike, with a much constricted orifice and a short cylindrical neck; the body is decorated by horizontal ridges giving the fragment a shingled appearance. The dark, metallic blue-gray color of this sherd is blotched with brown areas. There are 10 figurines of monochrome (buff to red) pottery of a crude oval type, the largest being 15 cm in height.

In addition to ceramics, the collection includes some 30 polished stone celts of various sizes, 3 round and knobbed mace heads, 1 metate fragment with an elaborate vulture head at the end, and one-third of a granite pot rest with two legs, and two carved feline-head ornaments. This last is similar in form to the two fragments from site 1 already described. Of the smaller objects, several small anthropomorphic carvings of a gray, greasy steatite are present, and there are several perforated jaguar teeth and a considerable number of talc beads. There is one large, round copper bell with a crude human face in relief, which has a hammered wire ring for suspension and one small smashed copper bell. Chipped stone artifacts include three large ovoid knives of brown chert, one small stemmed and one small oval projectile point, and some fragments of prismatic flake knives of obsidian. All of these latter objects suggest material from the Dixon offertory and probably supplement the list of offerings at site 1, Indian Hill.

OTHER SITES

There are undoubtedly places of aboriginal occupation on Barburata but we did not see or hear of any during our short stay. Mr. Haskell noted potsherds and conch shells on the top of the highest hill on the island (see map, fig. 19), and there are probably other offertories on the various hills and ridges. Very probably there are old dwelling sites near the ends of the island or on the north shore that we were unable to explore. It is highly desirable that if such exist they be very carefully excavated to check and supplement the apparent stratification, both vertical and horizontal, which occurred in the two badly disturbed offertories on Indian Hill.

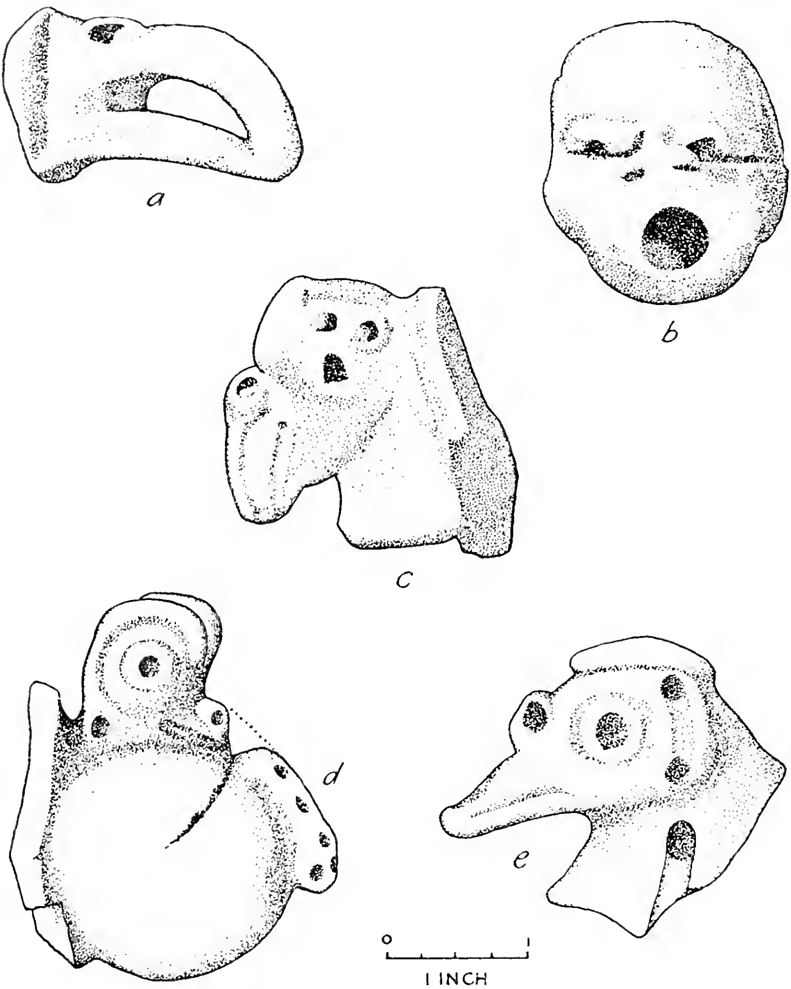


FIG. 32.—Monochrome lugs: *a*, Pine Ridge, Bonacca; *b*, Kelly Hill, Bonacca; *c*, Stanley Hill, Bonacca; *d*, *e*, Morat Island.

Morat Island

From Barburata we proceed to Morat Island (map, fig. 1) and anchored inside the reef on the eastern side. Haskell and Payne, with two of the boys, walked along the main ridge of the island. This ridge runs the length of the island and terminates in a hill at each end.

A little broken pottery and one stone artifact were picked up from the surface on the tops of these hills. From the hilltop to the southwest they brought back 2 well-modeled bird head lugs (fig. 32, *d, e*), and from that to the northeast about 10 small sherds. These include two rims from small bowls with constricted orifices and flaring lips, and a thick body sherd (.9 cm in thickness). All sherds from Morat are a reddish monochrome, except one curved sherd with a conventionalized manatee head lug. This lug has a purplish-red framework of design around it. The shape of the lug suggests Polychrome II, but the painted design is more like Polychrome I. The only nonceramic artifact recovered was the central portion of a cylindrical stone bark beater (pl. 16, fig. 1, *m*). One end is completely covered with narrow longitudinal grooves, the other rounded for a handle.

Possibly there are offertory deposits on top of these hills, but other than the few sherds, no surface indications were noticed. The shore line was not examined, and there may be aboriginal sites there. We had only a few hours on the island and did no digging.

Bonacca Island

This island seems to contain more striking surface indications of aboriginal occupation than do any of the others, but archeological material from here is not very abundant. An exception to this statement is the Mitchell-Hedges collection assigned to Bonacca, in the Museum of the American Indian, the bulk of which presumably came from the Sacrificial Spring. The Boekelman Shell Heap Expedition and the Smithsonian Expedition examined numerous sites on Bonacca, but owing to lack of time for any extensive excavations, they obtained comparatively little material. The island is one of the most attractive of the group and, given adequate time for exploration, would undoubtedly yield far more evidence of native occupation than is now available. The only modern town of any size is that of Bonacca on Sheen Cays (see map, fig. 33), but there are good anchorages on both the northwest and southeast shores, from which all portions of the island could be examined. At present, only a strip northeast across the island from the town of Bonacca and a narrow strip between Savannah and Mangrove Bights (see map, fig. 33) have been reported on. We were greatly assisted in our work by Sandy Kirkconnel of Bonacca town, who owns the Plan Grande portion of the island and who guided us on that portion of our trip. As was true on nearly all the other islands the local officials and residents were very friendly and gave us all possible aid. From Bonacca the great mainland mountains back of Belfata and Trujillo, and on Black River, are all clearly visible.

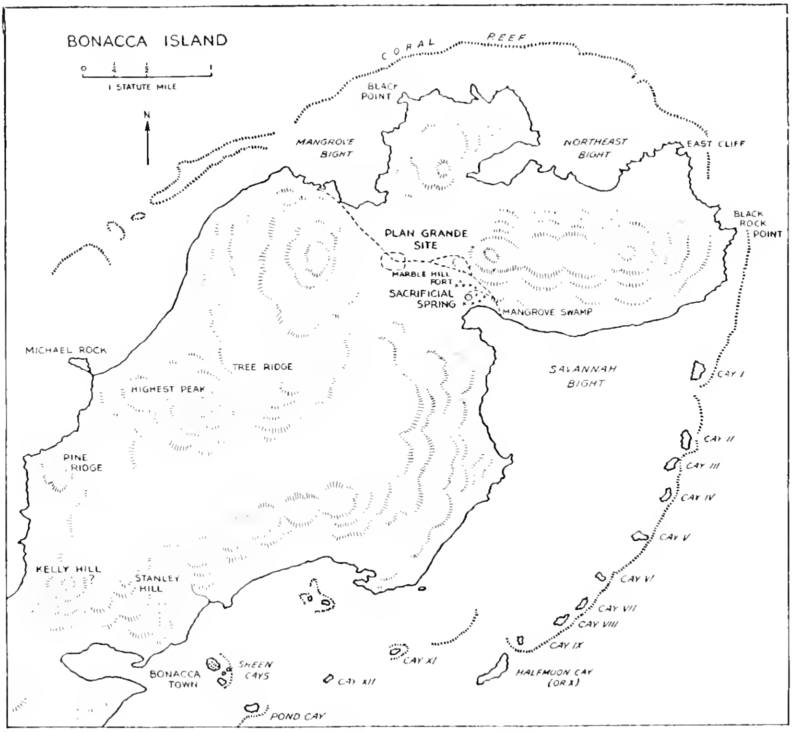


FIG. 33.—Map of Bonacca Island.

STANLEY HILL

The first site examined by us was Stanley Hill, which towers above the low coral reefs on which the little town of Bonacca is built (map, fig. 33). Mr. Payne climbed up and collected a small amount of broken pottery. He reported that the top of the hill appeared to have been terraced, leaving a mound of rocks in the center, and that there were several old trails. At least one of these appeared to have been artifically cut out and they all converged from different directions to the top of the mountain. At present there is a flag pole here on which a flag is raised on special occasions by the people of Bonacca town. There is a magnificent view from the hill. Bird reports that broken pottery occurs in the central pile of rocks and that some sherds are scattered over the surface of the hilltop, occurring to a depth of 6 to

8 inches in one small area. His small collection includes 16 much-weathered, red to brown (monochrome) sherds and lugs. The body sherds are rather plain, but the lugs include several of the vertical, centrally constricted type (compare fig. 26), a manatee head type, a snouted animal head, one conventionalized human figure, and a bird head (fig. 32, *c*). Two pottery balls from hollow leg rattles were found. Besides pottery, two disk beads of green talc and two cylindrical granite hammerstones are in the collection.

Payne's collection includes one complete shallow pottery plate (11.5 cm in diameter), and about two dozen sherds. All but one are of a uniform pinkish-red color without any slip, but the majority have rather elaborate incising and modeling. Two fragments are from open bowls with round bottoms, vertical, slightly concave walls, and slightly flaring lips; both have a well-executed incised step design on the walls. Two rim sherds are from large open bowls with an elaborate incised panel of double scrolls, each terminating in two dots on the side. Six others are from small bowls with low flaring or swollen rims, and elaborate geometric incisions. A fragment of a heavy loop handle has a conventionalized manatee head modeled on the bend and a polished brown surface but no visible paint. In form, at least, it suggests the Polychrome II type of handle (fig. 11, *a*, *d*). There are three elaborate and grotesque vertical lugs, one representing an alligator head; the others are too conventionalized for determination. Of the three detached and broken feet, two have human faces where they join the body of the bowl, and the third suggests a manatee flipper.

As a whole, the ceramic sample from the top of Stanley Hill is of high grade, elaborately incised and modeled monochrome ware and suggests a ceremonial rather than a utilitarian deposit.

KELLY HILL

In Bird's collection from Bonacca there is a small but very interesting lot of material from Kelly (or Kellie's) Hill, but there are no notes, map references, or photographs by which this hill may be located. I am inclined to believe that this is a somewhat higher peak to the west of Stanley Hill (see map, fig. 33) and have tentatively designated it as such, subject to future correction.[23] The potsherds

[23] While this report was in preparation, Mr. Bird was in Bolivia, and later in Labrador; hence it was impossible to consult him. In October 1934, however, just as this paper was going to press, he was in Washington. He confirmed the above general location and added to or corrected certain other points.

from this site include both an elaborately incised (and modeled) monochrome ware and three polychrome (Polychrome I) rim sherds. The former type is brown to red in color and is unslipped but highly polished in most cases. Flat-bottomed vases; jars with round bodies, contracted orifices, and flaring rims; and jars with annular bases are represented. The sherds are badly weathered but show traces of rather elaborate incised decoration. There are nine cylindrical feet; the majority are hollow and rather long with incised and punctate decoration; two suggest conventionalized alligator heads and two similar human figures. There are 11 lugs of an elaborately modeled type. One is almost identical with a lug from Helena Island (pl. 18, fig. 2, *c*), and one (fig. 32, *b*) vividly represents the head of a howling monkey "howling". Three rim sherds are of thin, polychrome ware (indubitably Polychrome I, like pl. 21). They are from cylindrical vases with slightly flaring rims and have an orange slip, three black rings around the neck, and black and red-purple body designs. The latter are too badly weathered for the designs to be made out. There is one broken lug, probably of the iguana type.

Besides pottery fragments there is one excellently worked ear spool (1.3 cm in diameter) made of what appears to be gray jade (pl. 17, *h*). There are also a small, ovoid, incised pendant of green talc (2 cm in length) with three dots suggesting a human face, and two cylindrical beads of green talc. The only bones present were a few from some species of small bird. The nature of this site is not clear, but from the type of material present (elaborate monochrome and thin Polychrome I pottery, with jade and talc ornaments) it would appear to have been a previously disturbed offertory.

PINE RIDGE

A somewhat similar but less interesting and smaller lot of material was collected by Bird on Pine Ridge (map, fig. 33). There are no notes or photographs referring to this site but it can be located in a general way on the map. There are some 10 potsherds, all of red, unslipped (monochrome) ware. One is the rim of a small jar with flaring lips, several are from open bowls with extremely rude incisions, and there are a few vertical loop handles and two small lugs. One of these is a conglomeration of globules, each with a punctate mark, the other the head and curved pointed beak of a bird in profile (fig. 32, *a*). Three much-weathered pottery disks (9 to 12.5 cm in diameter) are designated as "pot lids" by Bird, but I am inclined to regard them as the broken-out bottoms of cylindrical jars. There is a much-weathered stone implement (19.5 cm in length) with an ovoid head, flattened on two faces, and a small, cylindrical, round-ended handle. No grooves are visible on the two faces, but the implement strongly suggests a bark beater. The other objects consist of one fragment of a crude marble bowl; half of a discoidal marble stone; a fragment of pumice, grooved by use; two small fragments of cylindrical, polished roller pestles; and a crude disk bead of gray steatite. This material has a utilitarian aspect and contrasts markedly with the ornate and presumably ceremonial material from Kelly Hill.

THE SACRIFICIAL SPRING

The sites which we examined on the northeast end of the island can be reached from either Mangrove or Savannah Bights, but the latter, being on the lee side of the island, is the safest anchorage (see map, fig. 33). From the latter place we visited the Sacrificial Spring where Mitchell-Hedges and Lady Richmond Brown obtained a large collection in 1930. The site can be easily reached by following the trail half way to Marble Hill and then branching off across a mangrove swamp for a short distance (see map, fig. 33). Unfortunately, at the time of our visit we had not read Mitchell-Hedges' account of the discovery. This account in part is as follows:

Arriving there, Lady Richmond Brown and I, accompanied by our natives, entered a valley, on each side of which rose great hills. The first quarter of a mile we traversed of this sinister place almost dispelled any expectations entertained by us that within this region could possibly be the evidences of what was once a vast civilization.

The bed of the valley, which was almost perfectly flat swamp, seemed to hold the chill of death as one entered the gloomy depths of the jungle. The ground squelched beneath our boots and the stench which arose from the swamp as we cut our way through the undergrowth told of rotted and decayed vegetation—vegetation which had laid there disintegrating for thousands of years; poisonous—the very atmosphere was the breath of a sepulchre.

From the ooze towered a forest of white mangroves, their fantastic roots curling over the ground in every direction like the tentacles of a giant octopus. Hideous snakes, great land crabs and noisome fungi appeared to be the only life in this land of rot. Only that which was loathsome seemed to have its being in the faint ghostly glimmer, where a few sickly beams of sunlight struggled through the interlaced branches of the mangroves.

We toiled on cutting and hacking every foot of the way with our machetes. The heat was overpowering, mosquitoes and botlas flies swarmed about us, while the perspiration trickled down our bodies until finally our shirts, breeches and boots were sodden.

A miniature stream crept through the swamp, and this we followed. [There follows an account of a fierce encounter with an enraged iguana which, for lack of space, I must omit.] . . . .

Suddenly and without warning the swamp ended, and we stood at the base of a limestone cliff which rose sheer from the flat morass—an impassible barrier.

From breaks and fissures in the rock at its extreme base, the waters of a spring gurgled forth, limpid clear. We dashed ourselves flat gratefully burying our faces in the water. But in a flash we recoiled, spitting disgustedly—literally sickened. The water was highly mineralized, the taste of sulphur predominating.

But the moment of our mortification marked the beginning of a discovery which conceivably may change the scientific conception of the history and age not only of Central America, but of the entire continents of North and South America. For there, lying close to the rock wall and at the bottom of a pocket formed by the stream we saw a significant fragment of pottery.[24]

Digging in the mud at the base of the rocks where the spring issued, they found an immense amount of broken pottery and many complete pieces. These included figurines, incised and modeled pots, jadeite beads and plaques, bolas (mace heads?), painted pottery, a stone vase (soft " like tooth paste " when excavated) and a granite (sic) figurine (fig. 37, *h*). At the bottom of the mud they struck solid rock forming a marble basin. Mitchell-Hedges regarded this as a sacred well or *cenote,* the waters of which probably had highly curative properties, hence the belief in its sacred character. On the face of the cliff above he discerned a flat rock or " pulpit " from which he suggests that, as at Chichen Itza, " the most beautiful virgins were sacrificed " before the eyes of the populace spread out over the plain (sic) below. According to the account, over 1100 specimens were obtained here within a space of three square yards.[25] The collections made by Mr. Mitchell-Hedges assigned to Bonacca, now in the Museum of the American Indian, will be discussed as a unit later, since they are not segregated according to sites.

When we visited the site, mud completely covered the basin described by Mr. Mitchell-Hedges (pl. 32, fig. 1). There was a considerable flow of water issuing from the rocks, forming a stream 2 or 3 inches deep and about 3 feet wide. The water was slightly brackish but quite drinkable and refreshing. Mr. Payne took a bottle back to the hospital at Puerto Castilla, where it was analyzed by the authorities but no unusual chemical properties could be discovered. The muck area, some 20 to 30 feet in diameter, was littered with broken pottery (pl. 32, fig. 1). We dug to a depth of 3 feet and fragments of pottery apparently occurred below this. Aside from one almost complete tripod vessel (pl. 31, *c*), nothing was found

[24] Signed article by Mitchell-Hedges, The Washington Herald, Sunday, Aug. 10, 1930.

[25] Signed articles by Mitchell-Hedges, The Washington Herald, Sunday, Aug. 10, and Sunday, Aug. 17, 1930.

but sherds. The rock walls do not rise abruptly above the spring—rather they consist of a tumbled pile or talus slope of limestone and marble boulders. We climbed over these for a considerable distance but did not see the flat rock or " pulpit " described by Mr. Mitchell-Hedges.

We removed a sample collection of sherds and the one complete vessel. The latter (pl. 31, *e*) has short solid legs, and the edges appear to have been ground down. There are two borings for lacing across a crack. The vessel is a dull yellow color, and there is no slip, at least at present. Aside from the top flare and punctate marks on the feet, there is no decoration. The sherds are all of high-grade pottery but are rough-surfaced, probably as the result of long soaking. The majority are of elaborate monochrome type, but one sherd suggests Polychrome I and another Polychrome II in form. The former is a solid lug of brown pottery suggesting a bird's head with three crests. The latter is a rim with a broad, vertical strap handle (similar to fig. 11, *a, d*) but without the characteristic manatee head lug. In neither case are affiliations with Polychrome I and II ware positive, since no traces of paint remain. However, the forms fit in with these types better than any others.

About 24 sherds, mostly rims, are from elaborately incised vessels, many of which seem to have had the Uloa marble bowl type of decoration. Applique work is rather rare. Double scroll and dot incised decoration is common. There are two ornate lugs from this monochrome ware; one is of the vertical, centrally constricted type, the other of the projecting type with elaborate incision and applique work, giving it a grotesque appearance. Of the three basal fragments, one is an annular base with an incised step design and a row of holes around the bottom; another is from a small tripod vessel with short decorated feet (like pl. 31, *f*); and the third, from a large vessel of composite silhouette, has one hemispherical foot containing a clay ball. There are three separate feet; one is hollow and hemispherical with two holes and applique and incised decoration where it joins the body, one is a hollow cylinder flaring toward the top, and the third, a hollow cylinder with rounded tip, has an applique face where it joins the body, two perforations on one side and one on the other. As a whole, this collection suggests ceremonial rather than utilitarian ware, but it is a selected, not a random, sample.

MARBLE HILL FORT

Marble Hill is a steep little pinnacle, about 150 feet in height, of tumbled marble rocks. The great white cliffs and boulders and the tall trees give it a most picturesque appearance. It stands to the north of the mangrove swamp and on the southeastern edge of Plan Grande, being only a short walk from Savannah Bight (map, fig. 33). It is apparently inaccessible except from the northern side, where a narrow pathway, in part artificial, leads up to the top. This pathway is exceptionally interesting owing to two partially artificial terraces on the steep slope, which have been carefully built up with large flat slabs of rock. In the center of each of these is a series of narrow, rough steps, and on the outer edge of each terrace is a breast-high wall of boulders and piled slabs. A few men behind these fortifications could easily defend the hill top. There are potsherds, conch shells, and other cultural debris scattered amidst these crude but effective constructions. The density of the trees and hanging vines, combined with the impossibility of getting far enough away to gain perspective, prevented photographing. Owing to these factors, as well as to the wildly tumbled nature of the rocks generally, the fact that this approach is in considerable part artificial might easily be overlooked. Mr. Haskell and I made a very careful examination and concluded that considerable portions of the terraces, walls, and steps were definitely artificial.

The area on top is fairly level, with the exception of a number of steep pinnacles, and includes an acre or two. It had recently been partially cleared to make a small plantation. The rocky pinnacles contained a good number of potsherds, obsidian chips, broken artifacts, animal bones, fish bones, and conch and whelk shells. This type of material also occurred thinly scattered all over the top of the hill. We tried to work our way around the edge of the rim, but the tumbled rocks and dense brush made this impossible. So far as I could tell, there was no other practicable way up except the fortified trail already described. Test pits in the cleared area revealed little in the way of artifacts; these were more abundant under and around the rocks and on the surface. The place has all the appearances of being a fortified retreat to which the people of Plan Grande could retire in time of need. There is said to be a spring near the base of Marble Hill, but I did not visit it. On the north, west, and south sides of the hill, at the base, are a number of great crevices or cracks formed by huge slabs splitting off the cliff and piling up. We found only a few sherds in these, but Bird and his party got a considerable amount of material from such places, especially on the west and southwest sides of the hill. Mitchell-Hedges gives a thrilling account of explorations here, which penetrated deep into the very bowels of the earth,"[26] but we either missed this place or did not recognize it.

Bird has only a few notes and no photographs pertaining to this site but made a large and interesting collection. His catalog indicates that most of this material came from the crevices on the southwest side of the hill, the other material, I presume, coming from the north slope and the top. The ceramics from Marble Hill include Monochrome, Polychrome I, and Polychrome II types. Monochrome ware, mostly of the elaborately incised type, is the most abundant. Mr Boekelman found one small effigy jar (11 cm high) of dull, polished red ware (fig. 34, *a*) beneath a fallen rock slab. The only other complete vessel is a very crude, unpolished red bowl with a flat bottom and a slightly flaring rim. There are numerous sherds of the elaborately incised monochrome type from open bowls, vases, or jars with an annular base, and round pots with constricted orifices and slightly

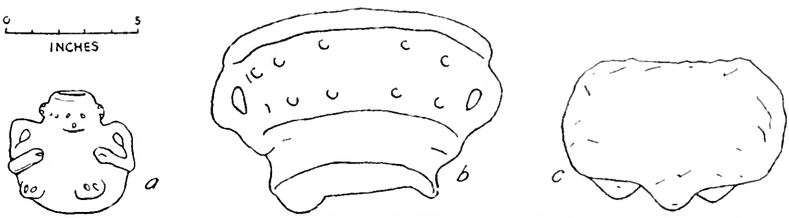


FIG. 34.—Monochrome vessels and marble bowl: *a*, Marble Hill Fort, Bonacca; *b*, Big Bight cave, Utila; *c*, Plan Grande, Bonacca.

flaring rims. Hollow cylindrical and conical feet which rattle, hemispherical feet with rattles, and solid, thin, rectangular feet (like fig. 18) of varying heights are present. The broken-off lugs include vertical, centrally constricted types; one death's head (similar to fig. 25, *e*); one grotesque animal with upturned snout; a bird's head; several manatee heads with the concentric circle design on each side (similar to pl. 18, fig. 2, *a*, *b*); and one crude turtle or alligator in relief.

Polychrome I ware is represented by one typical bodysherd (4 mm thick), which has an orange slip and part of a plumed serpent design in black and red-purple. Four lugs suggest that combination between Polychrome I and the elaborately incised monochrome types which occurred at site 1, Indian Hill. These include two polished, brown, delicately incised sherds with applique rider lugs, both of thin pottery; and two somewhat aberrant lugs, with coarse incisions, suggesting the iguana head type.

[26] See The Washington Herald, Sunday, Aug. 10, 1930.

Polychrome II ware is represented by one large rim sherd (5 mm thick) from a vessel with a restricted orifice, straight medium high rim, and swollen lip. The neck is decorated with a black line and dot design on a red-brown slip. Another rim sherd has a dark red slip and a conventionalized manatee head lug on the side. The vessel is 1 cm thick at the lip, and the lug is surrounded by a black line frame. There are six vertical loop handles with a manatee head in relief on the upper bend (similar to fig. 11, *a, d*). These are typically Polychrome II in type, but only traces of brown slip and no design elements remain, owing to weathering.

One fragment of a gray steatite jar, possibly a leg, and one-third of a broken granite bowl or mortar (15 cm high) with thin walls and thick bottom, all smoothly polished, were found. From "the floor of Marble Hill Cave" come two broken, oval bark beaters, both fully grooved around the edges; one is smoothly worn on both faces, the other has only one face, which has beautifully even, narrow, lengthwise grooves. From Marble Hill, area not specified, comes an exceptionally beautiful little celt (3.8 cm long) of dark green jade (pl. 17, *j*). There are also two small jade and three green talc cylindrical beads and a ball of marble (3 cm in diameter) with two holes started from each side but not meeting. There are traces of a rather elaborate herringbone design on this piece, but it is too badly eroded for analysis.

Bird's collection contains 39 human teeth "found scattered among the sherds", indicating that the Marble Hill "caves" were probably used for burial purposes. In his catalog Bird gives a "list of finds at site on southwest side of Marble Hill, Bonacca. Shell Ornaments: 76 *Marginella* shells, perforated; 18½ olive shells, end cut and side perforated; 1 olive shell, end bored; 1 cone shell, large end cut and side perforated; 1 cone shell, large end bored, center, cut on sides; 4 cone shells not cut or bored; 4 round shell disks (¾ inch diameter to ½ inch); 3 round shell disks with hole in center; 5 irregular shell pendants (¾ to ½ inch long); 8 shell beads; 2 perforated spondular shells (1-4 holes); 2 perforated cairs shells; 15 perforated *Turritella* shells". These specimens are in the possession of Mr. Boekelman.

Our small sherd collection from Marble Hill contains plain and elaborate monochrome pieces but no polychrome ware. Some 16 sherds of highly polished, dull red ware are present, and several of these pieces have been bored for crack lacing. A few have simple incisions, and one has an applique eye and nose. All but two are from bowls with low, slightly flaring lips or else direct rims. One of the former has a restricted orifice and high flaring lips, the other is part of a graceful cylindrical vase with three small, solid feet. There are a number of potsherds, both plain and incised. Two rather coarse vertical strap handles have angular rather than rounded curves. There are two detached lugs; one of these is of the vertical, centrally constricted type with elaborate punctate decoration, the other is a fragment of applique decoration. There are five separate feet; one is conical from a tall tripod bowl, two are similar but shorter, one is a solid cone, and the last is hemispherical and hollow with elaborate incised punctate and applique decoration. The collection is not particularly distinctive but seems for the most part to represent the more elaborate type of monochrome ware.

THE PLAN GRANDE SITE

The Plan Grande is the most striking ruin we visited in the Bay Islands. It was briefly mentioned by Young, in 1842 (Young, 1842, p. 48) as a stone wall a few feet high containing fissures or niches made for the admission of peculiarly cut, three-legged stone chairs, presumably the seats of idols. Conzemius also gives a brief description of the site, stating that it might possibly be of buccaneer rather than Indian origin.[27] The party of Mitchell-Hedges visited the site in 1930, and he has published a diagram of the enclosure [28] that differs very considerably from the plane-table map made by Haskell and myself (fig. 35).

Mitchell-Hedges compares the site to Stonehenge, but believes it to be incalculably older on the basis of the disintegration of the rock slabs. He mentions the trench started in mound 1 (fig. 35), which yielded broken pottery. His assistants, Mr. Stein and Mr. Hudson, obtained six very fine ax heads, several figurines, a small stone altar, broken decorated pottery, and fragments of large metates with legs from an earth mound, probably mound 4 (fig. 35). Their most spectacular discovery, according to the newspaper account, was a hollowed stone too heavy to move, which suggested a stone font.[29] This may have been the stone seat sketched by Bird (fig. 36). On the hills to the east of the site (map, fig. 33) Mr. Stein and Mr. Hudson found a large boulder with incised rectangular lines around a cross. All the lines are double with regularly spaced cross lines, giving the design

[27] 1928, pp. 66, 67. There seems no reason to believe that the site is not of native origin.

[28] Signed article by Mitchell-Hedges, The Washington Herald, Aug. 24, 1930.

[29] Idem. The illustrations in this article show this stone, the carved rock, and the diagram.

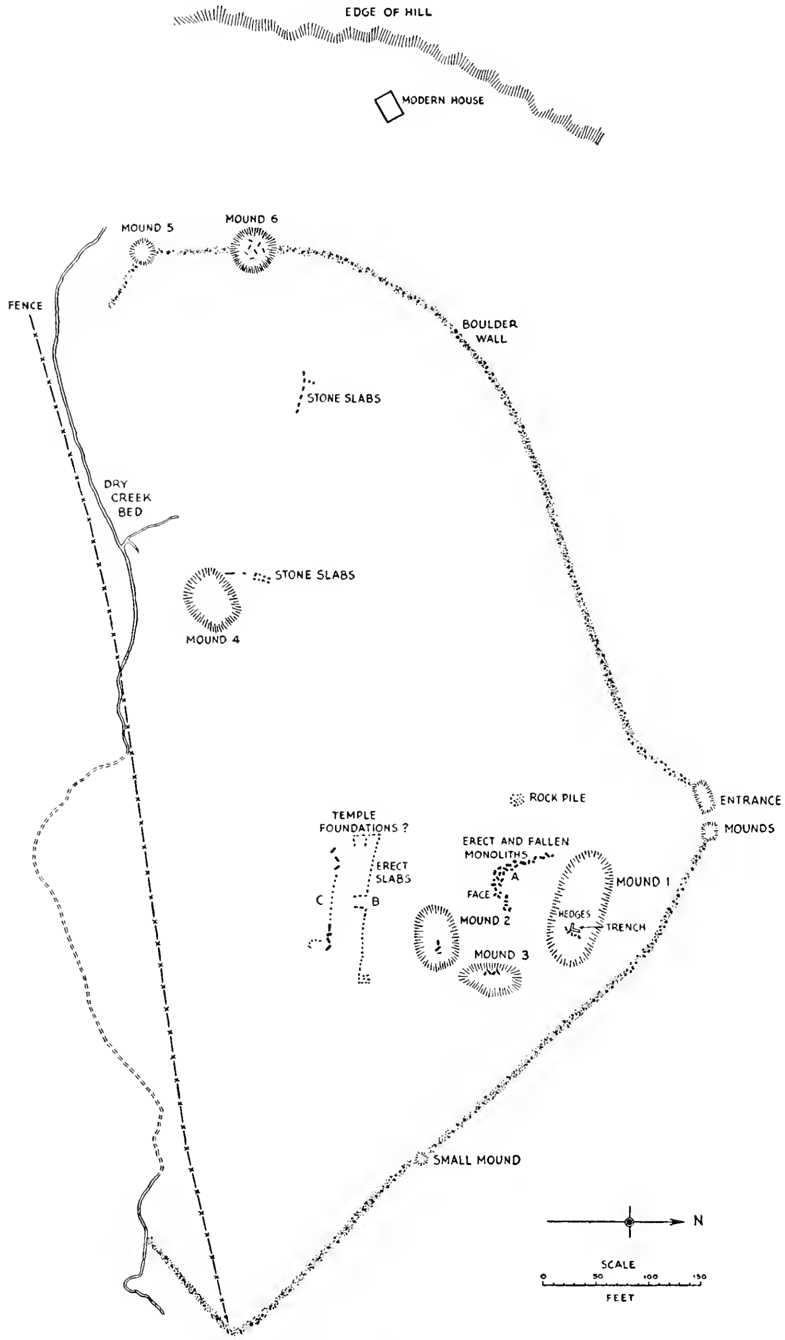


Fig. 35.—Map of Plan Grande site, Bonacca. (Made by Norman A. Haskell and W. D. Strong.)

a ladderlike appearance. A mile to the south are said to be outlying portions of the site; $4\frac{1}{2}$ miles due east Mitchell-Hedges reports figurines, obsidian spear heads, beads, etc; and 5 miles due west they found other specimens. As Mitchell-Hedges says, it is a big site, and is as yet barely scratched.

Bird and his companions spent one day at this site and made some valuable observations. They landed in Savannah Bight and walked across to Mangrove Bight, searching for the "tombstones" or "cemetery" as the Plan Grande site is called locally. They were told of a cave on the hill just south of Mangrove Bight, and near the base of this hill they found a few sherds and, under a large rock, a crude pot and a celt. Bird states that the place was not suitable for occupation, nor were there any shells or cultural detritus in the vicinity; hence he regards it as a casual storage place. The vessel is of coarse brown ware with crude decorations, and the celt (8.5 cm long) is of

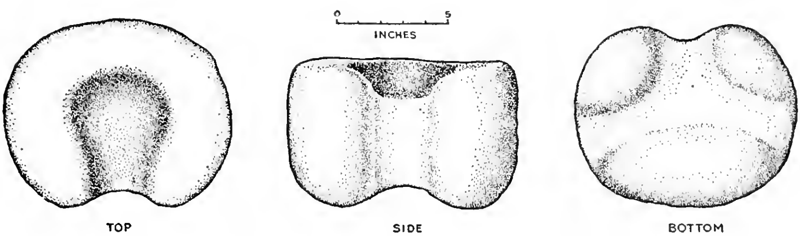


FIG. 36.—Sketch of small sandstone "chair for idol," Plan Grande site. (From sketch by Junius Bird.)

battered gray granite with a sharp, polished edge. The complete neck of a plain red vessel, originally about 1 meter in height, was found here. The other finds at this place were a very crude tripod pot with solid legs of coarse brown pottery and a small concave saucer of the same ware. We also visited a "cave" near here, after a very rough climb, which proved to be merely a deep fissure without any signs of human occupation.

That afternoon they reached the Plan Grande site and started a detailed survey of the enclosure, but owing to lack of time they were unable to finish it. They found a small stone mortar just protruding above the surface near mound 1 and a roughly cut stone suggesting the "chairs" described by Young. Possibly this is the same specimen as Mitchell-Hedges' "font" (fig. 36). It is made of hard, much-weathered gray sandstone and was imbedded in the ground. They left it beneath one of the leaning stone slabs, but it had either disappeared by the time of our visit or else we overlooked it. The stone "mortar" (fig. 34, *c*) mentioned above is of much-eroded white marble and has three short, conical legs, being practically identical with some of the marble bowls from site 1, Indian Hill. Bird also found on the surface inside the enclosure a fragment of a large metate with a squared leg. In addition to the above, his collection in the American Museum of Natural History includes a battered celt of hard green stone with both ends broken off, and (from a test pit west of mound 1) six thick red sherds (2 cm in thickness), two similar sherds with low flaring rims, one short cylindrical leg, and a vertical loop handle composed of two joined pottery coils. The heavy sherds and rims strongly suggest the burial urns from Utila, and it is very probable that an adequate series of trenches at this site would reveal urn burials, though none has as yet been reported from here.

The following description of the main site is based primarily on a plane-table survey made by Haskell and myself, which required a day and a half. The surface of the enclosure, although seemingly flat, is actually uneven and is covered with dense coconut palms and some low brush, making sighting difficult. I have also incorporated some of Bird's data as well, but a series of measurements that he made of a considerable number of the erect and fallen stones seems too detailed for incorporation at this time. The Mitchell-Hedges diagram, previously referred to, is too far off in directions, dimensions, and locations to make any comparison profitable. At present the site is a " cocale ", where copra is gathered; one of the mounds (fig. 35) is fenced in as a pigpen, and a wire fence stretches across the southern opening, cutting off the " cocale " from the brush land to the south. The overseer's house is located to the west of the enclosure.

As one approaches the Plan Grande enclosure from the north, a low wall of boulders is encountered (fig. 35). This is here about 6 feet high on the outside and only 3 feet high on the inside. The wall is from 3 to 4 feet wide and probably averages about 4 feet in height, the stones being piled in no particular order. It encloses a space about 350 yards long from east to west and 280 yards from north to south. There are a few hollows or rude shelves in this wall, which may be remnants of the niches containing " stone chairs " mentioned by Young in 1842. The southern half of the enclosure has no wall but is defined by the dry channel of a stream, forming a steep-walled canyon of some depth. On the west mound 5, a small mound 8 feet high, and a short spur terminate the wall. Slightly north of mound 5 is mound 6, a larger but lower mound (6 feet high), composed entirely of boulders and slabs, some of which

BONACCA

1. Sacrificial Spring.
2. Erect monolithic stones, Plan Grande.

Photographs by Junius Bird.

PLAN GRANDE, BONACCA

1. Temple foundation slabs (?).
2. Monolithic slab on mound 3.
3. Crudely carved, erect stone slab.

have recently been arranged as benches. From mound 6 the wall extends northeast in a double curve until it reaches two small mounds (6 to 7 feet high), between which is apparently the entrance to the enclosure. The wall curves sharply southeast here, and less than halfway down its extent is another small rock mound. At its southern extremity the wall turns diagonally west and in a considerably tumbled fashion crosses the creek, forming a low dam. Here it apparently terminates. The surface of the site generally is marked by monochrome potsherds and some other artifacts, and the creek bed especially is full of broken pottery. Mitchell-Hedges reported considerable deposits of sherds in the creek walls, but although we obtained a considerable collection in the bed itself, we found only a few sherds actually in the banks.

Coming through the entryway over a rise of ground, mound 1 is first encountered. This is the largest of the mounds, being 85 feet long, 55 feet wide, and 8 feet high, with a rounded top (fig. 35, mound 1). Toward the east end just west of the five erect stone slabs is an L-shaped trench some 15 feet long, $2\frac{1}{2}$ feet wide, and $3\frac{1}{2}$ feet deep at the deepest point, made by the Mitchell-Hedges party. We cleaned off the walls of this trench, which showed the upper mound to be composed of earth with some small rocks and a few monochrome potsherds in the upper 1 foot. Mound 3 is just south of mound 1 and is slightly smaller and only 3 feet high. It is marked by four big, erect stone slabs, one of which is 6 feet high (pl. 33, fig. 2), 3 feet broad, and less than 1 foot thick. It is not carved but nevertheless definitely suggests a stelae. With mound 2, which is $5\frac{1}{2}$ feet high and marked by three erect slabs, mounds 1 and 3 form an irregular rectangle closed in to the west by a large number of erect monolithic stones (fig. 35, A). These are set up in a rough L shape; some are erect, others are leaning over, and yet others have fallen flat (pl. 32, fig. 2). They resemble grave stones, and one or two are phallic in form. Only one stone at the site is carved (pl. 33, fig. 3); it has three incisions suggesting a crude face. The mass effect of these monoliths is much more impressive than the photographs indicate (pl. 32, fig. 2; pl. 33, figs. 1-3). The largest erect stone is $6\frac{1}{2}$ feet high, $2\frac{1}{2}$ wide, and less than 1 foot thick, and the largest fallen stone is 9 feet 10 inches long, 2 feet wide, and only 5 or 6 inches thick. The purpose of this monolithic complex is puzzling. We dug several test pits near the more striking monuments but found only a few potsherds. Adequate trenches here might well reveal urn burials.

South of mound 2 is an interesting alignment of small slabs set up on edge (fig. 35 B, pl. 33, fig. 1) and forming a rectangular alignment about 40 yards from east to west. The form of these erect slabs suggests the foundation of a temple or similar building, especially in the center, and again at the west end, where a double room is suggested. Test pits here were not productive. South of this low enclosure is an irregular alignment of large leaning or fallen rock slabs (fig. 35, C). Mound 4 (fig. 35, mound 4) is 7 feet high and appears to be composed of earth. Here, according to the newspaper account, the Mitchell-Hedges party secured a number of specimens. To the north and to the northwest are two more alignments of vertical rock slabs, many of which are still erect. About 80 yards west of the enclosure a great jungle-covered hill rises abruptly.

Although potsherds and other artifacts may be found almost anywhere within the enclosure, they are not very numerous and no refuse heaps were encountered in our work. The boulder walls, which are not especially well adapted for defense, the earth and stone mounds, and the stone alignments all suggest adjuncts of a temple or ceremonial site rather than a place of regular habitation. Taken in conjunction with Young's description of niches and " seats for idols ", the general arrangement here calls to mind the temple and idol on an island 15 Spanish leagues from Trujillo that were mentioned by Salcedo in 1527. There is no way to prove that this was the Plan Grande site, but, so far as present researches are concerned, the complex around Plan Grande (which includes Marble Hill Fort and the Sacrificial Spring) is by far the greatest and best-preserved island ceremonial site on record. One of our local guides, however, stated that there was another site very similar to Plan Grande near Black Rock Point, but we were unable to visit this site. Moreover, as will be shown shortly, both Bird's party and our own evidently missed an important ceremonial place at Stuart Hill on Utila Island (see Rose, 1904); hence it is undoubtedly premature to draw any such comparative conclusions at this time.

Our small sample pottery collection from Plan Grande was obtained from the surface, from the trial pits inside the stone walls, and from the dry creek bed. It includes a few Polychrome I and II sherds, but the majority of the pieces are of plain or elaborate monochrome ware. From the dry creek bed comes one restorable vessel (pl. 31, fig. 2, *c*), a globular pot 12 cm high of brick-red ware. It is fairly well polished and is decorated by a line of indentations making a sort of guilloche pattern caught up by small applique lugs. An iguana head lug showing traces of black paint is the only Polychrome I piece. Polychrome II is represented by a rim fragment (like fig. 11, *a*, *d*) and two fragments of similar handles with small conventional manatee head lugs.

These are without paint at present and are classified solely on form and surface finish. There are about 20 rim sherds of monochrome ware; four of these have elaborate incisions below the rim, and one has applique decorations as well. The others are plain and range from a well-polished to a coarse surface finish. All are from small to medium pots; some have medium-high, some low flaring lips, and others have none. Four have swollen rims. There are four separate lugs; two of the elaborate modeled and incised vertical type with a central constriction, and two of the conventionalized grotesque projecting type. Two fragments of annular bases with incised step designs, and in one case with a series of holes around the bottom, are present. Two large, hollow tripod feet have applique faces where they joined the body of the pot, another has six vertical openings in three rows but lacks the face, and still another is solid and cylindrical (7 cm in length). Four feet are solid cones with applique, incised, and modeled decoration. Two are hemispherical in form; one of these is hollow with incised and applique decoration, the other is solid and plain.

MICHAEL ROCK

While working at Plan Grande the *Amigo* was anchored in Mangrove Bight. On the completion of our survey we proceeded down the coast to Michael Rock (map, fig. 33), which is a tongue of high ground jutting out into the sea. The narrow neck on the shore end would be under water in a very high tide, but the rocky peninsula is perhaps 60 feet high near the tip. On the highest point amidst large boulders and fallen leaves we found considerable broken pottery. This was all on the surface and digging produced no results.

The collection obtained from Michael Rock includes one practically complete small tripod vessel (pl. 31, fig. 3, *f*). It is 13 cm in diameter, has short, solid but ornate feet, and is decorated outside the rim by a short curved line and dot pattern of incision. There are also about 20 sherds, which, like the above vessel, have all been blackened by recent brush fires. Owing to weathering and burning, all are coarse in surface texture with grit or coarse gravel tempering very prominent. They are rather ornately but carelessly decorated with incision and applique decoration. All are from small vessels. The majority are from vases with straight or slightly contracting walls without marked rim. Only two have contracted necks and low flaring rims. The majority have rude geometric incised patterns on the upper body and neck. Crisscross, angular, and short dash lines, as well as curved or straight lines enclosing punctate marks, are common incised design motifs. One applique design consists of a crude face composed of three raised circles and two modeled, four-fingered hands in relief. A larger sherd has a vertical handle; both the handle and body have vertical ridges enclosing punctate marks. Two sherds have small lugs suggesting a degenerate version of the vertical, centrally constricted type. There are five other lugs in the collection; three are irregularly modeled solid knobs, one consists of three applique circles in a group, and the largest (5 cm long) is crudely modeled and hollow, with long irregular slits down the side and a grotesque face at the tip. No artifacts, other than the above, were found at this site.

The Mitchell-Hedges Collection in the Museum of the American Indian, Heye Foundation

The storage material from this collection assigned to Helena and Barburata Islands has already been discussed. Before the Bay Island exhibition material at that Museum is considered, the storage material assigned to Bonacca must be briefly analyzed. Particularly striking are five complete or only slightly broken vessels of the thin polychrome (Polychrome I) type (fig. 37, *b, c, e, f, g*). I presume that

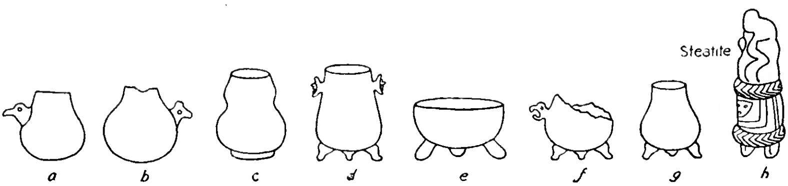


Fig. 37.—Outline sketch of Polychrome I vessels and carved steatite image (*h*), in the Mitchell-Hedges collection, Museum of the American Indian, Heye Foundation.

these are from the Sacrificial Spring, since nearly all but faint traces of the painted design and slip have vanished, evidently as a result of long soaking in water. At present they are all a rather uniform mottled gray or dull gray-brown color. From the traces of design still visible, the nature of the paste, the type of lugs, and the fact that there are two vessels without paint but otherwise almost identical with our Dixon site offertory vessel (pl. 1), there seems to be no doubt that they belong to the Polychrome I ware. This is highly important, since it throws light on many of the shapes characteristic of the type. One slightly broken jar has a white slip, a black line design, and iguana head lugs (fig. 37, *f*). There are a number of Polychrome I sherds that may have come from other sites on the island, since the paint is intact. These present many of the Polychrome I characteristics already referred to, but in addition there are variations in shape, color, and design, which could only be adequately treated by a more detailed analysis of this rich material than is possible here.

There is a large number of complete vessels, lugs, and fragments of the elaborately decorated monochrome ware, including some very tall pieces (30 cm in height). One large red vessel, beautifully fluted, is noteworthy. Numerous annular bases are present, and one of these has an opposed step design offset with upright and inverted T's, so deeply incised as almost to penetrate the walls. This is nearly identical with the design cut in the annular base of certain marble vases from the Uloa. Simple monochrome pottery types are rare, but the majority of the clay figurines assigned to Bonacca are crude, simple, and red in color.

One of the most interesting and significant finds made by the Mitchell-Hedges party in the Sacrificial Spring on Bonacca was a small image (38 cm high) of gray steatite, representing a human with an animal crouched on his head (fig. 37, *h*).[30] This little statue, although rather complex, is crude and presents a somewhat unfinished appearance. The upper figure suggests a seated monkey with a square featureless face; below this is a rounded cylinder with a pediment and capstone, both decorated with incised chevron designs. The combined figures are supported on three rectangular legs. On the front of the rounded cylinder is a broad semi-ovoid human face with definite features; two bent arms are faintly shown in relief and two small knobs on the chest. Although this little statue is crude, it definitely calls to mind the stone human figures supporting animals especially characteristic of the lake region of western Nicaragua. (See Lothrop, 1921, especially figs. 69, *c* and 70, *a*.) There are several simple steatite figurines, a fragment of a stone pot rest, and other more common types of ground stone artifacts in the Bonacca storage collection.

The selection of artifacts from the Mitchell-Hedges Bay Island collections on exhibit in the Museum of the American Indian is very striking. The specimens are not labelled as to island or other provenience but, taken as a whole, the case gives an excellent picture of the finer class of Bay Island artifacts. Of the Polychrome I ceramic type, there is one mottled gray vase with faint traces of design (fig. 37, *d*) which is almost identical in form with the Dixon site offertory

[30] See signed article by Mitchell-Hedges, The Washington Herald, Sunday, Aug. 17, 1930, for a brief mention of the finding and a photograph of this piece. It is on exhibit in the Museum of the American Indian.

vessel (pl. 1; pl. 6, fig. 2). This is probably from the Sacrificial Spring on Bonacca. A smaller vessel (fig. 37, *a*) with a bird head lug has a dull orange slip and a purplish-red and black design of geometric nature. There are a considerable number of Polychrome I lugs. The iguana head type is represented by both painted and unpainted examples; one of these, showing traces of paint, is unusual in having a high crest and a downward-curving proboscis. There are a large number of applique rider lugs, some of which are very large, but all of this type are unpainted. The nose-tiled type (fig. 37, *d*) is present, and all of these show painted design. In addition, there are several painted bird head lugs, one with three crests projecting (rather similar to fig. 37, *b*).

This exhibit material contains a splendid series of complete, restored, and fragmentary vessels of the elaborately decorated monochrome type. A simple outline sketch (fig. 38) indicates some of the variable shapes characteristic of this ware. A slender, tall, cylindrical

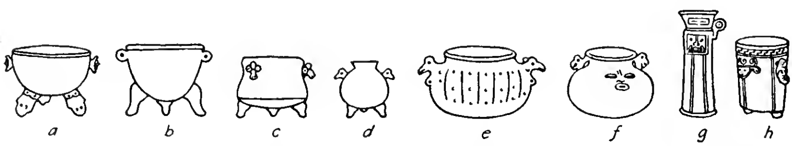


Fig. 38.—Outline sketch of elaborate monochrome vessels, in the Mitchell-Hedges collection, Museum of the American Indian, Heye Foundation.

vase (fig. 38, *g*) from the Sacrificial Spring and a small embossed pot with "lizard head" lugs (fig. 38, *e*) are particularly striking. A highly polished, centrally constricted vase with three solid cylindrical feet (fig. 38, *c*) is of especial interest, as it has two conventionalized manatee head lugs with incised concentric circles. To judge from the numerous fragments (pl. 18, fig. 2, *a*, *b*; fig. 24, *a*) of this type that we obtained, this was a common Bay Island form. As in our own collections, a few of the highly polished "monochrome" vessels show traces of a slip and simple painted design. Of the incised designs the grotesque human figure with octopuslike tentacles (similar to pl. 24, *a*, and pl. 26, *c*) is rather common, especially on vertical jars. There are many detached lugs of the grotesque monochrome type. An alligator lug, identical with one we recovered on Helena Island (pl. 18, fig. 2, *e*), is probably from the same vessel. The collection also contains a dark red (burial?) urn about 1 meter in height. It is conical in shape with a big, round bottom, a narrow neck, a short slightly flaring rim, and two large, solid, vertical loop handles.

Many pottery figurines are on exhibit; some of these, of dark brown pottery, have the grotesque features and fillet work decorations of the specimens from site 1, Indian Hill (pl. 28, fig. 1, *a-c*). One headless specimen, of brick-red pottery, is seated with arms akimbo and short, rounded legs projecting in front. One unusual lug or flat pottery head has the well-modeled features more common in the Uloa valley. (Compare Gordon, 1898a, pl. 10.) There are a number of the round or oval pottery whistles; three of these represent human figures and are unusual for the Bay Islands in having what appears to be a dull white slip. Two of these have grotesque conventionalized faces like Indian Hill figurines (pl. 28, fig. 1, *a-c*).

The Mitchell-Hedges exhibit collection has one complete roller stamp of plain brown pottery with an intricate incised diamond pattern. A hollow-ended and incised cylinder of steatite of about the same size suggests a similar usage. Another interesting artifact type is a small brown pottery labret identical in form with those made of shell from the Dixon site (pl. 15, *h-m*).

Two small copper celts (about 9 cm long) with broad, sharp blades and squared edges and butts are unique. They call to mind similar implements in the trader's canoe encountered by Columbus. Aside from these, work in metal seems rare in the Mitchell-Hedges collection.

There are several small carvings of what appears to be dark green jade or jadeite, and a number of green talc. One large, elaborately carved bead and a flat plaque with humanoid faces in relief are both of jade or jadeite. The remainder of the smaller carvings are somewhat similar to, but less complex than, the small carvings from the Dixon site (pl. 11). One bead of quartz crystal (like pl. 29, *f*) and a considerable variety of other beads like those from the Dixon site (pl. 14) are present.

A rather unique specimen is an unfinished, slender jar (18 cm high) with two vertical lugs, carved from a block of steatite. There are two small tripod bowls (similar to fig. 34, *c*) of white marble. Two beautifully shaped petaloid celts, each about 30 cm long, are present. One of these, of dark stone, still shows chipping on the butt, although the sharp blade is well polished. The other, of gray-green stone, is highly polished over its entire surface. Three cylindrical roller pestles, the largest about 45 cm long, are of the usual type. Although the foregoing description of this large collection makes no pretense at being either complete or exhaustive, it has been included as an essential part of our present knowledge of Bay Island archeology.

SUMMARY AND COMPARISON

THE BAY ISLANDS

Previous reports on Bay Island archeology are not extensive. For the island of Utila, Rose has presented some interesting observations.[31] He notes that there is considerable broken pottery scattered over the island and that large jars are occasionally dug out. Small earth and rock mounds are found in many parts of the island, and on the south shore these occur within 100 yards of the beach. In 1897 a mound on the north side of the island was opened by treasure hunters, and a large decorated red vessel covered with six red plates was found at a depth of several feet. The vessel contained smaller vessels, chipped points, stone and ivory (shell?) celts, coral beads, and clay figurines. The most striking of the smaller vessels was a " glazed " dark brown " water pot " in the form of a " bear ". The projecting head had a rattle, and the tail, which had been broken off, once served as a handle. According to Rose, Stuart hill (which neither Bird nor myself visited) is said to be the point of convergence of several cobbled causeways and appears to be paved on top with coral and black flint rock. One of these boulder causeways extends northeast to " an Indian burial ground at a place called Bamboo ", another leads in the opposite direction to Rock Harbor on the northern side, and a third leads to the vicinity of East Harbor. In places these causeways are covered with earth, but at others they are clearly visible and sometimes still in use. Rose carefully mentions two cobbled roads, one at the " Middle Path " and the other at the " Eastern Path ", which he had built, so that these will not be confused with the aboriginal constructions. We neither saw nor heard of any native causeways during our hurried visit to the island, nor of the " Indian Well " at East Harbor, which originally had a circular form with funnel-shaped walls of stone.

Roatan, the largest island, has received the fewest notices. Young (1842, p. 48) states that Roatan exhibits even more proofs of Indian occupation than does Bonacca, and Conzemius examined one elaborately carved, three-legged metate, which was said to have been found near Port Royal. It was held for an exorbitant sum as the only metate of this type in good condition found on the Bay Islands. (Conzemius, 1928, p. 67.) In the Museum at Liverpool are three tripod bowls, one of which has applique decoration and a human figure looking over the rim, which are from the island of Roatan

[31] Rose, 1904, chap. 4. This little book is rare; it is not in the Library of Congress, but the library of the Pan American Union has a copy.

" found on the top of a high hill, among what appeared to the finder, Captain Fraser, the ruins of an altar ".[31a]

In 1842 Young mentioned the occurrence of abundant traces of a large Indian population on Bonacca. Near Savannah Bight he reports a large savannah containing fruit trees and an aboriginal stone wall a few feet high with fissures or rude niches made for the admission of peculiarly cut three-legged stone chairs, presumably the seats of idols.[32] As previously mentioned, Bird was fortunate enough to find and sketch what seems to be the last of these on the surface at the Plan Grande site (fig. 36). Young also describes chairs elsewhere on Bonacca that had been cut from solid rock. Conzemius briefly describes the Plan Grande site and mentions the occurrence of other erect or leaning slabs on Bonacca. He states that many of the latter have partly obliterated rude carvings, one of these being near Marble Hill. According to the same authority, ornamented granite vases of the type described by Pownall in 1779 occur on the islands. (Conzemius, 1928, pp. 66, 67; Pownall, 1779, p. 320; Spinden, 1925, fig. 1.) Spinden made a brief visit to the islands and mentions shell heaps like those near Trujillo, which contained the same type of pottery. He adds that metates occur on the islands but not in large deposits. Certain of the flamboyant newspaper accounts of Mitchell-Hedges have already been referred to.

Although it is obviously premature to attempt a detailed classification of Bay Island sites and cultures on the basis of the foregoing observations and the reconnaissance work reported in the present paper, this may be done in a very tentative manner to facilitate comparison with adjacent regions. The major archeological types so far reported from the Bay Islands are summed up in table 1.

From this tabulation it appears that the majority of known sites are on hilltops (1, 10, 12, 15, 16, 17, 19, 21), next are caves or rock shelters (3, 9, 11, 19), whereas springs or water holes (4, 5, 18) and large level sites (2, 6, 20) are less frequent. The majority of the hilltop sites seem to have been offertories or shrines of some sort; the large Plan Grande enclosure looks like a religious center, one cave on Helena like a shrine, and the fresh-water spring (18) on Bonacca was full of varied and numerous offerings. Habitation sites are surprisingly rare. Black Rock Basin, the " Eighty Acre " site, cave 1 on Helena, and possibly Plan Grande are the only ones on record.

[31a] Bollaert, 1861, p. 314, pl. 3.

[32] Young, 1842, p. 48. LeBaron, 1912, p. 222, mentions these as " immense stone chairs."

TABLE 1.—*Summary of Bay Island Sites*

Sites	Nature of site	Ceramic types present	Other important remains
1. Stuart Hill (Utila).	Ceremonial.	?	Stone causeways and pavement (?) (Rose).
2. Black Rock Basin.	Urn and skull burials, shell and refuse heaps.	Monochrome (elaborate rare, plain abundant).	3-legged and flat metates, roller pestles, stone and shell celts, mace head (?), green stone pendant, obsidian flake knives.
3. Brandon Hill Cave.	?	Polychrome I (?). Monochrome (both elaborate and plain) (red painted sherds).	Stone bowl, shell celt, obsidian flake knives, mineralized human bone.
4. Byron Cave.	Water hole (?).	Monochrome (plain).	None observed.
5. Big Bight Cave.	Water hole (?).	Monochrome (plain).	None observed.
6. "Eighty Acre" site.	Habitation and burial.	Monochrome (plain).	Low earth mounds, obsidian flake knives (probably many other types of artifact).
7. Sucsac Cay.	Habitation (?).	Monochrome (plain).	None collected.
8. Port Royal (Roatan).	Buccaneer forts, town, and cave.	None seen.	One elaborate metate reported (Conzemius).
9. Jonesville Bight.	Offertory (and burial?).	Polychrome II. Polychrome I. Monochrome (elaborate common, plain rare).	Figurine fragments, small mace head, small jade celt, green stone pendant, stone beads, chipped knife and projectile points, shell artifacts, raccoon tooth necklace, scattered human bones.
10. Dixon site.	Offertory.	Polychrome I. Monochrome (both elaborate and plain).	Figurines, copper bells, copper rings, 3-legged and flat metates, roller pestles, manos, celts, mace heads (one star-headed), green stone pendants, chipped knives and projectile points, chipped T-shaped axes, shell artifacts, many stone beads.
11. Helena Island, caves 1 and 2 (Helena).	Ceremonial (2) and habitation (1) caves.	Polychrome II. Polychrome I. Monochrome (elaborate and plain) (also unclassified polychrome pieces).	Natural stone fetish (2), mace heads, ground T axes, chipped knife blades, chipped T axes, stone beads. (Mitchell-Hedges collection contains marble bowls, green stone pendants, petaloid and plain celts, stemmed chipped points, which may have come from these sites).

TABLE 1.—*Continued*

Sites	Nature of site	Ceramic types present	Other important remains
12. Indian Hill, site 1 (Barburata).	Offertory (and burial?).	Polychrome I. Plumbate ware. Monochrome (elaborate and plain).	Figurines, figurine stools, ocarinas, incensarios, 3-legged and flat metates, roller pestles, manos, stone pot rests, marble bowls, celts, mace heads (one star-headed), green stone pendants, pottery and stone beads, chipped T axes, shell artifacts, carved jaguar teeth, obsidian flake knives, fragments of human bone. (The Mitchell-Hedges collection contains copper bells probably from this site.)
13. Indian Hill, site 2.	Offertory (and burial?).	Monochrome (elaborate rare, plain abundant).	Manos, roller pestle, oval stone bark beater, obsidian flake knife.
14. Morat Island.	?	Polychrome (I or II?). Monochrome.	One cylindrical stone bark beater.
15. Stanley Hill (Bonacca).	Ceremonial.	Monochrome (elaborate).	None observed.
16. Kelly Hill.	Ceremonial (?).	Polychrome I. Monochrome (elaborate and plain).	Jade ear spool, green stone pendant, stone beads, bird bones.
17. Pine Ridge.	?	Monochrome (plain).	Roller pestles, cylindrical bark beater, marble bowl, steatite bead.
18. Sacrificial Spring.	Offertory (probably a water hole as well).	Polychrome II (?). Polychrome I. (Mitchell-Hedges collection). Monochrome (elaborate and plain).	Figurines, steatite carving of ape on human pedestal, jadeite and green stone carvings and beads, stone bowls, mace heads (foregoing mentioned in Mitchell-Hedges account, probably much other material not listed).
19. Marble Hill Fort.	Fortification, habitation, burial caves (?).	Polychrome II. Polychrome I. Monochrome (elaborate and plain).	Steatite vessel, granite bowl, jade celt, marble ball, stone beads, oval bark beaters, shell artifacts, human teeth (in caves).
20. Plan Grande site.	Ceremonial (habitation and urn burial?).	Polychrome II. Polychrome I. Monochrome (elaborate and plain).	Earth mounds, boulder walls, erect slabs, small stone "chair," metates with legs, roller pestles, stone celts, marble bowl.
21. Michael Rock.	?	Monochrome (elaborate and plain).	None observed.

At Plan Grande erect stones like foundation walls suggest rather pretentious buildings, but elsewhere we have no evidence as to houses. The earth and stone mounds at this place suggest ceremonial structures, whereas the low earth mounds at the " Eighty Acre " site are refuse heaps containing scattered burials. Similar mounds are reported from Utila and Bonacca but were not encountered by Bird or by our party. Caves such as that on Brandon Hill and number 1 on Helena indicate only transitory occupation, but the rock shelter at Jonesville Bight was evidently an offertory. This seeming paucity of habitation sites on the Bay Islands is striking. Whether this is a definite indication that the Bay Islands should be regarded as fundamentally a religious center, like Cozumel or the Island of Sacrificios, can only be demonstrated by more thorough investigation accompanied by adequate spade work.

Nor is the exact nature of the hilltop shrines or offertories altogether clear. The only undisturbed place of this sort encountered—the Dixon site—contained indubitable, carefully guarded offerings, but showed no trace of human burial, cremation, or deposition of partly cremated remains in jars. The other hilltop sites of like nature containing similar material, such as the Jonesville Bight, Indian Hill, and Marble Hill offertories, all contained scattered, fragmentary human remains, but all these had been too badly disturbed to determine their original nature. The best explanation seems to be that these sites were fundamentally shrines where devotees deposited offerings, ranging from the elaborate votive cache at the Dixon site, to ordinary utensils, model vessels, and handfuls of potsherds. In addition, to judge from the urnlike vessels at certain of these sites, in conjunction with small fragments of human bone, these offertories also served as the final resting place for disarticulated or partially cremated remains of certain priests or nobles. Whether these remains were placed in urns or special vessels must be determined by future discoveries. At present definite evidence suggesting cremation on the Bay Islands is confined to the few slightly charred human bones which Bird found in burial urn 2 at Black Rock Basin on Utila. Thanks to Bird's painstaking excavations on that island, the nature of certain urn and separate skull burials is clear. In the light of adjacent regions one would be inclined to suspect that these burials in old middens served for commoners, whereas priests and persons of distinction may have been disarticulated or cremated and certain portions of their remains placed in the offertories. The possibility of class distinctions in regard to the different ceramic and artifact types at the different offertories will be mentioned later. All these matters, however, require more extensive and careful work before they can be fully answered.

The occurrence and association of the known Bay Island ceramic types are indicated in table 2. Plain monochrome ware is present at all the sites and occurs by itself at five sites (table 2). The latter sites, with the possible exception of Pine Ridge, are either places of habitation or water holes. Elaborate monochrome is the next most abundant and occurs at 13 sites, nearly all of which seem to be ceremonial. These two wares blend imperceptibly into one another and are certainly related. At Black Rock Basin, and again at Indian Hill site 1, there were stratigraphic indications that the plain type predominated in the earlier periods. The more elaborate monochrome ware seems to have come into vogue later and is most often associated with Polychrome I. Polychrome I occurs definitely at eight sites, all of which

TABLE 2.—*Association of Bay Island Ceramic Types*

Site:	2[a]	3	4	5	6	7	9	10	11	12	13	15	16	17	18	19	20	21	Totals
Plain Monochrome	×	×	×	×	×	×	×[b]	×	×	×	×	×[b]	×	×	×	×	×	×	18
Elaborate Monochrome	×[b]	×	..	..	..	..	×	×	×	×	×[b]	×	×	..	×	×	×	×	13
Polychrome I	...	×(?)	..	..	..	..	×	×	×	×	...	.....	×	..	×	×	×	..	9
Polychrome II	...	.....	..	..	..	..	×	..	×(?)	...	...	×(?)	..	..	×	×	×(?)	..	6
Plumbate	...	.....	..	..	..	..	...	..	.....	×[b]	...	.....	..	..	..	..	.....	..	1

[a] Site numbers given in table 1.
[b] Rare.

are ceremonial. At Indian Hill site 1, it occurred in the upper portions of the ceramic deposit in association with elaborate monochrome. These two wares are also definitely related in form and decoration. Definite Polychrome II was found in small quantities at just three sites. All of these were ceremonial in nature. Stylistically, Polychrome II suggests a degeneration or simplification in style from Polychrome I, to which ware it seems definitely related. As to sequence, there is therefore some stratigraphic evidence that plain monochrome precedes elaborate monochrome ware and Polychrome I. The elaborate monochrome is evidently contemporaneous with Polychrome I. On stylistic grounds Polychrome II appears to be later than Polychrome I, but there are no stratigraphic clues as to its age. Finally, the Mitchell-Hedges collection with its considerable number of aberrant ceramic pieces indicates that the above is at best only a partial picture of the development of pottery styles in the Bay Islands.

The above evidence in part answers the question as to whether ceramic differences in offertories indicate differential age or social status. Site 2 on Indian Hill contained large amounts of plain monochrome pottery, only a smattering of elaborate monochrome, and no polychrome pieces. It also lacked copper, green stone pendants, or beads and generally suggested a simple culture. Since plain monochrome is early at site 1, Indian Hill, and at Black Rock Basin, I incline to regard site 2, Indian Hill, as an early offertory. From the uniformity with which Polychrome I and II pieces occur on ceremonial sites and are absent from habitation places, it seems probable that these painted wares were made or acquired for ceremonial or similar special functions. The fact that they are entirely lacking in a definite offertory at least suggests that they were not in vogue when the votive deposit was built up. Similarly, green stone and copper artifacts nearly all come from ceremonial sites or offertories, and in the great majority of cases these are associated with the most elaborate monochrome and the polychrome wares. The presumption is strong that this is a relatively late complex. At the Dixon site, where very simple monochrome pottery greatly predominated, the central votive cache consisting of a Polychrome I vase full of copper bells and ornate green stone ornaments was probably a later addition to an older offertory. It is difficult to explain on other grounds the discrepancies in artifact types occurring here.

As a whole, the present evidence suggests that with all its apparent diversity, Bay Island culture can be regarded as a more or less homogenous unit. Ceremonial and habitation sites share the same artifact types, although certain classes predominate in each kind of site. Thus, plain monochrome ware, so abundant in habitation sites, occurs also at all offertories or shrines. Similarly Polychrome II, Polychrome I, and elaborate monochrome have all been demonstrated as definitely linked, and the two monochrome wares are closely related. This indicates that the majority of Bay Island shrines were for the most part used by Bay Island peoples over a considerable period of time, rather than by visitors or pilgrims from elsewhere. The observable ceramic development alone postulates an occupation of considerable duration. When one comes to analyze the components of this local culture, however, it is clear that they have been drawn in from a number of sources, some of which must have been rather distant. This is equally true of the widespread and relatively simple culture manifested in the habitation sites and older shrines, and in the apparently later polychrome pottery, copper, and green stone artifact complex at other shrines. To approach this problem we must look farther afield.

At the present time it is difficult to institute adequate comparisons between the archeology of the Bay Islands and that of closely adjacent regions. This is due in part to the fact that the Bay Islands are incompletely known, but even more because they lie on the northern border of an extremely important but little-worked archeological field, including all of northeastern Honduras and northeastern Nicaragua. From Copan in the north to the lakes of Nicaragua in the south is an air-line distance of nearly 400 miles across a territory apparently rich in cultural remains. None of these sites has been scientifically excavated, and many have not even been located on the map. Yet so prolific are the cultures of this area that a type-by-type comparison of Bay Island artifacts with those on record through purchase or cursory excavation from this larger region would fill a considerable volume. All that can be attempted here is to indicate in some manner the possible relationship of certain Bay Island cultural types to those of the areas designated. For present purposes the latter may be somewhat arbitrarily classified as (a) northern Honduras east of Ceiba, (b) the Uloa River region, (c) Copan and other Maya sites, (d) the interior of Honduras, (e) western Nicaragua and northern Costa Rica, and (f) eastern Nicaragua.

Northern Honduras east of Ceiba

The coastal region of Spanish Honduras has been only superficially investigated and, with one exception, no scientific excavations have been made.[33] There are numerous large sites consisting of earthen mounds, either isolated or formally laid out around rectangular courts. Rubble walls and crude stone work occur at some of these. Spinden also reports numerous circular or oval villages with palisades and moats. At Bonito Farm, south of Trujillo, he examined an oval boulder fortification containing a rectangular mound ascended by rough slab steps. Pottery, chipped knives, and green stone celts were found here. Shell heaps occur near the coast, and these contain both extended and flexed burials. He does not mention urn burials, but there is a strong probability that they occur, since great urnlike vessels and human bones are frequently washed out along the banks of the larger rivers. Certain of these, such as the Aguan and Paulaya, have great masses of pottery and other cultural detritus in their banks. Votive caches appear to be rather numerous, especially along small streams, but unlike those on the Bay Islands they seem to contain

[33] See Pownall, 1779; Rogers, 1782; Spinden, 1925; Popenoe, 1931; Conzemius, 1932, pp. 42-46; and Strong, 1934 a, b. Bird excavated several shell heaps near Trujillo for the American Museum of Natural History, but the results are as yet unpublished.

elaborately carved stone bowls, elaborate metates, great carved stone "tables", but little or no pottery. The bulk of the ceramics from coastal sites and in local collections are of the monochrome, brown to red type with grotesque plastic ornaments. I have not seen any of the elaborately incised type so strongly suggesting Uloa River marble bowls, however. Painted pottery is less abundant but does occur. Spinden found pottery with red and yellow sizing near Olanchita, and crude figurines near Maloa. In shell heaps near Trujillo Bird got considerable pottery similar in form and color to Bay Island Polychrome II. This mainland ware, however, is considerably richer in color, especially dark reds, and long tripod feet modeled like alligator heads seem to be fairly common. At Esperanza on the Bonito River I found a few sherds of Bay Island Polychrome I.

A little carved jadeite and great numbers of green talc artifacts occur in this coastal region. Near Puerto Castilla local diggers have obtained great numbers of large and small anthropomorphic celts (pl. 12, *c*) and beads, especially very massive and long cylindrical types made of green talc. Many other Bay Island artifact types occur; elaborately carved stone bowls and metates are common, but copper artifacts, mace heads, bark beaters, pot stands, and figurines seem rare. Giant stone metates or tables and enormous carved roller pestles occur at sites just back from the coast. Small grotesque pottery masks, of the type figured by Rogers many years ago, and small boot-shaped pots occur in mounds on the Black River. The Museum of the American Indian has several chipped **T**-shaped axes, with a perforation through the blade, from the Paulaya River. When discovered by the Spaniards, this general region seems to have had a population of Jicaque and Paya peoples interspersed with some Nahuatl groups.

The Uloa River Region

For present purposes this area includes the lower valleys of the Uloa and Chemilicon Rivers and the district around San Pedro Sula. Some reconnaissance work and a little excavation has been accomplished here.[34] Cut stone architecture or elaborate stone structures have not been reported. Formally arranged mound groups seem to be

[34] Gordon, 1898 a; Blackeston, 1910 a, b; Steinmayer, 1932. Vaillant, 1927, pp. 266-271, has reclassified the pottery obtained by Gordon. An important paper by Dorothy H. Popenoe, "Some Excavations at Playa de los Muertos, Uloa River", is in process of publication by the Peabody Museum, Harvard University. I have not seen this paper but have read the brief and highly suggestive "archeological setting" provided for it by Vaillant.

rather common. These are usually of earth, often with a burned red clay core and sometimes capped or surrounded by rough stones. Rough stone causeways and encircling walls occur. One mound contained a stone vault with several jars full of offerings, including jade plaques, beads, and clay figurines. Broken pottery occurs in most of the mounds. Stone carving on a large scale does not seem common, but Gordon figures a crude anthropomorphic statue of Chorotegan type from near the Uloa.

On both rivers occur "Playas de los Muertos" (beaches of the dead), which are particularly extensive on the Uloa between Santiago and Santa Anna. In the river banks near such places Gordon and Blackeston found mixed human bones and artifacts to depths of over 20 feet. Blackeston obtained two dolichocephalic skulls from here.[35] Steinmayer notes that the graves of nobles are stone-walled and distinct from those of commoners. He also describes the finding of one of the elaborately carved Uloa marble bowls in this vicinity. According to Spinden (1925, p. 540) two of these marble vases were found near Santa Anna in a grave containing a typical Costa Rican amulet of the type imported into Chichen Itza during the twelfth century. This tends to date the marble bowls as a late type.

Mrs. Popenoe opened a number of undisturbed graves at one of these playas and was able to clearly separate the monochrome from the polychrome pottery wares. These have hitherto always occurred mixed, owing to redeposition by the river and other causes. Gordon obtained no definite stratification but noted that the deeper deposits were the richer. Urn burials probably occur, but I know of no definite record. When Mrs. Popenoe's data are available, both ceramic and burial types will be better known.

At present little that is definite can be said regarding Uloa monochrome wares save that many Bay Island monochrome types are present. These include tripod vessels, cylindrical handled incensarios, whistles, and flat and cylindrical pottery stamps. The Uloa whistles and stamps are both more abundant and elaborate than the few on record for the Bay Islands. The Uloa figurines and pottery heads, which are both modeled and molded, are better made than those of the Bay Islands, where figurines made in molds seem to be uncommon. The grotesque applique types of the Bay Islands are not on record for the Uloa district. Pottery labrets from this area are very similar to

[35] From near Santa Anna came a deformed male skull with filed and inlaid teeth of Maya type and with a jade bead in its mouth; Blom, Grosjean, and Cummins, 1933.

those of shell from the Dixon site. Tetrapod or shoe-shaped vessels, vessels with neatly engraved panels of Mayoid cast, and the spouted chocolate pot, forms which occur in the Uloa, are not on record for the Bay Islands.

The polychrome wares from the Uloa are abundant and complex. In the Vaillant classification, Uloa Polychrome I and II suggest degenerate early Maya types. One vessel from Helena, collected by Mitchell-Hedges, which has a white slip, crude red processional figures, and a panel of skeuomorphic glyphs, and also some sherds from there (pl. 18, fig. 1, *c*, *c*) in our collection, suggest these styles. Uloa Polychrome III and IV, however, find numerous analogies in Bay Island Polychrome I. All three wares seem to have the same basic colors, and all have design areas around the neck set off by black lines, conventionalized plumed serpent, or elaborate step or other similar painted designs. Bay Island Polychrome I and Uloa Polychrome III and IV ceramics appear to be thin, without swollen lips, and all three make use of similar animal head lugs. Owing to the rarity of complete vessels, total forms cannot be compared. Although there seems to be considerable resemblance here, the Uloa Polychrome III and IV wares appear to be richer in color and more crowded in design than the Bay Island Polychrome I.

According to Vaillant, Uloa Polychrome V develops out of IV by a simplification of patterns and a thickening of lines. Globular olla shapes occur that have low necks and handles with knobs on them. Although sometimes richer in color, the designs are more isolated and geometric, consisting of frets, dots, circles, wavy vertical lines, etc. This ware, Uloa Polychrome V, very definitely suggests Bay Island Polychrome II. Plumbate ware in the Gordon collection consists of two Type III effigy vessels, one of which has a Chorotegan body. This ceramic type seems to fall between Polychrome II and III in the Uloa series.

Of the ceramics of the region, Vaillant summarizes as follows (1927, p. 271):

There are in western Honduras, isolated fragments that suggest an occupation of the country by people with a culture affiliated to that generalized stage of human development in Middle America known as the "Neo-Archaic". Scattered through the Uloa valley are the remains of people who made a diverse and variegated pottery. The polychrome phases of this development represent degenerations of late Old Empire Maya pottery (Uloa Polychrome I) and a varied and complicated series of forms and decorations like those in the early (?) Pipil horizon in Salvador (Uloa Polychrome II-IV). Another style is like that made by the late (?) Pipil and the Lenca-Matagalpa in Salvador (Uloa Poly. V). A mass of undecorated [unpainted?] pottery exhibits, in the main, features more

Chorotegan and Neo-Archaic than Maya, although unpainted Maya wares are very imperfectly known. The trend of the pottery suggests the years after the fall of Copan, although what the successive stages are is conjectural.

By correlating the Uloa polychrome series with the dated ceramic series from Copan, Vaillant tentatively places Uloa Polychrome III and IV subsequent to the sixth century and Uloa Polychrome V about the close of the twelfth century. Plumbate III in the Uloa is placed immediately prior to Polychrome III.

In the present state of knowledge these datings cannot be regarded as final, but they are extremely suggestive as regards the Bay Islands. If the stylistic relationship here suggested between Uloa Polychrome III and IV and Bay Island Polychrome I on the one hand, and Uloa Polychrome V and Bay Island Polychrome II on the other, proves to be correct, then Bay Island Polychrome I may be approximately dated. Since the impetus of both these polychrome styles seems to have come from the west, their vogue in the Bay Islands would probably be of later date than the vogue of their ceramic prototypes in the Uloa Valley. This suggested time sequence fits in very well with the circumstances under which they occur on the Bay Islands, and the association there of Plumbate ware and Polychrome I offers further confirmation.

Work in metal seems to be rather rare in the Uloa valley. Gordon found none, but Blackeston (1910 b) reports on a great cache of elaborate copper bells from a cave. Many of these closely resemble Bay Island types. Steinmayer gives an analysis of a copper celt. The finest objects of carved stone are the exquisite marble bowls, but stone faces and other carvings occur. Numerous jade, jadeite, and talc heads and plaques occur, some of which are practically identical with the small elaborate heads from the Bay Islands. Oval and square bark beaters, obsidian flake knives, and perforated conch shells have been reported. The Uloa valley was thickly populated, presumably with scattered Jicaque, Lenca, and Maya groups, when the Spaniards first visited it in 1533, and with adequate excavation should yield a long and important record of human occupation.

Copan and Other Maya Sites

It is a far cry from the rudimentary temple enclosures, rough stone foundations, crudely marked monolithic monuments, and earth mounds of the Bay Islands to the enormous mounds, stone temples, sophisticated and luxurious stone carvings, and dated stelae of Copan. It is significant, however, that in the rubble foundations of certain early structures of Copan and in the adjacent forest occur rudely carved stone figures of Chorotegan style similar in type to those from Costa Rica, Nicaragua, and the highlands of Guatemala.[36] The structural comparison here made holds for all the great Mayan cities, whereas the smaller sites, especially those of British Honduras and northern Spanish Honduras, in their comparative simplicity somewhat lessen the gap. Natural shrines, similar to those in the Bay Islands, are apparently rather widespread throughout the Maya territories, especially in the later periods. Gann describes one of these just south of Chetumal Bay where Caucasian artifacts, late Maya pottery, jade, copper bells, and stone knives occurred. "The little island was not a burial-place, for not a human bone was found upon it, but rather one of those 'sacred places' found throughout the Maya-Toltec area, where it would appear that offerings were made to the gods, by being simply laid on the surface of the ground within a space covered by large stones. Most of these offerings, but not all . . . . were 'killed' before being offered, by being broken into fragments." The custom of making offerings at certain traditionally or scenically significant places is not confined to Middle America, but the above correspondence to Bay Island shrines is particularly close. The fact that far more ceremonial sites than habitation sites are known in the Maya area, as is true in the Bay Islands, may be more of a commentary on archeologists than on native customs.

At Copan, burials occurred in at least one mound and in numerous stone-lined vaults or tombs. Maudslay found many redware dishes and pots containing human bones and lime in one sepulchral vault. The vaults, which were in the main structures, under courts, or in small mounds, contained the richest offerings. In mound 36, both individual and mixed burials with simple gifts were encountered. Vaillant notes that this mound contained so many excellent potsherds that ceremonial breakage is suggested. In caverns about 4 miles from Copan masses of partially cremated human bones were found, and calcined human infant and animal bones occurred in jars. The pottery

[36] Owing to the depth and complexity of this field the present comparison can obviously have only suggestive value. The sources for specific statements made herein follow in the order cited: Morley, 1920, pp. 421-422; Lothrop, 1921, p. 316, 1926, p. XXVI, 1927 a, pp. 204, 197; Gann, 1927, p. 54, 1918, pp. 127, 75, 86, 61, 120-122, 1914-1916, p. 37; Maudslay, 1889-1902, vol. I Text, p. 31; Gordon, 1896, pp. 26-32, 1898 b; Vaillant, 1927, pp. 228, 227-262; Ricketson, 1925, pp. 391-392; J. E. Thompson, 1931, pp. 326, 332; Mason, 1928; E. H. Thompson, 1897 a, pl. 13, fig. 2, 1897 b, pl. 7, fig. 1 and pl. 8, fig. 2; Merwin and Vaillant, 1932, pp. 62-83.

associated with these cremations is a rather high-grade but plain ware in which bottle-necked forms are common. It is sparingly decorated with fluting or incision. This ceramic type does not occur in the main ruins and is presumably older.

Elsewhere in the Maya area cist or tomb burials and inhumations in mounds occur. Certain individuals were partially cremated and their ashes deposited in urns or vases. In northern British Honduras, Gann encountered three types of Maya burials, the poorest consisting of 40 to 50 flexed individuals in large flat mounds; single individuals with better gifts in high mounds; and third, "priests or caciques" in stone chambers containing painted vases, green stone ornaments, etc., in large high mounds. He found one example of half-burned human fragments in a large pottery urn. Eric Thompson found suggestions of what may have been urn burials in association with Pre-Holmul I pottery in the southern Cayo district, and Gann found a skull in what appears to be a Holmul I vessel in northern British Honduras. Gann also found 40 human skulls disposed in rows under a stone chamber in a mound in northern British Honduras. This suggests the orderly skull burials in Utila but appears to be rather unique in the Maya field. In general, skull burials seem rather rare, but urn burial in one form or another may have been a rather early ingredient of Maya culture.

On the basis of association with stelae caches, tombs, or other dated structures (and where these are lacking, on purely stylistic grounds), Vaillant has classified the ceramic collection from Copan into three major divisions (Copan I-III). Aside from the complete vessels, the sherd collection in the Peabody Museum was probably selected to obtain the finest pieces; hence various monochrome types may well be lacking. As the plain types from Copan would presumably show more resemblances to Bay Island ceramics than do the incomparably better polychrome wares, the collections are hardly comparable. Moreover, the matter is extremely complex, and to suggest correlations, should any exist, on the basis of descriptions and photographs would be more than hazardous. This stricture applies equally well to the correlation earlier suggested between certain Uloa polychrome and Bay Island polychrome wares, but there the geographic and cultural gap is not so extreme, and the attempt may be more justified. It may be noted that according to Vaillant's tentative scheme the earliest Uloa wares (Polychrome III-IV), which seem to resemble Bay Island Polychrome I, are apparently later than Copan III.

According to Vaillant, the occurrence of a single incised sherd and the crude sculptures previously referred to suggest that the earliest occupants of Copan derived the basis of their culture from some section of that shadowy, widespread civilization which embraced the various components at present designated as the Q complex. From the same evidence Lothrop is more specific in postulating that the antecedent culture at Copan was Chorotegan. It is of interest that tomb 10, containing vessels of Copan II type, also contained vessels and effigy jars of Nicoya Polychrome and Plumbate ware. An incense burner with a cylindrical handle was found in tomb 6. Copan III pottery includes Chorotegan pear-shaped forms (which also occur on the Bay Islands) and vertical braid panels around the neck (common in Uloa polychrome wares), and is without glyph bands. Maudslay (vol. I, pp. 22) figures two elaborate pot stands of coarse red pottery from Copan. The last periods at Copan, according to Vaillant, suggest that Chorotegan peoples may have lived in the buildings and occupied the tombs. According to Spinden (1915) and Lothrop (1927 a), Maya art of the " Old Empire " type survived a long time in eastern Salvador, finally fusing with the later Pipil cultures. It is this stylistic survival and fusion, subsequent to the " fall of Copan ", which seems to have passed from Salvador into the contemporary Uloa valley polychrome types.

To attempt a comparison between Bay Island ceramics and those from all other Maya sites is a task far beyond my capacity. The study of Maya ceramic growth, although still in its infancy, already indicates that there were several basic ceramic divisions within this one field. Moreover, the pottery available from most of the major sites is mortuary in type and hardly gives a representative sample of the average range. A few scattered notes, however, may be of value. In the Pre-Holmul I, and, to a less extent, in Holmul I pottery obtained by Eric Thompson in the southern Cayo district of British Honduras are certain resemblances in form, surface treatment, rim shape, incised and raised decoration, and handles, to the plain monochrome ware of the Bay Islands. The same can be said of the cruder vessels from caves in this region collected by Mason. These include large, crudely incised ollas, bowls with annular feet, and knobs employed for decoration. From northern British Honduras Gann obtained figurines seated on stools, crude figures attached to incense burners shaped like egg cups, pottery stamps, and a modeled pottery head with a socket, which in purpose vaguely suggests a handled head (fig. 13) from Roatan. The effigy human foot and leg vessels that he obtained in the same region have southern affiliations, though the type has not yet been reported from the Bay Islands.

In Yucatan E. H. Thompson collected small, monochrome, model pots from the chultunes of Labna that suggest Bay Island forms; and from the cave of Loltun he figures incised fragments, rims, legs, and handles similar to Bay Island monochrome sherds, both plain and elaborate. The pottery of Holmul I type collected by Merwin is mortuary in nature and perhaps too fine to be representative of the ware generally. According to Vaillant, Holmul I pottery includes bowls with round tetrapod supports, bowls with concave bottoms, pot stands, spouted pot forms, and annular bases, and there is sparing use of complicated design forms. The pot stand, he points out, is rare or lacking in the valley of Mexico but is common in Costa Rica and is apparently linked with the annular base. The pot stand of stone and various forms of the annular base occur in the Bay Islands. In the elaborate monochrome vases with designs like Uloa marble bowls the annular base and concave bottom are combined. Some similarities in form also exist between Bay Island monochrome tripod vessels and Holmul tetrapods and tripods. In painted design there are some resemblances between Holmul I and Bay Island Polychrome I in regard to degree of isolation of patterns, conventionalization, and combination of rectilinear and curvilinear motifs, but the forms of these two wares are widely different. The tetrapod foot and the spouted chocolate pot type, characteristic of Holmul I, are apparently absent from Bay Island sites. Thus, although there appear to be no correlations between early Holmul and any Bay Island ceramic types as a whole, there are certain traits which they share in common.

Vaillant states that Holmul I pottery generally does not resemble subfloor ceramics from Uaxactun. Holmul I and Huaxtec ceramics share the pot stand and annular base but are otherwise very different. The Holmul pottery tradition, he concludes, was apparently originally derived from the southeast and appears to be most closely connected with early forms from Salvador. Although qualitatively Holmul I might be considered on the "archaic" horizon, ethnologically it has no connection with the early cultures of the Valley of Mexico. The forms fit into a complex of shapes that are widely distributed through Central and South America but are not so characteristic of the Valley of Mexico.

From the foregoing sketch it is obvious that any adequate ceramic comparison must include a résumé of the pottery of Salvador, of the highlands of Guatemala, and of the Valley of Mexico, in addition to that from other Maya sites, but this is far beyond our present scope. All that can be suggested here is that certain of the Maya ceramic divisions, in their earlier and in their simpler manifestations, share certain traits which apparently persisted later in the Bay Islands.

The nonceramic culture of the Maya, aside from temples, sculptures, and stelae, has been little stressed. Just as ceramics were for so long overshadowed by stelae, so now the simpler artifacts are in danger of being overshadowed by ceramics. Any deep understanding of Maya culture must result from a correlation of all these factors. A brief sketch of small, nonceramic artifacts from the same sites that were mentioned in regard to pottery may give a sample for comparative purposes. At Copan Morley deals almost entirely with dating, Vaillant almost entirely with ceramics. Gordon concentrates mainly on buildings and excavation, but mentions the occurrence of obsidian spear points, disks of obsidian, a beautiful stone chisel, small stone axes, obsidian knives, arrow points, jadeite disk beads, and jade inlays in human teeth. In tomb 2 occurred cut shell ornaments, pottery whistles, bone needles, and two beautifully carved peccary skulls, and in tomb 3 a horse's tooth (perhaps carried in by rodents) and jadeite ornaments. Under stelae 3 (Middle Period, date 9.11.0.0.0) occurred four small jadeite ornaments, very well cut and polished, each piece with a longitudinal hole for suspension. At least one of these, now in the Peabody Museum at Harvard, rather closely resembles certain of the turbanned figures (pl. 11, *d, e, f*) from Bay Island offertories. Tomb 11 at Copan contained several elongated oval knives of chipped white flint, of similar shape but even finer workmanship than the best from the Bay Islands (pl. 16, fig. 2, *a, b*). The metates from Copan in the Peabody Museum are of a plain rectangular type, often of lava, and the mullers are either of the roller pestle or the flat rectangular type. Maudslay collected a small green stone " death's head " with a hollow perforated back, and, in a cylindrical votive jar, found numerous shell figurines similar to those of stone that Eric Thompson obtained with Holmul V pottery in the Cayo district. Maudslay also figures (vol. 1, pls. 21, 22) jade and diopside beads, elaborate stone faces, jade buttons (pl. 12, *d, g*), and a green jade ear spool (like pl. 17, *h* in material and shape). This list is not complete as regards published material from Copan, let alone collections not yet reported on, but gives a sample for comparative purposes.

From southern British Honduras, in small Maya sites of different periods, Eric Thompson reports many votive caches consisting of vases containing offerings placed under altars and in temple mounds. Two simple but excellent small jade heads came from such caches (Thompson, 1931, pl. 32, 1-4); one of these is very lifelike and has a hollow back with holes for suspending other ornaments (like pl.

11, *n*), the other is similar but has a distorted mouth suggesting the bird bill extension which Lothrop has shown to be characteristic of certain Chorotegan statues. The most common type of jade figurine, however, seems to be a small, full-length figure with folded arms. These are rather crude in execution. Jade beads, ear spools (similar in type to pl. 17, *h*), and "buttons" (similar to pl. 12, *d*, *g*) were found. Elaborate shell carvings, disks, and beads are common. An interesting find was a mirror of iron pyrites. A small celt with an asymetrically curved blade, and a long granite celt with inscriptions carved on the blade are figured, as is also an ovoid chipped knife of honey-colored flint with two notches at one end. From Maya burial mounds and similar sites that were opened by Gann in northern British Honduras come a number of artifact types. One pair of copper tweezers (copper bells are mentioned elsewhere, 1927, at a late site in the same region), a disk of iron pyrites, small jadeite masks with hollow backs (one of these, of limestone, has the "bird bill" type of mouth), green stone beads, and ear spools (like pl. 17, *h*) occur. A green stone chisel and a celt of the same material with inscriptions; round metates with three legs; long rectangular metates with and without animal heads; and long rectangular mullers and hammerstones are listed. A beautiful soapstone lamp, believed to be post-Caucasian, is unique. Chipped artifacts include slender oval knives, long stemmed spear heads, flint arrow points with stems, a chipped flint celt, obsidian flake knives, scrapers, and large numbers of flint eccentrics. Circular shell disks and shell beads also occur. Inlaid teeth are common.

In the chultunes of Labna, in Yucatan, E. H. Thompson obtained an object of iron pyrites, a stone collar, crude stone heads, four-legged metates, roller pestles, ovoid and grooved bark beaters, stone balls, jadeite and other stone beads (some of the latter painted green), knives of obsidian and flint (some similar to pl. 16, fig. 2), both side and end scrapers of flint, an engraved bone ring, an engraved shell disk, a lip plug of shell (type?), and other shell ornaments. From the caves of Loltun, in the heart of the northern Maya area, the same excavator obtained a considerable amount of material. The following artifact types are mentioned or illustrated: simple carved pendants of stone, clay and shell; jade, stone, iron pyrites, and shell beads; elaborately carved disks and "buttons" of shell; cut and perforated shell "danglers" (pl. 15, *c*); roller pestles; hammerstones; round stones; a broken celt; a small perforated stone; bone awls and needles; broken chipped "spear" points; ovoid chipped knife blades; obsidian flake knives; round and rectangular side scrapers of flint; small, stemmed arrow points; clay pellets (from hollow feet); and filed human teeth.

Merwin and Vaillant make the following report regarding smaller artifact types from various periods at Holmul. Metal artifacts, aside from iron pyrites, are unknown here, as is the case at all early Maya sites. Ground stone includes jade ear spools (similar in type to pl. 17, *h*), jade beads, iron pyrite beads, limestone spindle whorls, cupped stones, and rubbing stones. Mullers and metates are not mentioned. Shell work is very abundant; cut conches, shell rings, shell beads, elaborately inscribed shell disks, perforated and halved shells, shells containing pigment, and partially worked and unworked shells are listed. Chipped flint implements include chisels, picks, a rough flint celt, " spearheads ", and obsidian flake knives. Bone artifacts include bone beads, perforated animal jaws, a small inscribed skull, numerous sting ray barbs, finger rings, carved jaguar and alligator canines, perforated teeth, human teeth filled with pyrites, a bird bill perforator, and worked deer bones. In addition, green paint, red ocher, mica fragments, pieces of sulphur, and a piece of slate painted red are reported.

In the foregoing lists no attempt has been made to point out temporal or local group distinctions. The material is presented solely as a more or less random sample of presumably Mayan cultures which may be compared with Bay Island collections.

Finally, a word as to the probable sequence of cultures at Copan. Dated monuments prove that the major ruins were occupied by the Maya for a period of 276 years, then the dated monuments cease. It has often been assumed that this cessation marks the fall of Copan, and that the Maya abandoned the site at that time, but there is no proof of this. Rather, the fact that the region was occupied by numerous groups of Maya speaking the Chorti dialect, when it was discovered by the Spanish in 1530, suggests that though for some reason the cultural impetus lagged, the Maya population lingered on in the region. Possibly owing to pressure from Nahuatl tribes from the highlands, who seemed to have reached Salvador and points south by the tenth century, the Maya of the Copan region may have been reduced to scattered groups living amidst the Lencan and other bordering tribes. As to the earliest culture at Copan, Lothrop and Vaillant have already been cited to the effect that it appears to have been either Chorotegan or a similar but as yet undefined civilization, distinct from the Maya.

The Interior of Honduras

Our knowledge of this great area is extremely spotty and incomplete. No large scientific excavations have been attempted, and only a small portion of the country has been examined for sites.[37] In the vicinity of Copan are many smaller Mayan sites, as well as others like La Florida on the upper Chemilicon, which may be Chorotegan (Squier, 1869; Lothrop, 1926, p. 90). Farther to the east in the Department of Comayagua are a number of ruins consisting of large, terraced pyramidal structures, often stone-faced; conical mounds of earth; and walls of rough stone. Some stone carvings and well-made painted pottery have been reported from these sites (Squier, 1858). The best known site in this region is the hilltop fortress and religious center of Tenampua (Squier, 1858 and 1869; Popenoe, 1928). This site is strongly fortified by stone walls, and the surface of the mountain is covered with numerous terraces and rough mounds. The latter fall into three main groups, which are formalized in arrangement. The mounds are of earth paved with stones, or of rough rocks paved with slabs. Crude stone stairways ascend the terraces and certain mounds. Certain of the rocks are inscribed with simple geometric patterns of a local type. Elaborately painted tripod bowls, incised vessels, an elaborately carved stone metate of the openwork Nicaraguan type, obsidian lance points, and round stone balls are reported from the site. Plain metates, with and without legs, and oval mullers in a broken condition are numerous. Squier (1869) figures a remarkable painted vessel from here, with handles and legs suggesting twisted cords. It contained chalcedony beads and a pottery whistle. Mrs. Popenoe figures another tripod vessel with somewhat similar designs in dull red and coffee colors on a cream slip. Squier noted much broken pottery and numerous burned human and animal bones at the site. Tenampua is in the heart of the Lenca country and may have been one of the Indian strongholds reduced by Montejo. The remains are very probably Lencan. Mrs. Popenoe found little to suggest Mayan and a great deal to suggest Nicaraguan and Costa Rican influences.

Proceeding farther to the east into the Department of Olancho, one encounters other ruins, though none appear to be so impressive as Tenampua. On the Olancho and Guyape Rivers, in the general vicinity of Juticalpa, are several sites that were examined by the Smithsonian Expedition in 1933. These include one at a place called Dos Quebra-

[37] Sources cited are: Squier, 1858, pp. 133-139, and 1869; Spinden, 1925; Popenoe, 1928; and Strong, 1933 a.

das, where there are an enormous number of earth and stone mounds covering a very large area. Most of these mounds are small, suggesting house mounds, but some are large, ranging from 30 to 40 feet high. One mound is covered with big granite slabs, many of which formerly stood erect. The largest, about 12 feet high, had recently been knocked down by lightning. Broken pottery is abundant at the site. Most striking are large vessels of composite silhouette, which have long tripod feet. The feet are hollow, containing rattles and are often modeled to represent alligator or reptile heads. Large bowls with restricted orifices have vertical strap handles with small conventionalized manatee lugs at the bend. These vessels have a dull yellow or orange slip and red and black designs. The latter are either geometric or else elaborate and symbolic, suggesting degenerate Maya types. Fragments of obsidian flake knives, a pottery ear plug, and a small green stone celt were found here. At San Marcos, on the Guyape, are large earth mounds with the same ceramic types. Here, by superficial digging, we obtained a large restorable vessel of this polychrome type (see Strong, 1934 a, fig. 54) with manatee lugs on the handle and a " braided " design below the neck. This ware is reminiscent of certain late polychrome types from the Uloa region, the Polychrome II ware from the Bay Islands, and painted sherds at various sites in northern Honduras, from Trujillo south into the interior. At both Dos Quebradas and San Marcos, monochrome pottery, similar to the less elaborate Bay Island monochrome, was even more abundant, and at several other sites in Olancho where earth mounds occurred, only the monochrome ware was noted. Other types of artifacts are rare on the surface at all these sites, but adequate excavations would undoubtedly yield a rich harvest.

North of this region in the pine country there are a number of sites, such as that near Pataste, consisting of long earth mounds forming large rectangular enclosures supplemented by conical mounds, with long stone causeways leading down steep banks to the nearest stream. Potsherds or other artifacts are rare on the surface at these sites. At La Floresta, on the headwaters of the Conquirre River, which is a branch of the Sico, is a large and very impressive enclosure of this type with an elaborate arrangement of earth mounds, large stone monoliths, and a long boulder causeway 25 feet broad, stretching down to the river. Most of the broken pottery picked up at this site was coarse monochrome in type similar to the plainer ware from the Bay Islands. A few sherds were red with simple black geometric designs. Local people said that stone celts and green stone beads had been found here. Farther north on the headwaters of the Bonito

River, in rain-forest country, an impressive three-roomed rectangular enclosure was discovered. This building, or foundation, was 105 feet long by about 40 feet wide and consisted of three rooms surrounded by well-made stone walls about 4 feet in height and thickness. The central room contained five tables or altars consisting of great flat-topped, mushroom-shaped stones, each set on three rounded boulders. These have a general similarity to three altars at Uaxactun (Gann, 1927, pp. 193, 196). In the center of the rear wall was a walled-in pit, and paralleling the west wall a cobbled ditch. Architecturally, this " Temple of the Five Tables " was the most impressive ruin we encountered. In the dense bush to the south and east were long, high mounds of stone and earth. No artifacts were found at this site. All along the upper Bonito occur small earth and rock mounds and stone-walled terraces, and monochrome pottery is abundant. Slightly to the north one comes to the strip back from the coast visited by Spinden, which has already been mentioned.

East of this traverse from Juticalpa to Trujillo is a vast mountainous and jungle-covered region, which is practically unknown. Aside from a small section on the lower Sico, Black, and Paulaya Rivers, the only sites reported on are an offertory on the upper Plantain visited by Spinden (1925, pp. 538-539) and some mound groups on the middle Patuca, which we visited in 1933. Spinden does not describe any ruins but mentions the occurrence of stone bowls with animal and bird heads, and great metates and slabs similar to those at Mercedes in Costa Rica. Local tradition locates the famed " White City " of the Paya in the region of the upper Plantain. In 1933 we discovered a very large mound site about 100 miles up the Patuca River at Wankybila. This consists of a complex arrangement of great mounds, some 100 yards long and 30 feet high, around a series of plazas. Excavation showed that the mounds were of earth with cores of burned red clay. The pottery from this site was mostly monochrome, red to brown in type, consisting of broken bowls with a basal ring and loop handles or vessels with three short, cylindrical or long, curved conical feet. A small proportion of the ware had a dull red slip and simple black line decoration. Elaborate feet and lugs were rare. Other artifacts included three-legged metates, a small green stone bowl (Strong, 1934 a, fig. 52, *c*), several bevelled slate disks (one of which had well-carved heads on it), roller pestles, and crude quartzite scrapers. On the Wampu, and on a branch of the Cuyamel, we found small earth and stone mounds with coarse monochrome pottery. A mace head and a small stone stool with an animal head from the Wampu (Strong, 1934 a, fig. 52, *b*) are of interest.

This immediate region is occupied by the Sumu Indians at the present time.

If we consider the area as a whole at the time of the conquest, Maya and Lenca groups appear to have been interspersed in west-central Spanish Honduras. The Lenca appear to have held the greater part of central Honduras and eastern Salvador, extending around the north side of the Gulf of Fonseca on the Pacific coast. The Jicaque occupied the Atlantic region from just west of the Chemilicon River east to the vicinity of Trujillo. The Paya bordered them to the east and the Sumu reached west just across the Patuca River. Scattered through central and eastern Honduras at this time were a number of apparently immigrant groups speaking Nahuatl languages. The Miskito territory at that time probably extended north only to about the vicinity of Cape Gracias á Dios.

Western Nicaragua and Northern Costa Rica

Thanks to the painstaking excavations and publications of Hartman, Bransford, and a few others, the archeological outlines of this region are fairly well known.[38] From the archeological, and to a certain extent from the physiographic, standpoint this province may be divided into two parts, the Pacific and the Highland regions. The Pacific region includes western Nicaragua and the territory around the Gulf of Nicoya in Costa Rica. The Highland region incorporates the northern interior of Costa Rica and stretches eastward to the Atlantic. In the sixteenth century the Pacific region was occupied in order from north to south by peoples of Nahuatl, Maribio (Subtiaban), Chorotegan (Chiapanecan), Nahuatl, and again Chorotegan (Chiapanecan) speech. Of these the Maribio and the Chorotega appear as the oldest occupants, while the Nahuatl peoples seem to have been relatively late comers. In the same period the Highland region was occupied by a number of tribes, commonly designated as the Guetar, speaking Chibchan languages.

Of the major remains of the Pacific region the large stone statues characteristic of the Nicaraguan Lakes are perhaps the most striking. Bovallius figures many of these. The commonest types include human

[38] Literature cited: Bransford, 1881; Bovallius, 1886; Hartman, 1901, 1907 a, and 1907 b; and Lothrop, 1921 and 1926. The last reference, Lothrop's monumental work, "The Pottery of Costa Rica and Nicaragua", published by the Museum of the American Indian, Heye Foundation, incorporates the results of the earlier studies. Lothrop sums up the historical, linguistic, ethnological, and archeological data, and the present very brief synopsis is for the most part condensed from his masterly presentation.

forms with alligators or animals on their backs or shoulders, seated human figures with an animal head on the shoulders, human figures with an animal on the shoulders whose jaws enclose the human head, a man with a large gorget on the breast or in the hand, a man seated on a tall column with a tenonlike appendage on his head, seated statues with crossed arms, a seated female figure holding a child, and a figure whose lower face is covered by a projection suggesting a bird's bill. Lothrop (1921) has shown that the type centers in Chorotegan territory in Nicaragua and Costa Rica but also occurs, apparently at a very early period, in the highlands of Chiapas and Guatemala and in Honduras, where statues of this type were found in early structures at Copan, and elsewhere in the country. The miniature carving found by Mitchell-Hedges in the Sacrificial Spring on Bonacca (fig. 37, *h*) is of this type. The larger statues find stylistic resemblances in carved jades and decorated pottery of Chorotegan manufacture.

Petroglyphs, ranging from simple linear figures to complex interwoven patterns, occur in this region. Lothrop points out resemblances between these and certain types in northern South America and the West Indies. Flat-topped mounds made up of stones or earth, often surmounted by stone statues, were probably used as places of sacrifice. Low stone and earth mounds served as house foundations, but there are no records of temples occurring on mounds. Circular mounds of earth and stone, from 20 to 40 feet in diameter and not more than 6 feet high, served for burial purposes. Isolated statues or stone slabs with petroglyphs often occur in or around the base of these mounds. Refuse and shell heaps have been reported. Oviedo tells of a shrine on the summit of a volcano where Chorotegan *caciques* went to consult an oracle. There was a heap of excellent pottery deposited at this shrine, mostly broken, but some vessels were complete.

Urn burial was very common in this area. Bransford figures three types of urns, foot-shaped, circular, and boat-shaped. Complete, partial, and cremated human skeletons with simple gifts are found in these urns. On the peninsula of Nicoya inhumation, often in a mound, was practiced. Stone graves and graves marked by slabs occur at certain sites.

The majority of the known artifacts come from graves. Metates are common, and Hartman (1907 a) distinguishes a type with three circular legs and another with three elaborately carved triangular legs often with a projecting animal head at one end. The former are usually decorated with animal figures, the latter with geometric patterns. The excellent carvings and open work on the stone metates of this general region is exceptional. Manos are usually of greater length than the grinding plate. Carved jade and green stone ornaments are common, and anthropomorphic celt-shaped amulets (like pl. 12, *c*) are extremely abundant. Small effigies, labrets, and long tubular beads of jade or green stone are common. Circular slate disks with central and marginal perforations, rectangular stone gorgets, and stone ear spools (like pl. 17, *h*) occur. Stone mace heads are very common, and some of these are very complex, others simple. Hartman (1907 a, pl. 31, fig. *a*) shows a mace head almost identical with the mammiform specimen from the Dixon site on Roatan (pl. 19, fig. 1, *c*). Star-headed types also occur in Nicaragua and Costa Rica. Atlatl pegs (similar to pl. 11, *l*) are very characteristic. A long-handled round bark beater and a discoidal grooved form both occur. A specialized stirrup-shaped rubbing stone is rather unique. T-shaped chipped axes and numerous variants of this type occur. Hartman (1907 a) shows both ovoid and petaloid polished celts. The double-bitted stone ax is another specialized type. Gold ornaments are rather rare and, when found, are often of Chiriqui types. As Lehmann (1910) points out, the range of gold and jade here seem to be rather mutually exclusive. Copper work is apparently rare or lacking.

The ceramics of the Pacific region have been exhaustively analyzed by Lothrop, but it is impossible to go into any detail here. All that can be said is that the Bay Island Polychrome I ware shares characteristic forms, colors, and many of its design motives with the Nicoya Polychrome ware which centers in the Pacific region. Bay Island Polychrome I ware shares numerous details of form and decoration with certain Uloa polychrome types and is also similar to Nicoya Polychrome. Until sufficient Uloa polychrome pieces are on record for visual comparison, the strongest affiliations of Bay Island Polychrome I must be in doubt. Although there are numerous and striking resemblances to certain of the Pacific intermediate wares, and especially to the monochrome types, the Bay Island monochrome ware as a rule finds closer affinities in the Highland monochrome pottery. Pottery whistles and painted figurines from the Pacific region are generally better made than the monochrome examples from the Bay Islands. Certain figurines seated on stools, and various crude or grotesque monochrome figurines, especially those from Zapatero Island, are fairly close to those from the Bay Islands (see Lothrop, 1926, vol. 2, fig. 165 and pl. 132, *c*, *d*). Cylindrical pottery stamps and pottery labrets (like those of shell, pl. 15, *h*-*m*) resemble Bay Island forms.

In the central valleys of the Highland region mounds of refuse, often containing cist burials, are the most characteristic signs of aboriginal occupation. On the Atlantic coast mounds are so grouped as to enclose courts or series of courts, which is suggestive of the north. Certain of the latter mounds have been made by filling stone enclosures with earth. Low platform mounds and hut rings of stone occur. The Nicaraguan or Chorotegan types of statue and examples of the Chacmool type are on record for the Highlands. Hartman has shown that these were set on the top of the walls forming the sides of mounds. Stone slabs with elaborately carved edges served as grave markers. Rectangular stone cists are the most characteristic places of burial. These may occur in mounds or within hut rings. Secondary burials in small cists and extended burials in the larger type are common.

Metates are oblong and have four legs with a ridge around the edge, which necessitates a short mano. They are elaborately carved and usually have an animal head and curled tail projecting at respective ends. The type is practically identical with that of the Chiriqui area. Wooden and stone stools also occur. Stone and pottery pot stands are frequently found and a few carved stone bowls are on record. Small standing human figures, human heads, and seated figures with their arms across their knees, carved in stone, are common. In the Highland regions the polished celt is usually diamond-shaped in cross-section, but petaloid forms occur and both single- and double-bitted flaked celts are found.

Highland Polychrome pottery is apparently an offshoot of Nicoya Polychrome, somewhat modified by local traits and by influences from the art of Chiriqui. As such, it shows some similiarities to Bay Island Polychrome I but apparently not so many as does Nicoya Polychrome. The Simple Painted Wares of the Highland region share many traits with the Chiriqui. They seem to have form resemblances to Bay Island monochrome ware, but I can see little relation between them and Bay Island polychrome types. It is in the Monochrome and all types of Applique wares from the Highland region that the closest homologies to Bay Island monochrome pottery, both plain and elaborate, appear. In the Highland Applique group, Curridabat, Tripod, Stone Cist, and Handled Wares all show innumerable and close similarities or even identities with Bay Island types. Only the elaborate monochrome vases from the Bay Islands that have decorations of the Uloa marble bowl type are exempt from this obvious relationship. As one examines Hartman's work on Highland sites (1901), ceramic comparisons with the Bay Islands leap to the fore. Tripod globular bowls with identical conical and short cylindrical feet, goblet and ring-based forms, shallow bowls on long tripods, and closely similar (or identical) types of raised, modeled, incised, punctate decoration, and combinations of these techniques, all occur in both Bay Island monochrome and Highland Applique wares. The modeled alligator motif, which Hartman (1907 b) has shown to be related to the painted alligator motif in Chiriqui, is also present in the Bay Islands. The fully developed annular base is not overly common in the Highland area, but the pottery stands are closely similar to this type. Incensario types; occasional extremely crude vessels; pottery canoe models (with figures, but otherwise like pl. 8, fig. 2, *d*, *e*); large modeled pottery heads; hollow figurines, which are without legs or have only conical projections suggesting legs and with heads covered with grotesque applique adornment (Lothrop, 1926, vol. 2, pl. 190); pottery whistles; and cylindrical pottery stamps occur in the Highland region and in the Bay Islands.

Since the Guetar tribes seem to have been the only historic people known to the Highland region, much of the prehistoric culture of the area can in all probability be ascribed to them.[39] To the south the culture of the Highland Region blends with that of the Chiriqui area, which was likewise occupied by various tribes belonging to the Chibchan linguistic stock of South America. As was true in the north, any exhaustive comparison must extend further, in this case embracing the prehistoric cultures of Chiriqui, Coclé, and northern South America, but here again our scope must be limited.

Eastern Nicaragua

From south to north, this region was occupied by Chibchan, Mosquitoan (Miskito), and Ulvan (Sumu) tribes. There is a very strong probability that both the Miskito and Sumu languages are related to the Chibchan stock. The true Chibchan tribes occupied only the southeastern corner of Nicaragua, the Miskito held the coast, and the Sumu the greater part of the interior. The terrain here passes from rolling hills eastward to the swampy Mosquito Coast, and most of the dense jungle-covered area has not even been explored from the archeological standpoint.[40]

Le Baron gives a plan of a small ceremonial site on the Prinzapolca River consisting of three rude monoliths set up to form a triangle,

[39] Spinden, 1925, p. 542, disagrees with Lothrop in this regard.

[40] See Le Baron, 1912, and Spinden, 1925. Conzemius, 1932, also gives some archeological data on this region.

which is paved with rocks. One monolith had a crude face incised at the top and others had simple circular or geometric petroglyphs. No artifacts were found. On the Rama River, which enters the Caribbean near Monkey Point, Spinden notes the occurrence of small mounds containing abundant pottery. Painted and modeled ware, including tripod bowls, figurines, whistles, etc., were found here. Cookra Hill, near the south end of Pearl Lagoon, formerly had ancient graves from which gold amulets, a marble mace head of Nicoyan type, abundant pottery, and other artifacts have been removed. Near Bluefields occur large and interesting shell heaps. Pottery from these is usually unslipped but is elaborately modeled. One type, with tripod feet decorated with faces and containing rattles, suggests a local variant of Costa Rican pottery. A small stone figure of a man, and two interesting types of monolithic axes, figured by Lothrop (1926, vol. 1, pl. 12, *c*, *e*), come from here. Spinden calls attention to stone bowls with projecting heads, tripod supports, and a band of interlaced decoration, which come from this area. The well-made metates with animal heads from eastern Nicaragua form a link between Costa Rica and northern Honduras. Spinden also states that small pots with plastic decoration and gold figurines are said to have been found in the Pispis mining district. He observed many elaborate petroglyphs near falls and rapids on these eastern rivers. At the junction of the Yasica and Tuma Rivers, within the wet belt and in the vicinity of mounds, he found two carvings of the Nicaraguan lake type. One of these depicted a man with an alligator clinging to his back.

From the surveys made by Spinden, it thus appears that eastern Nicaragua forms a cultural link between the Highland region of Costa Rica to the south, and the Bay Islands and the Honduras coast to the north. Too little is yet on record, however, to attempt a more detailed comparison of types.

CONCLUSION

Although the foregoing study of Bay Island archeology is very incomplete, owing to the lack of adequate excavations at any large sites, certain interesting correlations are already apparent. The available material indicates that the islands had been occupied by a people of fairly homogeneous culture for a considerable time prior to the visit of Columbus. As to the relative age of this occupation, nothing definite is known, but no conclusive evidences of great antiquity have been reported. Analysis of the collections indicates that although much of Bay Island civilization was developed *in situ,* this development took place under strong alien influences from different regions at different times. On the basis of site segregation, stylistic sequence and some stratigraphy, an attempt has here been made to suggest the gross sequence of Bay Island prehistory. Acknowledging the shakiness of this structure as at present conceived, it may with caution be employed in gauging the relative periods and the directions from which these different cultural thrusts appeared. There is little in the available evidence to indicate that the Bay Islands were ever an important cultural center but much to indicate their peripheral receptivity.

The outline sketches of adjacent regions have indicated that Bay Island culture was very similar to that of the northern coast of Honduras, although many artifact types from the islands are as yet unreported for the mainland. In mound types and rough stone structures the Bay Islands, the northern coast, and the Uloa region share fundamentally similar types. Suggested correlations between Uloa polychrome pottery types and those of the Bay Islands indicate that the latter wares were relatively late. The same can be said in regard to the Uloa marble vase type of decoration, copper bells, and small, plumed heads of jadeite or green stone, all of which are shared with the Bay Islands. Although there are many other artifact types in the Uloa region which also occur in the Bay Islands, they are as yet undated and cannot help us here.

Between the developed architecture and carved stone technique of the Maya and the rough stone and earth mound complex of Honduras and the regions to the south, there appears to be a complete break. The Bay Islands share this latter complex. Whether the simpler type represents a substratum from which arose the complexity of Maya architectonics is a problem that cannot be entered upon here. However, the assumption sometimes made that the southern complex was merely a crude borrowing from developed Maya styles seems rather illogical in the light of general distribution and the sharp break between the two. Certain similarities between Bay Island and Maya methods of disposal of the dead appear in the cases of urn burial, inhumation in mounds, and rare skull burials, recorded for the Maya; however, Maya practices in this regard are so varied and the Bay Island record so incomplete that any conclusions seem futile.

Maya ceramics, including early types at Holmul and in British Honduras, and some simple types at other sites, show a number of general resemblances to monochrome pottery wares from the Bay

Islands. The same can be said in regard to a number of other rather widely distributed artifact types. Whether these resemblances are more or less fortuitous or are actually generic and derived from some common but as yet undefined cultural substratum, like the Q complex of Lothrop and Vaillant, can only be determined by more exhaustive analysis than is possible here. More specific similarities to Bay Island artifact types occur in the small plumed heads, incised "buttons", and ear spools of jade or green stone, as well as in the delicately retouched flint knives, all of which come from tombs at Copan. This similarity in certain small jade or green stone artifacts, in carved animal teeth, and in cut shell work, holds for other Maya sites both early and late. Similarly the jars holding votive offerings of this type found beneath certain Maya structures resemble votive caches at Bay Island offertories. These more specific similarities between the developed Maya culture and the Bay Islands also occur in the intermediate Uloa region. In the Bay Islands they appear to be late, and there is a strong probability that they were transmitted to the Bay Islanders through intermediate peoples at a relatively late date. The bulk of Bay Island ceramic forms and numerous artifact types such as stone pot rests, carved metates with animal heads, mace heads, petaloid celts, and T-shaped axes are rare or lacking in Maya sites. Thus, aside from certain rather general resemblances in structural, ceramic, and artifact types, which may or may not prove to be generic, the relationship between the Maya proper and the people of the Bay Islands seems to have been indirect and relatively late.

Turning to the prehistoric evidence from western Nicaragua and northern Costa Rica, one searching for Bay Island correspondences finds himself much more at home. Both the Pacific and Highland areas share the same style of stone statues, rough stone and earth mounds, rough stone walls and monoliths, inhumation in mounds, grotesque applique figurines, figurines seated on stools, carved metates with animal heads, carved green stone amulets of more or less conventionalized form, anthropomorphic celts of green stone, stone mace heads, discoidal and cylindrical bark beaters, petaloid celts, and T-shaped axes. All these types occur in the Bay Islands, and many of them, as in the case of mammiform mace heads and anthropomorphic celts, are of identical forms. The urn burials of the Nicaragua lake region are closely similar to those from the Bay Islands.

In ceramics, the Nicoya Polychrome ware of the Pacific area shares numerous traits of form and decoration with Bay Island Polychrome I. Between Pacific area and Bay Island monochrome wares there are also many resemblances, but these are overshadowed by the more numerous point-for-point correspondences between Bay Island monochrome ceramics and the Highland Applique wares. These are not identical, but there is obviously a very close relationship. If Bay Island ceramics were more fully and accurately classified, comparison with the various Highland Applique subtypes might be profitable, but this cannot be done at present. In the above, and in numerous other traits, there seems to be a much closer correspondence between the Highland area and the Bay Islands than there is between the latter and the Pacific area. However, as a whole, the prehistoric remains from the Bay Islands fit into the archeological patterns of western Nicaragua and northern Costa Rica surprisingly well. Unlike the late traits which the Bay Islands share with the Uloa district, and indirectly with the Maya, these southern traits permeate the whole culture and seem to be early and basic. If they were eliminated from our present picture of Bay Island prehistory, the residue would appear as entirely marginal to relatively late periods in the Uloa region.

Too little is yet on record for central Honduras and eastern Nicaragua to throw much more light on Bay Island connections. All that can be said regarding the interior of Honduras is that the known sites are primarily of " Chorotegan " type. More exact determinations must await excavation. The problem of the exact interrelationship between the various polychrome pottery types of the Bay Islands, the Uloa district, eastern Salvador, the Honduras interior, and the Nicaragua-Costa Rica region can only be solved by others much more intimately acquainted with the latter ceramics than the present writer. In regard to the eastern coast of Nicaragua, Spinden's brief notes suggest that the Highland culture of Costa Rica extends north until it blends with that of the north coast of Honduras. At present the Bay Islands appear as a surprisingly strong northern outpost of the Highland culture. This bears out Lothrop's prediction (1926, vol. 2, pp. 344, 345), based on the observation of three tripod bowls of Costa Rican type from Roatan, that, " were the archeology of the Atlantic coast of Nicaragua and Honduras better known [it would probably appear] that the drift of Isthmian and South American culture to the northward was along the Atlantic coast rather than the Pacific coast of Central America ".

This brings us to a consideration of the probable carriers of this culture. In Honduras the term " Chorotegan Culture " is generally employed. This naturally implies that the bearers were of Chiapanecan speech. Granting the probability that the Chorotega proper once occupied a much wider range than they did at the time of the conquest, I strongly doubt that they were the people who were responsible for the majority of the so-called "Chorotegan" remains in northern Honduras and on the Bay Islands. The chroniclers of Columbus and other early writers describe a native culture on the Bay Islands and the adjacent Honduras mainland that fits the known archeological evidence remarkably well. Jicaque and Paya tribes (with a few immigrant Nahuatl groups) were then in possesion of these regions and must have been the people encountered by the early explorers. As Spinden points out, and Conzemius demonstrates at considerable length, the ethnology of these native peoples, along with the Sumu, shows strong affiliations with northern South America. Similarly, most of the archeological remains on the Bay Islands and the adjacent mainland show strong connections with the prehistoric Highland area of Costa Rica, and Lothrop has demonstrated that in this area South American traits are most abundant. In fact the only people of the Highland region at the time of the conquest were the Guetar, who belong to the Chibchan linguistic stock of South America, and to them Hartman and Lothrop ascribe most of the archeological remains. Lehmann, although his evidence is not entirely conclusive, links the Lenca, Jicaque, Paya, Sumu, and Miskito in the Talamancan subdivision of the Chibchan stock, to which the Guetar also belong. Thus, historical evidence, ethnology, archeology, and linguistics all combine to suggest that peoples of South American affiliations must have been responsible for most of the archeological remains on the Bay Islands and probably in northern Honduras as well. For this reason I cannot agree with Spinden that the historic tribes of this region were late immigrants replacing an older population of Chiapanecan speech. The problem as to who were the main originators of the "Chorotegan Culture" in its southern centers, whether Chiapanecan, Subtiaban, or Chibchan, is outside our province, but that peoples of Chibchan or affiliated speech at least served as carriers of the culture seems clearly demonstrable.

As to the age of the "Chorotegan Culture", or as it might be called, "Western Nicaragua-Northern Costa Rica Culture", either in its centers or in the Bay Islands, there are as yet few direct clues. Certain of its manifestations are believed by some to antedate the Maya occupation of Copan, whereas the Highland aspect in Costa Rica seems relatively recent, and the same may be true of its attenuated manifestations in eastern Nicaragua and northern Honduras. As for the Bay Islands, the southern influences apparently antedate the influx of northern traits via the Uloa region. These are matters which can only be satisfactorily determined by future excavations.

The occurrence of this marked prehistoric thrust of South American influence as far to the north and west as the Bay Islands has interesting theoretical connotations. It forms another link in the growing chain of evidence indicating that the answers to many basic problems of Middle American culture history lie buried in the southern continent. The time is hardly ripe, nor is this the place, to attempt to trace out more specific relationships. These will become evident as the nature and sequence of culture horizons in the Chiriqui, Coclé, and adjacent regions of South America are investigated and reported on. Their importance to the entire field of Middle American research is strikingly indicated by Vaillant (Merwin and Vaillant, 1932, p. 65) in discussing the apparent diversity of Maya ceramic origins. "Moreover, those ceramic groups which are Early in southern Central America differ from those in central Mexico, and an examination of Central American ceramics reveals a group of forms that have in essence stronger connections with South America than with Mexico. It also seems evident from our involved discussion that we have not yet begun to scratch the surface of the history of the rise of Central American and South American ceramics".

LITERATURE CITED

Alcedo y Herrera, Dionisio

1883. Piratérias y Agresiones de los Ingleses y de otros Pueblos de Europa en la América Española desde el Siglo XVI al XVIII. Madrid.

Anghiera, Pietro Martire d'

1812. The historie of the West Indies. *In* A selection of curious, rare, and early voyages, published by Richard Hakluyt. A Supplement, pp. 366-688. London.

Blackeston, A. H.

1910 a. Archeological investigations in Honduras. Records of the Past, vol. 9, pt. 4, pp. 194-201, Washington.

1910 b. Recent discoveries in Honduras. Amer. Anthrop., n. s., vol. 12, no. 4, pp. 536-541.

Blom, Frans

1932. Commerce, trade, and monetary units of the Maya. Tulane Univ., Middle Amer. Research Ser., Publ. no. 4, New Orleans.

Blom, Frans, Grosejean, S. S., and Cummins, Harold

1933. A Maya skull from the Uloa Valley, Republic of Honduras. Tulane Univ., Middle Amer. Research Ser., Publ. no. 5 (Middle American Pamphlets, no. 1). New Orleans.

Bollaert, William

1861. Observations on the Peruvian tomb pottery and some gold objects from South America in the Museum of Joseph Mayer. Trans. Hist. Soc. Lancashire and Cheshire, n. s., vol. 1, pp. 311-322, Liverpool.

Bovallius, Carl

1886. Nicaraguan antiquities. Stockholm.

Bransford, J. F.

1881. Archaeological researches in Nicaragua. Smithsonian Contr. Knowl. vol. 25.

Brinton, Daniel G.

1882. The Maya chronicles. Philadelphia.

Columbus, Ferdinando

1867. Vita di Cristoforo Colombo descritta da Ferdinando, suo figlio e tradotta da Alfonso Ulloa. Nuova edizione, diligentemente riveduta e corretta. London.

Conzemius, Eduard

1928. On the aborigines of the Bay Islands (Honduras). Atti del XXII Congresso Internazionale degli Americanisti, Roma, Settembre 1926, vol. 2. Roma.

1932. Ethnographical survey of the Miskito and Sumu Indians of Honduras and Nicaragua. Bur. Amer. Ethnol. Bull. 106.

Cummins, Harold. See Blom, Grosjean, and Cummins.

Fiske, John

1892. The discovery of America, vols. 1 and 2. Boston and New York.

Gann, Thomas W. F.

1914-16. Report on some excavations in British Honduras. Ann. Archaeol. and Anthrop., Inst. Archaeol., Univ. Liverpool, vol. 7, pp. 28-42.

1918. The Maya Indians of Southern Yucatan and Northern British Honduras. Bur. Amer. Ethnol. Bull. 64.

1927. Maya Cities. London.

Gordon, G. B.

1896. Prehistoric ruins of Copan, Honduras. Mem. Peabody Mus., Harvard Univ., vol. 1, no. 1.

1898 a. Researches in the Uloa Valley, Honduras. Ibid., no. 4.

1898 b. Caverns of Copan. Ibid., no. 5.

Grosjean, S. S. See Blom, Grosjean, and Cummins.

Hakluyt Society

1933. See Jane, Cecil.

1847. See Major, R. H.

Harrisse, Henry

1866. Bibliotheca Americana Vetustissima. New York.

1871. D. Fernando Colon, historiador de su padre. Ensayo critico. Sevilla.

Hartman, C. V.

1901. Archaeological researches in Costa Rica. Stockholm.

1907 a. Archaeological researches on the Pacific coast of Costa Rica. Mem. Carnegie Mus., vol. 3, no. 1.

1907 b. The alligator as a plastic decorative motive in Costa Rica. Amer. Anthrop., n. s., vol. 9, no. 2, pp. 307-314.

Herrera, Antonio de

1726-30. Historia General de los Hechos de los Castellanos en las Islas y Tierra Firme del Mar Oceano, vols. 1-5. Madrid.

Jane, Cecil, Editor and Translator

1933. Select documents illustrating the four voyages of Columbus. Vol. 2, The third and fourth voyages. Hakluyt Society Publ., 2nd ser., no. 70, issued for 1932. London.

JOYCE, THOMAS A.
1914. Mexican archaeology. New York and London.
LAS CASAS, BARTOLOME DE
1875-76. Historia de las Indias, vols. 1 to 5. Madrid.
LE BARON, J. FRANCIS
1912. Description of a stone ruin in eastern Nicaragua, with notes on the location of other ruins in Central America. Records of the Past, vol. 11, pp. 217-222, Washington.
LEHMANN, WALTER
1910. Ergebnisse einer Forschungsreise in Mittelamerika und Mexico, 1907-1909. Zeitschr. Ethnol. vol. 42 no. 5, pp. 687-749, Berlin.
1920. Zentral-Amerika. Teil 1, Band 2. Berlin.
LOTHROP, S. K.
1921. The stone statues of Nicaragua. Amer. Anthrop., n. s., vol. 23, no. 3, pp. 311-319.
1924. Tulum: An archaeological study of the east coast of Yucatan. Carnegie Inst. Washington.
1926. Pottery of Costa Rica and Nicaragua, vols. 1 and 2. Mus. Amer. Ind., Heye Foundation.
1927 a. Pottery types and their sequence in El Salvador. Mus. Amer. Ind., Heye Foundation, Ind. Notes and Monogr., vol. 1, no. 4.
1927 b. The word "Maya" and the Fourth Voyage of Columbus. Mus. Amer. Ind., Indian Notes, vol. 4, no. 4, pp. 350-363.
MAJOR, R. H., Editor and Translator
1847. Select letters of Christopher Columbus, with other original documents relating to his four voyages to the New World. Hakluyt Soc. Publ. [vol. 2]. London.
MARTYR, PETER. See ANGHIERA, PIETRO MARTIRE D'
MASON, GREGORY
1928. Pottery and other artifacts from caves in British Honduras and Guatemala. Mus. Amer. Ind., Heye Foundation, Ind. Notes and Monogr., no. 47, New York.
MAUDSLAY, A. P.
1889-1902. Archaeology. Biologia Centrali-Americana. London.
MERWIN, R. E., and VAILLANT, G. C.
1932. The ruins of Holmul, Guatemala. Mem. Peabody Mus., Harvard Univ., vol. 3, no. 2.
MITCHELL, R. C.
1850. Statistical account and description of the Island of Roatan. United Service Magazine, August.
MORLEY, S. G.
1920. The inscriptions of Copan. Carnegie Inst. Washington, Publ. no. 219.
NAVARRETE, MARTIN FERNANDEZ DE
1829. Coleccion de los Viages y Descubrimientos, que Hicieron por mar los Españoles, vols. 1-3. Madrid.
OVIEDO Y VALDEZ, GONZALO FERNANDEZ DE
1851-55. Historia General y Natural de las Indias, vols. 1-4. Madrid.
POPENOE, DOROTHY H.
1928. Las Ruinas de Tenampua. Tipografia Nacional, Tegucigalpa, Honduras.

Popenoe, Wilson and Dorothy
1931. The human background of Lancetilla. Reprinted from Unifruitco Magazine, pp. 5-11, August.

Pownall, Thomas
1779. Observations arising from an enquiry into the nature of the vases found on the Mosquito Shore in South America. Archaeologia, vol. 5, p. 318-324, London.

Ricketson, O. G.
1925. Burials in the Maya area. Amer. Anthrop., n. s., vol. 27, no. 3, pp. 381-401.

Roberts, Orlando W.
1827. Narrative of voyages and excursions on the east coast and in the interior of Central America. Edinburgh.

Rogers, Charles
1782. An account of certain earthen masks from the Mosquito Shore. Archaeologia, vol. 6, p. 107, London.

Rose, Richard H.
1904. Utilla: Past and present. Dansville, N. Y.

Spinden, H. J.
1915. Notes on the archeology of Salvador. Amer. Anthrop., n. s., vol. 17, no. 3, pp. 446-487.
1925. The Chorotegan culture area. Compte-Rendu XXI[e] Congrès International des Américanistes, Göteborg, 1924, pp. 529-545. Göteborg.

Squier, E. G.
1858. The States of Central America; their geography, topography, etc. New York.
1869. Tongues from tombs, or the stories that graves tell. Frank Leslie's Illustrated Newspaper, June 26.

Steinmayer, R. A.
1932. A reconnaissance of certain mounds and relics in Spanish Honduras. Tulane Univ., Middle Amer. Research Ser., Publ. no. 4, pp. 1-22, New Orleans.

Strangeways, Thomas
1822. Sketch of the Mosquito Shore, including the territory of the Poyais. Edinburgh.

Strong, W. D.
1934 a. Hunting ancient ruins in Northeastern Honduras. Explorations and Field-Work of the Smithsonian Institution in 1933, Smithsonian Publ. 3235, pp. 44-48.
1934 b. An archeological cruise among the Bay Islands of Honduras. Ibid., pp. 49-53.

Swanton, John R. See Thomas and Swanton.

Thomas, Cyrus, and Swanton, John R.
1911. Indian languages of Mexico and Central America and their geographical distribution. Bur. Amer. Ethnol. Bull. 44.

Thompson, Edward H.
1897 a. The Chultunes of Labná, Yucatan. Mem. Peabody Mus., Harvard Univ., vol. 1, no. 3.
1897 b. Cave of Loltun, Yucatan. Ibid., no. 2.

THOMPSON, J. ERIC
1931. Archaeological investigations in the Southern Cayo District, British Honduras. Field Mus. Nat. Hist., Anthrop. Ser., vol. 17, no. 3.

VAILLANT, G. C.
1927. The chronological significance of Maya ceramics. [Manuscript submitted for degree of Doctor of Philosophy at Harvard University. Three additional copies made at expense of Carnegie Institution of Washington and American Museum of Natural History deposited in above institutions and the Peabody Museum of Harvard University.]

VAILLANT, G. C. See also MERWIN, R. E., and VAILLANT.

YOUNG, THOMAS
1842. Narrative of a residence on the Mosquito Shore, during the years 1839, 1840, and 1841: with an account of Truxillo, and the adjacent islands of Bonacea and Roatan. London.