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

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CONTENTS

THE DARKER SIDE OF DAWN

BY
ANANDA K. COOMARASWAMY
Fellow for Research in Indian, Persian and Muhammadan Art
Museum of Fine Arts, Boston

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By ANANDA K. COOMARASWAMY

INTRODUCTION

Students of theology and mythology are well aware that the concept of deity presents itself to us under a double aspect; on the one hand as gracious, on the other as awful. He evokes both love and fear. He is both a light and a darkness, a revelation and a mystery. In the latter and awful aspect, clouds and darkness are round about him. The Light is Life, the Darkness Death. The one corresponds to our concept of Good, the other to our concept of Evil, within the recognized definitions of good as " that which all creatures desire ", and of evil as " that which all creatures would avoid." A majority of religions in their exoteric formulation treat these contrasted aspects in outward operation as distinct and opposed forces, divine and satanic, celestial and chthonic. Satan is commonly thought of as a Serpent or Dragon and is often so represented, upon the stage or in art. Yet the Solar hero and the Dragon, at war on the open stage, are blood brothers in the green room. From the Christian point of view, the fallen Angels are " fallen in grace, but not in nature "; and from the Islamic, Iblīs is restored at the end of time; in other words Satan becomes again Lucifer. The same deity, Zeus for example in Greek mythology, may be worshipped and represented both in anthropomorphic and in snake forms. Serpent worship and its iconography, despite their outwardly " primitive " appearance, have profound metaphysical foundations.

Metaphysical religion envisages a " Supreme Identity " (in the Ṛg Veda *tad ekam*, " That One ") in which the outwardly opposing forces are one impartible principle; the lion and the lamb lying down together. The contrasted powers are separated only by the very nature of reason, which sees things apart as subject and object, affirmation and negation, act and potentiality, Heaven and Earth. Contemplative practice alike in East and West seeks to approach divinity in both aspects, avoiding a one-sided vision of the Unity; willing to know Him both as being and non-being, life and death, God and Godhead. The *contemplatio in caligine,* for example, is directed to the dark side of deity; and corresponds to the Indian cult of Śiva-Rudra, for the

primordial Darkness remains in Him as Rudra (X. 129, 3 and *Maitri Up., V, 2*).

Evidence can be assembled from the Ṛg Veda and other sources to show that the deity in the darkness, unmanifested, in his ground, not proceeding, or as it is technically expressed, *ab intra*, is conceived of in forms that are not human-angelic, but theriomorphic; and typically in that of a brooding serpent or fiery dragon, inhabiting a cave or lying on a mountain, where he guards a treasure against all comers, and above all restrains the Rivers of Life from flowing. The creative act involves a maiming, division, or transformation of the girdling serpent, often thought of as " footless and headless ", that is with its tail in its mouth. The contraction and identification of this primordial and impartite Unity is envisaged on the one hand as a voluntary sacrifice, or on the other as affected by violence, exercised by the life-desirous Powers of Light. The celebration of the conquest of the Serpent by the Powers of Light is a basic theme of the Vedic hymns; an aspect of the Great Battle between the Devas and Asuras ("Angels " and " Titans ") for the possession of the worlds of light. It is the battle between St. George and the Dragon. At the same time there can be no question that the Powers of Light and Powers of Darkness are the same and only Power. Devas and Asuras are alike Prajāpati's or Tvaṣṭṛ's children; the Serpents are the Suns. It is entirely a question of " orientation ". At the end of an Aeon the Powers of Darkness are in turn victorious.

The Powers of Darkness are also at home as Water-snakes (Indian *nāga*) or Merfolk in the Sea that represents the maternal possibility of being. The first assumption in Godhead, Death, is being. Life and Death, God and Godhead, Mitra and Varuṇa, *apara* and *para* Brahman, are related from this point of view as a progenitive pair (Indian *mithuna*). The determinative, paternal principle accomplishes in conjunction with the passive maternal principle " the act of fecundation latent in eternity " (Eckhart). The generation of the Son " is a vital operation from a conjoint principle . . . . that by which the Father begets is the divine nature " (St. Thomas, *Summa Theologica*, I, q.27, a.2, and q.41, a.5). The Father is Intellect, the Mother Word, the Child Life (*Bṛhadāraṇyaka Upaniṣad*, I, 5, 7). Just as the Father works through the Son, so the human artist works " by a word conceived in his intellect " (St. Thomas, loc. cit., I, q.45, a.6). In this way every ontological formulation affirms the duality of the Unity as well as the unity of the Duality. It will be evident that whatever holds for the masculine will hold also for the feminine aspect of the Unity; in the following essay it is primarily the Vedic concept of the *ab intra* form of the feminine principle that is discussed.

For many readers the ontological principles outlined above will be of interest and value, not so much by first intention as " traces " of the Way, but rather and only as providing a logical explanation for certain typical forms of the creation myth that is a common property of all cultures. Regarded, however, even from this purely " scientific " point of view, the student of mythology, folklore, and fairy tale will find in these principles a valuable means of recognizing and correlating the varying forms that the world myth assumes. The story is not only of a time before history began, but was already told in a time before history was recorded. We may be sure that the pseudo-historical aspects that the story has assumed, for example in the Volsunga Saga, in Beowulf, or the Mahābhārata, are later developments and partial rationalizations. Fragments of the story will be recognized in the dogmatic life of every Messiah: in the miracles, for example, attributed to Cuchullain, Buddha, Moses, and Christ. Other fragments survive in fairy tales and even in nursery rhymes; in the story, for example of the human hero who crosses water or climbs a tree and thus returns to the magical otherworld, where he rescues or carries off the imprisoned daughter of a giant or magician; and in the stories of mermaids or Undines, who fall in love with a mortal, acquire a soul, and feet in place of their scaly tails.

The author trusts that the foregoing remarks will serve to introduce, however inadequately, the theme of the Darker Side of Dawn, the real sense of which may not be immediately apparent to the general reader. For the professed student of the Ṛg Veda the actual evidences of the texts are assembled in the accustomed and more technical manner: the thesis, although it might have been expanded at much greater length, may be taken to be complete in itself.

THE DARKER SIDE OF DAWN

In an article due to appear in the Journal of the American Oriental Society, but of which the publication has been delayed for lack of space, I have discussed the relation of the masculine Angels (*devāḥ*) on the one hand with the Titans (*asurāḥ*) and Serpents (*sarpāḥ*) on the other, showing that the former are to be regarded as sacrificial conversions or transformations of the latter. By way of introduction to what follows, and for the sake of the parallel wordings, the general nature of the evidence for the transformation of the Serpents in this sense may be indicated. The evidence is primarily Ṛg Vedic, but is conveniently resumed in *Pañcaviṁśa Brāhmaṇa*, XXV, 15, where the Serpents, by means of a sacrificial session, are enabled to

cast their inveterated [1] * skins (*hitvā jīrṇān tacam*) and to glide forward (*ati-sṛp*), changing their forms, and thus " the Serpents are the Ādityas " (*sarpyā vā ādityāḥ*) ; cf. *Śatapatha Brāhmaṇa*, VII, 3, 2, 14, where Agni is found upon the lotus leaf, having " crept up out of the Waters " (*adbhya upôdsṛptam*). The evidence for the identification of Agni *ab extra* with Ahi Budhnya *ab intra* need not be presented in detail, but it may be noted that in IV, 1, 11,[2] Agni, " footless and headless, hiding both his ends " (*apād aśīrṣo guhamāno antā*) is clearly thought of as a coiled snake, perhaps with its tail in its mouth ; and that in the same way the Sun is originally " footless ", but is given feet by Varuṇa that he may proceed (*apade padā prati dhātave*, I, 24, 8) ; in other passages, Indra, Agni, Soma, and Varuṇa are similarly described as " footed " (*padavīḥ*, m.) ; cf. *padavī* (f.) as footprint, *vestigium pedi*,[3] in I, 72, 2 and X, 71, 3, and similarly *pada, passim*. *Apād*, on the other hand, is a natural kenning for " snake " ; in III, 30, 8, the demons Kunāru and Vṛtra are handless and footless (*ahastam, apādam*), and Vṛtra similarly in I, 32, 7. The *Śatapatha Brāhmaṇa*, I, 6, 3, 9, in connection with the transformation of Soma, is explicit " In that he was rolling, he became Vṛtra ; in that he was footless, he became Ahi " (*yad apāt samabhavat tasmād ahis*). In the following shorter discussion, complete in itself, there is assembled a part of the corresponding evidence on the side of the feminine principles.

We now proceed to consider the case of Dawn (*uṣas*), whose lauds are so familiar to every student of the Ṛg Veda. It is well known that Night and Day or Dawn (*naktôṣasā* du. f.) are sisters, of like mind, who move successively upon a common path, Night " when she hath conceived for Savitṛ's quickening yielding the womb to Dawn " (I, 113, 1-3). " Sister to mightier sister yields the womb " (I, 124, 8 ; it is the younger sister that is victorious, the Devī replacing the Asurī, cf. *Mahābhārata* XII, 35, 25, " The Asuras are the elder brothers, the Devas indeed the younger "). " Successively they nurse the Yearling Calf " (I, 95, 1), i. e. Agni, who has thus two mothers (*ubhe sa mātror abhavat putra*, III, 2, 2, and *dvimātā, passim*) ; " One mother holds the Calf, the other rests (*kṣeti*). . . . . Ye, variant pair, have made yourselves twin beauties (*vapūṁṣi*), one that is black (*kṛṣṇam*) and one that shines " (III, 55, 4 and 11, cf. V, 2, 2). In the same way the Bambino, whether Sun or Fire, has two aspects corresponding to those of the sister Dawns (*uṣasā virūpe*, V, 1, 4), " with one of whom is he glaucous (*hari*), with the other bright

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(*śukra*) and shining (*suvarcā*)", I, 95, 1; as Pūṣan he is of two different aspects, like Day and Night, one bright, one dark (VI, 58, 1); like the Dawns, he " goes back and forth ", I, 164, 38, " now becometh sterile (*starīḥ*), now begets (*sūte*, tantamount to *savitā bhavati*, ' becomes Savitṛ '), he shapes his aspect as he will ", VII, 101, 3; cf. Atharva Veda, VI, 72, 1, "As the black snake displays himself, assuming such forms (*vapūṁṣi*) as he will, by titan magic "; " Immortal, uterine-brother (*sayoniḥ*) of the mortal, they move eternally conversely, men mark the one and fail to mark the other ", I, 164, 38.[4] When Night and Day (*uṣasā*, the " sister dawns ") have carried him, Agni is born " full strong and white, in the beginning of days " (V, 1, 4); [5] the use of *uṣasā* (du. f.) here to mean Night and Day is paralleled by " days of diverse hue " (*viṣurūpe ahanī*, I, 123, 7 and VI, 58, 1), and " black day and white day " (*ahaś ca kṛṣṇaṁ ahar arjunaṁ ca*, VI, 9, 1).[6] These sister Dawns are not only thought of as mothers of the Sun or Agni, but are brides of the Sun, as in I, 123, 10 where Dawn is desired by the Sun to be his maiden (*yoṣā*), IV, 5, 13 where the Dawns (pl.) are called the consorts (*patnīḥ*) of the immortal Sun, VII, 75, 5 where the generous Dawn (*maghonī uṣā*) is called the maiden of the Sun (*sūryasya yoṣā*); in VII, 69, 4, she is again the Sun-maiden (*sūryasya yoṣā*), and in AV., VIII, 9, 12, the sister Dawns are called the Sun's consorts (*uṣasā . . . . sūrya-patnī*). The Dawn is also a sister of Bhaga and kinswoman (*jāmi*) of Varuṇa (I, 123, 5); and is " Heaven's daughter ", *passim*. In VII, 69, 4, she is the daughter of the Sun (*yoṣā . . . . sūro duhitā*), involving the incest motif more familiar in connection with Prajāpati, cf. also V, 55, 6, where Pūṣan is called the second husband of his mother and the seducer of his sister (*mātur didiṣum . . . . svasur jāraḥ*); " incest " being inevitable because of the kinship (*jāmitva*) of all the manifested principles, *ab intra*. Pūṣan is Sūryā's lover in VI, 58, 3. The identity of Dawn (*uṣas*) with Sūryā is thus evident, as is also that of the sister Dawns (*uṣasā*) with Saraṇyū and her *savarṇā*.[7] In *Vājasaneyi Saṁhitā*, III, 10, Night (*rātrī*), and Dawn (*uṣas*) or Day (*ahas*) are Indra's consorts (*indravatī*), Indra representing the Sun.

That *Uṣas* may thus denote as well the Night as Dawn or Day renders intelligible certain neglected passages of RV. in which the Dawn is referred to as a sinister power; sinister, that is, essentially, and not merely accidentally in that the passing days shorten the span of life (I, 92, 11) whence Uṣas is called *jarayantī* (VII, 75, 4) from *jṛ*, " to inveterate ".[8] In IV, 30, 8-11, Indra is praised as having " struck down Heaven's daughter, that ill-designing woman " (*striyaṁ*

yad durhaṇāyuvaṁ . . . . duhitāraṁ divaḥ),[9] who is described as
"flowing away" (*sarat*) from her ruined chariot; viz. that chariot
that she, "the Daughter of Heaven, and Mistress of the Universe,
yokes afar (*parākāt*, i. e. *ab intra*) and straightway visits the Five
Homes, to look upon the restless ways of the Kindreds" (VII, 75, 4):
Similarly, in X, 138, 5, Uṣas is afraid of Indra's bolt, and goes her
way (*akrāmat*), abandoning her lovely chariot, cf. II, 15, 6. Agni
is commonly called "ravisher" or "spoiler" of Dawn (*uṣo na
jāraḥ*); this has usually been rendered as "lover of Dawn", but
jāra, from *jṛ* "to inveterate", even when it means "lover", has
always a somewhat sinister significance, and in the passages referred
to, Yāska's and Sāyaṇa's equations of *jāra* with *jarayitṛ* are certainly
correct, in this sense, that with the rising of the Sun, the Dawns
are always thought of as retiring and departing, to join the former
Dawns, e. g. in I, 113, 10. In VII, 6, 5, Agni, "driving off the
Nights (*nirudhya nahuṣaḥ*), makes the Dawns to be consorts of the
Arya" (*aryapatnīr uṣasaś cakāra;* Sāyaṇa equates *arya* with *sūrya*).[10]
In I, 123, 1, Dakṣiṇā, synonymous with Uṣas in the same hymn,
"rises from the dark night as herself an Aryā" (*kṛṣṇād ud asthāt
aryā*), where it is, of course, to be understood that she had been
anaryā; it may be noted that Dakṣiṇā is Indra's mother by Yajña
in *Taittirīya Saṁhitā*, VI, 1, 3, 6, and that Dakṣiṇā is Vāc, whose
asura origin is notorious.

Dawn precedes the actual day, and must not delay, lest the Sun
scorch her like a thief or enemy (V, 79, 9). It is not until the
thirty parts of the whole twenty-four hours have elapsed that she
becomes again an auspicious power, meanwhile as in VI, 59, 6, b,
"moving headless, with babbling tongue, she descends thirty grades"
(*hitvī śiro jihvyā vavadac carat triṁśat padā ny akramīt; hitvī śiro*
combined with *ib.*, a, *apād,* cited below, giving us the analogy to Agni,
apād aśīrṣo guhamāno antā in IV, 1, 11); and similarly in I, 123, 8,
where the sisters are said to "traverse thirty leagues (*triṁśataṁ
yojanāni*), alternately"—to reappear in due course, *paritakmyāyām,*
for the "ancient Dawn is born again and again (*punaḥ punar jāya-
māna purāṇī*) decking herself with the selfsame hue" (*samānaṁ
varṇam*[11] *abhi śumbhamānā*, I, 92, 10). Meanwhile the Sun, through-
out the thirty stations of her decline, rules supreme (*triṁśad dhāma
vi rājati*, X, 189, 3).

What is then the status of the Dawn *ab intra*, in the Night, as Night,
and especially at the end of the Night's course (*paritakmyāyām*), as
in V, 30, 14, where "Night at the end of her course shines-forth-as-
Dawn (*aucchat*) at the coming of the Debt-collector[12] king of the Glit-

tering-folk ", and in VII, 69, 4, where " at the end of her wandering,
the Daughter of the Sun chooses *his* glory (*śriyam*) " ? The proces-
sion of Uṣas is in fact described in terms exactly parallel to those
of I, 24, 8 cited above with respect to the procession of the Sun: in
I, 152, 3, " The footless-maid proceeds as first of footed things "
(*apād eti prathamā padvatīnām*), and this is nearly identical with
VI, 59, 6 " This footless-maid came earliest forth to footed things "
(*apād iyaṃ purvā ā agāt padvatībhyaḥ, apād* in both passages repre-
senting *apadī*). That is as much as to say that she, who had been a
" serpent ", now assumes an angelic-human form. The same is im-
plied when it is said that " Our Lady puts off her dark robe " (*apa
kṛṣṇān nirṇijaṃ devī avarityāvaḥ*, I, 113, 14, cf. VIII, 41, 10, where
it is Varuṇa that " makes the black robes white ", *śvetān adhi nirṇijaś
cakre kṛṣṇān*) ; for this is the same as putting off desuetude and
impotence (I, 140, 8 *jarāṃ pra muñcan, Pañcaviṃśa Brāhmaṇan*,
XXV, 17, 3 *jarāṃ apāhat*, etc.), it is really the snake-skin, the
old skin, *jīrṇān tacam* as in *Pañcaviṃśa Brāhmaṇa*, XXV, 15,
that is taken off. It is similarly that Urvaśī and her sisters, in
X, 95, 8-9, " evade Purūravas like snakes " (*tarasantī na bhujyuḥ*),
but when they yield " display themselves as swans " (*ātayo na tanvaḥ
śumbhata*), or " with swan-skins ", for *tanu* is often tantamount to
" skin ".

In I, 185, where Day and Night (*ahanī*) are if not absolutely
identified with, at least very closely assimilated to Heaven and Earth
(*dyāvāpṛthivī*, or *rodasī*), it is said, in the second verse, that " The
twain (unspecified),¹³ though not proceeding (*acarantī*) and footless
(*apadī*), yet support a mighty Germ (*garbha*=Agni) that proceeds
and hath feet " (*carantam padvantam*). This is closely related to X,
22, 14, " Thou smotest Śuṣṇa to the right for sake of Universal-Life
(*viśvāyave*, i. e. for Agni), that Earth (*kṣāḥ*) that had neither hands
nor feet (*ahastā yad apadī*, cf. III, 30, 8, cited above) might wax "
(*vardhata*), and III, 55, 14 where "As having feet (*padyā*) she
standeth up erect (*ūrddhvā tasthau*), adorned with many beauties ".

We can now compare all of the foregoing matter with a part of the
account of the marriage of Sūryā in X, 85, 28-30. Here, immediately
before her actual wedding, Sūryā is called Kṛtyā,¹⁴ and it is only
when this *kṛtyā* nature that is like a clinging garment (*āsakti*) is
put off that she comes to her husband: " Kṛtyā that clingeth close is
taken off (*vyajyáte*) . . . . this Kṛtyā hath come to be with feet and
consorts with her husband as a bride " (*kṛtyā eṣā padvatī bhūtvā
jāyā viśate patim*).¹⁵ The text goes on to describe the inauspicious
aspect of the Sun himself when united with this same Kṛtyā, *ab intra:*

" Inglorious (*aśrīrā*) becomes his form when it glitters in (*ruṣatī*) this evil (*pāpayā amuyā*, as in X, 135, 2 with reference to the evil way of Yama), what time the husband wraps his body in the garment of his wife ", which is, of course, the " robe of Night " of I, 115, 4. Analogous to this is the allusion in I, 105, 2, where it is a part of Trita's [16] complaint that " the wife holds fast her husband " (*ā jāyā yuvate patim*) ; it is in fact only " when the parents that cohabit in the dark are separated that they pass over the Babe " (*kṛṣṇaprutau vevije asya sakṣitau ubhā tarete abhi mātarā śiśum*, I, 140, 3) ; " In the Angel's mansion were the First, from their diremption rose the others " (*kṛntatrād eṣām uparā udayan*, X, 27, 23) ; it is when the sacrificer makes his Soma offering that mighty Father Heaven breaks from the embrace, I, 71, 6 ; and this separation of Heaven and Earth, effected by the sacrifice, is the essential act of creation, RV. *passim* (e. g., VII, 80, 1) for thereby there is made that " space ", *antarikṣa*, in which the desirous principles are destined to find a home and prolong their line, as in a promised land.

If the husband is inglorious when he wears the woman's robe, that is in fact a snake-skin, she herself becomes glorious when she puts off the dark robe (I, 113, 4 cited above), and shines forth radiant in robes of light (*śukravāsaḥ*, I, 113, 7), when as in I, 92, 11 " She wakes, uncovers Heaven's ends [17] and drives her sister far away . . . . shines out in the bright-eye of her seducer " (*jārasya cakṣasā vi bhāti*, cf. X, 189, 2, *antaś carati vocanâsya*), That is indeed her marriage when she becomes a woman clothed with the Sun, when as in VII, 81, 2, " The rising Sun, refulgent Star, pours out his beams in company with hers ; and then, O Dawn, may we partake together of thy shining and the Sun's ; and her death, for when he suspires then she expires " (*asya prâṇād apānatī*, X, 189, 2, called the hymn of the " Serpent Queen ", Sarpavājñī).

Another version of the Dawn's procession can be recognized in the story of Apālā, whose name means " unprotected ", i. e., husbandless and free woman. In VIII, 91, where Indra represents the Sun and is described in terms appropriate to the Sun, the maiden (*kanyā*), who is at enmity with her (former) husband (*patidviṣaḥ*) [18] reflects, " What if we go and wed with Indra ? " [19] She gives him Soma, that is, virtually performs a sacrifice to him, and asks him to raise up hair upon her father's (bald) head, his field, and upon her own body, " here below the waist ", that is, to restore the fertility of the universe [20] ; the reference to her own body indicating her extreme youth. Indra draws her through the three apertures (*kha*) [21] of his (solar) chariot, and so cleansing (*pūtvī*) her makes for her a " sunny skin " (*sūrya-*

tvacam). According to the quite intelligible legend cited by Sāyaṇa, Apālā, daughter of Atri, had in fact suffered from a skin-disease, and the three skins that Indra removed from her became reptiles. In the *Jaiminīya Brāhmaṇa* version (I, 220) we are told that Apālā desired to be rid of her " evil colour " (*pāpaṁ varṇam*) ; with the two first cleansings she becomes successively a lizard (*godhā*) and a chameleon (*kṛkalāsa*), with the third cleansing she becomes *saṁśviṣṭikā* (evidently " whitened " : the *Śatapatha Brāhmaṇa* version has *saṁśliṣṭikā*, apparently " fit to be fondled ") and her form is called the " most beautiful of all forms ". In the nearly identical version of *Pañcaviṁśa Brāhmaṇa,* IX, 2, 14, the woman's name is Akūpārā (in literal significance identical with "Aditi", " In-finite "), she is an Āṅgirasī (thus of Agni's kin), and it is expressly stated that her " skin was like a lizard's " (*godhā*), that is reptilian and scaly. In X, 85, 34, Sūryā's cast off garment (*śāmulyam*, to be connected rather with *śamala*, " foul ", than any word implying " woollen ") is significantly described as " rasping, coarse, prickly, poisonous, and inedible " ; the curious expression " inedible " (*na . . . . attave*) corresponding to *Atharva Veda,* I, 11, 4, where the chorion or after-birth (*jarāyu,* a term applied to the slough of a snake in *ib.* I. 27, 1) is said to be " for the dog to eat " (*śune . . . . attave*). In any case, it is clear that the old skins are removed, and a glorious skin revealed, making Apālā fit to be Indra's bride,[22] i. e., Sūryā to be the Sun's. With *sūryatvacam* above cf. Atharva Veda, II, 2, 1, where the Gandharva Viśvāvasu (= Vena, the Sun, *ib.* II, 1) is himself " sun-skinned " . . . . (*sūrya-tvak*) ; in *Pañcaviṁśa Brāhmaṇa,* XXIII, 16, 5, where the sacrificers " make a skin for themselves " (*tvacam eva kurute*) a " sun-skin " is to be understood ; like that of those who are sun-skinned " in *Vājasaneyi Saṁhitā,* X, 4.[22]

We have long suspected that Apālā becomes in the Buddha legend Sujātā, who in the Jātaka (I, 69) is the daughter of a farmer, desires a husband, and brings an offering of milk to the Bodhisattva, seated beneath the Bodhi tree, on the eve of the Great Awakening. Sujātā, in fact, becomes the consort of Indra. The fullest account occurs in *Jātaka* No. 31, text I, p. 205. Here Sujātā is the fourth of Indra's handmaidens (*pādaparicārikā*) ; three having died are re-born in the same status, according to their virtue, but Sujātā, " because she had performed no deed of virtue " (*kusalakammassa akatattā,* cf. " *akṛtyā* " discussed in Note 13) is reborn as a crane. Indra seeks her, finds, and instructs her, and proves by a trial that she has experienced a change of heart. She is next reborn in a potter's family ; Indra seeks her out, and makes her a gift in acknowledgment of

her virtue. She is reborn a third time as the daughter of the Asura
Vepacittiya (it will not be overlooked that the three births correspond
to the three cleansings of Apālā),[21] and because of her virtue is
very beautiful (*abhirūpa*); her father (who corresponds to Tvaṣṭṛ
in the Sūryā versions) arrays her for marriage, and summons an
assembly of Asuras so that she may choose a husband for herself.
Indra assumes the "Asura colour, or appearance" (*asuravaṇṇam* =
asurya-varṇam, and this corresponds to X, 85, 30 quoted above) and
takes his place in the assembly (really a *svayaṃvara*) where Sujātā
chooses him to be her husband, and he makes her his chief queen.
Indra in this story represents a previous incarnation of the Buddha.
In the last incarnation where the Bodhisattva is no longer identified
with Indra (in the sense of the Vedic dual Indrâgnī) the require-
ment of the narrative makes it impossible for Sujātā to become
the Buddha's wife, and she remains Indra's, though we may suspect
that the Bodhisattva's actual wife Yaśodharā is really the *alter ego*
of Sujātā.

Given the other parallels, it is worth noting that Uṣas is more than
once in RV. addressed as " well-born ", or if we treat this as a name,
as " Sujātā " (I, 123, 3, *uṣo devī . . . . sujāte;* VII, 77, 6, *divo
duhitar . . . . uṣaḥ sujāte*); this merely confirmatory evidence was
remarked only after the identification had already been in mind for
some years. Conversely, the designation of Uṣas as Maghonī in VII,
75, 5, is already suggestive of Maghavan, i. e. Indra. We are also
inclined to identify the *kanyā* and *sujātā* of our texts with the *sukanyā,*
daughter of Śaryata, who becomes the wife of Cyavana in *Śatapatha
Brāhmaṇa,* IV, 1, 5; but as this involves a discussion of the identity of
Cyavāna, Atri, and others, the possibility must remain to be taken
up on another occasion. It may, however, be pointed out that just as
the Sun is inglorious when he wears the guise of Kṛtyā, so in *Śa-
tapatha Brāhmaṇa,* IV, 1, 5, 1, the inveterated (*jīrṇaḥ*) Cyavana is
" of Kṛtyā's aspect " (*kṛtyā-rūpaḥ*); that *jahe,* " he was left behind ",
corresponds to X, 53, 8, " leave we there the impotent " (*atra jahāma
. . . . aśevaḥ*) and X, 124, 4, " I leave behind the Father " (*pitaraṃ
jahāmi*); and that the name Cyavāna or Cyavana, " fallen away ", cor-
responds to X, 124, 4 where "Agni, Varuṇa, and Soma fall away "
(*cyavante*). Cf. too the " five-fold offering " made by Sūnṛtā to
Brahmaṇaspati [22] in RV. I, 40, 3.

Atharva Veda I, 27 offers unmistakably a condensed account of
Indrāṇī's procession and marriage. Verse 1 opens, " On yonder shore
(*amūḥ pāre*) are thrice seven adders (*pṛdākvaḥ*) that have cast their
skins "(*nirjarāyavaḥ*)."[23] All that the cast skins are good for is to

blindfold the vicious beings that beset the paths, the highwaymen (*paripanthinaḥ*) who are inimical to the proceeding principles. Verses 2 and 3 are apotropaic in the same sense. Verse 4 continues in a language which is now readily comprehensible, " Let the two feet go forward, let them visibly proceed; bear (her) to the homes of Pṛṇa (*vahatam pṛṇataḥ gṛhān*) ; let Indrāṇi go forth foremost, unconquered, unrobbed, to the East ". Here *vahatam gṛhān* is a quite technical expression implying " lead home the bride ". Pṛṇa is a designation either of the Sun, cf. *Śatapatha Brāhmaṇa*, VIII, 7, 2, 1 where the " world-filling " (*lokam-pṛṇa*) brick represents the Sun, who " fills the worlds " (*lokam pūrayati*) ; or of Indra as the Sun, cf. RV. IV, 19, 7, where Indra " fills the waste-lands ", *apṛṇak dhanvāni;* or of Agni who " fills the regions " (*ā rajasī apṛṇat*, III, 2, 7, *pṛṇakṣi rodasī ubhe*, X, 140, 2, and *passim*).

In any case, the evidence assembled above suffices to show that the procession of the " Serpents " on the male side, who " creep further " (*ati sarpante*) and become Ādityas, as related in the *Pañcaviṁśa Brāhmaṇa*, XXV, 15, ample support for which can be cited from the Ṛg Veda, is paralleled on the female side. Apart from their ontological interest, the general conclusion provides a sound basis for the interpretation of many peculiarities of the later Indian iconography.[25]

NOTES

1. The Angels (*devāḥ*) in RV., although from one point of view, that is to say throughout the duration of their aeviternity (*amṛtattva*), incorruptible (*ajara, ajurya, amṛta, amartya*), are subject nevertheless to inveteration at the end, and resurrection at the beginning, of every aeon (*yuga*) ; for example, Agni, the very principle of life (*āyus, viśvāyus*, RV. *passim*) " Being inveterated, is forthwith born youthful " (*jujurvān yo muhur ā yuvā bhūt*, II, 4, 5), and with respect to the aeviternity of his manifestation is also said to be "of unaging youth " (*yuvā ajaraḥ*, V, 44, 3), and called " Life-universal, deathless amongst them that die " (*viśvāyur yo amṛto marteṣu*, VI, 4, 2). Similarly in X, 124, 4 " Agni, Varuṇa, and Soma decline " (*cyavante*), in IV, 19, 2 the inveterated deities are re-emanated (*avâsṛjanta jivrayo na devāḥ*), and in V, 74, 5, " From him that hath declined (*cyavānāt*) ye (Aśvins) loosed the covering cloak, when ye made him young (*yuvā*) again, and stirred the bride's desire ".

2. All references unspecified are to the *Ṛg Veda Saṁhitā*.

3. For the significance of the *vestigium pedi* in Vedic, Zen, and Christian tradition see my *Elements of Buddhist iconography*, 1935, p. 16 and Note 146.

4. These two forms of his are the same as the two forms (*dve rūpe*) of Brahman, " immortal, imageless " (*amṛta, amūrta*) and " mortal, in a likeness " (*martya, mūrta*) of *Bṛhadāraṇyaka Up.*, II, 3, 1, cf. *Maitri Up.*, VI, 3, 15, and 22. The immortal form is that of Varuṇa, Death, the *para-* and *nirguṇa-* Brahman : the mortal that Mārtāṇḍa (= Vivasvan, Sūrya) whom "Aditi bore hitherward unto repeated birth and death ", RV., X, 72, 9 ; Purūravas " when in altered aspect I kept with mortals ", X, 95, 16 ; Puruṣa, whom the Angels sacrificed, X, 9 ; Agni as the sacrifice, X, 88, 9 ; Bṛhaspati as the sacrifice, Yama " who gave up his own dear body ", X, 13, 4 ; Yama, " the sole mortal ", X, 10, 3 ; Vasiṣṭha of the " only birth ", VII, 33, 10 ; the " only son " (*ekaṁ putram*) of Varuṇa, Mitra, and Aryaman, VIII, 101, 6 ; the *apara-* and *saguṇa-* Brahman of the Upaniṣads. " Mitra is the Day and Varuṇa the Night ", *Pañcaviṁśa Brāhmaṇa*, XXV, 10, 10.

5. The Vedic hymns to Dawn are primarily concerned with her first appearance at the beginning of the aeon, and analogically with her constant reappearance, cf. I, 123, 9, where Dawn, coming forth day after day, " hath knowledge of the first day's name ". In the same way the " Days " are primarily periods of supernal time, and only analogically human days, cf. I, 164, 51 " Day after Day the Waters rise and fall ", and II, 30, 1, " Day after Day the sparkling of the Waters moves ". Another version of the hesitation before the battle occurs in the *Kulavāka Jātaka*, No. 31, *Jātaka*, text I, pp. 202-203, where Indra (Śakra) corresponds to Arjuna and Mātali to Kṛṣṇa ; Indra's words " Let me not for the sake of empire (*issaram = aiśvaryam*) destroy life, rather would I for their sake sacrifice my own life to the Asuras ", very closely parallel those of Arjuna in the *Bhagavad Gītā*, I, 33-35, though the detail of the motivation is brought out in a slightly different manner.

6. The concatenation of *kṛṣṇa* and *arjuna* here is by no means fortuitous, but corresponds to that of Kṛṣṇa and Arjuna in the *Mahābhārata*, where the Great Fight is nothing else but the Vedic conflict of Devas and Asuras. Kṛṣṇa, whose name is significant of his descent, comes over from the other side to aid

the Aryan Pāṇḍavas, just as does Vibhiṣaṇa in the *Rāmâyaṇa*, and Uśanas Kāvya, who is the priest of the Asuras but is won over to the side of the Devas. in *Pañcaviṁśa Brāhmaṇa*, VII, 5, 20 *Bandh. Sr. S.*, XVIII, 46, and *Jaiminīya Brāhmaṇa*, I, 125-126; cf. Viśvarūpa, Vṛtra's brother, called "priest of the Devas" in *Taittirīya Saṁhitā*, II, 5, 1 and Indra's *guru* in *Bhāgavata Purāṇa*, VI, 7-13. It is because of the intimate relationships of the Devas and Asuras that Arjuna, in *Bhagavad Gītā*, I, 28 ff., shrinks from the slaughter of "kinsmen and teachers"; cf. *Śatapatha Brāhmaṇa*, IV, 1, 4, 8, where Mitra (= "Arjuna") dislikes to take part in the slaying of Soma, while in the same way *Taittirīya Brāhmaṇa*, I, 7, 1, 7-8, where Namuci reproaches Indra as the "betrayer of a friend" (*mitra-dhruk*), and *Pañcaviṁśa Brāhmaṇa*, XII, 6, where Namuci reviles him as "guilty hero-slayer of the guiltless" (*vīrahaṇṁ adruho druha*), provide a literal prototype for *Bhagavad Gītā*, I, 38, where Arjuna shrinks from the "sin of the betrayal of a friend" (*doṣaṃ mitra-droheḥ*). Arjuna, in fact, shrinks from taking upon himself what in RV. are Indra's typical *kilbiṣāṇi*. It is also very significant, though the implications are too many to be followed up here, that of the two original brothers of the lunar stock, Dhṛtarāṣṭra is blind, while Pāṇḍu means the "son of a eunuch", the former corresponding to the form of deity *ab intra*, the latter to his generated aspect *ab extra*, as son of him that had been impotent *ab intra;* "blindness" and "impotence" being typical of the interior operation (*guhya vrata*) in RV. *passim*, as may be seen by an analysis of those verses in which are found the words *andha*, and *vadhri* or *stari* (it may be noted in this connection also that *śroṇa*, "halt", generally coupled with *andha*, "blind" in the texts alluded to, corresponds to *apād*, "footless", as cited in the present article). Can we not indeed identify Pāṇḍu with the "golden-handed son" (the Sun) whom the Aśvins gave to her "whose consort was unmanned" (I, 117, 24)? The victory of the Pāṇḍavas corresponds to RV., X, 124, 4, where Agni, Varuṇa, and Soma decline (*cyavante*) and the "kingdom is reversed" (*pary āvart rāṣṭram*). The Epic naturally concludes with the final return of the Pāṇḍavas to Heaven, their disappearance *ab intra*, accompanied by Draupadī, whose *alter nomen* "Kṛṣṇā" confesses her Asura origin, and who as the wife of the five Pāṇḍava brothers may be compared to Uṣas or Sūryā, successively the wife of Soma, Gandharva, Agni, and a "mortal" (sc. Vivasvan, Purūravas, Yama), X, 85, 40, and elsewhere also referred to as the consort of the Aśvins; or may be compared with Vāc, as participated in by the Five Kindreds (*pañca jana*). The correspondences outlined above could be followed up in great detail.

7. For some of these equivalents see Bloomfield in *Journ. Amer. Oriental Soc.*, XV, 172, ff. It should be added that the whole concept of the two wives and two mothers survives in the nativities of Buddha, Mahāvīra, and Kṛṣṇa. Apart from the more obvious parallels, it will be remarked that Māyādevī, the Buddha's mother who does not survive, derives by her name itself from the Asura side, while the co-wife Pajāpatī, called in the *Buddhacarita*, II, 19, her *samaprabhavā*, tantamount to *savarṇā*, lives; and that Devakī, the mother of Kṛṣṇa, is the sister of the Asura Kaṁsa, in whose realm both parents are imprisoned, while the child is taken over water (the Yamunā, although in flood, becoming fordable for him, like the Sarasvatī in RV. *passim*) to the human-angelic world where he is fostered by another mother. In the case of Mahāvīra, the circumstances of whose nativity are so exactly paralleled in RV., I, 113, 2 and I, 124, 8 cited above, the choice of the Kṣatriya womb (and similarly in Buddhism, the

opposition of Kṣatriya to Brahman) by no means necessarily reflects a con-
temporary social conflict of values, but can be better understood in the light
of the whole Vedic concept of the contrasted relations and functions of the
spiritual (*brahma*) and temporal (*kṣatra*) powers, the former being primarily
those of Varuṇa = Brahman, the latter those of Indrāgnī. Nor need we be
confused by the fact that when the relation of Agni to Indra is considered
per se, and *ab extra*, this is again that of the spiritual to the temporal power :
for just as Agni delegates the temporal power to Indra (VIII, 100, 1-2, X,
52, 5 and 124, 4, etc., cf. *Śatapatha Brāhmaṇa* V, 4, 4, 15) though sometimes
playing an active part, so the Buddha (who for the most part corresponds to
Agni, " Gautama Buddha " for example reflecting Agni *uṣar-budh*) declines the
temporal power and as an actual teacher plays the Brahman part, although in
the conflicts with Māra (= Mṛtyu = Vṛtra, etc.) and the "Ahi-nāga" (*sic*
in *Mahāvagga*, I, 15, 7) of the Jaṭila shrine, he takes that part which is played
more often by Indra than by Agni or Bṛhaspati in person.

8. " Sinister " also in a literal sense : for the act of creation and procession
is an extroversion, as appears in innumerable texts, e. g. X, 124, 4 " the kingdom
was reversed " (*pary āvart rāṣṭram*), IV, 1, 2 " O Agni, turn thy brother
Varuṇa round about " (*bhrātaraṃ varuṇam agne ā vavṛtsva*), cf. *Aitareya
Brāhmaṇa*, IV, 5 where, the Angels and Titans being of equal heroism, " there
was a delay in turning back " (*na vyavartanta*) the latter ; and this extroversion
is a right hand or sunwise turn, as in III, 19, 2 = IV, 6, 3, " Agni, choosing
rightwise the angelic office " (*pradakṣiṇit devatātiṃ urāṇaḥ*), or X, 22, 14,
" Thou (Indra) smotest Śuṣṇa to the right (*pradakṣiṇit*) for Viśvāyu " (i. e.
Agni). Cf. *Śatapatha Brāhmaṇa*, III, 2, 1, 13 and VII, 5, 1, 37.

Remembering that Night and Dawn are the two wives of Indra (*Vājasaneyi
Saṃhitā*, III, 10, cited above) it is obvious that RV. X, 145—in application a
spell directed against a co-wife (*sapatnībādhanam*)—is by first intention an
imprecation launched by Indrāṇī herself, to whom the hymn is attributed, against
her rival sister Night ; while X, 129, attributed to Śacī Paulomī (Indrāṇī) is
her song of triumph (cf. X, 125, attributed to Vāc). Atharva Veda I, 14, is
apotropaic in the same sense as RV. X, 145.

The application of these hymns illustrates very well the basic principle of
magical incantation ; the recital of what was done in the beginning is held to be
effective in particular application here and now. In the same way, for example,
RV. V, 78, the immediate reference of which is to Agni's or the Sun's nativity,
is employed as a birth rune. The application is by analogy, and takes for
granted the correspondence of macrocosm and microcosm.

9. Night and Day (*uṣasānaktā*) are both favorably regarded " Daughters
of Heaven " in X, 70, 6, but this is as being seated together at the altar
(*yonau*), that is analogically *ab intra*, for *yoni* as altar corresponds to " navel "
(*nābhi*) " where Aditi confirms our kinship " (*jāmitva*) X, 64, 13, and it is at
the " navel of Order " (*ṛtasya nābhau*) that " I throughly purify " (*saṃ
punāmi*, X, 13, 3).

10. The word *nahuṣaḥ* contrasts with *uṣasaḥ*, both fem. pl. acc. Nahuṣa (m.),
from a root *nah* implying " bondage ", is a designation of Agni's father in I, 31,
11 and V, 12, 6 ; in fem. pl. it may therefore appropriately designate at the
same time " nights ", (as rendered also by Fay in *Journ. Amer. Oriental Soc.*,
XXVII, p. 411, q. v.) and the recessive " false dawns " that have been Agni's
" first mothers " in his successive manifestations, but are set back yielding

place to the true dawns that are the Suns' brides and Agni's "second mothers".
It is further noteworthy that in some later texts Nahuṣa is or becomes a
serpent. In literal significance and as an essential rather than personal name,
nahuṣa may be compared to *varuṇa* and *vṛtra,* as derivates of *vṛ.*

11. The *samānaṁ varṇam* daily put on is of course the *āryaṁ varṇam* of
III, 34, 9 as distinguished from the *asuryaṁ varṇam* of IX, 71, 2 (= *pāpaṁ
varṇam* in *Jaiminīya Brāhmaṇa,* I, 220, with reference to Apālā) ; and being
in fact the "cast(e)" of the Sun, the Dawns are described virtually as becoming
every morning *savarṇā* in Bloomfield's second sense of "like (Vivasvant) in
character or class" (*Journ. Amer. Oriental Soc.,* XVI, p. 178).

12. *Ṛṇañcaya,* lit. "debt-collector": either Bṛhaspati-Brahmaṇaspati, as in
II, 23, 11 and 17 (*ṛṇayā, ṛṇacid ṛṇayā*), or Indra himself (*ṛṇacid . . . .
ṛṇayā,* IV, 23, 7), the toll being exacted in either case from the fiend (*druh*).
Monier-Williams, for *ṛṇañcaya,* has nothing better to offer than "name of a
man", and it is in this fashion that essential names have generally been
treated by translators of the Vedas. How many needless obscurities and
complications have been introduced into Vedic studies by a persistent neglect
of the warning "Even as He seemeth, so is He called" (V, 44, 6) it would
be hard to tell. *Kaṭha Up.,* IV, 14 can be pertinently cited: "He who sees
the principles separately, pursues them separately".

13. Heaven and Earth, as parents of Agni, "The son within his parents'
lap, as being the Eternal Germ" (*garbham . . . . nityaṁ na sūnuṁ pitror
upasthe, ib.*). This *nityam,* incidentally, recurs in *Kaṭha Up.,* V, 13, "Eternal
mid the transient" (*nityo' nityānām*).

14. Kṛtyā as feminine personification of *kṛtya,* "that to be done", is per-
spicuous in the present context; where that which should be, but is not yet
done, and merely *in potentia,* is as such evil. The putting off of *kṛtyā* is
procedure from potentiality to act, nonbeing to being, privation to abundance,
death to life. For the conception, typical also in Christian Scholastic philosophy,
there may be compared in connection with Indra's procession "Many a thing
not yet done I have to do" (*bahūni me akṛtā kartvāni,* IV, 18, 2, cf. "Wot ye
not that I must be about my Father's business?", Luke II, 49) ; in connection
with Uṣas, "Delay not to go about thy labour" (*mā ciraṁ tanuthā apaḥ,* V,
79, 9) ; again in connection with Indra, "Do what thou hast to do" (*kariṣya
kṛṇuhi,* I, 165, 9), who indeed "does what must be done" (*cakṛiḥ yat kariṣyan,*
VII, 20, 1), i. e. in Christian formulation "Those things which God must will
of necessity" (St. Thomas, *Sum. Theol.,* I, q. 45, a. 2 c), who is also described
as being "wholly in act". The principle involved underlies *Bṛhadāraṇyaka Up.,*
III, 2, 13, "What they praised was Action (*karma*)", and the doctrine re-
garding *karma yoga* in the *Bhagavad Gītā.* Cf. also *kusalamassa akatattā*
(= *kuśalasya akartatvāt*) in *Jātaka,* text, I, 205; *akārya* as "sin" in *Mṛccha-
kaṭika,* VIII, 22, 4; and *akaraṇasaṁvaram* as "sins of omission" in *Sādha-
namālā* No. 98 (Gaekwad's Oriental Series, XXVI, p. 201).

The following verse is apotropaic with respect to the "consumptions"
(*yakṣmā*) which may be transmitted from the bride's stock (*yanti janāt anu*),
and which the Angels are besought to return to the place of their origin.
Yakṣma is, of course, a disease always thought of as proceeding from Varuṇa
in his unfriendly aspect. Following words derived from RV., X, 17, 1 re-
ferring to Tvaṣṭṛ's gift of his daughter Sūryā in marriage, the *Atharva Veda,*
III, 31, 5 similarly expresses the wish "May I be separated from evil

(*pāpmanā*) and consumption (*yakṣmeṇā*) and united to life (*āyuṣa*)", cf. RV. VII, 59, 2 " Release us from the bonds of death, not those of life" (*bandhanāt mṛtyor mukṣīya na amṛtāt*), that is in effect also " May we pass over from Varuṇa, from Death, to Agni Vaiśvānara, to Life ".

16. I. e. Agni, *ab intra*, and eager (*icchan*, etc.) to proceed.

17. Converse of *guhamāno antā* in IV, 1, 11. The " ends " are either as here the halting places of the Sun, or as in *Jaiminīya Up. Brāhmaṇa*, I, 35, Winter and Spring, the two ends of the Year; or, indeed, any pair of contrasted and limiting concepts which are united *ab intra* and divided *ab extra*. The distinction of the limits is temporal and spatial; their indistinction eternal.

18. The husband (*pati*) with whom she is at variance is no doubt the Gandharva, the jealous protector of unwedded maidens, cf. X, 85, 21-22, " Rise up from hence, Viśvāvasu; this maiden hath a husband . . . . Seek in her father's home another willing maid ". Compare also X, 95, 2, where Urvaśī (who corresponds to Uṣas, Sūryā, and Apālā, as does Purūravas to Sūrya and Indra) deserting Purūravas says " like the first of Dawns I leave thee ". From the Brāhmaṇa and other versions of the legend (knowledge of which is taken for granted in X, 95) we know that Urvaśī is in fact taken back into the Gandharva world (the "Assumption of the Virgin"), and that it is only when the sacrifices of the Year have been completed that Purūravas himself recovers his Gandharva status and is reunited to his immortal bride. Purūravas is " mortal ", not as man is mortal by contrast with the *devas*, but as the *devas* are mortal when contrasted with the *asuras*, as Mitra is mortal by contrast with Varuṇa (I, 164, 38 and X, 85, 17-18) ; he is the " dying god ", the Year, the father of " Life " (*āyus*).

19. Apālā's uninhibited procedure corresponds to the shamelessness of Dawn, RV. *passim*, where she is referred to as like a dancer, as unbaring her bosom, or unveiling her charms (I, 92, 4; I, 124, 3-4; VI, 64, 2), or described as rising as if from a bath (V, 80, 5-6; Apālā's meeting with Indra also taking place beside the river, where, as Sāyaṇa takes it, she has gone to take her morning bath). Urvaśī and her sister *apsarases* are similarly described in X, 95, 9. Cf. RV., VII, 80, 2 speaking of Dawn, " Youthful and shameless she goeth forward, having come to know of Sun, and sacrifice, and Agni", and also *Jaiminīya Up. Brāhmaṇa*, I, 56, " In the beginning, the woman went about in the flood, desirously seeking a husband (*strī . . . . saṁcarantī icchantī salile patim*, perhaps a reflection of RV. V, 37, 3, *vadhur iyaṁ patiṁ icchanti*, " This woman desiring a husband ", whom Indra makes his chief queen). The woman's boldness, of which the memory survives in the later rhetorical allusions to the inconstancy of Śrī-Lakṣmī, is admirably illustrated in the early Indian representations of *apsarases*, best perhaps in the Mathurā Museum example, J 2.

20. Cf. *Atharva Veda*, III, 17, 5, " Tvaṣṭṛ made a marriage for his daughter, and all this universe went forth " (*idaṁ viśvam bhuvanaṁ vi yāti*), where in spite of Bloomfield (*Journ. Amer. Oriental Soc.*, XVI, p. 183, I venture to think that *vi yāti* is intransitive and has *viśvam bhuvanam* as subject. It is in the same way that Urvaśī "bestows upon her husband's father wealth, when her lover (*uṣah*, m.) woos her from the nearby home" (X, 95, 4), i. e. from the Gandharva world, from within, cf. the reference to the origin of Vāc in " another's house ", RV. X, 109, 4.

21. Apālā is drawn three times " through the opening of the chariot, the opening of the wain, the opening of the team " (*khe rathasya, khe anasaḥ,*

khe yugasya). In *Jaiminīya Up. Brāhmaṇa*, I, 3, the *kha anasaḥ* and *kha rathasya* are identified with the *divas chidra* or "hole in heaven", which is "all covered over by rays", and is the Sun through the midst of which the Comprehensor "utterly escapes" (*atimucyate*); cf. *Chāndogya Up.*, VIII, 6, 6, where the Sun is called the "portal of the worlds" (*lokadvāra*) and RV. V, 81, 2 where it is the Sun that "lets out the forms of all things" (*viśvā rūpāṇi prati muñcate . . . . savitṛ*). Obviously the way out and the way in are the same (cf. John, X, 9); to be dragged forward through the hole of the chariot is to be born into the worlds, to pass out through the hole is to die, whether temporarily or finally. With the description of the axle-hole as all covered over with rays", cf. X, 132, 6, "Wash her (Aditi) with sun-rays" (*sūro ninikta raśmibhiḥ*).

In all probability *kha rathasya, kha anasaḥ, kha yugasya* are synonymous expressions, all equivalent to *kha* as "hole in the wheel through which the axle passes", see my "*Kha* and other words denoting 'Zero', in connection with the metaphysics of space", in *Bulletin of the School of Oriental Studies*, VII, 1934. But even if we hold with Sāyaṇa that three successively smaller openings in different parts of the chariot are intended (which seems improbable), it by no means follows that the three operations by which the "delivery" is made are to be understood as taking place upon one and the same occasion; we understand in any case that Indra drags Apālā three times through the "hole of his chariot", in other words makes her to be born thrice, as in the story of Sujātā cited below; cf. *khād-iva yoni-jātaḥ* in *Buddha Carita*, i, 30.

Since writing the above I find in *Jaiminīya Brāhmaṇa*, II, 419, *yathā ratha-nābhau arāḥ pratiṣṭhā*, "when the spokes are affixed to the hub of the chariot"; and inasmuch as "hub of the chariot" can only mean "hub of the chariot wheel", so we may take it that "aperture of the chariot", *kha rathasya*, means "aperture of the chariot wheel", as the sense requires.

There is an analogous ritual use of "ringstones", which are regarded as *yonis* or female symbols of generation (see Marshall, *Mohenjo-Daro*, p. 62, and references there cited); those who are passed through such ringstones are, as it were, "born again". That such stones are really symbolic representations of the solar *loka-dvāra* through which one "escapes altogether" (*atimucyate*) is clearly seen in the case of the well-known example at Śatruñjaya, where the opening in the stone is called the "door of liberation" (*mukti-dvāra*).

For further references to the story of Apālā see Oertel in *Journ. Amer. Oriental Soc.*, XVIII, 26 f.

22. With all the purifications referred to above may be compared those performed by the Sāman and Ṛk antecedent to the consummation of their veiled union on the night of the sabbath (*upavasathiyāṁ rātriṁ, sadasi, Jaiminīya Up. Brāhmaṇa*, I. 54). In this case (in many respects analogous to that of Yama and Yamī, RV. X, 10, but with a "happy ending"), that which Ṛk removes and casts forward (*pratyauhat*) becomes the "vision of living creatures" (*dhīr eva prajānāṁ jīvānāṁ eva*), and the whole is once more a story of creation.

23. Not an independent "Person", but an essential name of Agni, as explicitly recognized in I, 38, 13.

24. *Amūḥ pāre*, i. e. "on the farther shore", awaiting transportation over the flowing river, like, for example, Bhujyu, *samudra ā rajasaḥ pāra iṅkhitam*, whom the Aśvins bring across in their winged ships, X, 143, 5. The thrice

seven adders or addancs are no doubt the twenty-one rivers of X, 5, 5, 64, 8, and 75, 1, cf. X, 99, 4 where the young restless streams that Indra pours out hitherward are as yet "footless and carless", and IX, 77, 3 where the Soma streams are referred to as "beautiful like snakes" (*ahyo na cāravo*). If the latter comparison seems strange in view of what has been said so far, it must be remembered that the beauty of *nāginīs* becomes a cliché in later Indian literature, and that at least a *beauté de diable* must be attributed to Night, with whom the Sun is in love before her transformation takes place; just as in folk-lore the human hero is in love with the mermaid before she acquires a human form and soul. *Nirjarāyavaḥ* is literally "freed from the chorion", the commentators supplying "with skin sloughed from the body, chorionwise" and "as Devas, freed from the chorion". Comparison may be made with RV. X, 106, 6 "Do ye (Aśvins) make my corrupted chorion to be incorruptible" (*jarāyv ajaram marâyu*); X, 123, 1, where the Sun is new risen from the chorion, or in a chorion of light (*jyotir-jarāyū*); Atharva Veda, I, 12, 1 where the Sun is *jarāyu-ja*; *Satapatha Brāhmaṇa*, VI, 6, 1, 24, where Agni is due to be born from the chorion (*jarāyuṇo jāyamāna*) which is called "putrid", like Sūryā's cast off garment in X, 85, 34, cf. AV. I, 11, 4; and especially *Jaiminīya Brāhmaṇa*, II, 438, where Saramā, "splitting open the chorion of the Waters" sets them free to flow. The word *jarāyu* itself derives from *jṛ* "to be inveterated"; such expressions as RV. I, 140, 8 *jarāṁ pra muñcan*, and *Pañcaviṁśa Brāhmaṇa*, XXV, 17, 3, *jarāṁ apāhat*, "put off eld", and such expressions as *jarāyu-ja* cited above, equally imply a birth and rejuvenation. In other words, the young unwedded streams are newly born; Indra's bride is one of them, or one like them, just as Urvaśī in X, 95, 6 is one of the "seven" Apsarases, in V, 42, 9, "Urvaśī of the streams". "Unrobbed" (*amuṣitā*) has reference to the powers of darkness that lie in wait to steal away the "names" of those that proceed, as in V, 44, 4, where Krivi *nāmāni vane pravaṇe muṣayati*.

25. For example, in VIII, 17, 5, *pṛdāku-sānu* is an epithet of Indra; the words appear to mean "serpent-shouldered" (*sānu*, primarily "high plain" or "table-land", metaphorically the upper part of the back, as in RV. I, 32, 9). There is an image answering to this description in the Mathurā Museum (see Vogel, *Ars Asiatica*, XV, Pl. XXXIX and p. 46). The female counterpart of this image (*ib*. Pl. XL) has long been known as the "Serpent Queen". And Sarparājñī, or "Serpent Queen" is a designation of Vāc and of Earth in *Satapatha Brāhmaṇa*, IV, 6, 9, 16-17. The two images are then rightly to be called those of Indra and Indrāṇi.

The Sarparājñī hymn is also called the Mānasa Stotra or "mental laud", because its verses are "recited mentally" (*manasā stuyante*, *Taittirīya Saṁhitā*, VII, 3, 1, 4, cf. *Satapatha Brāhmaṇa*, II, 2, 1, 30); hence the name of the well-known Bengali snake-goddess, Manasā Devī, who is at once Indrāṇi and the Earth, and of whom the Mathurā "Serpent Queen" may be regarded as one of the earliest known representations.

The Serpent Queen must also be recognized in Sasarparī "the daughter of the Sun" and "Lunar Maiden" (*pakṣyā; pakṣa*, according to Sāyaṇa, is here the Sun, the usual sense of "Moon", as in *Buddha Carita*, II, 20, seems to be more acceptable, and would allude to Sasarparī's *āsurya* origin), "who puts forth the New Life" (*navyam āyur dadhāna*), RV. III, 53, 15-16; where Āyus is primarily Agni (see Bloomfield in *Journ. Amer. Oriental Soc.*, XX, p. 181), "the one and only Life" (*ekāyus*, I, 31, 5), and "Universal Life" (*viśvâyus*, I, 67, 5; IV, 28, 2; VI, 4, 2).

CONCERNING THE BADIANUS MANUSCRIPT, AN AZTEC HERBAL, "CODEX BARBERINI, LATIN 241" (VATICAN LIBRARY)

(With Four Plates)

BY

EMILY WALCOTT EMMART

The Johns Hopkins University

FOREWORD

The present pamphlet is published to make known the discovery of the Badianus Manuscript in the Vatican Library and to give an idea of the value and interest of this unique Aztec herbal. It is believed to be the earliest herbal produced on this side of the Atlantic, and from this consideration alone it deserves all the notice that it will undoubtedly receive. It is a matter of regret to the Smithsonian Institution that funds are not available to publish a facsimile of the full manuscript with its 91 color sketches of plants. Such a publication, in the usual edition issued by the Institution and with 91 color plates, would involve a considerable sum, but the text with black and white illustrations and a few color plates could be published for a comparatively moderate amount. If there are those who would be sufficiently interested to contribute toward the publication of this valuable manuscript as a whole or in such modified form, I should be glad to have them communicate with the Institution.

C. G. ABBOT,
Secretary, Smithsonian Institution.

CONCERNING THE BADIANUS MANUSCRIPT, AN AZTEC HERBAL, "CODEX BARBERINI, LATIN 241" (VATICAN LIBRARY)

By EMILY WALCOTT EMMART

The Johns Hopkins University

(With Four Plates)

The Badianus manuscript is a sixteenth century Mexican Herbal composed in the year 1552 in the famous College of Santa Cruz at Tlaltelolco, Mexico City. This beautiful manuscript has long been in the possession of the Vatican Library, where its real identity has been obscured by the title " Codex Barberini, Latin 241 ". Except for a few scholars,[1-2] it was practically unknown until 5 years ago, when,

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[1] In a personal communication (Mar. 16, 1930) to Dr. C. U. Clark, Mrs. Zelia Nuttall suggests that " Codex Barberini, Latin 241 " might be the " small book " sent by Muñoz Camargo to King Philip. It contained a " demonstración, pro pinturas y colores de sus formas y hechuras y propriedades " of the flowers esteemed by the Indians (Muñoz Camargo, Historia de Tlazcala, edition issued in Tlazcala, Imprento de Gobierno, 1870).

[2] Thorndyke, Lynn, Vatican Latin Manuscripts in the History of Science and Medicine. Isis, vol. 13, 1929-30.

" This sixteenth century manuscript is a work on medicinal herbs of the Indias which an Indian physician of the College of Holy Cross composed, taught by no reasons, but by experience only, in the year 1552.

" There is a dedication by Martin de la Cruz to Francisco de Mendoza, and the work closes with a letter of John Badianus, the Latin translator, to the reader.

" Barberini 241, paper, 63 fols., Libellus de Medicinalibus Indorum Herbis quem quidam Indus Collegii Sanctae Crucis medicus composuit, nullis rationibus doctus, sed solis experimentis edoctus Anne Domini Servatoris 1552."

In a personal communication from Dr. C. U. Clark, the author is informed that Dr. Gabrieli, of the Corsini Library in Rome, discovered a copy of the Badianus manuscript, in Italian hand, in the Royal Library at Windsor Castle.

Gabrieli, G., Due codici iconografici di piante miniate nella Biblioteca Reale di Windsor. A proposito di Cimeli Lincei. Rend. Acc. Lincei, ser. 6, vol. 10, 2 sem., fasc. 10, November 1929.

through the generosity of Ambassador Charles G. Dawes, the Smith-
sonian Institution sent Dr. Charles U. Clark to Europe in search of
early Latin American texts. Through the courtesy of the Vatican
Library, Dr. Clark was able to obtain photographs of the original
manuscript, and it is from these that the present translation has been
made. The manuscript is a complete herbal consisting of 63 folios
approximately 6 by 8¼ inches in size, clearly written in Latin and
Aztec. It is divided into 13 chapters, each representing an attempt
to group maladies of either similar type or similar location of the
body. The first eight chapters follow the latter arrangement, begin-
ning with the head and continuing to the feet; in the last five chapters
an attempt has been made to group them according to subject matter.
The text is exquisitely illustrated with pictures of 204 herbs and
trees, and these illustrations still today retain their brilliancy of color.
Through the kindness of Dr. Charles G. Abbot, of the Smithsonian
Institution, the original water-color sketches for the colored plates,
made by Mrs. Missonnier, niece of Mgr. Eugene Tisserant, Pro-
Prefect, Vatican Library, have been obtained, and it is hoped that it
will be possible at a later time to publish the herbal in colored facsimile
with a translation.

The herbal is the work of two Aztecs who were educated at the
College of Santa Cruz. It was first written in Aztec and then, with
the exception of the names of the plants, stones, and animals, trans-
lated into Latin within the same year. The exact title reads as follows:

A book of Indian Medical Herbs composed by a certain Indian physician of
the College of Santa Cruz, who is not theoretically learned, but is taught only
by experience. In the year of our Lord Saviour 1552. [Pl. 1.]

There seems little doubt that the principal author of the manu-
script is one Martin de la Cruz, whose name appears in the first line
of the dedication; the second author is Juannes Badianus, the trans-
lator, whose signature appears in the postscript at the end of the last
chapter. Both of these men were natives taught in the first college
erected for the Indians, the College of Santa Cruz.

The manuscript is fittingly dedicated to Don Francisco de Mendoza,
son of Don Antonio de Mendoza, the first viceroy to New Spain.
Although the dedication is addressed to Don Francisco de Mendoza,
it is none the less a tribute to the first viceroy. That it is not ad-
dressed directly to the viceroy may be explained by the fact that
Don Antonio de Mendoza had been transferred to Peru 2 years be-
fore. Since history records his death on July 21, 1552, the day before

the completion of the translation, it is certain that he was not aware of the well-deserved tribute which reads as follows:

> For the most eminent Don Francisco de Mendoza, most excellent son of Don Antonio de Mendoza, first viceroy of this India, his unworthy slave, Martin de la Cruz, prays for the greatest health and prosperity.[3]

> Since in you the graces and adornments of every excellence, and the accomplishments of the good, which are desired by everyone, shine forth O most magnificent Master, I do not know, indeed, what quality of yours to praise especially. Indeed, I do not see by what praises I may extol your remarkable love, by what words I may express gratitude for your unsurpassable kindness. For I cannot express in words how your father, a man at once most christian and most devoted, has been above all others my benefactor, for whatever I am, whatever I possess, and whatever renown I have, I owe to him. I can find nothing equal to, nothing worthy of his benefits. I can give great thanks, indeed, to my Maecenas, but little repayment. On that account, I offer, dedicate, and consecrate myself, whatever I am, to be your property. Not in truth to him alone, but also to you my most eminent master, as a most supplicant token and testimony of my singular devotion.

The herbal was written at the request of Don Francisco de Mendoza and was intended as a gift to " His Holy Caesarian Royal Catholic Majesty "—Charles V. It is evident that Don Francisco, who followed in his famous father's footsteps in fostering the protection and education of the Indians, wished to commend the work of the Indians and to enlist His Majesty's support of the College of Santa Cruz.

The latter part of the dedication reads as follows:

> Indeed I suspect that you demand this little book of herbs and medicaments so strongly for no other reason than to commend us Indians, even though unworthy, to his Holy Caesarian Catholic Royal Majesty. Would that we Indians could make a book worthy of the king's sight, for this certainly is most unworthy to come before the sight of so much majesty. But you will recollect that we poor unhappy Indians are inferior to all mortals, and for that reason our poverty and weakness implanted in us by nature merit your indulgence. Now accordingly, I beg that you will take this book, which by every·right I ought to inscribe with your name, most magnificent Master, in the spirit in which it is offered, or, what would not surprise me, that you cast it out whither it deserves. Farewell. Tlatilulci. In the year of our Lord Saviour 1552.
>
> Your Excellency's most humble servant.

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[3] In the space between this item and the following appears " Exlibris didaci Cortavila." The handwriting is entirely different from that of the manuscript, so we can surmise that the book was once in the possession of someone by the name of Cortavila.

Whether this beautiful little manuscript ever came into the hands of Charles V is not known, but Mendieta[4] records the fact that His Majesty contributed to the support of the College:

His Majesty gave to the College of Santa Cruz, where they were taught Latin a thousand pesos for each year for certain years. To those who taught in the Chapel of Santa Jose to read, write and sing and play instruments of the church, three hundred ducats was given for some years. To illuminate the Holy Sacrament he commanded to give to each monastery six measures in each year, one half measure for each month. For celebration of mass in the monastery he commanded wine.

and in addition we read—

for the hospitals of St. Francis of Mexico and convent of Los Angeles 100 pesos per year. And in order that the sick Indians should not remain untreated, he ordered to be built a royal hospital near Saint Francis of Mexico where they were cared for.

Entirely apart from wishing to enlist His Majesty's support of the college which, after the early prosperous period, was always in need of funds, Don Francisco undoubtedly had a keen interest in the herbs and medical knowledge of New Spain. Verification of Don Francisco's personal interest in herbs is to be found in the quotation from the Frampton translation of Monardes:[5]

Don Frauncis De Mendosa, Sonne unto the vise Roye, Don Antony de Mendosa did sowe in the new Spaine Cloaves, Pepper, Ginger, and other spices, of those whiche are brought from the Orientall Indias, and that whiche by hym was begonne was loste, by reason of his death, onely the Ginger did remain, for it did growe verie well in those partes, and so thei bryng it greene from newe Spain and other partes of our Indias, and some they bring drie, after the maner of that of the East India.

Besides the personal interest of Don Francisco in herbs and his desire to foster the education of the Indians, a third and more forceful influence gave impetus to the writing of this herbal; namely, the demand on the part of Europeans for herbs and medicaments.

The expansion of the West had been stimulated by a desire to find a shorter trade route to the spice-producing countries of the East. The tales and accounts of voyages of Columbus (1492-1502), Vespucci (1499-1503), Balboa (1512-13) and Magellan (1519-22) and others had already awakened Europeans to the value of spices and herbs from

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[4] Icazbalceta, Joaquin Garcia, 1870.
Mendieta, Fray Gerónimo de Mendieta-Historia Eclesiástica Indiana. Publ. Mexico, 1870. Antiqua Libreria, portal de Augustinos no. 3, 1870.
[5] Frampton, John, 1577—Joyfull Newes of the Newe Founde Worlde . . . . tr. of Monardes, Nicholas, vol. 2, p. 5, Introduction by Stephen Gaselee, Constable and Co., Ltd. London, 1925.

the New World. With the coming of Cortez and the fall of Tenoch-
itlan in 1521, news of the medical knowledge of the Aztecs drifted back
to Europe. In a letter to Charles V concerning the district of
Tlaltelolco, the marketplace of Tenochitlan, Cortez mentions espe-
cially a street of " herb sellers where there are all manner of roots and
medicinal plants that are found in the land. There are houses as it
were of apothecaries where they sell medicines made from these herbs
both for drinking and for use as ointments and salves." [6]

These letters, accounts of ship captains and explorers, even at this
early date carried news to Europe of a knowledge of the use of herbs
and medicaments which appeared to rival that of the Old World.
This interest is reflected in accounts of later historians and travelers,
and in the works of some of the great European herbalists of the
sixteenth century.

Of the translator Juannes Badianus, we have brief but precise data
in the last two pages of the volume (pl. 2), where he adds a word of
explanation to the reader which is self explanatory:

JUANNES BADIANUS, THE TRANSLATOR, TO THE GENTLE READER

I beg again and again, most excellent reader, that you consider that I have well
employed the labor that went into the translation, such as it is, of this little book
of herbs. For my part, I preferred to have that labor go for nothing than to
undergo your most exacting judgment. Further be sure that I put so many
spare hours on this edition, not to show off my own talent, which is almost
nothing, but only because of the obedience which I very rightly owe to the
priest of this Monastery of St. Jacob, the apostle of the Spaniards and my most
excellent patron, and very much to his superior the reverend Franciscan father,
brother Jacobo de Grado, who laid this task upon my shoulders. Farewell in
Christ the Saviour. At Tlatilulci in College of the Holy Cross, on the feast
day of Saint Mary Magdalene during the Holy Holidays, A.D. 1552.

End of the Book of Herbs, which Juannes Badianus by nation an Indian of the
Xuchimilcanus country, reader of the same college, translated into Latin.

Glory be ever to him by whose gift I translated this Book which you per-
ceive, Good friend Reader.

Badianus was apparently a native Indian from the district of
Xochimilco, and he was undoubtedly among those first students who
attended the college after it opened in 1535. It is most fitting that
the translator was a native of the district of the floating gardens of
Xochimilco, which had long been the gardens of the Aztec kings and
princes. Centuries before the conquest the Aztecs had brought flowers
and herbs from the lowlands and had developed a truly botanical gar-

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[6] Cortes, Hernando, Five letters, 1519-1526. Translated by F. Bayard Morris,
Robert M. McBride & Co., New York, 1929. Second letter, p. 87.

den of plants from many districts in Mexico. The historian Juan de Torquemada,[7] who was for a time a member of the faculty of Santa Cruz, tells us that " Montezuma kept a garden of medicinal herbs and that the court physicians experimented with them and attended the nobility. But the common people came rarely to these doctors for medical aid, not only because a fee was charged for their services, but also because the medicinal value of herbs was common knowledge and they could concoct remedies from their own gardens." These gardens were undoubtedly flourishing in good condition at the time the manuscript was written, and even today they furnish all the flowers and vegetables for Mexico City. It is quite within reason that both Martinus de la Cruz and Juannes Badianus were familiar with the flora of this district from early childhood.

Of " the Reverend Franciscan father, Brother Jacobo de Grado ", no other historical reference has as yet been found—a most singular fact since he held the position of superior at the convent at a time when both the historians Fray Bernardino de Sahagun and Fray Torquemada were in Mexico, the former Fray Bernardino de Sahagun being a member of the Governing Board of the Order of Franciscans at the time of the completion of this manuscript.

As to the origin of the famous College of Santa Cruz of Tlaltelolco (Tlatilulci), both the modern writers Bourne[8] and Merriman[9] accredit its founding to Bishop Zumarraga in the year 1535. Bourne adds : " Besides the elementary branches, instruction was offered in Latin, philosophy, music, *Mexican medicine*, and the native languages. Among the faculty were graduates of the University of Paris and such eminent scholars as Bernardino de Sahagun, the founder of American anthropology, and Juan de Torquemada, himself a product of Mexican education, whose Monarquia Indiana is a great storehouse of knowledge of Mexican antiquities and history. Many of the graduates of this college became alcaldes and governors in the Indian towns."

[7] Torquemada, Juan de, Monarg. Ind., lib. 14, chap. 14 : " El emperador Moctezuma tenia jardines de yerbas medicinales, y mandaba á sus médicos que hiciesen experiencias con ellas, y curasen á los señores de su corte. La gente común occurria rara vez a los medicos, por excusarse de pagarles, y porque era general el conocimiento de varios remedios, con los cuales se curaban, como podian, de sus enfermedades."

[8] Bourne, E. G., The American Nation—a history, vol. 3, p. 309, Harper & Brothers, New York, 1904.

[9] Merriman, R. B., The rise of the Spanish Empire, vol. 3, p. 663, Macmillan Co., New York, 1925.

If we return to the sixteenth century work of the historian Mendieta, who went to Mexico 19 years after the founding of the college, a more intimate picture may be obtained. Before the opening of the College of Santa Cruz in 1536,[9a] the Indians were taught in the convent of S. Francisco of Mexico in the chapel of S. Jose. Here " the good father and guide Fr. Pedro de Gante " instructed them in " Christian doctrine and in all the arts and exercises ". " The first teacher in grammar was Fr. Arnaldo de Bassacio, a Frenchman and a great linguist of Indian language, with whom they made such progress that the first viceroy Antonio de Mendoza, true father of the Indians, noting their progress gave the order that they should build a college in the principal suburb of Mexico a quarter of a league from S. Francisco (where we, the lesser friars have a second convent of the name of the apostle Santiago, in the suburb which is called Tlaltelolco). [Pl. 4.] In order that the guardian of that convent should have in his charge the administration of the college, and that this work should not burden the brothers of the principal convent, the viceroy Don Antonio himself built the college at his own expense and gave certain estates and farms which he had, in order that the rent of them might sustain the Indian college."

The students at the tender age of 10 to 12 years were carefully selected from the " sons of gentlemen " of the principal towns and larger provinces of this New Spain. " The priests of their native town selected only those who appeared most able, and thus were gathered together about a hundred children and young men." The ceremonies of the dedication of the college were impressive. Among those present were the viceroy, Antonio de Mendoza, Bishop of Mexico, Don Fr. Juan Zumarraga, the Bishop of S. Domingo, D. Sebastin Ramirez and " with them all the city ". The ceremonies began with a sermon preached by Dr. Cervantes at the convent of S. Francisco of Mexico. Then a great procession marched to the Convent of Santiago, where a second sermon was preached by Fr. Alonso de Herrera and a third and last by Fr. Pedro de Rivero in the refectory of the Friars of the Convent of Santiago—where, adds Mendieta, " The gentlemen ate at the cost of the good Bishop Zumarraga."

Mendieta also gives us the names of the teachers who taught during those early prosperous years and who quite probably were the instructors of the two authors of our herbal. Fr. Arnaldo de Bassacio, who first taught Latin, was followed by Fr. Bernardino de Sahagun and

Fr. Andres de Olmos. All three of these were gifted scholars of the Aztec language, and undoubtedly gave instruction in the writing of Aztec. (The Nahuatl grammar of Olmos is still today the background for all recent studies of the language.) Fr. Juan de Gaona also taught rhetoric, logic, and philosophy. And in addition we read " For a short time they taught also Medicine to the Indians, which they still use in their knowledge of herbs and roots and other things which they apply in their illnesses."

The fame of the college grew and flourished to such an extent that by the time of the second viceroy D. Luis de Velasco (1550-64), the rents of the college were not sufficient to sustain so many students. Through the intercession of the viceroy, the Emperor, Philip II, aided each year with two to three hundred ducats.[10] But after his death, the college lost favor with both the church and the governors. For a while the Indians themselves made an attempt to support the college, and we read the following notes from Mendieta: " The convent of Santiago of Tlaltelolco (in the borough of Mexico) has sustained itself very abundantly with the alms of the Indians, having continuously a gathering of Indian guests." . . . . " Indian butchers brought meat to the convent of Tlaltelolco on Saturday as their offerings." But by the time Mendieta was completing this history, approximately in 1598, we find him writing: " But this all is finished, and now the college serves for little more than to teach the Indian children who gather there, who are from the town of Tlaltelolco itself, good manners and to read and write."

Of all those who taught in the College of Santa Cruz, Friar Bernardino de Sahagun was the most eminent. Of his long life in Mexico (1529-1590), a large part was spent at Tlaltelolco. He was the first of the Europeans to gather together data on native materia medica. For the most part this was assembled in books 10 and 11 of his " Historia General de las Cosas de Nueva España ". In a note of especial interest attached to the end of book 6 (Codice Florentino, libro 6 lam. 17), he tells us that he obtained his knowledge of Aztec medicine from eight native physicians of the district of Tlaltelolco, Santiago, and includes their signatures as follows: Gaspar Mattias, Francisco Symon, Felipe Hernandez, Miguel Garcia, Pedro de Santiago, Miguel Damian, Pedro de Raquena, and Miguel Motolinia. Book 6 was assembled in the year 1547, one year after the great plague, but the major part of all his writings on native medicine was not compiled until after 1557, when Fray Francisco Toral, Provincial of the Franciscan Order, commanded him to put his vast amount of

[10] Icazbalceta (tr. of Mendieta), p. 415.

information into two volumes. To complete this work he was sent to the Pueblo of Tepeopulco, of the district of Texcoco, where with the assistance of 10 or 12 Indians who were former students, the work was completed in 1569.[21]

A review of the known dates of his life shows that he was teacher of Latin at the College of Santa Cruz between 1536 and 1540. Between 1540 and 1545 he was visiting commissioner to various Franciscan convents. In 1545 he returned to the Tlaltelolco and was there until 1546, the year of the great plague. While nursing his beloved Indians he acquired the infection and was himself removed to the mother convent in Mexico City proper. The next year he returned to Tlaltelolco. Between the years 1547 and 1552 his residence is not known, but since in 1552, as a member of the governing board of the Order, we find his signature affixed to a letter to the Emperor, this would seem to indicate that he was in all probability in or near Mexico City at the time. It is possible that he was in residence at the Convent of Xochimilco, since we know that he was superior in that convent about this time.

As might be expected, the medical writings of Sahagun and text of the Badianus manuscript are closely related in subject matter as well as in the etymology of the Aztec words. However, the former is written in the manner of a notebook while the latter is a completely organized treatise. Also the Badianus manuscript deals with many more plants than the Sahagun. The illustrations are superior to the Sahagun manuscript both in number and in anatomical detail.

The use of Aztec symbols to assist in the identification of plants is to be found in both manuscripts. In the Badianus manuscript the Aztec water symbol is sometimes drawn under the roots of plants to indicate that it grows by flowing water. Where the water is not flowing the background around the roots of aquatic plants is painted blue. The use of the stone symbol, which is also found in the Sahagun manuscript, becomes a highly developed art in the Badianus manuscript, where it occurs with various modifications of form and color. In all cases it is found beneath the roots of plants.

In attempting to identify the various infirmities under the Latin title it is necessary to keep in mind that the manuscript is a description of diseases and ailments of natives of Mexico; and in addition that it deals with the materia medica of a people who lived in a tropical country at an altitude of approximately 9,000 feet. Although it was written within 31 years of the Conquest, the subject matter reaches

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[21] Bandelier, F. R., Ancient Mexico. Fisk University Press, 1932.

far back into pre-Conquest times. The Nahuatl or Aztec Empire drew from its conquered peoples, the Toltecs and the Mayas, for much of its cultural background. Of these two peoples only Mayan medical texts have come down to us. All of these were written long after the Spanish Conquest and are believed to post-date the writing of the present Aztec herbal. To gain an adequate idea of the significance of much of the data of this herbal it is necessary to reach back into Aztec times and at the same time turn to our most recent writings in the field of tropical medicine and botanical research.

For the most part the materia medica deals with methods of treatment empirically derived. There are no incantations and only a few references to charms. The first chapter deals with head ailments, such as heat and cold in the head, abscess of the head, scales or mange, scabes. falling hair, and fractured head. The second chapter includes a treatment for sore eyes, fever, blood shot eyes, cataract, eversion of the eyelid, swelling of the eye, insomnia and a remedy to repel drowsiness. The third chapter deals with ear infection.

As a typical example of the method of treatment of the text, chapter four, because of brevity, permits of publication here. It reads as follows:

Fourth Chapter

Concerning catarrh, medicine to be instilled in the nose, herb for the blood.

Catarrh

Below this title are depicted two herbs, the Tzonpilihuizxihuitl and the Atochietl. An etymological analysis of the former name gives us the usage of the plant. Tzonpilihuiz-xihuitl is a compound word derived from the Aztec verb Tzompiliui (Simeon, p. 666) [12] meaning " to have a cold in the head " and the suffix, -xihuitl (Simeon, p. 699) meaning " plant " ; so we may refer to Tzonpilihuizxihuitl as " cold in the head plant," or briefly " catarrh plant ". Jimenez [13] (book 1, chap. 3) refers also to the use of catarrh medicine (Tzompilihuitz-patli), and Hernandez [14] (p. 29) refers to Tzimpalihuiz-patlin and gives the variant name Texaxapotla, which he identifies as *Ptarmica indica,* but this does not agree with the picture in the Badianus manuscript. The extract of Tzonpilihuizxihuitl is also used as a vermifuge (Bad. Ms., p. 51).

[12] Simeon. Reni, Dictionnaire de la Langue Nahuatl. Paris, Imprimerie Nationale, 1885.

[13] Jimenez, F., Quatro Libros de la Naturaleza .... Mexico, 1615.

[14] Hernandez, Francisco, Rerum Medicarum Novae Hispaniae Thesaurus .... 1651.

For the Atochietl, the second plant shown on the same page, we have but a single reference in which it is described as an aromatic plant, the pennyroyal (Simeon, p. 37).

The text for the treatment of catarrh reads as follows:

GRAVEDO

Qui narium distillatione seu coriza infestatur herbas atochietl, et Tzompili-huizxihuitl olfaciet et ita gravedini subveniet. [Those troubled with a dripping nose or cold are to sniff the herbs Atochietl and Tzompilihuizxihuitl and help the cold thus.]

A second remedy in the fourth chapter is entitled " Medicine to be instilled into the nose." The following remedy for a headache reads, " The root of the herb Yztac pahtli [lit. " white-medicine "] is to be bruised in a little clear water and the liquor poured into the nostrils drop by drop for those suffering from a headache."

The herb depicted above the text is of the family Mimosaceae, belonging to the genus *Acacia farnesiana* Willd.[15] An ointment made from the flowers is used today in Mexico as a remedy for headache. In addition an infusion of the flowers is used for dyspepsia.

The chapter closes with a remedy to stop nose bleeding. The plant Atzitzicaztli, or water nettle, is used also for maladies of the neck (Simeon, p. 664).

The remedy reads as follows:

The juice of nettles ground with salt in urine and milk poured into the nostrils, stops bleeding.

Two of the most interesting plants used as a cure for pain are the Tolohuaxihuitl and the Nexehuac (pl. 3). Both of these are Daturas (Solanaceae). The first of these, Tolohuaxihuitl or Tolohua plant, is referred to by Hernandez as *D. stramonium*. Sahagun[16] and Clavigero[17] refer to it as Toloache. Both the white-flowered and purple-flowered forms of this species occur in Mexico as well as in the United States; the purple forms are usually called *D. tatula*. The white-flowered forms may bear either smooth or prickly capsules, the smooth variety being called *D. inermis*.[18] The adjacent plant, called

[15] Standley, P. C., Trees and shrubs of Mexico. Contr. U. S. Nat. Herb., vol. 23, pt. 2, p. 378, 1922.

[16] Sahagun, Historia General de las Cosas de Nueva España (1590). Publicase con fondes de la secretaria de instrucion publica y bellas artes de Mexico, por Francisco del Paso y Troncoso. Publ. Madrid Tototipia de Hauser y Menet, 1905-07.

[17] Clavigero, F. J., Historia Antigua de Mexico. London, 1826.

[18] Safford, W. E., Narcotic Daturas of the Old and New World. Ann. Rep. Smithsonian Inst. 1920, Publ. 2644, 1922.

Nexehuac (Nexeua—the rambler—Simeon, p. 307), is depicted as an erect, white-flowered form with purple, smooth-skinned fruit resembling this type. The flowers are drawn as erect, the fruits pendant, but since all the arborescent Daturas have unarmed fruits we may consider either the drawing or the etymological derivation misleading. Its smooth pods would probably place it as a variety of *D. stramonium* known as *D. inermis* Jacq.

Varieties of *Datura* have been used the world over for their narcotic properties, the effect being due to the presence of the drug atropine.

Besides these remedies just discussed in detail, there are others for dysentery, skin disease, gout, pain in joints, various helminth infections, and afflictions such as burned body, cracks in soles of feet, and wounds of various types, and a number of other items. It is worthy to be noted that fear, fatigue, and feeblemindedness are looked upon as diseases and treated as such.

In chapter 10 we find a reference to a charm for getting across the river safely; chapter 11 is devoted to afflictions of women; chapter 12 refers to remedies for children; and the book closes very fittingly with two pages entitled " Of certain signs of approaching death."

The identification of plants depends to a large extent upon the etymological analyses, which frequently give the usage, the place of habitat, or a description of the plant itself. A complete analysis of all the 313 Aztec or Nahuatl words has been made in the preparation of the text for publication of this manuscript.[19] About 40 percent of these are new words—that is, they do not occur in the early sources, Molina,[20] Sahagun, Hernandez, or in the standard Simeon Aztec-French dictionary. From Simeon however, the roots have been derived, so that it has been possible to give a translation based upon the etymological sources of the word.

This system of the Aztecs of building up a descriptive compound noun results in the grouping of plants as to their color or form or as aquatic plants, eatable plants, sweet or bitter plants, fragrant, spinous, or medicinal. Examples of these when divided into their respective roots are as follows: A-caca-pac-quilitl (an-agreeable-eatable-water plant), Aca-mallo-tetl (water-plant captive (in) stone),

Caca-matlalin (blue-colored herb), Chichic-xihuitl (bitter herb), Colomecatl (trailing cord), Hahuiyac-xihuitl (fragrant plant).

The credit for this as a system of plant identification was first recognized by Francisco Flores,[21] eminent Mexican medical historian, who mentioned it in his " Historia de la Medicina en Mexico " (1888), but he does not give such an analysis. Instead he groups Aztec plant names according to usage, such as tonics, antispasmodics, stimulants, etc. Until the translation of the present volume, as far as is known, no complete analysis of Aztec plant names has been undertaken.

The recognition of the modern botanical classification is most difficult. Without an analysis of the Aztec nouns, the usages of each plant and the colored-plate identification would be impossible. In addition it has been necessary to cross-reference every Aztec plant name with sixteenth century Aztec-Latin botanical texts. Again, without Standley's important volumes on the trees and shrubs of Mexico and the flora of Yucatan, this would have been impossible.

Of the sixteenth century Aztec-Latin sources, only two are of the greatest importance. The first, volumes 10 and 11 of the Sahagun manuscript, is the most important, since the work is both contemporary with, and deals with plants of the same district as, the Badianus manuscript. The second is the great Hernandez volume, which was written in the latter half of the sixteenth century, and although not published until 150 years later, was one of the greatest herbals of the sixteenth century. The excellent illustrations of the Hernandez volume have been invaluable in checking the more primitive Aztec drawings in the Badianus manuscript.

Besides the use of plants, animals, stones, and various kinds of earth, salts and carbon were used in the concoction of Aztec medical formulas. Of the stones, pearls of various kinds, the eztetl (jasper), the tetlahuitl (precious ocre stone), and the tlahcalhuatzin are the most frequently used. Numerous references are found to the use of bezoar stones, which they obtained from 10 different species of birds. Earths of various kinds classified according to their color were used, as well as soda and salt. The latter was obtained in cakes from the salt lake of Texcoco and, in the Aztec Empire period, was one of the chief articles of trade. Animal charcoal was used then as it still is today—although in a purer form—in the preparation of bitter principles for infusions and tinctures.

Of the animals used, the greater part were birds, although the stag, dog, fox, jaguar, monkey, and many other kinds were included.

Medicaments were either taken internally or used as lotions and unguents, and modes of treatments, intervals between dosages, and symptoms are also included. In many respects the treatments compare favorably with those of Europe. That Aztec medical knowledge was considered superior is obvious from the fact that it was taught at the College of Santa Cruz in preference to European medicine. It is especially significant that Philip II sent Dr. Francisco Hernandez, under the title of Protomedico of Spain, to New Spain with the commission to gather together the knowledge of native plants and their usage. Parts of his great work were collected by Dr. Nardo Antonio Recchi and published in one great volume by the Lyncean Society in 1651. The interest of Europeans in Aztec medicine is also reflected in the writings of Dr. Nicholas Monardes, whose work on the medical knowledge of the Occidental Indies was published in 1569 and translated into English in 1577 by John Frampton. The works of Carlos Clusius, Caesalpinus, and others all reflect the introduction of Aztec medical knowledge into Europe. The extent to which Aztec medical knowledge influenced the medical practices in Europe can only be judged by a careful examination of the later sixteenth and seventeenth century herbalists in whose work references to Mexican plants occur.

All these latter works of European authors present a picture of Aztec medical learning as it appeared when viewed through the eyes of Europeans. The Sahagun manuscripts alone show a close kinship to the Badianus manuscript. This would be expected because of both the time of writing and the source of material.

The Badianus manuscript holds the unique position of being the earliest written Aztec herbal as well as being the only one written by the Aztecs themselves. It marks the beginning of herbal literature on this side of the Atlantic. To the list of native Aztec students of the College of Santa Cruz who distinguished themselves in the field of letters, we add the names of Martin de la Cruz and Juannes Badianus. The volume is a lasting tribute to the teachings of Fr. Bernardino de Sahagun and the brothers of the Franciscan order who taught at Tlaltelolco during the first 50 years of its existence.

Libellus de medicinalibus Indorum herbis, quem quidam Indus Collegii sanctæ Crucis medicus composuit, nullis rationibus doctus, sed solis experimentis edoctus. Anno domini seruatoris 1552:

Clarissimo domino Francisco de Mendoza illustrissimi superioris huius Indie proregis domini Antonij de Mendoza filio optimo Martinus de la Cruz, indignus seruus salutem precatur plurimam & prosperitatem.

+

ex libris didaci cortauila

Cum in te omnium uirtutum decora atqz ornamenta & bonorum munera, quæ a quouis mortali desiderantur reluceant domine magnificentissime. nescio profecto. quid in te potissimum laudem. Equidem non iudeo. quibus laudibus efferam insignem uestrum amorem: quibus uerbis gratias agam uestro beneficio qz maximo. Pater enim tuus uir christianissimus simul et piissimus, uerbis consequi nequeam qz maxime omnium mihi benefecerit. quicquid enim sum, quicquid possideo & quicquid nominis habeo, illi debeo. Nihil par, nihil ue dignum inuenire

FACSIMILE OF THE FIRST PAGE OF THE BADIANUS MANUSCRIPT. "CODEX BARBERINI, LATIN 241" (VATICAN LIBRARY)

meris impofuit. Vale in Chrifto Seruatore. Tlah
luloi in Sanctæ Crucis Collegio Dinæ Mariæ Magda
lenæ sacratis ferijs. Anno ab orbe reftituto Mileßi
mo quingenteßimo quinquageßimo secundo.

Finis libelli herbarij. quem lati-
mtate donauit Joannes Ba
dianus natione Jndus
patria Xuchimilca-
nus ciufdam Col-
legij prælector.

Gloria semper ei sit cuius munere uerti-,
Quem cernis librum lector amice bone.

FACSIMILE OF PAGE 49 OF THE BADIANUS MANUSCRIPT

"Against pain in the side. The application of the herbs Tolohuaxihuitl and Nexehuac, ground in water takes away pains in the side."

Tolohuaxihuitl, *Datura stramonium;* Nexehuac, *Datura inermis.*
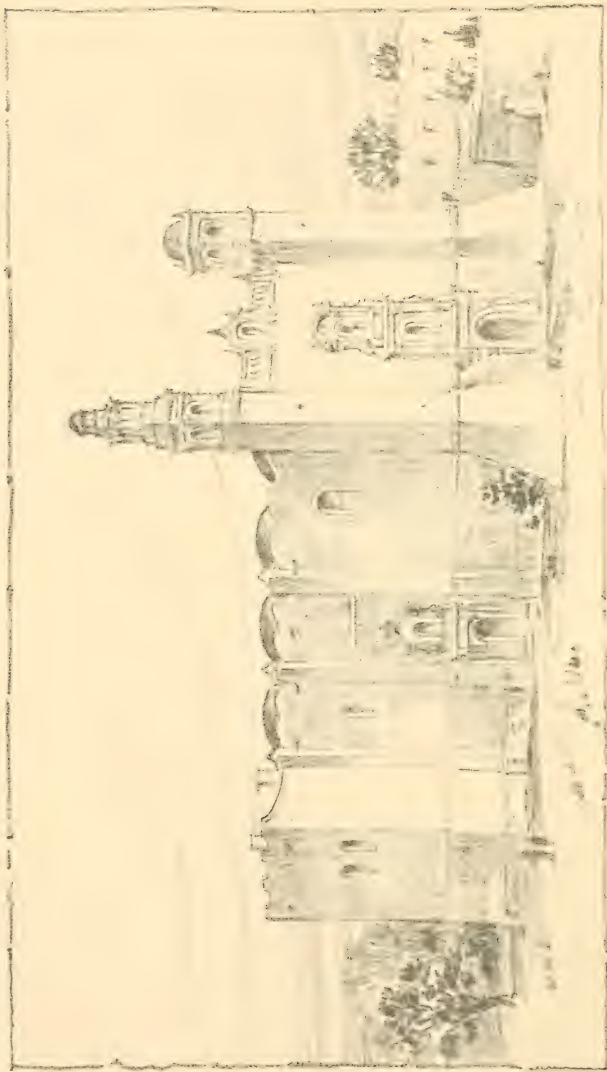
CHAPEL AND CONVENT OF TLALTELOLCO (COLLEGE OF SANTA CRUZ)

Redrawn from an old print. "Templo y Convento de Tlaltelolco. Estado actual", in "Historia de la Iglesia en Mexico", by M. P. Cuevas, Tomo I, p. 387, 1928.
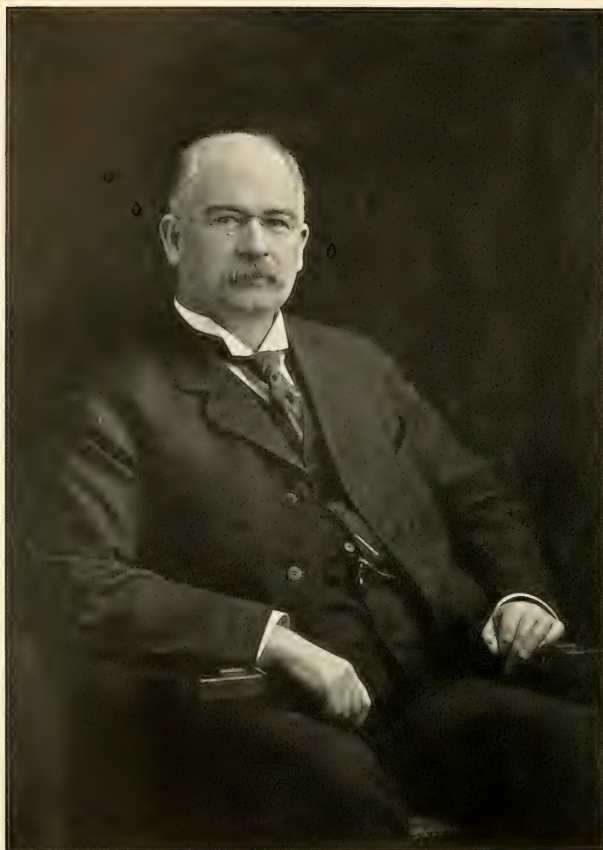
Very sincerely yours
Thos. L. Casey

Thomas Lincoln Casey Fund

THOMAS LINCOLN CASEY AND THE CASEY COLLECTION OF COLEOPTERA

(WITH ONE PLATE)

BY

L. L. BUCHANAN

Bureau of Entomology and Plant Quarantine,
U. S. Department of Agriculture

FOREWORD

The Casey Collection of Coleoptera bequeathed to the United States National Museum by Thomas Lincoln Casey, basis of a lifetime of investigation on the part of one of the foremost coleopterists in America, rich in types, with carefully selected specimens of a high degree of perfection in preparation, contains material that is of constant and permanent value to other systematic workers in the multitude of families that Colonel Casey covered in his extended and painstaking researches. It is the most important single gift that has come to the section to which it pertains in the Division of Insects.

Few words are necessary to explain that a private collection used by one highly trained and careful individual may be kept and handled successfully under an arrangement that is impossible in a public institution where material is consulted by many research workers. To conserve space Colonel Casey pinned his specimens as closely as possible. To conserve time he used a method in labeling that, while safe and effective for his purposes, would certainly lead to disastrous confusion if placed in the hands of many. No one had fuller understanding of these facts than Colonel Casey himself, and usually he handled his specimens personally when examining them with scientific visitors.

The question of safeguarding this collection adequately became paramount at once on its receipt in the National Museum. Dr. J. M. Aldrich, Associate Curator of the Division of Insects, with the advice of S. A. Rohwer, Entomologist in Charge of Taxonomic Investigations, Bureau of Entomology, on March 3, 1925, called a conference of coleopterists and others interested to consider this matter. At this meeting Mr. Rohwer presented a set of resolutions, adopted after due discussion, that indicated the importance of the collection and the necessity of careful labeling and arrangement before the material was thrown open to general consultation and use. The necessary funds for effecting this were a matter for some consideration. The matter rested here until August 12, 1925, when I appointed a committee to consider recommendations for procedure, consisting of Dr. Aldrich as chairman, assisted by W. S. Fisher and H. S. Barber of the Bureau of Entomology, and Dr. E. A. Chapin of the Zoological Division of the Bureau of Animal Industry, United States Department of Agriculture. After due and careful consideration this group rendered a report on September 15 which, with some slight modification, has

served as the method for the handling and installation of the collection. The details of this are described by Mr. Buchanan in the following report and need not be itemized here.

A beginning in labeling and arrangement was made by H. S. Barber, but it was evident at once that definite assistance was required to carry the matter forward. Realizing this need and desiring in every way to hasten the arrangement of the material so that it might be made available as promptly as possible, Mrs. Laura Welsh Casey established a special fund carried in her name under the Smithsonian Institution and made available the necessary money to carry on the work. An agreement was made with the Bureau of Biological Survey, United States Department of Agriculture, whereby Mr. L. L. Buchanan was released for half time employment under this fund for work on the Casey Collection, and the arrangement began on April 1, 1926. This cooperative arrangement was continued later with the Bureau of Entomology following Mr. Buchanan's transfer to that service. Cases for storage also were purchased. In addition to all this, Mrs. Casey, with the advice of Dr. W. M. Mann, supplied an excellent microscope of modern type, and arranged for binding many of the reference works in the special library that accompanied the collection.

That the long task of arranging the collection went forward from this time without delay has been due entirely to the steady interest and encouragement of Mrs. Casey, to whom all thanks are due for furthering this monument to the memory of her distinguished husband.

In addition to supplying funds for the arrangement of the collection Mrs. Casey has by gift to the Smithsonian Institution established a permanent endowment known as the Thomas Lincoln Casey Fund, the income of which is to be used for maintenance of the Casey Collection and for the general promotion of research in Coleoptera. Under this fund there will be published from time to time in the Smithsonian Miscellaneous Collections papers dealing with the Casey Collection and with Coleoptera in general, the present account by Mr. Buchanan initiating this series. All publications appearing under these auspices will be designated as under the Thomas Lincoln Casey Fund.

In closing it is fitting that I should express to Mr. L. L. Buchanan the thanks of the Smithsonian Institution for the careful and conscientious manner in which he has carried forward to completion the exacting task of arranging the Casey Collection. The present installation has aroused the admiration of all who have visited the Casey room since this work has been completed.

<div style="text-align:right">

ALEXANDER WETMORE,
Assistant Secretary, Smithsonian Institution.

</div>

Thomas Lincoln Casey Fund

THOMAS LINCOLN CASEY AND THE CASEY COLLEC-
TION OF COLEOPTERA

By L. L. BUCHANAN [1]

Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture

(With One Plate)

Thomas Lincoln Casey was both soldier and man of science. Seldom does one lifetime present substantial and valued achievement in two fields as widely separated as were the two provinces of this coleopterist who was also an army engineer.

Born in 1857 at West Point, he was the son of Brig.-Gen. Thomas Lincoln Casey, who as Chief of Engineers of the United States Army was to carry through the construction of the Congressional Library building, and of the upper part of the Washington Monument. One of his grandfathers was Maj.-Gen. Silas Casey, and the other was Robert W. Weir, for 50 years professor of drawing at the United States Military Academy. After a year in the Sheffield Scientific School of Yale University he entered the Military Academy at West Point. There he was a high-stand man through the four years of his course. Upon his graduation in 1879 his position in his class admitted him to the Corps of Engineers, and by the time he retired from active duty in 1912 he had reached the rank of colonel.

Astronomy was the field in which the young lieutenant did his earliest scientific work. His first military assignment took him to the Engineer and Submarine Mining School at Willet's Point, now Fort Totten at one of the entrances to New York harbor; here he made a specialty of theoretical and applied astronomy, to such good effect that in 1882, when Prof. Simon Newcomb led an expedition to the Cape of Good Hope to observe the transit of Venus, Lieutenant Casey was a member of the party and acted as assistant astronomer. He was also a member of the Greer County Commission, which went to Texas in 1886 to mark the boundary lines between a portion of what was then the Indian Territory and the State of Texas.

In 1898 Captain Casey was married to Miss Laura Welsh, of Philadelphia, and they made their first home in Virginia. Captain Casey had been in charge of construction work at Fort Monroe; upon the outbreak of the Spanish War he was made major and was entrusted with the submarine mine defenses of Hampton Roads.

Early in the present century Major Casey was assigned to duty on the Mississippi River, and here began an interest in conchology which was to continue throughout his life. For 4 years he was a member of the Mississippi River Commission, stationed first at Vicksburg and later at St. Louis. It was at this time that he began to build up the notable collection of recent and fossil shells of the lower Mississippi which served as basis for studies carried on during the later years of his life.

For 40 years Thomas Lincoln Casey was an eager and devoted student of Coleoptera. Half a dozen of his papers on North American beetles appeared in the year 1884, and from then on they were frequent. The 50 or more publications which came out before 1910 were confined to Coleoptera of North America, but with the " Memoirs on the Coleoptera " (1910-1924) he enlarged his field to include Central and South American species as well. Every paper was the fruit of careful and accurate study.

By field work and by extensive purchases, the young officer was carefully building up a collection of American Coleoptera and a library of the publications dealing with them, which were to excite the admiration of all who were privileged to examine them. The constant shifting of base which was involved in his army career enabled him to do field work and make additions to his collection in almost every section of our country, for he was stationed successively on Long Island, in Philadelphia, in California, in Texas, in Rhode Island, at New York, in Virginia, at Vicksburg, at St. Louis, and finally at Washington, D. C., where he continued to make his home after his retirement in 1912.

His studies were based on specimens in his possession, and were a regular feature of his early schedule. Two hours of the leisure left by his military duties were devoted to entomology. In this daily period he put his specimens under his binocular compound microscope and subjected them to an examination that was detailed and thorough to the last degree. Measurements, when taken, were painstakingly accurate, and every fine point of habitus and sculpture was covered in his notes. Many of his papers were privately printed and were distributed so as to put their findings at the disposal of all students to whom they would be of value.

Colonel Casey died February 3, 1925, and the microscope he had used throughout his long entomological career was buried with him. His large and valuable entomological and conchological collections, each with its comprehensive library, were left to the United States National Museum. His other property was left to Mrs. Casey for life, the estate to be given eventually to three scientific societies, the National Academy of Sciences, the New York Academy of Sciences, and the Astronomical Society of the Pacific. Mrs. Casey was named sole executor.

The Casey collection of Coleoptera was transported by automobile from the Casey apartment by H. S. Barber and E. A. Chapin and was stored for a short time in a tower room of the Old Museum building; later it was transferred to a room in the Natural History building where it remains. Casey's entomological library, consisting of about 900 volumes and many separates, accompanied the beetle collection, and the two items now form a compact and accessible unit for research on matters connected with Casey's work.

The collection as received was housed in about 260 boxes of the Schmitt type, contained in wooden cabinets. The specimens themselves were clean, well mounted, and in good condition. In general, the series of the different species were clearly segregated, the first specimen bearing the name label, the others grouped after it in the conventional manner. Because of the uniformity of mounts, the unusually small locality labels, and the precise alignment of material, Casey was able to get an astonishingly large number of specimens in some of the boxes. His manual skill in handling material gave to parts of the collection a deceptive appearance of ample spacing, but the abnormal compression immediately became evident when attempts were made to remove or to replace individual specimens, and showed the impracticability of allowing students the privilege of studying the collection in the original boxes.

The uniformity of mounts, so conspicuous a feature of the collection as a whole, is due to a practice Casey followed for a good many years; besides preparing the considerable quantities of material he himself collected, he remounted all specimens received from correspondents. In Memoir 7, page 35, 1916, he speaks of careful mounting as a " prime necessity ", even though such curatorial work " absorbs a very large proportion of all the time available for such [research] studies in the daily routine of life, which flows along and ebbs away with ever increasing speed ". Suggestions as to the proper mounting

of small Staphylinidae are given in Memoir 2, page 2, 1911, while in Memoir 1, page 1, 1910, objections are made to the European method of mounting on cards.

The collection contains considerable amounts of exotic material, both named and unnamed, in nearly all the groups monographically studied, especially in the families Scarabaeidae, Staphylinidae, Curculionidae, Tenebrionidae, and Cryptophagidae. The regions represented are chiefly Europe, Mexico, and Central and South America. There is also a quantity of undetermined North American material, the bulk of it in those families not critically studied by Casey.

Here and there throughout the collection stand specimens labeled simply " L ". These are part of the old Levette cabinet, concerning which Casey says (Coleopterological Notices, 2, p. 501, 1890) : The material is " from the Carolinas, Georgia, Florida, and Colorado, much of which was probably collected by Morrison ". In recording locality for those " L " specimens surmised to be from the eastern part of the United States, Casey generally suggests either " Indiana " or " Indiana? "; for those thought to be of western origin, he often gives Colorado. A good many of Casey's specimens bearing label "Ari" or "Ariz " are probably Levette collection material.

The abbreviation " typ.", which frequently appears on the name labels of species of other authors, stands for " typical " (not " type ") and shows that Casey regarded the specimen as a typical example because of its agreement with the original description or with the actual type. Considerable reliance can be placed on such determinations, especially in the case of Leconte or Horn species, with the types of which Casey compared much of his material.[2]

Name labels reversed or folded generally indicate that Casey regarded the specimen as incorrectly determined, or considered the species a synonym. In a few cases name labels were folded for no apparent reason other than to reduce their size.

Compared to most modern collections, the Casey Collection contains a rather small average number of specimens per species, though this condition would naturally follow in the case of a private cabinet where species lines are closely drawn. However, Casey's series were often ample, including from several up to 20 or more specimens, and moreover there is evidence, in the case of certain species, that he examined many more specimens than now appear in the collection. For example,

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[2] In Coleopterological Notices, 5, p. 599, 1893, Casey says that *Centrinus canus* "is the only species not described from the original type or a specimen carefully compared therewith". There are many statements of similar purport in his writings.

in Memoir 7, page 2, 1916, he refers to the study of 275 individuals of *Saprinus lugens* Erichson from Arizona, though at present there are but six Arizona specimens of this species in the collection. Again, among Casey's 16 examples of *Tyloderma foveolata* Say is a pair from Indiana, the smaller of which bears a folded label in Casey's handwriting, " smallest of 65 ", the larger a similar label, " largest of 65 ". The greater convenience of small, selected lots for study purposes was no doubt Casey's principal reason for restricting the size of his series, with insufficient storage space a contributory factor. It is not to be supposed that he discarded all the duplicates, as on more than one occasion consignments of excess material were sent to the National Museum and possibly to other institutions or correspondents as well.

Casey's unusual scheme for indicating the locality of his specimens deserves special mention. The base of this system is a small State abbreviation label to which he added various marks or symbols—dots, dashes, and crosses—in black or red ink. The nature, number, arrangement, and color of these marks on the label gives the clue to the definite locality within the State and sometimes to additional information as to date and collector. For example Ari denotes Sabino Canyon, Santa Catalina Mountains, Arizona, collected by J. F. Tucker. There are altogether about 160 different kinds of these cryptic labels represented in the collection. A complete list of them, together with their more precise locality equivalents, arranged alphabetically by States, is kept on file in the Casey room with the collection, so that the exact locality of any specimen can be quickly ascertained.

In adopting this unorthodox method of labeling, Casey's purpose was to obtain a label which, while giving the essential data or clue to such data, at the same time was small enough to permit unobstructed examination of the ventral surface of the specimen. The short focal distance and high magnification attendant on the use of his old-fashioned binocular compound microscope made small labels a virtual necessity; in the case of minute beetles, such labels had the further merit of conserving space, increasing the available pinning area in his boxes by one-third or more. Casey followed this scheme of labeling for many years, but finally gave it up, doubtless because the growth of his collection rendered the system too complicated for easy use. The conventional locality labels which were attached to later material were reduced to the desired smallness by folding, either once or twice, but always so as to leave the State name uppermost.

Of the 9,400 species described by Casey, the type specimens of most have been located. The types of a few however, some 19 in number,

appear to have disappeared from the collection. These are: *Amara marylandica, Amercedes subulirostris*,[2] *Bembidion militare, Celia ferruginea, Celia pallida, Epipocus punctipennis, Eumononycha opaca, Euplectus impressiceps, Lathropus pubescens, Laemophloeus floridanus, L. horni, L. schwarzi, Phyllophaga subpruinosa, Ptilium sulcatum, Stenolophus gracilis, Stethobaris cicatricosa, Tachys occulator, Telephanus lecontei, Thesium laticolle*. The disappearance of most of these types is referred to by Casey in Memoir 5, page 283, 1914, and in Memoir 8, page 291, 1918. The types of two other species, *Colon decoris* and *Trichopteryx fungina,* which were at one time thought by Casey to have been lost (Memoir 5, p. 283, 1914, and Memoir 11, p. 155, 1924), were located during the progress of the curatorial work on the collection, the former among a lot of small *Silphidae,* the latter in the set of *Acratrichis parallela* Mots. In addition to Casey's own types, the collection contains type material of 100 or more species of various other authors.

Shortly after the public announcement of Casey's bequest of his collection to the National Museum, tentative plans were made looking toward the future care and upkeep of this notable accession. Details of the preliminary arrangements that led finally to my appointment as Specialist for the Casey Collection of Coleoptera under the Smithsonian Institution are outlined in the foreword to this article. The main objective was to transfer the Casey material from the overcrowded original boxes to standard Museum insect drawers, with each species segregated in an individual cork-lined box or tray. Until this transfer of material could be accomplished, the collection remained sealed, as any attempt at unrestricted study of the specimens as they were left by Casey inevitably would have resulted in more or less breakage and confusion. The curatorial work was started by the writer on April 1, 1926, and was continued, half a day at a time, for a period of 5 years.

The cardinal rule guiding the curatorial work was to preserve exactly Casey's concept of each species. Regardless of occasional conflict with accepted synonymy, Casey's arrangement of specimens was strictly followed; furthermore, steps were taken to virtually guarantee the permanent preservation of this arrangement, so that students, both now and in the future, will have equal assurance that before them stand Casey's actual original series of each species, and not a hodgepodge resulting from accidental misplacement of specimens or inter-

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[2] A specimen of this species in the collection bears a label on the back of which appears this statement in Casey's handwriting: " The type is in Carnegie Mus. Pittsburg."

polation of later and irrelevant material. Casey's arrangement was indicated by attaching to each specimen a label giving the specific name of the species and its sequence in the series, as, Casey det., minuta 1   Casey det., minuta 2   Casey det., minuta 3   Each species was then placed in a suitable-sized tray on which appears the full scientific name. No material is to be added to these trays, and none is to be transferred, except in a few special cases.

In addition to the " Casey det." and type labels, used of course only on identified material, a small pin label bearing legend " Casey bequest 1925 " was attached to every specimen in the collection, named or unnamed. Also, a record of all the North American species in the collection was entered in a copy of Leng's Catalog of Coleoptera.

When the work of arrangement had been completed, a manuscript catalog of the entire collection was prepared by Miss Marie Siebrecht, working under my direction, that will serve as an historical record for future reference should any question arise as to any of this material. Data in this catalog are arranged systematically, the order of genera and families being essentially that of the Leng Catalog of North American Coleoptera. The list gives the total number of specimens for each species, with indication of types. A synopsis at the end serves as an index to the families and to the number of specimens that these include. The collection as thus recorded is found to contain 19,245 named forms, with a total of 116,738 specimens, and more than 9,200 holotypes.

It is well known that Casey did not make a practice of marking the types in his collection. The various terms now in common use to distinguish different categories of type material were not uniformly applied by Casey in his writings [4] and very seldom used on the specimens themselves. However, Casey did make the verbal statement that the specimen bearing the name label was to be considered the true type, as shown in this extract from a letter of November 3, 1927, from J. C. Crawford to Dr. Alexander Wetmore, Assistant Secretary, Smithsonian Institution:

About ten years ago Dr. Hopkins and I visited Colonel Casey at his request to see both his collection and the conditions under which he worked. At that time both Dr. Hopkins and I complained to Colonel Casey of the types in the Casey Collection not being labeled. Colonel Casey made the statement, which

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[4] Memoir 1, p. 20, 1910, " Sexual characters are not evident in the types"; ibid., p. 122, " The types are females "; ibid., p. 136, " The type is from San Diego " (four other localities mentioned) ; Memoir 2, p. 6, 1911, " *minuta* cotypes " ; Memoir 6, p. 330, 1915, " three cotypes ".

he said was to be regarded as official and for our information in case he should die without making a similar statement to other people, that the specimen bearing the name label was in all cases to be regarded as the true type. To this he added that the true type was the only specimen with which he was really concerned, and that therefore what we call paratypes were not indicated.

(Signed) J. C. CRAWFORD.

Casey's purpose is disclosed, though less definitely, as early as 1886, (Descriptive Notices, 1, p. 162) where he says, " It will be observed that the descriptions refer in all cases to the single specimen assumed as the type ", and " I have preferred, therefore, in the existing state of knowledge, to describe one definite type and give such general remarks as may indicate the variation exhibited by the material at hand."

The type labeling has been carried out to respect this clearly stated intent on Casey's part. A special U.S.N.M. type label was attached to the labeled or first specimen of each of Casey's species—that is, where no discrepancies between specimen and description were noticed—whereas paratype labels were attached to those specimens evidently examined by Casey at the time of the original description. A query sign, preceding the name of the species on the paratype label, as

Paratype USNM $\genfrac{}{}{0pt}{}{?ruber\ 2}{38669}$, indicates that the specimen, though doubtless a paratype, had been set apart slightly by Casey as possibly distinct; while the query mark before the number, but not before the name, shows that the specimen, although clearly placed with the species by Casey, fails to meet the paratype requirements in one way or another. Where the true holotype could not be located with certainty, a neotype label was used. These neotype designations, of course, have no binding value unless published, but they permitted the assignment of a catalog number, which in turn afforded a ready means of recording. The actual types of some of these " neotype " species will certainly come to light sooner or later either in the Casey collection or in the cabinets of other workers or institutions. In the meantime, the neotype label acts as a sufficient warning that this particular specimen probably is not the original type.

Certain complications in the curatorial work resulted from the inexact citation of type locality in some of Casey's original descriptions. In several places Casey cites a regional locality when the label on the specimen is definite, as, " Southern Shore of Lake Michigan " or " Rocky Mountains ", when the labels themselves read " Milw.Co. Wisc." and " Garland Col.", respectively. Again, we may have the exact locality of the second or following specimen of a series, when the type itself (that is, the specimen bearing the name label) carries

only a general or State label. An illustration is found in the staphy-linid, *Datomicra surgens* Casey. The type locality of this species is given as Glenora, B. C.; the collection contains two specimens, the first of which, or type, bears the label " Br.C.", the second, or para-type, " Glenora, B.C., Wickham ". In this case there can be no doubt that the first example formed the basis of Casey's original description, represented in his eyes the true type, and by any reasonable interpreta-tion must receive the type label, even though the specimen, on visible evidence, does not come from the stated type locality. Any other plan for handling such cases (and it may be said that serious thought was given to other possibilities) leads only to endless and insoluble complications. Bearing directly on this matter are some remarks by Casey himself in regard to *Acmaeops variipes* Casey. In Memoir 4, page 239, 1913, he explains that " The locality Sta. Cruz Co., given under the original description of *variipes* (Annals N. Y. Academy Sciences, vol. 6, p. 38) was taken from a specimen of the series bear-ing this definite label; others had simply ' Cal ' as a label, one of which, the type, I find had a minute label concealed by the other and bearing the initials ' S.D '." In other words, Casey's original set of *variipes* really included three different labels, " S.D,Cal ", " Cal ", and " Sta.Cruz Co." The original description calls for Sta.Cruz Co. alone, but Casey 22 years later positively states that the real type, (doubtless the specimen on which his description is based) is from " S D (San Diego) Cal ". A considerable number of similar dis-crepancies were met with, but the *Acmaeops* sample happens to be one that Casey comments on in a definite enough way to give an insight into one of his rather free methods of locality citation.

Another puzzling situation grew out of Casey's occasional misin-terpretation of locality symbols. For instance, N Y̲, translated by Casey's list of localities as " Catskill Mts (Shokan) ", is more than once confused with N̲ Y, given as " New York City (Brooklyn) " by the same list.

Again, there are instances where Casey evidently had private in-formation as to the exact source of certain specimens that carry a State label only, and we may find " Ia " being published as " Cedar Rapids, Iowa ". Also, Casey sometimes gives the locality of the same specimen with a different degree of definiteness in successive treat-ments; for example, " Pa " in 1900 may be cited as " Philadelphia, Pa." in 1920. One of the more difficult of the curatorial problems resulted from the fact that Casey occasionally shifted the name label from the original type to some other specimen in the series. In all observed cases of such label transfer the specimen bearing the name

label was of course not marked type. If the actual type could be located it was so labeled; if not, a neotype label was attached to the substitute, to serve until the holotype is recognized.

Casey's interpolation of later material among his original series sometimes prevented the assignment of paratype labels. For example, *Euphoria nitens* Casey, described from 10 specimens from Texas, was represented in the Casey box by 14 examples, showing that four specimens were added later to the original lot. All the specimens except no. 1 and no. 3, which are unlabeled but which nevertheless are almost certainly part of the original series of 10, bear Texas labels, and all except one agree with the original description. That is, only one example of the present 14 can be eliminated as a possible paratype; consequently no paratype labels could be added. It may be explained that Casey followed no consistent method of incorporating later specimens, sometimes placing them at the end, but oftener somewhere in the middle, of his original series.

The curatorial work made no pretense at a synonymical review of the field, but aimed simply at the necessary clearing of the ground that precedes critical study. Casey's individualistic methods and voluminous writings have created many zoological and nomenclatural problems that can be solved only by the patient investigations of future students. Many generations must pass before the final verdict is reached, but in the meantime it is hoped that the collection as it now stands, cleared in part of confusing factors, will lend itself more readily to a study of those problems in which Casey was so deeply interested, and concerning which he once said: " These fields of scientific enquiry are all parts of one grand cosmos, and I cannot conceive one of them to be more soul-inspiring than another; they are all equally wonderful, equally beautiful, and equally beyond the ken of finite intellect."

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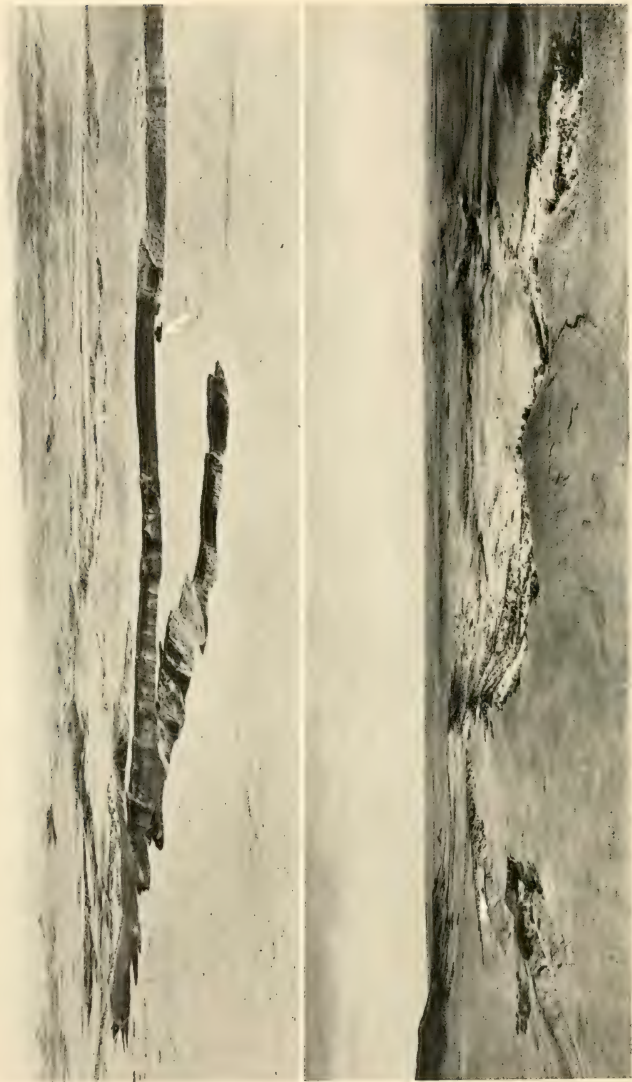
GENERAL VIEWS OF THE LINDENMEIER SITE

Top picture is toward the south. Deep pit in bank of ravine to right of car; arrow indicates car. Bottom view is toward the east.

A FOLSOM COMPLEX

PRELIMINARY REPORT ON INVESTIGATIONS AT THE LINDENMEIER SITE IN NORTHERN COLORADO

(With 16 Plates)

BY
FRANK H. H. ROBERTS, JR.
Archeologist, Bureau of American Ethnology

CONTENTS

ILLUSTRATIONS

PLATES

TEXT FIGURES

A FOLSOM COMPLEX

Preliminary Report on Investigations at the Lindenmeier Site in Northern Colorado

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INTRODUCTION

Investigations at the site that yielded the first definite complex of stone implements attributable to so-called Folsom Man came as the culmination of an interesting series of events that began in May 1934. In that month D. I. Bushnell, Jr., collaborator in anthropology, United States National Museum, discovered in two collections gathered from various parts of Virginia examples of the type of projectile point which has been called Folsom. Announcement of this fact was made by the Smithsonian Institution in one of its press releases. The article, with photographs of the specimens, was printed in slightly revised form in the Literary Digest for June 9, 1934. This notice loosed a veritable flood of letters, and queries poured in from collectors all over the country. There was some confusion about what constituted a Folsom point, and the editors of the Digest felt that a second article, one describing its characteristics in detail, was advisable. In response to a request from them the writer prepared a statement which appeared in the issue for July 28. The latter brought letters from many parts of the United States from people who had examples of the Folsom type.

Among the letters were several which were received indirectly. Maj. Roy G. Coffin, professor of geology at Colorado State College, Fort Collins, had on two occasions, prior to the Digest articles, written to Dr. John B. Reeside, Jr., geologist in charge, section of stratigraphy and paleontology, United States Geological Survey, concerning a site in northern Colorado. At that place he and a brother had found a considerable number of Folsom points, several other kinds of chipped tools, and indications that the implements had been made on the spot. Following the appearance of the second Digest article, Major Coffin again wrote to Dr. Reeside. The latter brought the correspondence to the attention of Henry B. Collins, Jr., division of anthropology, U. S.

National Museum, and he in turn transmitted the information to the Bureau of American Ethnology. Several letters were exchanged between the writer and Major Coffin, and as a result of the correspondence it was decided that a first-hand inspection of the site was advisable. In September the writer was sent to Fort Collins. The owner of the land, William Lindenmeier, Jr., gave permission for a series of investigations, and preliminary prospecting was started.

The site is north of Fort Collins, Colo., just south of the Wyoming line. It was first discovered in 1924 by Judge C. C. Coffin and his son A. L. Coffin. Since then they and Major Coffin, with various friends, have visited it from time to time and have collected numerous specimens. When the writer went to Fort Collins, they had gathered 83 points or portions of points and about the same number of other artifacts. From the very beginning of their finds the Coffins were impressed with the fact that all of the points picked up at this location differed from the usual Indian arrowheads which are so abundant in that general region. Although they were convinced that the points constituted a distinct type, they were not aware of their true significance until informed by Dr. E. B. Renaud, of the University of Denver, that they were Folsom points.

In the summer of 1930 Dr. Renaud and a number of his students, under a project sponsored by the Smithsonian Institution Cooperative Fund, the University of Denver, and the Colorado Museum of Natural History, were making a survey of local collections and of former village sites in Colorado and adjacent regions. Their purpose was to plot distribution maps for various types of implements, with the places where they were found. It was during these investigations that the Coffin series was noted.[1] In June 1931 Dr. Renaud visited the location from which the artifacts came, and he describes it briefly in one of his reports.[2] No digging was done, but portions of two Folsom points were picked up from the surface at that time. The Coffins continued their visits intermittently and added specimens to their collections. Most of the material was picked up from the surface, but a few pieces were scratched out of the soil. No extensive work was attempted until the autumn of 1934.

The place where the points and other implements were found by the Coffins is a denuded area approximately 70 by 150 yards in extent. The bulk of the material came from a small section covering only about 30 square yards. The surface over a greater portion of this site

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[1] Renaud, 1931 a, p. 17.
[2] Renaud, 1932 a, pp. 27-28.

is the top of a hard, compact layer of grayish earth. The artifacts recovered from it had undoubtedly been in top-level material which was eroded away by wind and water. The implements, because of their weight, had remained until picked up. In some places, there remained portions of the sand, gravel, and nodule layer which had overlain the compact deposit, and a few objects were found on the contact line between the two. This part of the site did not offer any particular inducements for digging, especially if it was desired to find material in situ. At the close of the first day's inspection the writer was not sanguine over the prospects for getting information beyond that already obtained by Judge Coffin and Major Coffin.

On the second day, however, when the writer, with Judge Coffin and his son, was exploring the adjacent terrain, the Judge picked up a portion of a Folsom point along the bank of a ravine which cuts through the terrace some distance above the original site. Close inspection of the precipitous bank in the vicinity of this find revealed an undisturbed and intact layer of midden material 14 feet below the present ground level and 12 feet above the bed of the gully. A brief investigation demonstrated that the deposit, which is a quarter of a mile away from the spot where the majority of the Coffin specimens was found, was a likely place for excavation. Work was started and continued through the month of October and into the first part of November. Some digging was done at other portions of the site, but the major activity was restricted to the deep pit in the gully bank where most of the specimens described in following pages were found.

The type of point called Folsom has been known for a long time. Variations of the form have been found from the Rockies to the Atlantic, from southern Canada to the Gulf of Mexico. It is represented in collections in numerous museums and in at least one case has been called by another name, the Seneca River point. Except for a few instances,[2] it did not attract particular attention despite its peculiar characteristics. This was in part due to the fact that most of the examples were surface finds. Its true significance was established in 1927, and the interest focused upon it brought to light many which had previously passed unnoticed.

Because of a certain amount of confusion and misunderstanding concerning the original Folsom finds, a brief review of the subject is germane to the present discussion. In the summer of 1925 Fred J. Howarth and Carl Schwachheim of Raton, N. Mex., both now de-

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[2] Beauchamp, 1897, figs. 13, 14, p. 21. Brown, 1926, fig. 45, p. 138. Thruston, 1890, fig. 139, pp. 231-232.

ceased, notified Director J. D. Figgins of the Colorado Museum of
Natural History, Denver, of a bone deposit which they had found in
the bank of an arroyo on the upper sources of the Cimarron River
near the town of Folsom in eastern New Mexico. Samples of bone
sent to the museum indicated that the remains were those of an
extinct species of bison and of a large deerlike member of the
Cervidae. Prospects for fossil material were so promising that the
Colorado Museum sent a party to the site in the summer of 1926.
During the course of the excavations, carried on under the super-
vision of Frank Figgins and Mr. Schwachheim, parts of two finely
chipped projectile points were recovered from the loose dirt at the
diggings. Near the place where one of them had been dislodged a
small, triangular piece of " flint " was found embedded in the clay
surrounding an animal bone. This fragment was left in the block of
earth, and when the latter was received in the laboratory at Denver,
the dirt was carefully cleaned away from the bit of stone. It appeared
to be from the same material as one of the points, and close examina-
tion showed that it actually was a part of the point. This evidence
seemed unquestionably to demonstrate that here was a definite asso-
ciation between man-made objects and an extinct bison.[4]

Director Figgins was so impressed with the find and was so
thoroughly convinced that it was of importance to students of Ameri-
can archeology that he took the points with him that winter when he
visited several of the large eastern museums on paleontologic busi-
ness. In most places his announcement was courteously yet skeptically
received. One authority on stone implements marveled at the quality
of workmanship that the specimens exhibited and even remarked
that they were reminiscent of the finest examples from Western
Europe. He was doubtful, though, of the trustworthiness of the asso-
ciation. He thought that it could perhaps be attributed to an accidental
mixing of material. Others said that the points had no significance
because they could be duplicated in existing collections. At a few
museums, notably the American Museum of Natural History, Mr.
Figgins was urged to continue the work in the hope that additional
evidence could be obtained.

The Colorado Museum again sent a party to Folsom in the summer
of 1927 and had the good fortune to find additional points. One of
these was noted before it was removed from the matrix, even before
it was completely uncovered. Work was stopped immediately on that
part of the excavation, and telegrams were dispatched to various

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[4] Cook, 1927. Figgins, 1927.

museums and institutions inviting them to send representatives to view the point in situ. The writer at that time was attending the first Southwestern Archeological Conference at Pecos, N. Mex., and, upon receiving notice of the find and travel instructions from Washington, proceeded to Folsom. Arriving at the fossil pit, on September 2, he found Director Figgins, several members of the Colorado Museum board, and Dr. Barnum Brown, of the American Museum of Natural History, New York, on the ground. The point, which became the pattern and furnished the name for the type, had just been uncovered by Dr. Brown. There was no question but that here was the evidence of an authentic association. The point was still embedded in the matrix between two of the ribs of the animal skeleton. In fact it has never been removed from the block, which is now on exhibit in the Colorado Museum at Denver. On returning to Raton, N. Mex., that evening, the writer telegraphed to Dr. A. V. Kidder at Pecos and urged that he visit the site. Dr. Kidder arrived 2 days later, and he and the writer drove out to the bison quarry. After the whole situation had been carefully studied, it was agreed that the association could not be questioned. Furthermore, it was ascertained that the points were totally different from the ordinary types scattered over that portion of the Southwest.

At the meeting of the American Anthropological Association held at Andover, Mass., in December of that year Dr. Barnum Brown and the writer reported on the Folsom finds. There was considerable discussion of the subject, and although many agreed that the discoveries were important, there was still a general feeling of doubt. Numerous explanations were offered to show that the points might have gotten into such an association without actually being contemporaneous with the bison remains. Several mentioned that points of that type were numerous in collections from certain mound sites, from village sites in New York State, and elsewhere, and for that reason they could not be very old. Others insisted that, although they accepted the conclusions on the genuineness of the finds, there must be some mistake about the antiquity of the animal remains.

The summer of 1928 saw the American Museum of Natural History and the Colorado Museum cooperating at the Folsom site. The expedition was under the leadership of Dr. Barnum Brown, who was assisted by several graduate students in anthropology. The latter were under the general supervision of Dr. Clark Wissler. Additional points and bison skeletons were found, and telegrams reporting the discoveries were sent to various institutions. This time numerous special-

ists—archeologists, paleontologists, and geologists—rushed to see the evidence. The consensus of the informal conference held at the site was that this constituted the most important contribution yet made to American archeology. Some of the most skeptical critics of the year before became enthusiastic converts. The Folsom find was accepted as a reliable indication that man was present in the Southwest at an earlier period than was previously supposed.

In subsequent years there has been considerable activity on the part of those interested in tracing the distribution of the type of point found there. Some have endeavored, without marked success, to find new locations where further evidence could be obtained in situ. Others have been content to make surveys showing the occurrence of the type. There have been a few significant discoveries, but most of the information thus far available concerns material found on the surface. The latter is of value from the standpoint of distributional studies, as an indication of likely spots for intensive work, and in showing local variations in the type. Yet, so far as chronological significance is concerned, it has added little to the knowledge gained at Folsom. The most important contributions have come from sites in New Mexico, where E. B. Howard, of the University of Pennsylvania Museum, has been engaged in a series of investigations. In a cave in the Guadalupe Mountains in the southeastern part of the State he found a Folsom point in conjunction with musk ox and an animal of the musk ox group.[5] The musk ox is a cold-climate animal and when found as far south as New Mexico, is generally considered good evidence of an ice-age fauna. The association was of further significance because it occurred in a stratum underlying a level containing Basket Maker material. The latter belongs to the oldest definitely established horizon in the culture-pattern sequence in the Pueblo area of the Southwest. This is a good indication that the points antedate the Basket Makers.

Near Clovis, N. Mex., Mr. Howard has been exploring a site where large numbers of chipped implements, including Folsom specimens,[6] and bones of extinct species of animals are found together. The chief difficulty at this location, however, is that the material occurs in what are known as " blow-outs," places where all of the top soil has been carried away by action of the wind. For that reason accurate indications on associations are hard to obtain. The finds are in old lake beds, and the geologic evidence is of significance. At the time of the pres-

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[5] Howard, 1932.

[6] Anonymous, 1932; 1933. Howard, 1933; 1934, fig. 1.

ent writing, official reports on the Clovis work have not been published; hence, reference can be made only to the investigations.

The exinct bison from the fossil pit at Folsom, *Bison taylori*[7] (*Stelabison occidentalis taylori* and *Bison oliverhayi*[8]), are considered to be Pleistocene forms, animals that were living in the glacial period. This fact, coupled with the finding of points in association with bones of the musk ox and of other extinct bison in additional localities, furnishes the basis for the conclusion that the Folsom points represent considerable antiquity. This belief is substantiated by the fact that at a number of sites points bearing certain characteristics of the true Folsom type, yet not definitely assignable to that class, have been found with remains of extinct species of animals. One of the sites best illustrating this phase of the problem was that at Dent, Colo., where two points, one of which is decidedly Folsomoid, came from a deposit containing mammoth bones.[9] Several pits in Nebraska and Kansas have yielded points, in some cases with mammoth bones and in others with bison bones.[10] Near Colorado, Tex., an articulated skeleton of an extinct bison and some chipped points were recovered from a reputedly Pleistocene deposit.[11] Although the majority of the blades in this group of finds are not primarily Folsom in type, the conditions under which they were discovered tend to substantiate the Folsom evidence for an early occupation of the New World. In the latter connection, though they have no bearing on the Folsom problem proper, might be mentioned an association of man-made objects and traces of the ground sloth in Nevada,[12] and human bones with sloth remains near Bishop's Cap, N. Mex.[13] These occurrences are additional contributions on the "antiquity of man" in the Southwest. Whether all of this evidence from the various places mentioned actually dates man in the closing days of the Pleistocene, indicates his presence at the beginning of the post-glacial period, or demonstrates a later survival of ice-age animals is a phase of the problem which the geologist and paleontologist must solve.[14] Some insist that the evidence unequivocally proves that man was here in the Pleistocene, others that he came during the transition between the glacial and

[7] Hay and Cook, 1930.

[8] Figgins, 1933 b.

[9] Figgins, 1933 a.

[10] Bell and Van Royen, 1934. Schultz, 1932 (contains lengthy bibliography).

[11] Figgins, 1927.

[12] Harrington, 1933.

[13] Bryan, 1929. Thone, 1929.

[14] For a discussion of this subject see Antevs, 1935.

Recent periods, but was not actually here in the ice age. All agree that more data are essential. Archeologists generally concede that the points belong to the earliest phase of aboriginal culture yet discovered in America.

Distributional studies have demonstrated several facts. The most significant of these is that there are two main classes of Folsom type points: the true Folsom, and a larger, more generalized form embodying most of its characteristics but not exhibiting the skilful workmanship or mastery of the stone-chipping technique apparent on the true example. Present evidence is that the true Folsom is restricted to the strip of terrain, known as the High Plains, extending along the eastern slopes of the Rockies. The other form not only occurs in the High Plains but is widely distributed across the eastern portion of the United States.[15] There are several places about which the latter seems to center, notably the Finger Lakes section in New York State, in Ohio, Tennessee, and southern Virginia. Sporadic examples have come to light in various localities in practically every State east of the Rockies and in portions of southern Canada. The problem of distribution for the eastern area received considerable attention several years ago from Alfred Kidder, II, then a graduate student at Harvard University. E. B. Howard began his studies at about the same time, and when Kidder's interests were turned to other fields, his unpublished manuscript and all of his information were turned over to Howard. The latter is still actively engaged in the study.

From the letters, photographs, and actual specimens sent to Mr. Bushnell and to the writer, following the publication of the Digest articles and press notices of the work in Colorado, much more information has been added to the data on the occurrence of the eastern type. This work is still being continued, and a tabulation of the results and a consideration of their significance will be incorporated in a larger and more comprehensive study of the subject. It is in this connection that investigators must face the problem of whether the generalized form indicates an earlier phase which reached its perfection in the true Folsom or whether it represents a degenerate and later variation. Another aspect of this phase of the study is the diffusion of the type. There is the possibility that it traveled south along the cordillera, then swept east and north. On the other hand the two forms may represent off shoots from an original basic type which spread along two separate lines, one skirting the eastern slopes of the mountains, the other moving eastward and then south.

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[15] Howard, 1934, pp. 13-14.

Studies of distribution in the area adjacent to the Rockies are being carried on by Dr. Renaud and several of his students. Others are interested in the problem but are not actively engaged in the work. In the course of his surveys Renaud noted a type of implement which, in some districts, apparently occurs in conjunction with the Folsom points. Because the largest and finest series of this other type to pass under his observation was in an extensive collection at Yuma, Colo., he named it the Yuma type.[16] Yuma and Folsom points are found together at many sites as surface material, and their association no doubt has some significance, although just what it may be is not now apparent. On the basis of typology Renaud considers the Yuma older than the Folsom.[17] Others, notably Mr. Figgins,[18] do not agree. The age of the Yuma type has not been satisfactorily established, though one find of a debatable nature is frequently cited as proof of the antiquity of the form,[19] and another is still under discussion.[20] Since neither the Folsom pit nor the Lindenmeier site yielded Yuma points, further consideration and detailed descriptions of them are beyond the requirements of this paper. It was deemed advisable to mention them because the two names so frequently appear together. Persons interested in the Yuma types will find them described in Renaud's papers.

The importance of the Lindenmeier site lies in the fact that for the first time traces of an occupation level which can be assigned to a group of Folsom men have been brought to light. Whereas prior to the work in northern Colorado the only indications of this presumably early hunting people were typically chipped stone points, there is now a definite complex of associated implements. The last few years have been marked by much loose talk and writing about the " Folsom Race," the " Folsom Culture," and " Folsom Man," when actually all that was known was the characteristic point. From a strict anthropological point of view it is still incorrect to speak of " Folsom Culture " because the remains so designated probably should be considered only as one aspect of a basic, widespread early hunting pattern which may have extended across the eastern half of the continent. So far as Folsom Man himself is concerned, he is still persona incognita. No skeletal material that can properly be assigned to him has to date been discovered. Recent reports of a Folsom Man in Minnesota

[16] Renaud, 1932 b, p. 1.

[17] Renaud, 1931 a, p. 15; 1934 b, p. 2.

[18] Figgins, 1934.

[19] Cook, 1931.

[20] Barbour and Schultz, 1932. Bell and Van Royen, 1934. Figgins, 1934.

cannot, in the opinion of the writer, be accepted as evidence of such a find, because published illustrations of the points found with the human bones indicate that they are not Folsom, either of the true type or of the widely distributed generalized form. Nor are they Yuma, although identification of the skeleton as Folsom Man is based on the deduction that the points are Folsom in outline and Yuma in flaking, and hence intermediate in time and development between the two.[21] In view of the status of the Yuma, as discussed in a preceding paragraph, a form midway between it and the Folsom is not particularly significant. The Minnesota man may represent a local aspect of the general hunting culture of the period indicated by Folsom; he may even be older. That is beyond the question here at issue, namely, that present evidence does not show him to be Folsom Man.

Not only has the Lindenmeier site furnished a variety of implements for the Folsom horizon, but in addition there are numerous stone flakes,—typical workshop debris. These occur in the deposits with the tools and give mute but accurate evidence of much of the technique employed in the manufacture of the implements. Furthermore, the numerous spalls, nodules, and large cores indicate that the stone working was done on the spot. Considerable raw material was available in the neighborhood, and this may have been one of the attractions which led to the occupation of the site. Other items influencing this choice probably were the presence of a large spring and an abundance of game animals. The midden deposit contained quantities of cut and split bones. This material is very scrappy in its nature, but nevertheless it has been possible to identify some of the animals represented. Two of the species contribute support to the belief that the Folsom complex represents an appreciable antiquity. There is also the chance that better bone specimens will be obtained there and that more animals will be represented, thus increasing the information on that phase of the problem. The site holds possibilities from a geologic point of view, and it is hoped that careful studies by a number of specialists will give an accurate indication of the probable age of the deposits.

Great credit is due Judge Coffin and his son for the discovery of this site and to the Judge and his brother, Major Coffin, for their efforts to protect it and bring it to the attention of the scientific world. Their whole-hearted cooperation during the investigations by the writer facilitated the work and made possible better results than would otherwise have been attained in so short a time. A. L. Coffin assisted

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[21] Anonymous, 1934 a; 1934 b. Jenks, 1934; 1935, pp. 7-11.

in the digging throughout the period that the excavations were being made. The kindness of Mr. Lindenmeier in granting permission to work on his land is deeply appreciated.

THE LINDENMEIER SITE

The Lindenmeier site, where the specimens described in the following pages were found, is 28 miles (45.062 km) north of Fort Collins, Colo., and 1¾ miles (2.816 km) south of the Wyoming line. Specifically, it lies in sec. 27, T. 12 N., R. 69 W., sixth principal meridian. The site is on a terrace (pl. 1, frontispiece) above the valley of an intermittent tributary to a series of creeks which ultimately join the South Platte River. Whether this is a part of the old terrace system of the Platte, which is being extensively studied by geologists in the region farther east, is still to be determined. The formation is generally called the White River. It consists of a bed of grayish clay covered with a conglomerate composed of sand, gravel, and occasional large boulders. The clay is a Tertiary deposit, Oligocene, with a possible admixture of some volcanic ash. The capping conglomerate is indeterminate in age. It may be rather old, or it may be comparatively recent.

The Lindenmeier site presents an interesting geologic problem in the question of the wearing away and building up of the terrain. The man-made material and animal bones occur in a dark soil layer which rests on the clay bed and underlies the conglomerate. A tentative reconstruction of the topography at the site, based entirely upon the writer's interpretation of conditions and not upon observations by a competent geologist, suggests that at one time there was a short, narrow valley lying between a series of conglomerate-topped ridges, a situation comparable to that existing today at no great distance above the archeological location. (See pl. 2, fig. 1.) The valley bottom consisted of a soil layer, several inches in thickness, resting on the Oligocene deposit. Here and there were small ponds or marshy places, as indicated by the siltlike strata of dark soil in depressions in the clay bed. The human occupants of the valley lived on top of this soil layer. As a result of their continued presence, numerous objects associated with their daily round of life—charcoal and ashes from their fires, bones from the animals that supplied the meat for their meals, stone chips from the implements that they made, broken tools and other artifacts—were scattered over the surface. These in time became embedded in the rising soil level, were subsequently buried by additional soil layers after the people departed, and eventually were covered by
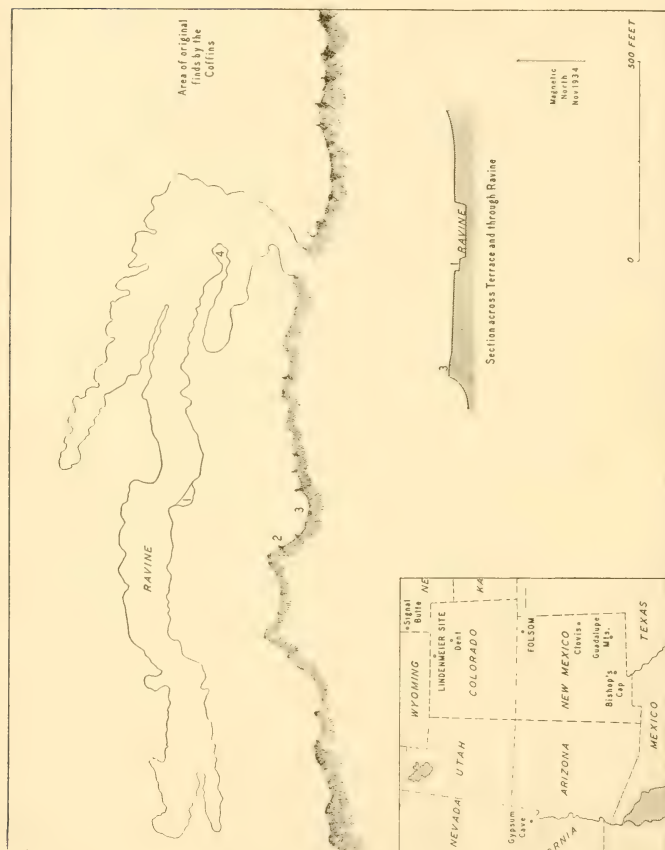
Fig. 1.—Sketch map of the Lindenmeier Site. 1, location of deep deposit; 2 and 3, places where bones and "flints" were found; 4, implements obtained at this spot. Insert shows location of the site with respect to other finds indicative of considerable antiquity.

the present overburden when sand, gravel, and boulders were swept
down into the valley from its bordering hills. Later, water, coursing
its way down the hillsides and along the valley, cut the gully in whose
banks the midden deposit was revealed.

The present ravine is only one of several channels which have from
time to time been worn in that portion of the terrain. Traces of other
water courses which did not cut so deeply into the valley fill are
apparent in the sides of the gully. One old channel passed directly
over the top of a portion of the layer in which most of the stone and
bone material was found. It did not wear its way down into the old
soil line but stopped a few inches above it and then began to build up.
It gradually became filled, until, so far as surface indications are con-
cerned, it was completely obliterated. The direction of the old channel
at this point had been almost at right angles to the now existing gully.
In character the former suggests a meandering stream, one which
probably continued to the lower end of the valley a mile or so east of
the mouth of the channel of today. The filling of the stream bed may
have resulted from damming by alluvial gravels washed in from one
of the side canyons near its mouth. Considerable time is probably
represented by all this action, although conditions in the West are
such that channel cutting, filling, and shifting may occur in a relatively
short period of years. Other factors indicate that the process here
could not have been extremely rapid because ridges from which some
of the valley fill was eroded have since completely disappeared, having
been weathered away in the opposite direction. This is shown by the
fact that the soil layer—the artifact-bearing stratum—topping the clay
bed is still on the upslope, where it appears along the edge of the
terrace above the broad valley to the south of the site. The complete
erosion of the ridge transformed the level from a valley bottom to
what may possibly be considered to be a terrace.

One aspect of the problem which is of interest, although it bears
only indirectly on the archeological factor, concerns the original scour-
ing of the valley bottom and removal of material down to the Oligo-
cene stratum. Whether this resulted from action by mountain glaciers,
by water from them, or from some more recent agent is one of the
many phases of the subject which geologic studies may explain.
Should it be established that the Oligocene deposit was laid bare at the
time of the great mountain glaciers, which are considered to have been
contemporaneous with the Wisconsin ice sheet, a significant inference
could be drawn, namely, that makers of the implements arrived on the
scene not long after the retreat of the ice, since evidence of their

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presence occurs immediately above the eroded surface. This would place the occupation of the locality at the beginning of the present geologic period. Although speculation of this nature suggests interesting possibilities, it must be borne in mind that it is only conjecture and that careful examination of the deposits by specialists may result in entirely different conclusions. The chief purpose of this supposititious reconstruction is to call attention to some of the questions raised by conditions at the site.

Preliminary prospecting indicated that the main concentration of archeological material occurs in the strip of land lying between the present gully and the edge of the terrace (fig. 1). The area is approximately 250 yards (228.6 m) long by 100 yards (91.44 m) wide. The artifact-bearing stratum varies in depth below the surface. Along the edge of the terrace its average depth approximates 2 feet (60.96 cm), increasing rapidly toward the bank of the gully, where it is 14 feet (4.267 m) below the present surface at the place where most of the digging was done. (See pl. 2, fig. 2.) It is 6 feet (1.828 m) down from the top at the mouth of the ravine. The difference in depth between the upper and lower ends along the bank is due not so much to variation in the old soil line level as to the slope of the present surface. Digging at a number of places, both along the edge of the terrace and in the sides of the ravine, yielded stone implements and broken animal bones. The specimens occurred in greatest numbers at the deepest point, however, and for that reason most of the preliminary work was restricted to that portion of the deposit. The material at this location suggested a midden or refuse layer, whereas that from other portions of the site was more of the nature of chance accumulations. The objects, bone and stone, were found for the most part just above the clay stratum in a layer 6 inches (15.24 cm) to 1 foot (30.48 cm) in thickness (pl. 3). Some were lying flat at the line of contact between the layers, others extended down into the top of the clay as intrusions.

The deep level, where most of the work was done, seemingly constituted the peripheral vestiges of one of the depressions in the top of the clay bed, as mentioned in a preceding paragraph. It suggested that the material had been deposited along the edges of a shallow pond or a marshy spot. The main portion of the old depression was washed away when the present ravine was formed. A wedge-shaped excavation was driven into the bank following along the top of the clay bed. Because of the large amount of overburden to be removed, the necessity for extremely careful digging, and the short time available for

the investigations, only a small area was uncovered. It measured 53 feet (16.154 m) along the ravine, extended into the bank 38 feet (11.582 m) on one side and 26 feet 6 inches (8.077 m) on the other. In view of the small size of the excavation the number of specimens obtained was gratifying both as to quantity and variety.

In the following descriptions of the various kinds of tools found at the Lindenmeier site, only the more general features will be considered. A detailed typological study, discussions of the technique of manufacture, and comparisons of this material with similar objects from sites not necessarily Folsom in nature are not advisable at this time, since further excavations are planned. Additional and more comprehensive evidence will no doubt be available when the investigations are completed. The various kinds of stone represented by the implements in the present group are: Chalcedony, jasper, chert, quartzite, petrified wood, moss agate, geyserite (rare), and white sandstone. The chipper's debris—flakes, cores, and nodules—also exhibits the same variety. The most popular " flints " were chalcedony and jasper. (The writer does not believe it necessary to go into the question of flint and flintlike materials in the present discussion. Where the term flint is used, it refers only to the implements, not to the particular stone involved.) The other kinds of material found in the region do not flake and chip as readily, nor do they permit as high a degree of workmanship. The recent Indians inhabiting the district made greater use of quartzite and geyserite.[22] The sandstone objects from the old horizon were not cutting or penetrating implements, but rubbing and polishing stones.

POINTS

True Folsom points occur in two forms. The better known variety, based on the first example found actually in situ at the Folsom pit, is a thin, leaf-shaped blade. The tip is slightly rounded, and the broadest part of the blade tends to occur between the tip and a line across the center of the face (fig. 2, A, a, b). A typical feature is a longitudinal groove or channel extending along each face, C, about two-thirds of the length. These grooves produce lateral ridges paralleling the edges of the blade. A cross-section of the object gives a biconcave appearance as shown in the diagram. The base is concave,

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[22] Major Coffin has studied extensively the tools made by the different Indian groups which inhabited the Fort Collins area at various times and has determined most of the sources for the materials used. A summary of his findings appears in Renaud, 1931 b, p. 61.

the concavity varying in outline on different specimens, and there are frequently long, sharp base points often called " ears." Between the edges of the blade and the lateral ridges produced by the central grooves is a more or less fine marginal retouching, a secondary removal of small flakes. Points in this group tend to be somewhat stubby, as they are broad in proportion to the length. The second form, B, was present in the type site but is rarely mentioned in discussions because of the general lack of information on the subject. It is also a thin,

a   *b*
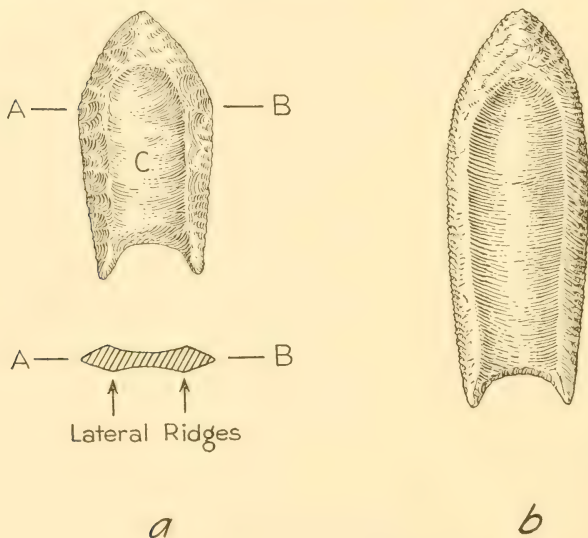
FIG. 2.—Two forms of the Folsom type point.

leaf-shaped blade with characteristic fluting on the faces. In contrast with the first form, however, it is long and slender in outline and has a tapering rather than a rounding tip. The type of base for this second form is not known from Folsom, as the specimens found there were broken, the butt ends being missing. Similar points from the Lindenmeier site have concave bases. Hence it is permissible to assume that the same was true for the specimens from the type site. It is quite possible that some of the broken bases from Folsom were from B form blades, although there is nothing to substantiate that assumption.

The various features that characterize the Folsom points may be found singly or in different combinations on specimens originating in several sections of the country, but unless all are present on each individual artifact it cannot be considered as a true example of the type. Failure to observe this fact has led to some confusion and misunderstanding. Mere concavity of the base or leaflike shape does not constitute a Folsom point. The groove is an essential feature. Whether grooves on both faces should be insisted upon is a debatable question, because in at least one of the specimens from the original site it was present on only one face. This point, or rather portion of a point, was picked up by Mr. Howard from the dump at Folsom during the summer of 1934. Except for the absence of the fluting on one side, it is in all respects characteristic of the type. It is the only example from that location which was made from quartzite, and as that material is so difficult to work, it is possible that the groove was omitted for that reason. One example from the B group at Folsom, which has been pictured a number of times, seemingly has a groove on but one side.[23] As a matter of fact the specimen in question shows that it did have a groove on each face, though one was unusually short and most of it was lost when the butt end was broken off. Just a trace of the upper end of the channel is to be observed. That so short a flake was removed was due, as the specimen clearly shows, to a flaw in the stone. This caused the flake to turn out rather close to the base instead of farther along the face. A number of fragmentary points from the Lindenmeier site have the channel on only one side. Most of these appear to be implements broken and discarded before completion, however, and for that reason are not a good criterion. In view of the evidence from Folsom, and despite the contradictory nature of such a statement, it may be said that a true Folsom point should be fluted on both sides, but an otherwise typical example may occasionally have the feature on only one side.

The rarity of perfect specimens has been commented upon in various articles on the subject of Folsom points. A large majority consists of broken examples. There was only one complete blade in the group of 19 found at Folsom, and the proportion at other sites has been even smaller. This may be attributed, as has frequently been suggested, to the brittleness caused by the fluting. The removal of the longitudinal flakes so thinned the points that they became extremely fragile. The purpose of the grooves is not known. A number of explanations have been made, and any or all may apply. Perhaps the

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[23] Figgins, 1927, fig. 3.

most logical is that they were to facilitate hafting the head to the shaft of the spear or arrow. Other interpretations are that they were to reduce the weight, to improve the penetrating qualities, to permit the point to break off in the animal, to allow the head to slip out of the fore-shaft, and to promote bleeding. It is possible that a number of such ideas were contributing factors in the perfection of the type.

With the exception of two specimens, all the points or portions of points found at the Lindenmeier site are of one or the other forms of the true Folsom type. One variant is an extremely thin example which would not have permitted the removal of such flakes (pl. 5, *i; 6 i*). In its general outline and style of chipping it indicates a relationship to the group, but nevertheless, it cannot be considered a Folsom point. It probably represents a different type, because similar points have been found at Clovis and other sites. A single example is not sufficient for definite conclusions, but there may be some significance in the fact that this specimen was found on top of the old soil layer—not down in it as were most of the true forms. The other point that does not conform was made from a scrap flake not primarily intended for such use, and hence was not properly shaped in the beginning (pl. 7, *h; 8, h*). This object came from the deep deposit and was in association with typical Folsom material. It is too indeterminate in character to be considered other than an aberrant form. Furthermore, since the base edge is chipped in a fashion suggestive of a scraper rather than a projectile point, it is possible that it was one of the former.

From the time that the Folsom type and its longitudinal grooves first attracted attention there has been considerable discussion about the technique employed in the removal of the long flakes. Some have insisted that they must have been dislodged before the blades were worked down to their characteristic shape. The writer has maintained from the beginning, as have several others, that the major part of the shaping constituted the initial stage, and that the long flakes were then removed.[24] The final touch was the secondary chipping between the lateral ridges and the edges.[25] This was suggested by the fact that the longitudinal channels cut through the smaller cross grooves left by the primary shaping process. Another indication was the " hinge fracture " on the ends of broken specimens. This resulted from a reverse action on the part of the flake. Instead of turning out, it turned in and went through the blade, breaking off the tip and leaving a smooth, rounded end on the butt. There are several examples of

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[24] Cook, 1928, p. 40.
[25] Renaud, 1934 b, p. 3.

this in the present collection. In one instance both the tip and the butt were found (pl. 7, *l*; 8, *l*), and another specimen exhibiting the feature has already been described in print.[26]

This proof was not sufficient to convince a number of the investigators; now, however, there is clear-cut evidence. The Lindenmeier site contributed portions of flakes which came from the longitudinal channels. The Coffins found a number of such flakes in their work, and several were obtained during the digging by the writer. Major Coffin expressed the belief that they were from the channels, and the additional specimens show this to be the case. In every instance the flakes are smooth on one side—the side that formed the groove in the blade—and flaked on the other (pl. 4). The latter surface was part of the face of a completely shaped point. Furthermore, fragments of blades broken in the process of manufacture and consequently discarded substantiate the conclusion. What may seem to be an exception to this procedure (although actually it is not) is occasionally noted. Some specimens suggest that use was made of a random flake which already had a groove on one side. With such material, all that was required was the shaping and fluting of the other face. But the same method was followed for the single side as in the making of a complete point. Examples of this nature are not common, however.

The technique of removing the long flake is not definitely known, but the scrap material from the midden gives some good clues. Both the fragments of the points and the pieces of channel flakes indicate that a hump was left in the center of the concavity when the base was chipped (fig. 3, *a*). This formed the " seat " for the implement used to eject the flake. That percussion, not mere pressure, was resorted to is evidenced by the definite bulbs of percussion on the flakes and by the reverse impressions in the bases of the points which had not been secondarily chipped. It would be extremely difficult to strike a nubbin as small as the " seat " with a hammerstone; hence it seems logical to suppose that the blow must have been an indirect one. A tool of bone or antler probably served as a punch to transmit the impact required to flip out the flake. Indirect percussion was employed by certain recent Indian stone chippers in making some of their implements,[27] and it may well have been part of the ancient technique. When the groove had been obtained on one side, the nubbin was retouched, if necessary, and the process repeated on the other side. The rechipping of the " seat " was no doubt partially responsible for the depth of the

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[26] Renaud, 1934 b, p. 4.
[27] Holmes, 1919, pp. 295-296.

concavity and the length of the " ears." There is nothing to show whether the work was entirely that of a single individual or whether two were needed. It is quite possible that one held the point with the punch firmly seated at the proper spot on the nubbin while another gave a quick, sharp tap on the flaking implement with a hammerstone. This unquestionably would require skill on the part of both but probably would not be as difficult a task as though one person tried to do it alone. Present day experts in stone chipping may be able, through experimentation, to solve the problem of which would be the more efficient method. In a majority of cases a single, long flake was removed at a single blow. Occasionally the first attempt was not satis-
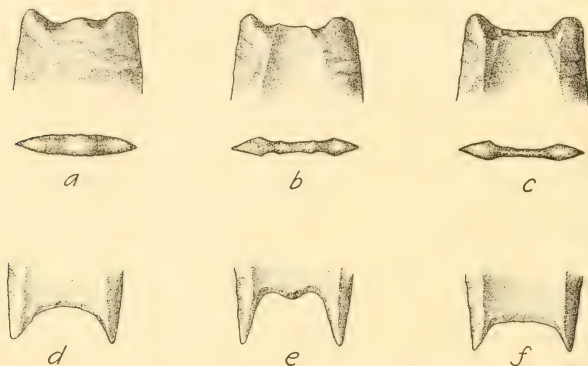
Fig. 3.—Stages in the removal of the channel flakes and three forms of base on Folsom points.

factory and a second try was made. Major Coffin has two flakes in his collection which show this clearly. The first one was rather short and very thin, the second thicker and much longer. The first fits perfectly into the groove in the second.

After the fluting was accomplished, the edges and base of the point were refined by secondary chipping. This is evidenced by the fact that those broken in the grooving process, and consequently not completed, do not have the retouch. Occasional specimens show an additional treatment in that the base and the edges for about one-third of the length of the blade were smoothed. Whether this was intentional or accidental is not known. This smoothness may have resulted from the hafting of the stone in a wooden or bone handle, or, as one writer has suggested, it may be due to a deliberate dulling of the edges to pre-

vent the cutting of the lashings used to fasten it to the shaft.[28] This feature is present on only a small proportion of the true Folsom points but is common on the generalized eastern forms. On an occasional specimen, one-third to one-half the length of the blade above the base, is a small notch in each edge. These probably were to facilitate the fastening of the point to a shaft.

The extent to which the base was subjected to the final retouching process determined the contour of the concavity—whether it was curved, figure 3, *d*; wavy, figure 3, *e*; or squarish, figure 3, *f*. In most of the specimens from the Lindenmeier site it is wavy, because the bulk of the material was broken and discarded before completion, but there are some which show entire obliteration of all traces of the flaker " seat." In his distributional and typological studies on Folsom points Renaud worked out the percentages of base types and found that the curved concavity predominated, although the squarish and wavy forms were a close second.[29] He describes the latter as separate base types, C-1 and C-2, but groups them together as C in his tables, so that it is not possible to determine the number of each. Since the squarish or C-1 form on the basis of typology is the most highly developed and represents the ultimate stage in the perfection of the technique, percentages might be significant. A site with a predominance of the C-1 forms could be regarded as representing a higher cultural level than one where the C-2 was the main form.

Most of the point specimens from the Lindenmeier site are fragmentary, and all but a few of the pieces are butt ends. The scarcity of tips was puzzling at first. Consideration of the problem led to the conclusion that the prevalance of basal portions was due to one factor, the replacing of damaged points. Because of their brittleness, many were no doubt broken by hunters in the chase—snapped off in the killing of game. The shafts of the spears or arrows, unharmed and still serviceable, were carried back to camp and fitted with new points, the broken pieces being tossed into the midden. The fragment remaining in the shaft would naturally be the butt end; hence the numbers in the deposit material. It may be mentioned in passing that there is nothing to indicate whether the points were used in arrows or spears. Present thought is that the bow and arrow was a late development in the New World and that the older cultures employed a spear and spear thrower. Without evidence in the matter, archeologists concerned with the Folsom problem have gone on the assumption that the points were used in a shaft hurled from a spear thrower.

[28] Renaud, 1934 b, p. 3.
[29] Renaud, 1934 b, pp. 8, 9.

Measurements for the size range of points in the present collection are unsatisfactory because of their fragmentary nature. In his tabulations on specimens studied in numerous collections, including both the generalized and the true Folsom types, Renaud has compiled the following figures: Length, 17 to 115 mm; width, 14 to 36 mm; thickness, 3 to 14 mm.[39] For the true forms the range is not as great: length, 17 to 75 mm, with a 45.41 mm average; width, 14 to 32.5 mm, with a 21.94 mm average; thickness, 3 to 6 mm, with a 5.38 mm average.

SCRAPERS

A large proportion of the specimens in the collection belongs to the scraper group. There are several varieties of this type of implement, and the tools exhibit different degrees of workmanship. Some have as minute and careful chipping as that to be seen on the finest projectile points, whereas others are extremely crude and rough, only the minimum of effort necessary to make a usable implement having been expended on them. Most of the scrapers belong to the curved-end type, the so-called " thumb-nail " or " snub-nosed " form (pl. 9). Next in order, from a numerical standpoint, are the side scrapers. In this group are tools with straight, convex, and concave scraping edges. There are some turtleback scrapers and a few implements difficult to classify because they combine several features.

The " snub-nosed " type has a number of different subforms, but all are characterized by one convex, carefully chipped end. The treatment of the other end and the edges, as well as of the lateral surfaces, varies. To make such an implement, a flake of stone roughly the shape of a trigonal pyramid was struck off from a larger core. For the simpler form of the tool this flake was chipped along the base to produce the typical, thick, rounded end. The cutting edge then received an additional chipping which made it very sharp (pl. 10, *a, b, c*). The other end was left untouched, the bulb of percussion caused by the blow when the flake was detached furnishing a satisfactory tip. The side edges were not chipped, nor was anything done to the faces or lateral surfaces. This form is triangular in cross-section. A second subform was similar to the first except that the side edges were worked. A still more refined implement, the third subform, was made by removing the ridge or top edge so that the cross-section became pentagonal instead of triangular. Some additional minor retouching on the lateral surfaces occasionally accompanied this feature. The

[39] Renaud, 1934 b, pp. 9-10.

two side edges were also chipped. The removal of several long flakes from the top produced a fourth subform, one with a quadrangular cross-section. The latter also resulted from the removal of a single, long, broad flake, which produced a fluting similar to that on the projectile points. On practically all of the pentagonal and quadrangular forms the smaller end, as well as both edges, was modified by additional chipping. Rarely was the ventral surface, the bottom of the tool and the side which came off the core, altered in any way.

A very elaborate classification could be made for the subforms of this type of scraper by segregating the different specimens according to the various combinations of features. For the purposes of this paper that is not essential, but in a more detailed study such a subdivision would be advisable, especially when the subject of comparisons is considered. The " snub-nosed " scraper was not peculiar to this horizon or locality. Forms of it are found on recent Indian sites in the general High Plains area and elsewhere throughout the country. By means of an elaborate typological grouping it may be possible to point out distinctions, to determine criteria for identifying early and late forms. Such an attempt will be deferred, however, until a larger series from the Lindenmeier site is available. The " snub-nosed " scrapers from this site vary in length from 21 to 25 mm, in breadth at the cutting edge from 25 to 30 mm and in thickness from 4.5 to 11 mm.

The side scrapers exhibit considerable range in quality, degree of finish, and the types of flakes used in their manufacture. Some are light in weight and paperlike in their thinness. Others are thick and heavy. Certain examples display careful dressing of the faces of the blade as well as minute and precise chipping along the edges (pl. 11). There are other specimens that are little more than rough flakes with chipping along one edge or only on a portion of the edge (pl. 12). In some cases part of the siliceous crust or outer covering of the nodule from which the flake was struck is still present. The purposes for which the tool was intended no doubt governed the amount of work expended in its shaping. As will be noted from the illustrations, several of the implements combine both the convex and concave blades on a single tool (pl. 11, g). Others have one straight edge and one convex (pl. 15, n), or a straight and concave combination. The carefully worked side scrapers range from 30 to 62 mm in length, 15 to 33 mm in width, and 2 to 4 mm in thickness. The rough-flake forms vary from 40 to 60 mm in length, 20 to 45 mm in width, and 7 to 12 mm in thickness.

The turtleback is an interesting form of scraper (pl. 15, *i, j*). In the strict sense of the word these objects are not true turtlebacks, inasmuch as they are faceted on only one side, the other being flat or slightly concave. This feature can be attributed to the fact that they were made from large, thick flakes rather than from complete nodules; consequently, it was necessary to shape them on only one side. The convex surface of such tools is characterized by large facets suggestive of the back of a turtle. The edges exhibit the fine retouch typical of most of the specimens of the entire complex. If it was not for the latter feature, many of the turtlebacks might be considered as discarded cores from which flakes had been removed to be used in making small implements. Or they might even be classed as blanks waiting the specialization which would make them tools. Specimen *i*, plate 15, has a length of 53.5 mm, a width of 49 mm, and a thickness of 18 mm. The measurements for *j*, plate 15, are: length 57.5 mm, breadth 41.5 mm, and thickness 14 mm.

There is no definite knowledge about the uses to which the side scrapers and turtlebacks were put, but their functions were no doubt manifold. They could have served for dressing hides, for removing flesh from bones, for cutting bones, for smoothing spear and arrow shafts. In short, they combine in one implement the qualities of a knife, an adze, a gouge, and an abrading or finishing tool. The scraper in its various forms was indispensable in the daily life of the later Indians, and this was no doubt true for the dwellers at the Lindenmeier site. The general character of the different kinds of scrapers is well illustrated by the examples shown in the photographs; hence, more detailed descriptions of their various peculiarities are not necessary at this time.

BEVEL-EDGED TOOLS

The implements of the bevel-edged type are generally triangular in outline with a small, rounded tip and two chipped edges. The base is smooth and the faces comparatively flat. These tools might well be considered as points, although not in the sense of projectile heads (pl. 11, *b*). Their characteristic feature is the beveled edges. In making such a tool the chipping was all done from one side so that the cutting edge slanted obliquely to the opposite face. The stone was then turned over and the operation repeated. This produced an implement rhomboidal in cross-section, the faces constituting the width and the edges or short sides the thickness of the blade. When viewed with the point directed upward, the beveling is usually toward the left;

only a rare, sporadic example shows the reverse, with the chipping sloping away to the right. Perhaps this constitutes a record of right- and left-handedness in the group which made and used them. A few specimens in the collection do not correspond to the general pointed type, but have broad, unworked ends. Their sides, however, are beveled in characteristic fashion. The beveled edge is not confined to tools of this type; it occurs, singly, on some of the side scrapers. Per- haps the beveled points should only be considered as broken tips from knife blades. Yet basal portions have not come to light, and it would seem that the implements found represent the complete tool. They would serve well in the capacity of a knife, particularly in the skinning of an animal, where the cutting motion was toward the user. Those with the broad, unchipped ends would not do for such a purpose and must have been employed as a variety of scraper. The triangular examples could also be used as reamers in enlarging holes started with a small punch or borer.

The bevel-edged tools in this collection are not unique for North America, but it is interesting to note that the form occurred in the Folsom horizon. Henry B. Collins, Jr., has examples that he found in Alaska.[31] Kidder obtained a number of knife blades in his work at Pecos which exhibit the feature.[32] There are examples from late Plains sites, and they are fairly numerous in certain districts in Ohio, Alabama, Tennessee, and Georgia.[33] These forms are more definite in their shaping, however, and are presumably of a much later date.

The triangular forms of the bevel-edged tool found at the Linden- meier site range from 25 to 30 mm in length, 26 to 32 mm in width, and 4 to 6 mm in thickness. The flat-ended forms are from 27 to 40 mm in length, 29 to 33 mm in width, and from 6 to 8 mm in thickness.

GRAVERS

The tools given the designation " gravers " constitute one of the most interesting groups in the whole collection (pl. 13). This is due not so much to the actual nature of the specimens themselves as to their indication that some form of the engraver's art was practiced by the makers of the Folsom points. No objects exhibiting such handi- work were found, but the character of the implements suggests that further work may uncover pieces of bone or other material, similarly resistant to the agents of decay, upon which designs were scratched.

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[31] Collins, 1931, 1932.

[32] Kidder, 1932, pp. 30-34.

[33] Fowke, 1896, pp. 160-161, 177-178. Wilson, 1899, pp. 931-934.

The later Indian tribes employed the engraver's art extensively, although it never reached a high degree of excellence north of Mexico, and it is not unreasonable to suppose that it was one of the cultural features in earlier periods. Other peoples in comparable stages of development are known to have responded to the creative urge by drawing with stone on bone, and it is not assuming too much to concede the ability for delineation to such skilled chippers of " flint " as the Lindenmeier group, particularly since there was so abundant a supply of stone and bone ready at hand.

The simplest and most numerous gravers consist of fortuitous flakes which were modified only to the extent of chipping a small, sharp point on one side or end (pl. 13, a–g). These short, needlelike points are superficially similar to those commonly classed as drills or borers. They differ, however, in that one face is flat, while the other has beveled edges and a chisellike tip. The usual drill points are chipped on all sides. Furthermore, on several of the present examples small, almost microscopic, flakes have been broken away from the point. The appearance of this feature is such as to suggest that it was caused by a scratching or gouging movement of the implement rather than by a rotary twist such as is used in drilling. On only one of the tools in this group is the point long enough to have functioned as an awl. A hole could be punched through a thin hide with it, but its shape is not adapted to even the slight twisting motion ordinarily accompanying such a procedure. The gravers in this group are from 20 to 44 mm long, 18 to 28 mm wide, and 2.5 to 3 mm thick. The points are consistently from 1.5 to 2 mm long and 1 to 1.5 mm wide at the base.

Some of the gravers are more definitely shaped than the scrap-flake series just described. (See pl. 13, h–j.) They were also made from flakes, but the points are broader, more elongated, have a definite bevel on the tip, and exhibit superior workmanship. The chipping is not confined to the actual point but extends along the edges. The finest specimen in this group is j, plate 13. The tool was made from a flake, but the entire stone was chipped to obtain the desired shape for the implement. Both faces, the lateral surfaces, and the ends received careful attention from the maker. In addition there is a fine marginal retouch along two edges and around the narrow end. The tip of the latter has a pronounced bevel. The entire object is suggestive of modern tools used in lathe work. Perhaps this particular implement should be classed as a chisel rather than a graver, yet it would have functioned well in the latter capacity. As a matter of fact, there is a certain over-lapping of meaning in the terms " chisel " and " graver,"

and in the present preliminary classification fine distinctions are not essential. The more definitely shaped gravers are from 32 to 38 mm long, 16 to 29 mm wide, and 5 to 9 mm thick. The points are from 9 to 10 mm long.

Several combination tools were found (pl. 13, *k-m*). These incorporate the qualities of the scraper and the graver in a single implement. One typical " snub-nosed " scraper (pl. 13, *k*) has a small sharp-tipped graver point at one end of the convex scraper edge. There is a second graver midway along one lateral edge. With these two points the implement could have functioned as an instrument for drawing parallel lines or for making circles. The point at the end of the tool could have been used for any purpose that the single, simple gravers served. The opposite lateral edge is a good concave side-scraper. With a tool of this type the artisan could perform a number of operations without changing implements. This specimen has a length of 38 mm, breadth of 28 mm, and a thickness of 6.5 mm. The graver points are 2 and 1 mm long and 2 and 1.5 mm broad at the base.

The two specimens *l* and *m,* plate 13, are combination gravers and sidescrapers. The scraper features are concave and convex. One of the artifacts has two graver points, in this case on opposite sides, whereas the other has only one. The latter, however, is one of the most precisely chipped points in the entire collection. These implements are 39 and 42 mm long, 22 and 22.5 mm wide, 3.5 and 4.5 mm thick. The single point on the one is 2.5 mm long and 1.5 mm broad at the base. The points on the other are 1.5 and 2 mm long and 1 mm wide at their bases.

KNIVES

There are a number of specimens which may be classed under the heading of knives. The best examples are carefully chipped blades which exhibit typical Folsom characteristics in their fluted faces and the marginal retouch along the edges. Their ends, however, are rounded, and the sides tend to be parallel rather than bulging or tapering as in the case of the points (pl. 7, *m, n*). The complete specimen is 51 mm long, 23 mm wide, and 4 mm thick. The broken one is 25 mm wide and 3 mm thick.

The channel flakes from typical Folsom points were not always discarded. Several examples show that they were used as knives. Close inspection of the edges reveals minute retouching, which perfected the cutting qualities of the stone and made a serviceable tool from one of the by-products of the process of point manufacture.

There is extreme variation in the length of these objects. This may be attributed to their thinness and liability to breakage. Specimens range from 23 to 46 mm in length, 13 to 17 mm in width, and 1.5 to 2 mm in thickness.

A crude, yet efficient implement was the flakeknife (pl. 14, *a-e*). Tools of this type were made from large, ribbonlike fragments of stone modified only to the extent of chipping along the edges. On some of these implements the chipping is large and irregular. On others it is as minute and precise as could be desired. Both concave and convex edges are present in the series, occuring either singly or in combination on the same implement. Study of such flakes suggests that they were first employed as struck off the nodule, the razor-keen edge of the stone being ideal for cutting purposes. Then as the edge became nicked and dulled through use, it was touched up with the flaking tool until, eventually, the whole edge was chipped. Because of their rough, unfinished nature, implements of this type have received scant notice in American archeology and, if mentioned at all, have frequently been dismissed with the explanation that they were rejects, scrap " flints " tossed aside because they were not good enough to work into finished tools. This certainly was not true of the present group, as the objects obviously are implements. They would readily function for cutting chunks of meat for the stew-pot or even for the skinning of an animal. The length of the specimens in this group varies from 49 mm to 88 mm, the breadth from 15 to 36 mm, and the thickness from 4.5 to 10 mm.

A second group of flakeknives consists of a border-line series of larger implements which could serve either as knives or scrapers and which could be included in one or the other category with equal justification (pl. 14, *f-n*). The main reason for listing them as knives is that most of them have a peculiar twist to the flake which makes them more adaptable for cutting purposes than for scraping. These implements, as mentioned also in the discussion of other types, no doubt served a variety of purposes, and a hard and fast classification of the form is out of the question. The group ranges in length from 53 to 111 mm, in breadth from 38 to 74 mm, and in thickness from 8 to 10 mm.

BLADES AND CHOPPERS

Included in the collection are leaf-shaped blades and several large points which appear to be ends broken from such blades (pl. 15, *a-h, k*). The blades are reminiscent of the so-called blanks which represent the intermediate stage between the original nodule and the

completed implements. Ordinarily, among the later Indians, the
specialization of the blanks was not undertaken at the quarry where
they were roughed out. Instead they were taken home and then per-
fected as time permitted. At the Lindenmeier site, however, the proc-
ess was probably carried through from start to finish on the spot
because the material was right at hand. The present specimens are
not true blanks despite their close resemblance to those forms. They
are actual implements. This is shown by the careful secondary chip-
ping along the edges. Such blades may be considered as combination
knives and scrapers. Whether the broken ends should simply be
regarded as such or whether they should be classed as scrapers is a
difficult question to answer. Primarily they are portions from larger
blades, but they also served as implements in their present state.
The smooth-fractured surfaces on the ends of several examples have
minute facets, the result of chipping along their edges. In some cases
this appears to be the result of use. On others the removal of the
tiny flakes was unquestionably intentional. Points of this type, al-
though only a portion of the original tool, would be serviceable as
knives or scrapers. The ends are from 32.5 to 50 mm long, 39 to
48 mm wide at the base, and 7.5 to 9 mm thick. The blades measure
52 to 88 mm in length, 28 to 41 mm in width, and 7.5 to 10 mm
in thickness.

The class of implements tentatively called choppers might well be
considered variations of tools generally known as hand axes and rough
celts (pl. 15, *l, n*). Because they do not answer in many respects to
the usual definitions of such tools and since they obviously were for
the same purpose, despite their difference in form, it is thought less
confusing to group them together under the designation of choppers.
Such tools would have been efficient in splitting and hacking bones.
That some such implement was employed is indicated by the bone
fragments. One of the examples pictured (pl. 15, *l*) was made from
a chalcedony nodule and is one of the few true " core " specimens
found at the site. It must have been made definitely for this purpose,
as the flakes removed in shaping it were not large enough to have
served in the manufacture of other tools. Although the main chipping
is large, there is a fine retouch on portions of the edges. The broad
end of the tool is well adapted for grasping, and the smooth, flat base
would protect the palm of the hand from injury. This implement is
86 mm long, 61 mm broad, and 15 mm thick. The second specimen
(pl. 15, *m*) is a pseudo-core; it is the core of a large flake, not that
of a complete nodule. In its general shape it strongly suggests the

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adze or celt of the later Indians. The workmanship is cruder, how-
ever and although it may be an example of the prototype of such
tools, it will be considered here as a chopper. Little effort was ex-
pended on this implement. The chipping is confined to the one chisel-
like end. The base is rough, some of the edges being sharp enough to
cut the palm of the hand holding it. It would need to be wrapped in a
piece of buckskin or a similar substance to prevent slipping and for
the comfort of the user. The stone is 74 mm long, 40 mm broad, and
21 mm thick. There are no marks on either of these specimens to
indicate that they might have been hafted in some kind of handle.

MISCELLANEOUS OBJECTS

The pieces of sandstone in the collection cannot be assigned to any
definite class of implements, yet all show signs of use. There is no
material of this nature in the immediate neighborhood, and the stones
must have been carried in for a particular purpose. Two of them,
although irregular in form, have a slight groove along one side. The
surface of the stone in the grooves is rubbed as though the objects
might have served as shaft polishers (pl. 16, a, b). They are not
typical of the implements generally called shaft polishers, however.
One stone is flat, roughly oval in outline, and has a shallow concavity
in one face (pl. 16, c). Traces of red pigment still adhering to the
stone suggests that it functioned as a pigment bowl. It does not seem
likely that this was a mortar for grinding paint, as it shows no effects
of a pestle. It was merely a palette. One irregularly shaped stone has
a smooth surface on one side, which indicates that it served as a
rubbing stone (pl. 16, c). Another was shaped, but there is nothing
to suggest what its purpose may have been (pl. 16, d). One example
is flat with one curved edge. The specimen obviously is not complete,
and it may be the remaining portion of a lid or cover for some con-
tainer. The curved outer edge has a series of facets where flakes were
knocked off in the shaping process (pl. 16, f). The material is soft
and could easily have been ground into the desired form but, in accord
with the prevailing technique of the horizon, the flaking process was
employed.

A number of pieces of hematite were recovered from the deposits.
The surfaces of all of them are smooth and striated from rubbing.
This is a good indication that they supplied pigment material, a factor
which correlates with the presence of the sandstone object suggestive
of a pigment bowl. Hematite in its various forms was extensively
used by the later Indians for making implements, ornaments, and

small objects whose purpose is unknown. It also served as a source for paint, the compact red, earthy varieties known as red chalk and the pulverulent red ocher being especially popular for this purpose. Powdered hematite was mixed with grease or saliva and then applied to the object to be painted. It was used for facial decoration, for coloring skins and hides, for painting spears, arrows, shields, skin tents, and other objects which the Indian desired to embellish. The finding of the material at the Lindenmeier site is good evidence that the makers of the Folsom points were also users of red paint. None of the fragments indicate that they were shaped to serve as ornaments, nor are they of the problematical object type.

Several nodules with battered ends were found, and there is one flat stone of granite, roughly circular in outline but with one flattened edge, which is broken away along one side as though from blows. These objects no doubt served as hammers. They could be employed in knocking flakes off large nodules, for cracking bones, and in other capacities where a striking implement would be required. The flat granite specimen has one convex, smooth side, which suggests that it also may have served as a rubbing stone (pl. 16, g).

There are a number of bones in the collection which, although they are only chance scraps, indicate that they could have served as tools. Each of these objects has a tapering, blunt-pointed end which shows some signs of wear. They may have functioned as punches or awls, but because they are not definitely prepared implements and do not exhibit pronounced signs of usage, they will be regarded only as fortuitous tools at this time. When more evidence is available, it may develop that split bones with such ends actually should be classed as a type of implement. For the present, definite conclusions will be held in abeyance.

IDENTIFICATION OF BONES

Owing to the scrappy nature of most of the bone material recovered, it has not been possible to identify all of the animals represented. Some of the fragments are from small mammals, but most of them are bison. Part of the latter material, portions of jaws and a good series of teeth, was referred to Director J. D. Figgins, of the Colorado Museum of Natural History, who has made a specialty of the study of bison remains. He reports that the bison found at the original Folsom site, *Stelabison occidentalis taylori* and *Bison oliverhayi*,[24] are

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[24] Figgins, 1933 b.

represented in the material from the Lindenmeier site. In this con-
nection he wrote:

> There was no trouble identifying the material not too badly damaged. We
> have the types of all the bison we have described, in addition to many jaws and
> separate teeth, so that it was merely a matter of comparison and measurement.
> You may be assured of the accuracy of the identifications, as your specimens
> check, in every respect, with our Folsom, New Mexico, types. I entertain no
> slightest doubt that your material is typical of the two Folsom races.[35]

The occurrence of the same species of bison at the two sites is of
particular interest and serves to tie them to the same general horizon.
The full significance of the material, however, is still to be determined.
The bison with which the Folsom artifacts are associated were larger
than the modern species and had more massive, less sharply curved
horns.

Other bones, identified by Dr. Remington Kellogg, assistant cura-
tor, division of mammals, United States National Museum, are from
the fox (*Vulpero velox*), the wolf (*Canis nubiltus*), and the rabbit
(*Lepus townsendii companius*). Unfortunately, none of these throws
any light on the question of the age of the site, as it is not possible to
differentiate between the Pleistocene and present-day forms. It is
interesting, though, to have this addition to the fauna of the Folsom
horizon.

SUMMARY

At the Lindenmeier site in northern Colorado is the first occupation
level yet found which can be definitely correlated with the makers of
the now well-known Folsom points. Distinct traces of a former camp-
site and workshop are present at this location. Midden deposits have
yielded a series of implements actually associated in situ with typical
Folsom points. Similar tools have been found at various surface
sites, but this is the first evidence to demonstrate that they belonged
to the Folsom complex. In addition to the assortment of artifacts,
there are flakes, spalls, and nodules, indicating that the implements
were made on the spot. Furthermore, this chipper's debris gives good
clues to some of the methods used in shaping the tools. The artifacts
in the collection show that the lithic component in the local culture
pattern was primarily a flake industry, only a few implements of the
core type being found. Cut, broken, and split animal bones from the
deposits have been identified as being from bison, fox, wolf, and
rabbit. The bison remains indicate that those animals belonged to the
same extinct species as those found at the original Folsom quarry.
This is a significant link between the two sites.

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[35] Letter from Mr. Figgins to the writer, Feb. 28, 1935.

A FOLSOM COMPLEX

Preliminary Report on Investigations at the Lindenmeier
Site in Northern Colorado

By FRANK H. H. ROBERTS, JR.

ERRATA

On page 32, paragraph 3, lines 3 and 4 should read as follows:

the fox (*Vulpes velox*), the wolf (*Canis nubilus*), and the rabbit (*Lepus townsendii campanius*). Unfortunately, none of these throws
. . . . .

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1. RAVINE IN WHICH MAIN DEPOSIT WAS FOUND

2. DEEP PIT AT THE BEGINNING OF INVESTIGATIONS
Man is standing on level where material was obtained.

1. SOIL LAYER IN WHICH SPECIMENS OCCUR

Bones are resting on top of Oligocene bed. A. L. Coffin at right of picture.

2. BONES AND "FLINT" IN SITU IN DEPOSIT

Arrow points to implement.
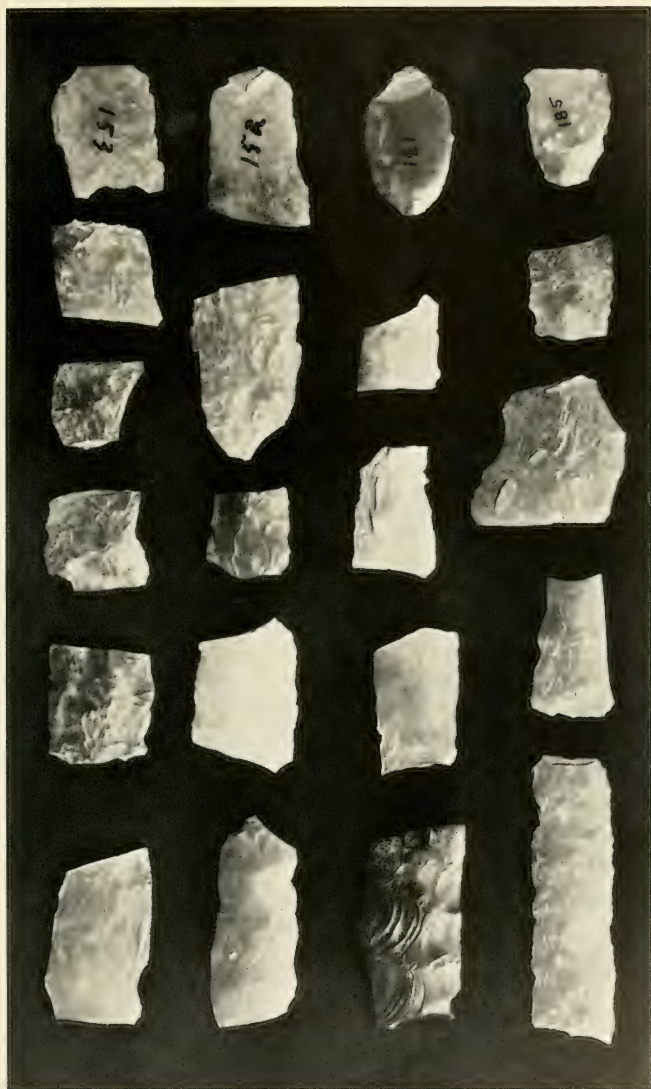
CHANNEL FLAKES FROM FOLSOM POINTS

Actual size.
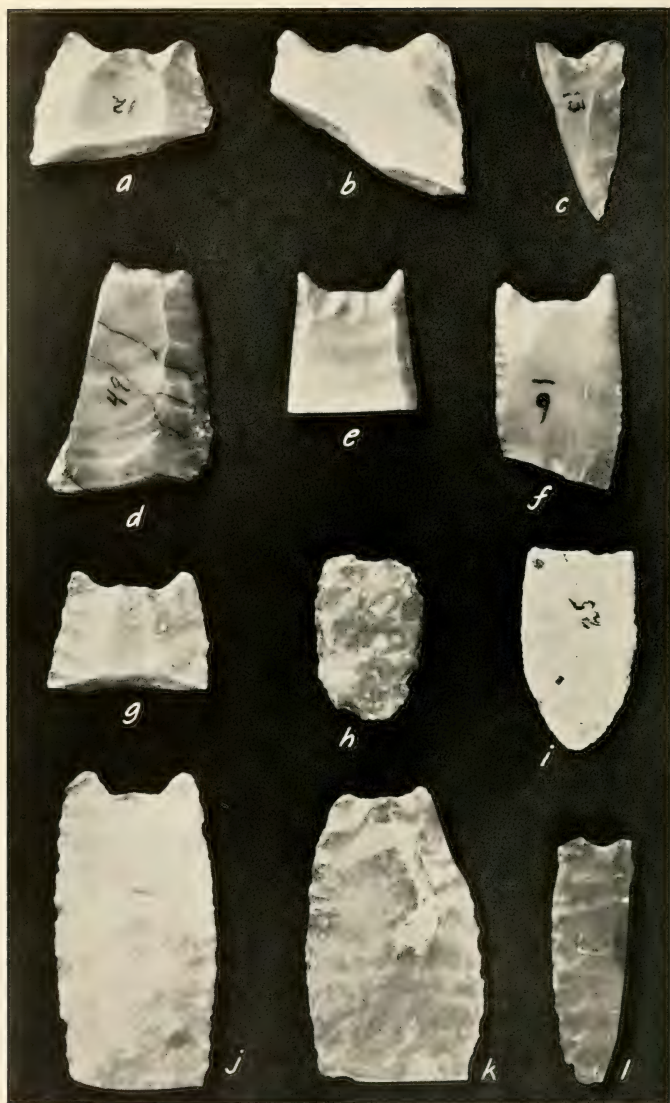
PORTIONS OF FOLSOM POINTS

Actual size.
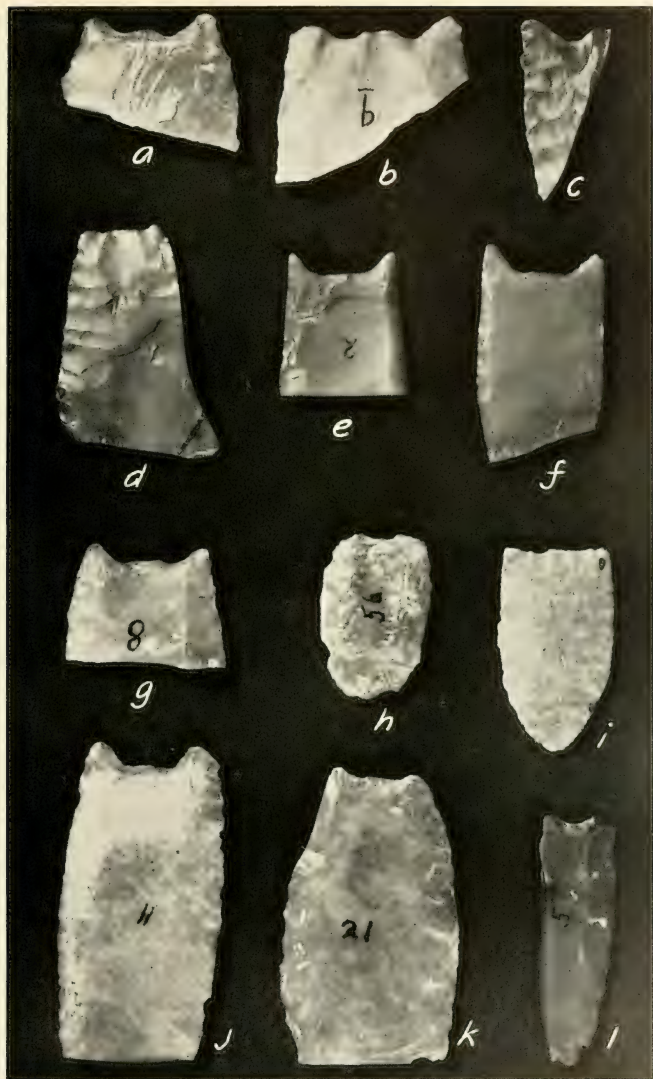
REVERSE OF POINTS SHOWN IN PLATE 5
Actual size.

FRAGMENTS FROM FOLSOM POINTS AND KNIVES

Actual size.

REVERSE OF POINTS AND KNIVES SHOWN IN PLATE 7

Actual size.

"SNUB-NOSED" SCRAPERS

Actual size.

END, SIDE, AND BACK VIEWS OF "SNUB-NOSED" SCRAPERS

Actual size.

SIDE SCRAPERS

Actual size.
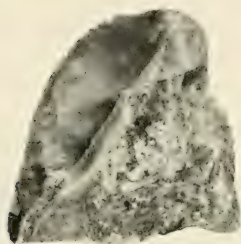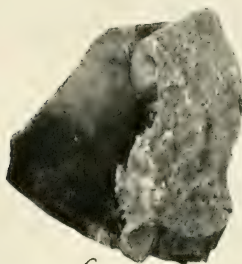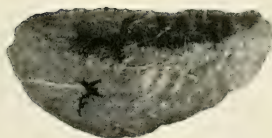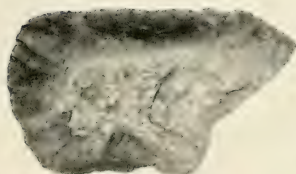
ROUGH-FLAKE SCRAPERS

Actual size.
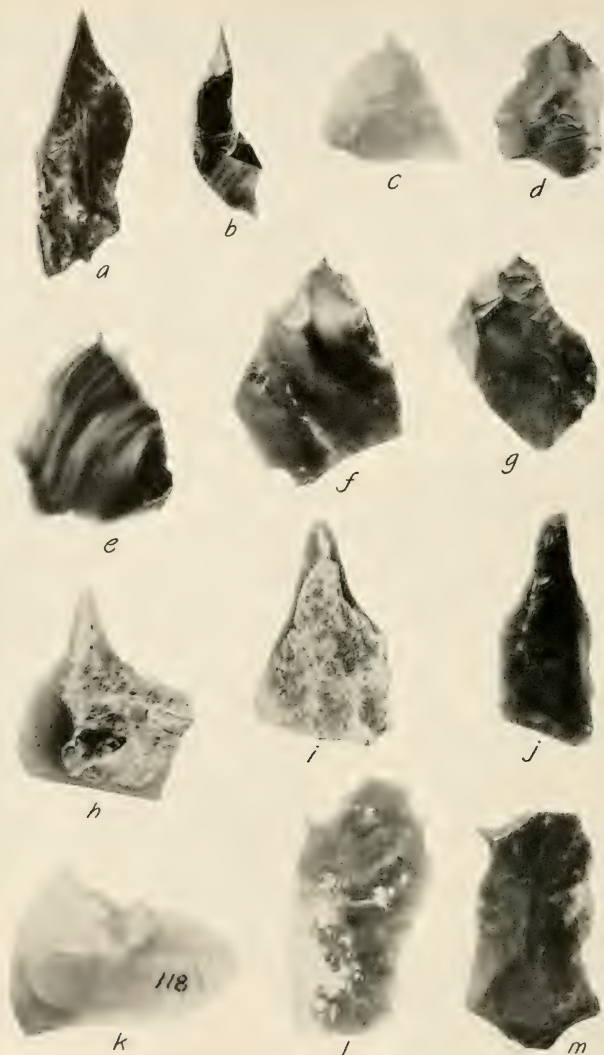
GRAVERS
Actual size.

ROUGH-FLAKE KNIVES

One-half size.

BLADES, POINTS, TURTLEBACKS, AND CHOPPERS
One-half size.
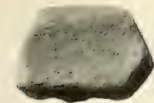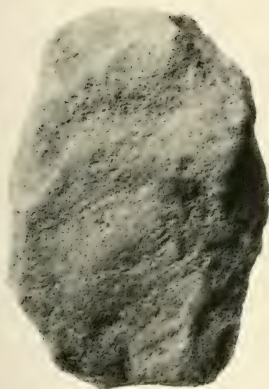
SANDSTONE OBJECTS AND GRANITE RUBBING STONE
One-half size.

WAVE LENGTHS OF RADIATION IN THE VISIBLE SPECTRUM INHIBITING THE GERMINATION OF LIGHT-SENSITIVE LETTUCE SEED

BY

LEWIS H. FLINT

Division of Seed Investigations, Bureau of Plant Industry,
U. S. Department of Agriculture

AND

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INTRODUCTION

In studies of the light-sensitivity of " dormant " lettuce seed previously reported (3)[1] it was noted that radiation of the longer wave lengths of visible light, characterizing the colors yellow, orange, and red, promoted germination, whereas radiation of the shorter wave lengths of visible light, characterizing the colors violet, blue, and green, inhibited germination. The material appeared to be unusually well adapted to the study of response to radiation, and steps were taken to establish the relative effectiveness of radiation of various wave lengths with respect to the germination of the seed.

While these studies were in progress, Johnston (6) at the Smithsonian Institution reported the results of a careful series of measurements of phototropic response of the etiolated oat coleoptile, which emphasized the fact that the shorter wave lengths of visible light were responsible for such bending. He interpreted this activity as due to an inhibitory effect of the shorter wave lengths upon the cells exposed to such radiation.

On account of the obvious analogy between the results obtained with the shorter wave lengths of light in respect to inhibition in germination and in phototropism the facilities of the two research divisions were combined in the furtherance of the germination study, the cooperative investigation leading to the results here presented.

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[1] Numbers in parentheses refer to list of literature cited, at the end of this paper.

REVIEW OF LITERATURE

With respect to light and germination three classes of seeds have been recognized for many years: (1) seeds germinating equally well in light or darkness, (2) seeds whose germination is hindered by light, and (3) seeds whose germination is favored by light. This classification has emphasized the variety of the responses that may occur and has proved satisfactorily descriptive for studies involving sunlight or other white light.

In 1883 Cieslar (2) reported with respect to certain seeds that yellow light favored germination, whereas violet light retarded it and rendered them appreciably dormant. This varying response to different wave lengths of light made it evident that in sunlight or other white light certain components were acting to promote germination, while certain other components were acting to retard it. Upon the relative effectiveness of these two groups of components, either through the radiant energies involved or through the particular sensitivity of the seed, one might presume to depend the gross effect of the white light with respect to germination. From the more technical standpoint, therefore, there were but two classes of seeds with respect to germination: (1) those whose germination was not influenced by light, and (2) those whose germination was influenced by light. Seeds of the latter class were designated " light-sensitive seeds," as contrasted with the widely occurring seeds of the class which germinate equally well in light and in darkness. The present considerations are confined to light-sensitive seeds.

Light-sensitivity as reported by Cieslar was limited for the most part to small seeds without reserve food materials. In the seeds of *Poa nemoralis, Agrostis stolonifera,* and *Nicotiana macrophylla* germination was reported as favored by white light, whereas the germination of seeds of *Viscum album* was reported as hindered by white light. In large measure the researches on light and germination by various workers in subsequent years have been concerned with the extension of these respective lists. In this respect it is to be noted that sensitivity to light is now generally recognized as a widely occurring characteristic of seeds.

The early distinction between the effect of " yellow " light and " violet " light gained precision through subsequent researches, and one finds in Molisch (9) the statement that yellow to red light promotes germination, whereas violet, blue, or green light inhibits germination. This information, however, has not been widely appreciated, and the more recent studies of light in relation to germination, such

as those of Gardner (4), Lehmann (7), Maier (8), Nathammer (10) and Shuck (11), have concerned themselves for the most part with white light as a quantitative factor in germination.

Wholly unaware of the foregoing background of researches by German workers in this field, the senior author discovered that so-called " dormant " lettuce seed would germinate readily in white light, and further, that yellow, orange, or red light promoted this germination, whereas violet, blue, or green light inhibited it. It now appears that the germination response to radiation of specific wave lengths noted for dormant lettuce seed represents types of reactions of wide occurrence among seeds. This fact suggests that the further study of such responses may be warranted as promising results of both practical and theoretical significance in relation to germination and possibly also in relation to other aspects of growth. The results obtained by Flint (3) with green Wratten filters indicated that color alone was not a safe criterion to use in the interpretation of results obtained with filters, thus directing attention to their wave-length transmission.

METHODS

The principal line of attack in this investigation involved the use of a spectrum, and to a large extent the work comprised successive improvements in the technique of utilizing the spectrum to the greatest
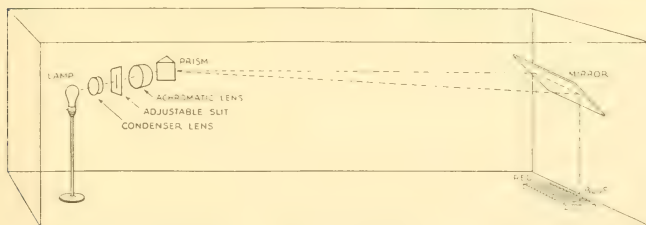
Fig. 1.—Schematic drawing of the apparatus used in the study of spectral light in relation to germination.

advantage in relation to germination. The set-up as finally elaborated (see fig. 1) consisted of a fixed light source, a condenser lens concentrating light upon an adjustable slit, an achromatic lens, a prism, and a silvered mirror. A light-proof house surrounded the set-up, with a partition at the slit (not shown in the figure). With this set-up, using a single filament 1,000 lumen 6.6 ampere Mazda street-lighting bulb as a light source, a spectrum was obtained which was about 1 foot long in the visible range.

For exposures of the material in the spectrum special boxes 10 x 4 x 1 inches were made of brass and provided with parallel center plates of monel metal about 4 x 1 inches, spaced at 0.4 inch. Two such boxes placed end to end thus more than filled the visible spectrum, and each of the 48 compartments was subjected to a band of radiation ranging in width from the order of 50 A in the low violet to that of 200 A in the high red. The spectrum and boxes were provided with a secondary light-proof housing, in which, at an elevation of about 1 foot, were installed two 20-inch milk-glass lumiline lights wrapped in red cellophane having no appreciable transmission for wave lengths shorter than 6000 A. These lights were so arranged that in conjunction with end-mirrors no shadows were cast in any compartment of the boxes. The intensity of illumination was regulated by a rheostat.

The focal plane of the spectrum obtained was located by inserting a plate of didymium glass between the condenser lens and the slit. The sharp absorption lines of didymium also provided a convenient means of establishing the wave lengths of all regions of the visible spectrum. Wave lengths in the near ultraviolet region were established by substituting a mercury arc as a light source and using uranium glass to pick up through fluorescence the lines characteristic of mercury. Wave lengths in the infrared region were established by following the absorption characteristics of water vapor with a thermopile. The radiation energies throughout the entire spectrum were established by means of a thermocouple.

The procedure in each experiment was as follows. Two boxes were placed in the spectrum and half filled with tap water, which served as the medium of germination. Dormant or light-sensitive lettuce seeds were then scattered into the compartments, surface tension bringing about a fairly uniform distribution of the seeds over the available water surface. About 100 seeds could be conveniently accommodated in each compartment.

After 2½ hours presoaking the seeds were given exposures of spectral light, of red lumiline light, or of both lights, depending upon the particular objective. The red lumiline light, by suitable modification of the duration or intensity of the exposure, was used for the most part to effect a 50 percent germination of the seeds independent of the spectral light—a feature ordinarily offering some difficulty, but entirely feasible with the material at hand, as had been attested by tables 2 and 3 of Flint's paper (3). Upon this base the nature and extent of any promoting or inhibiting influence of the spectral light was registered as a departure. After 24 hours the boxes were removed,

and the seeds in each compartment were transferred immediately to numbered petri dishes, placed in a refrigerator at 3° C., and exposed to blue light (to prevent further germination), where they were kept until germination counts could be made.

In plotting the germination percentages against radiation the wave length falling on the median line of each compartment was taken as the wave length for the seeds of that compartment.

In plotting the inhibitory influence in the violet-blue-green region as corrected for energies involved, the curves were inverted to facilitate subsequent comparison with other data.

The transmission curves of the Wratten filters and of the ether extracts of lettuce seeds were made in the conventional manner with a double monochromator and a thermocouple.

RESULTS

In the experiments of Flint (3) two green Wratten filters were found to transmit light that promoted germination, and 10 green Wratten filters were found to transmit light that inhibited germination. The spectral transmission of all the green Wratten filters was studied, and the energy transmission curves were obtained by multiplying the percentage transmission by the energy radiated from a Mazda lamp at each wave length. The energy radiated by the lamp at each wave length was obtained from its known spectral energy curve. These energy values were used in conjunction with the inverse square law and the distances at which the respective filters (when used with the Mazda lamp) gave equal response with a Weston photronic cell. The energies transmitted by representative green Wratten filters are shown in figure 2.

It is to be noted from the curves of figure 2 that the two green filters which had been found to transmit light promoting germination (64 and 67) transmitted more of the ultraviolet and less of the long visible red than the green filters which had been found to transmit light inhibiting germination (56 and 60). This fact suggested that the promotion was associated either with a promoting influence in the ultraviolet or with an inhibiting influence in the long red or near infrared.

A substantial series of exposures of moist dormant lettuce seed to various wave lengths in the ultraviolet ranging from the lower limits of the visible spectrum to below the ultraviolet characterizing solar radiation gave uniformly negative results, whereupon attention was directed to the infrared regions. Earlier studies with a spectrum

by the senior author had given an approximate range of 5200 to 7000 A for the promoting effect, with a sharp falling off in germination in the long red. No inhibitory effect had been suspected as associated with this falling off, however, until the effort was made to
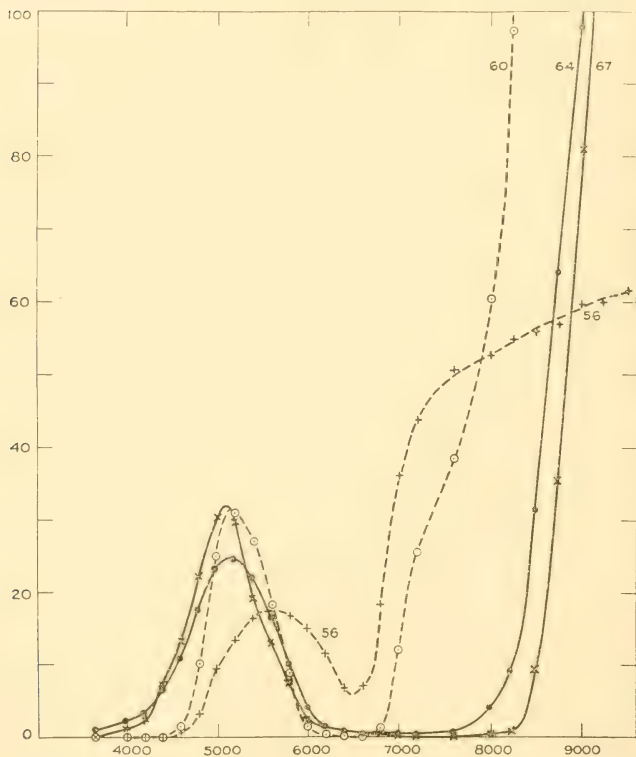
Fig. 2.—Energy transmission curves of green Wratten filters. The ordinates are relative energies transmitted at each wave length (indicated as abscissae). Numbers 56 and 60 are typical of the green filters transmitting light that inhibits germination. Numbers 64 and 67 transmit light that promotes germination.

explain the physical basis for the promoting effect of the light transmitted by the two aberrant green filters. The spectrum set-up previously used by the senior author had been considerably modified in these cooperative studies to permit a more precise measurement of the wave

lengths to which seeds were exposed. With the apparatus and procedure described in the foregoing section such results as those given in figure 3 were obtained in the long red region.

Such results as those presented in figure 3 established the presence of a strong inhibitory influence in the region of 7600 A.

By applying the same methods to the violet, blue, and green regions of the spectrum, such results as those presented in figure 4 were obtained.

In conjunction with the foregoing experiments a study of ether extracts of lettuce seed was carried out. These extracts contained oil and pigments. Definite absorption in the region 4200 A to 5200 A was evidenced by the transmission curves. These remained bimodal, even after appreciable oxidation had taken place, and thus appeared suggestive in relation to the bimodal curve of inhibition given in figure 4. Definite absorption in the region 5200 A to 7000 A was also evidenced by the transmission curves, suggesting the presence of some precursors of chlorophyll and allied pigments. No appreciable absorption in the region 7600 A was noted.

DISCUSSION

The discovery of a strong inhibitory influence in the region of 7600 A, although made in an effort to explain the difference in the response to the light transmitted by certain green Wratten filters, and quite incidental to the study of the precise nature of the curve of inhibition in the regions characterizing violet, blue, and green light, may well transcend in importance the original objective of the cooperative studies. Since this discovery appears to offer a clearer approach to biological problems involving light, it has been given precedence in these considerations.

All the green Wratten filters used by Flint (3) were found to transmit in the 7600 A region, but the two filters transmitting light which promoted germination had such a low transmission in this region that the effects of the promoting regions—the yellow, orange, and red—predominated over the effects of the inhibiting regions—the long red, the violet, the blue, and the green. Since many blue and violet glass, liquid, or gelatin filters transmit in the region 7600 A, it follows that the newly discovered inhibitory band becomes a potential source of confusion as to the effectiveness of radiation in the more visible spectrum with respect to the germination of light-sensitive lettuce seed. Moreover, since the same type of light-sensitivity has been recognized as characterizing other seeds, this factor may well be of some general significance with respect to light-sensitivity in seeds.
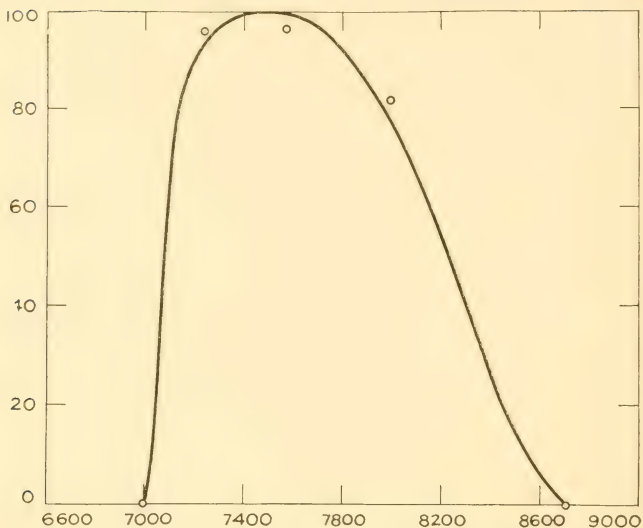
Fig. 3.—Curve of inhibition in the 7600 A region. The ordinates are percentage departures from expected germination values following exposure to promoting radiation, and are corrected for differences in the energy of the applied radiation indicated as abscissae.
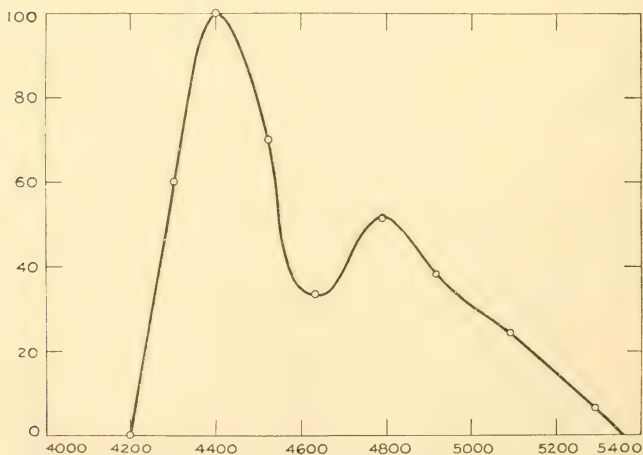
Fig. 4.—Curve of inhibition in the violet-blue-green region. The ordinates are percentage departures from expected germination values following exposure to promoting radiation, and are corrected for differences in the energy of the applied radiation indicated as abscissae. The maximum inhibition was arbitrarily taken as 100.

In connection with the later consideration of inhibitory influences associated with wave lengths characterizing violet, blue, and green light, it is to be noted that with both solar and Mazda radiation the energy at 7600 A is much greater than at the shorter wave lengths of the visible spectrum. In solar radiation there is a sharp absorption band in the 7600 A region interpreted as due to oxygen in the sun and water vapor in the earth's atmosphere. Notwithstanding this absorption, however, the energy of solar radiation at this wave length region is large. In consequence it would appear that under natural outdoor conditions and under customary indoor experimental conditions radiation of a wave length in the long red exerts a relatively powerful inhibitory influence upon the germination of dormant lettuce seed, although this influence is ordinarily more than counteracted by the promoting influence in the yellow-orange-red region. The extent to which the 7600 A region has an analogous effect upon other seeds and upon other phases of light-sensitivity is not known at this time, but because of the high energy and universal occurrence of the radiation, its potential significance becomes one of the most intriguing results of its discovery. Further studies of the possible effectiveness of this region in respect to the germination of other seeds and in respect to other phases of light-sensitivity are now in progress.

An examination of the germination responses to light of the wave lengths indicated in figure 4 reveals that there are two maxima of inhibition in the violet-blue-green region—a major one at 4400 A, and a somewhat subordinate one at 4800 A. It may now be noted that Bachmann and Bergann (1) and Johnston (6), studying the etiolated coleoptiles of *Avena sativa* Culberson, obtained curves of phototropic sensitivity having two maxima at about these same regions. The two types of data, the one indicating an inhibitory influence of light on the germination of seeds, the other an influence of light on the direction of growth of young etiolated shoots, have been brought together to facilitate comparison in figure 5.

An examination of figure 5 reveals that within the range of experimental error the two types of plant response to light show identical critical wave lengths. Johnston (6, p. 14) and others interpret phototropic response as an index of growth retardation on the theory that the light on the exposed side of the shoot inhibits elongation, while on the opposite unexposed side elongation is relatively uninfluenced. The results here reported obviously tend to sustain the correctness of this interpretation. Both of the foregoing types of plant response to light involved etiolated structures, and further studies are in progress relating to the types of plant response characterizing green tissues.

In résumé, the results obtained with the Wratten filters, taken in conjunction with the curve of violet-blue-green inhibition given by the spectral data and with the newly discovered inhibitory influence in the 7600 A region, make it more than ever obvious that the effects obtained through the use of any color filter may not safely be interpreted without an analysis of its spectral transmission.

The results presented in this paper indicate the general relative effectiveness of radiation of various wave lengths in the visible spectrum found to inhibit the germination of light-sensitive lettuce seed.
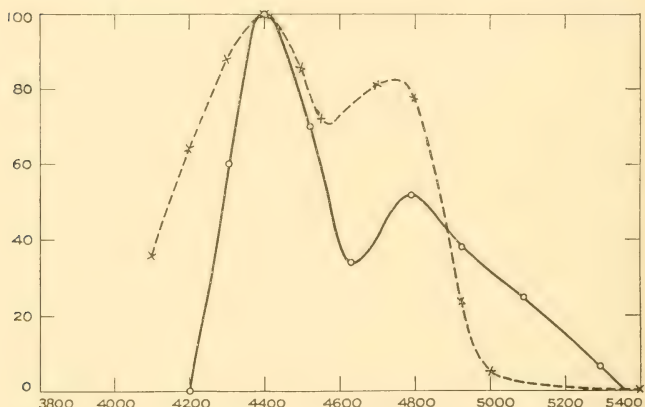
Fig. 5.—Curve of inhibition in the violet-blue-green region compared with the curve of phototropic response of oat coleoptiles obtained by Johnston. Heavy line represents the inhibition; dotted line the phototropic response.

Further studies designed to yield quantitative results as to the relative effectiveness of both promoting and inhibiting radiation are now in progress.

SUMMARY

Announcement is made of the discovery of a band in the region of 7600 A which inhibits the germination of light-sensitive lettuce seed far more effectively at the energies characterizing both solar and Mazda radiation (in this region) than do similar inhibitory influences previously noted in the regions 4200 A to 5200 A.

The relative effectiveness of radiation in the violet, blue, and green regions of the spectrum—at 4200 A to 5200 A—in inhibiting germination in light-sensitive lettuce seed is found to be the same as its relative

effectiveness in bringing about phototropic response in etiolated coleoptiles of oats. Both phenomena may be represented by bimodal curves showing critical wave lengths in the regions 4400 A and 4800 A.

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THE ABDOMINAL MECHANISMS
OF A GRASSHOPPER

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R. E. SNODGRASS

Bureau of Entomology and Plant Quarantine,
U. S. Department of Agriculture

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CONTENTS

INTRODUCTION

This paper on the abdomen of Acridoidea is intended to follow sequentially an earlier paper in the same series entitled " The Thoracic Mechanism of a Grasshopper " (Smithsonian Misc. Coll., vol. 82, no. 2, 1929). Hence it will be observed that the numerical designation of the abdominal muscles continues from that of the thorax.

The primary object of the work here presented has been to arrive at an understanding of the mechanisms of copulation and oviposition in the Acrididae, which in this family present many peculiar features. Neither of these processes, the writer believes, has been fully understood or correctly described, though careful observations have been made on the processes of copulation and egg-laying among grasshoppers. With the closer studies on the behavior of insects now found necessary for economic purposes, it is becoming obvious that we must understand more fully the structure and mechanics of the anatomical mechanisms on which depends so much of the insect's activities. In addition to the functional phase of morphology, however, there is the no less important taxonomic aspect. Hence, in the following pages much attention is given to structures bearing on the relationships between the Acrididae, Tetrigidae, and Tridactylidae, and a brief comparative study of the anatomy of the external male genitalia is included, since these structures will undoubtedly be found to contain many characters of importance for the separation of species where other features are not sufficient for exact determinations.

The writer follows Blatchley (1920), Walker (1922), Brues and Melander (1932), and others in regarding the grouse locusts as constituting a family (Tetrigidae, or Acrydidae) distinct from that of the typical grasshoppers (Acrididae). Aside from superficial differences in such characters as the length of the pronotum, and in certain features of the tarsi, the grouse locusts are distinguished from the grasshoppers by the lack of the characteristic tympanal organs of the latter, and in the totally different nature of the external male genitalia, which in the grasshoppers have a unique and highly standardized type of structure that distinguishes the Acrididae from all other Orthoptera. The tetrigids, of course, in many ways, particularly in the general structure of the abdomen and in the structure and mechanism of the female ovipositor, show their relationship with the Acrididae, but this relationship is much more distant than is that of the several acridid subfamilies with one another. Some orthopterists, furthermore, would link the Tridactylidae with the Tetrigidae and Acrididae, but to the writer a close association of the tridactylids with the acridoid families seems doubtful, notwithstanding the close similarity of the ovipositor in these two groups.

I. GENERAL STRUCTURE OF THE ABDOMEN

The morphology of the adult insect abdomen is difficult to understand because of the complete suppression of the segmental appendages in the pregenital region, and the probable union of the appendage bases

with the primitive sterna in the definitive sternal plates. The lateral
tergo-sternal muscles of the abdomen appear to have no counterparts
in the thorax, unless it is to be assumed that they represent the leg
muscles that have retained their ventral connections with the coxal
elements of the definitive sterna, but a study of larval insects seems to
indicate that the limb muscles have been lost with the suppression of
the appendages. The abdomen of the imago is so completely adapted
to its principal mechanical functions of respiration, copulation, and
oviposition that the generalized structure in this region of the body
is almost entirely obscured by secondary modifications. The acridid
abdomen is a good subject for anatomical study, but it throws no light
on the general morphology of the insect abdomen.

CHARACTERISTIC FEATURES OF THE ABDOMEN OF ACRIDOIDEA

The acridid abdomen consists of 11 distinct segments (fig. 1). The
enlarged first segment is firmly attached to the thorax by its dorsal
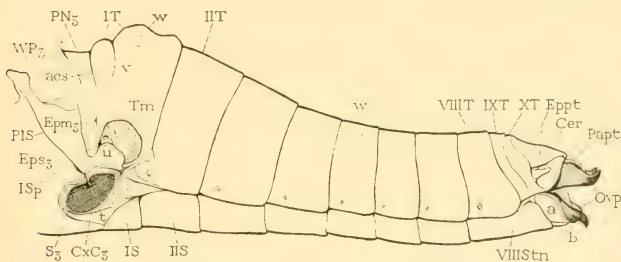
Fig. 1.—Abdomen and base of thorax of *Dissosteira carolina*, female.

and ventral plates (IT, IS), though these plates are widely separated
from each other laterally by the hind coxal cavities (CxC_3). On the
sides of the first tergum are situated the tympanal organs (Tm)
characteristic of the Acrididae, and the first spiracles (ISp) are located
in the anterior parts of the tympanal depressions. The following
seven segmental annuli ($II-VIII$) are simple secondary segments
separated by ample conjunctivae that allow a considerable extension of
the abdomen, as that of the female abdomen during oviposition. The
tergal and sternal plates are united by inflected lateral membranes that
permit the respiratory movements of vertical expansion and compres-
sion. The spiracles of these segments are located in the lower margins
of the terga.

In the female the sternum of the eighth segment (fig. 1, $VIIIStn$)
is the last of the series of ventral segmental plates. It is prolonged

beyond the tergum, and its posterior margin is reflected into the floor of the genital chamber beneath the base of the ovipositor. In the male (fig. 33 A) the abdomen terminates ventrally with the ninth sternum, which is much enlarged and subdivided into a proximal sternal plate (*IXS*) and a distal sternal lobe (*IXSL*). The terga of the ninth and tenth segments are narrow (figs. 1, 33 A) and are united with each other in both sexes. The tenth tergum of some species bears a pair of small median processes, known as the furculae, projecting backward from its posterior margin (figs. 38 A, B, 39, *f*). The ventral part of the ninth segment in the female is reduced to a narrow median space between the bases of the dorsal prongs of the ovipositor, and the venter of the tenth segment is a small membranous area above the base of the ovipositor. In the male the venter of the tenth segment is contained in the membranous dorsal wall of the genital chamber (fig. 24 A, *X.V*). The eleventh segment is the conical end piece of the body formed of a triangular dorsal plate, the epiproct (fig. 1, *Eppt*), and of two lateroventral plates, the paraprocts (*Papt*). Between the apices of these plates is the anus. The appendicular cerci (*Cer*) arise laterally on the base of the eleventh segment from membranous areas between the adjoining angles of the epiproct and paraprocts. The exposed part of the female ovipositor consists of four short, strongly sclerotized prongs (*Ovp*) projecting backward from the ventral parts of the eighth and ninth segments. The complex copulatory apparatus of the male (fig. 33 B) is ordinarily concealed within a genital chamber between the terminal lobes of the eleventh segment and the upturned lobe of the ninth sternum (fig. 24 A).

The abdomen of Tetrigidae is in general similar to that of the Acrididae, though it differs from the latter in several respects. The tergum of the first segment (fig. 2 C, *IT*) is solidly joined to the thorax, but the sternum (D, *IS*) has a flexible connection. Tympanal organs are absent. The first spiracles (C) are contained in the first tergum, but the other spiracles lie in membranous lateral areas of the dorsum beneath the lower edges of the terga, though the last two on each side (fig. 18 A) are contained in weakly developed laterotergal sclerites. Between the spiracles and the sterna of segments *II* to *VII* there is on each side a series of small laterosternal, or " pleural," sclerites (fig. 2 C, *lst*) best developed anteriorly, where there are two sclerites in segments *II* to *IV*. The terminal segments of the tetrigid abdomen, in both the female (fig. 18 A) and the male (fig. 27 A), are essentially the same as those of Acrididae, and the female ovipositor (fig. 18) has little to distinguish it from the acridid ovipositor. The phallic

organs of the male, however, are very simple in structure and in no way resemble those of Acrididae (fig. 27 D).

The abdomen of Tridactylidae has certain features that are suggestive of the tetrigid abdomen, but in many respects it is quite differ-
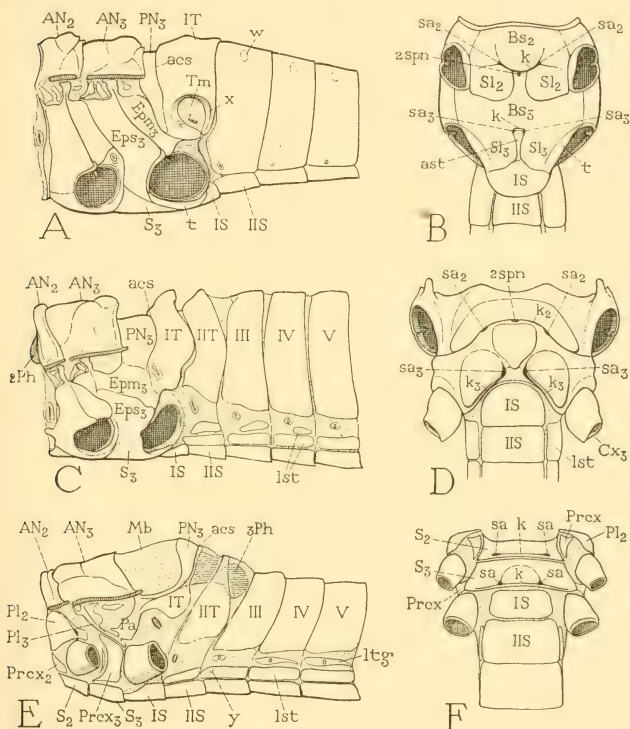
Fig. 2.—Relation of the abdomen to the thorax in Acrididae, Tetrigidae, and Tridactylidae.

A, B, *Melanoplus mexicanus.* C, D, *Tettigidea lateralis.* E, F, *Rhipipteryx biolleyi.*

ent from the abdomen of either the Tetrigidae or the Acrididae. The base of the tridactylid abdomen (fig. 2 E, F) presents characters that are peculiar to the family, and will be described later. The first seven pairs of spiracles lie in the lateral membranous areas of the dorsum beneath the edges of the terga, where some of them may be contained

in narrow laterotergal sclerites (E, *ltg*). The spiracles of the eighth segment lie in the lower parts of the tergum of this segment (fig. 19 A). The median sternal plates of segments *II* to *VI* or *VII* are flanked by narrow laterosternites (fig. 2 E, *lst*) and the sterna overlap the edges of the terga, the laterosternites being inflected. In *Tridactylus* and *Rhipipteryx* a small internal vesicle opens by an external pore (E, *y*) on the laterosternite of the third segment. According to Carpentier (personal communication) a similar anterior vesicle opens on the laterosternite of the second segment in *Rhipipteryx carbonaria*. The terminal segments of the tridactylid abdomen have many peculiar features, as will be shown in the description of the genital organs; but
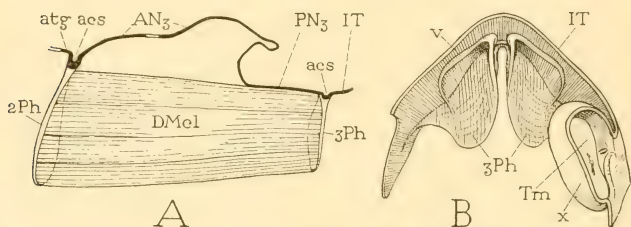
Fig. 3.—Relation of the phragmata to the segmental plates of the dorsum. *Dissosteira carolina.*

A, vertical section of dorsum of metathorax just to right of median plane, showing the antecostal sutures (*acs*) and phragmata (*2Ph, 3Ph*) marking the true intersegmental lines; the dorsum is occupied by a wing-bearing plate, the alinotum (*AN₃*), and a postalar postnotum (*PN₃*) equivalent to the acrotergite (*atg*) of the alinotum. B, posterior view of the first abdominal tergum, the lobes of the third phragma, and the right tympanal capsule.

the well-developed ovipositor of *Rhipipteryx* (fig. 19 A, *Ovp*) is surprisingly similar to the ovipositor of Tetrigidae and Acrididae. The male organs, on the other hand, have no resemblance whatever to those of Acrididae or to those of Tetrigidae.

The abdominal terga of the Acrididae, except the tergum of the first segment, are simple plates with no sutural divisions (fig. 1). The dorsal muscles arise on each tergum some distance behind the anterior margin (fig. 10 A), and the line of attachment here is marked, particularly in the male, by a short secondary tergal ridge (*tr*) on each side. True antecostae appear to be absent, since the muscles are inserted posteriorly on the weak anterior margins of the tergal plates. In the Tetrigidae, on the other hand, each tergum has a distinct marginal antecosta. Tergal apodemes are absent, except in the ninth segment, where, as in *Dissosteira* (fig. 14), there may be a pair of apodemal

lobes (*Ap*) projecting forward from the anterior margin of the tergum for muscle attachments.

The abdominal sterna of the Acrididae resemble the terga in that each is an undivided plate, but the sterna, as with pterygote insects generally, are presumably coxosternal plates in composition, though there are no styli on any of the abdominal segments. The first abdominal sternum (fig. 4, *IS*) is closely united with the metasternum of the thorax by an anterior extension (*ast*), which appears to be the acrosternite; otherwise it is a simple plate. The following sterna have each a pair of large apodemes on their anterior angles. The apodemes of the second and eighth sterna in the female (fig. 4), or of the second and ninth in the male (fig. 12), are simple anterior arms; but the intervening apodemes have lateral expansions that form distinct lateral apodemes in the more anterior segments of the female (fig. 4, *lAp*) and in all the segments of the male between the second segment and the ninth (fig. 12). The lateral apodemes give attachment to the dilator muscles of the abdomen (fig. 10 B, *lc*), which have their dorsal attachments ventrally on the lower edges of the terga. The intersegmental ventral muscles of the abdomen have their anterior attachments on the sterna some distance back of the anterior margins of the latter (figs. 8, 10 A), but they are attached posteriorly on the anterior margins of the sterna following. In the male the lines of origin of these muscles are strengthened in each segment by a well-developed transverse sternal ridge (fig. 12, *sr*); in the female the ridges are present only on the sterna of the more anterior segments (fig. 4). The musculature of the abdomen, and cuticular developments related to the muscles are in general weaker in the female than in the male.

In the Tetrigidae the median sternal plates of the abdomen appear to correspond with the sternal plates of Acrididae since they bear the sternal apodemes on their anterior angles. The small laterosternites (fig. 2 C, D, *lst*), therefore, are probably secondary developments in the membranes laterad of the sterna, and in a loose sense may be termed "pleurites," though there is nothing to suggest that they represent remnants of limb bases. According to Ford (1923) there are no muscles attached on the laterosternites of Tetrigidae, but there are groups of small lateral muscles attached dorsally in the membrane before and behind the spiracles and ventrally on the sterna. These muscles are evidently dorsosternal muscles, since the region of the spiracles is to be regarded as a part of the dorsum. The principal lateral muscles in Tetrigidae, as in Acrididae, are tergosternal muscles.

RELATION OF THE ABDOMEN TO THE THORAX

In both the Acrididae and the Tetrigidae the tergum of the first abdominal segment is firmly attached to the tergal and pleural sclerotization of the metathorax, and in Acrididae the first abdominal sternum is solidly joined to the metasternum. The movements of the abdomen as a whole take place between the first and second segments of the latter, and are produced by the longitudinal muscles of the first abdominal segment attached posteriorly on the second. In the female of *Dissosteira* there is one pair of very small oblique lateral muscles between the metathorax and the first abdominal segment (fig. 9, *140*).

The union of the first abdominal tergum with the metathorax in Acrididae and Tetrigidae is formed by the greatly expanded acrotergite of the first abdominal tergum, which becomes a large postnotum in the dorsum of the metathorax (fig. 2 A, C, PN_3). The postnotum is separated from the main part of the first abdominal tergum (*IT*) by a prominent transverse antecostal suture (*acs*), which extends across the back and downward on the sides. From this suture there depend internally the two lobes of the third phragma (fig. 3 A, B, *3Ph*). In *Dissosteira* the inner margin of each phragmatal lobe is braced posteriorly on a secondary ridge (B, *v*), which is marked externally by a short tergal suture on each side (fig. 1, *v*) behind the antecostal suture. The lobes of the third phragma give attachment to the posterior ends of the dorsal muscles of the metathorax (fig. 3 A), and thus attest that the antecostal suture (*acs*) through their bases is the true (primary) intersegmental line of the dorsum between the metathorax and the first abdominal segment.

Anteriorly the postnotum is continuous (fig. 3 A, PN_3) with the inflected scutellar margin of the alinotum of the metathorax (AN_3); its lateral extensions are united with the posterior (or dorsal) margins of the metathoracic epimera (figs. 1, 2 A, C, Epm_3). By these connections of the postnotum with the dorsal and pleural sclerotic parts of the metathorax, the lobes of the third phragma are securely braced against the pull of the dorsal muscles attached on them (fig. 3 A). The force of the muscles, therefore, is expended on the alinotum of the metathorax (AN_3), which responds by an upward curvature that depresses the wings on the pleural fulcra. In the usual intersegmental mechanism of secondary segmentation, in which the acrotergite is a mere flange on the anterior margin of the tergum following, and is separated by a conjunctival membrane from the preceding tergum, the contraction of the longitudinal muscles produces an approximation or overlapping of the consecutive segmental plates. The enlargement

of the acrotergite of the first abdominal tergum, accompanied by an obliteration of the conjunctiva behind the wing-bearing plate of the metathorax, is clearly, therefore, a device to suppress intertergal movement at this intersegmental junction.

Fig. 4.—Dorsal view of the inner surface of the skeletal plates of the metathorax and abdomen of *Dissosteira carolina*, female; ovipositor removed exposing the floor of the genital chamber, the gonopore (*Gpr*), and egg guide (*eg*).

The ventral union of the abdomen with the thorax in Acrididae is even more complete than is the dorsal union. The sternum of the first abdominal segment (fig. 2 B, *IS*) forms virtually a part of the pterothoracic plastron. Its acrosternite is either a broad lobe (fig. 4, *ast*), or a narrow tongue (fig. 2 B, *ast*), but in either case it is solidly fused

with the metasternum in the notch between the sternellar lobes (Sl_3).
There are no ventral muscles that extend from the thorax into the
abdomen in Acrididae, and the first ventral muscles of the abdomen
take their origin on a transverse ridge of the first abdominal sternum
at the base of the acrosternite (fig. 8, 143). This ridge, therefore, is
evidently the antecosta of the first sternum, and corresponds with the
phragma of the first tergum, that is, it marks the true intersegmental
line of the venter between the thorax and the abdomen. In the Tetrigi-
dae the sternum of the first abdominal segment (fig. 2 D, IS) has a
rounded anterior edge inserted into a wide emargination of the meta-
sternum, but it is attached to the latter by a narrow, flexible mem-
branous suture, and is, therefore, does not give the abdomen a firm
ventral connection with the thorax as in Acrididae. There is no evi-
dence, therefore, that the small median area between the bases of the
metasternal apophyses (sa_3) in the Tetrigidae represents the acroster-
nite of the first abdominal sternum; it appears rather to be the ster-
nellum of the metathorax, which is suppressed medially in the
Acrididae.

When we turn to the Tridactylidae by way of comparison it is to
be seen that there is little similarity, either in the thoracic sclerotiza-
tion or in the basal structure of the abdomen, between this family and
the Acrididae or Tetrigidae. The pleural sclerites of the pterothorax
in the tridactylids are reduced and widely separated by membranous
areas (fig. 2 E). The sterna are simple segmental plates (F, S_2, S_3)
entirely separated from each other. In the mesosternum the bases of
the apophyses (sa) are far apart at opposite ends of a transverse
sternacostal suture (k). The metathoracic apophyses are somewhat
more approximated, and from each a suture extends forward in the
basisternal region. These sutures in *Rhipipteryx* (fig. 2 F) are con-
tinuous anteriorly in a transverse arc, but in *Tridactylus* they remain
separate, as shown by Ander (1934). The sternellum of each ptero-
thoracic sternum is a narrow margined area behind the sternacostal
suture (k), and is not produced into lateral lobes as in Acrididae. The
first abdominal sternum (IS) is entirely distinct from the metasternum.

In the relations of the base of the abdomen to the thorax the tri-
dactylids present some very unusual features. The tergum of the
first abdominal segment is much reduced and does not contain the first
spiracles (fig. 2 E, IT); the posterior dorsal and lateral parts of the
segment are membranous. The acrotergite (PN_3) is a strongly de-
veloped though narrow sclerite on the anterior margin of the first
abdominal tergum, but it is widely separated dorsally from the wing-
bearing plate of the metathorax (AN_3) by a large membranous area

(Mb). Laterally, however, it is connected on each side with the posterior angle of the metanotum (AN_3), and by a strong postalar arm (Pa) with the lower end of the narrow metapleuron (Pl_3). The third phragma ($3Ph$) consists of a pair of long lobes projecting posteriorly from the antecostal suture of the first abdominal tergum through the first and second abdominal segments. The extraordinarily long dorsal muscles of the metathorax extending back to the third phragmatal lobes are plainly visible through the membrane separating the postnotum from the metathoracic alinotum.

THE ABDOMINAL SPIRACLES

The spiracles of insects, the writer assumes, belong to the dorsum. In a generalized arthropod the limb bases lie between the dorsum and the venter, and there is no evidence that the insect spiracles are developed on the bases of the limbs. The spiracles may be included in the tergal sclerotization of the dorsum, or they may lie free in a laterodorsal membrane, or again, they may be situated in small laterodorsal sclerites. The abdominal spiracles of Acrididae are all contained in the lower parts of the tergal plates (figs. 1, 2 A) ; in the Tetrigidae all but the first lie in the laterodorsal membranes below the terga (fig. 2 C) ; in the Tridactylidae the first two spiracles on each side are in the laterodorsal membranes of their segments (E), the others are contained in small laterotergites (ltg), except the last, which lies in the lateral part of the eighth tergum (fig. 19 A).

The abdominal spiracles of Acrididae are of the type of structure in which the closing apparatus is at the inner end of the atrium where the latter is joined by the spiracular trachea. They thus differ, as abdominal spiracles usually do, from the thoracic spiracles, which are closed by an approximation of the outer lips of the atrium.

The large first abdominal spiracles of *Dissosteira*, as already observed, lie in the anterior walls of the tympanal capsules (figs. 1, 6 A, 9 A, ISp). Each of these spiracles presents externally an oval aperture, the long axis of which is somewhat oblique. The walls of the atrium are direct inflections of the body wall. The dorsal atrial wall is immovable and is firmly supported by a dense sclerotization of the body wall above it ; the ventral atrial wall, on the other hand, is a freely movable plate, and a small area of the body wall below it is membranous. Viewed internally (fig. 5 A), it is seen that the movable ventral wall of the atrium (c) is produced posteriorly in a handle-like process, or manubrium (g), on which the spiracular muscles are inserted. The short occlusor muscle (148) takes its origin on the

margin of the tympanal capsule just above the spiracle; the long slender dilator muscle (*147*), together with the tensor of the tympanum (*146*), arises ventrally on an inflection of the membranous body wall (fig. 9 A) posterior and mesad of the hind coxa behind the small triangular lateral sclerite of the metasternum (fig. 1, *t*). The occlusor muscle closes the inner aperture of the atrium into the spiracular trachea by bringing the inner margin of the movable plate of the ventral atrial wall against the inner margin of the immovable dorsal wall. The antagonistic dilator muscle counteracts against the occlusor and opens the tracheal aperture.

The other abdominal spiracles have essentially the same structure as the first spiracle, though they are successively smaller to the eighth,
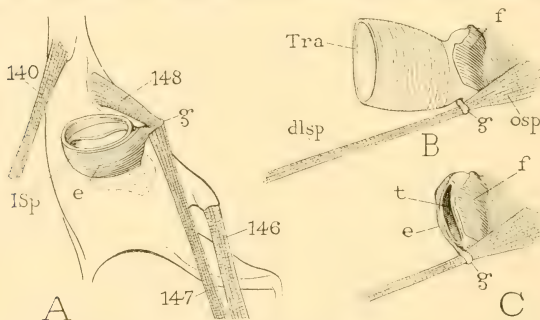
FIG. 5.—Structure of the abdominal spiracles. *Dissosteira carolina.*

A, right spiracle of first segment in rim of tympanum, inner view, showing occlusor (*148*) and dilator (*147*) muscles. B, right spiracle of eighth segment with end of trachea, inner view, showing occlusa (*osp*) and dilator (*dlsp*) muscles. C, same, trachea removed, showing tracheal entrance (*t*) from atrium and movable anterior valve (*e*) with manubrium (*g*) on which muscles are attached.

which again is of larger size (fig. 1); also the obliquity of the aperture is more pronounced in these spiracles (fig. 5 B, C), so that the movable wall of the atrium (*c*) becomes anterior, with the manubrium (*g*) directed downward, and the immovable wall (*f*) posterior. The short, fan-shaped occlusor muscle of each spiracle (*osp*) arises on the tergal wall behind the spiracle, and the long dilator muscle (*dlsp*) takes its origin ventrally on the anterior part of the lateral margin of the cor-responding segmental sternum.

THE TYMPANAL ORGANS

On the lower part of each lateral area of the first abdominal tergum just behind the spiracle is located the large tympanal organ of Acrididae (fig. 1, *Tm*). In *Melanoplus* the tympanum is contained in a

simple oval depression of the tergum (fig. 2 A), the margin of which
is interrupted ventrally, and the tympanum is thus continuous through
a narrow cleft in its frame with the membranous body wall below the
tergum. The same is true but less evident in *Dissosteira* (fig. 1). The
development of the organ in the nymph shows clearly that the tym-
panum is derived from a part of the laterodorsal membrane of the first
abdominal segment enclosed in a notch in the lower margin of the
tergum. In *Dissosteira* the tympanal depression is much deeper than
in *Melanoplus* and forms a large capsule-like cavity expanded within
the outer opening (fig. 6 A, *x*). The rear wall of the capsule is deeper
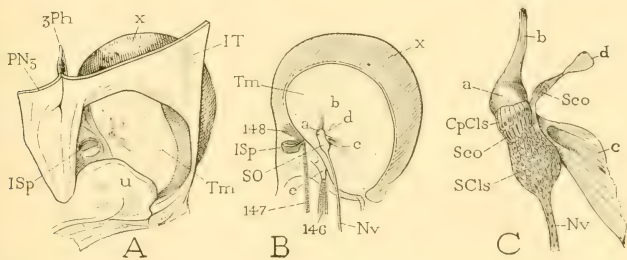
Fig. 6.—Tympanal organ of the first abdominal segment. *Dissosteira carolina.*

A, external view of left tympanal capsule and surrounding parts of body wall.
B, inner view of right tympanum and associated structures. C, tympanal sense
organ and its supports, inner view.

a, sclerotic tubercle of tympanum with arms (*b, c*) supporting the sense
organ; *CpCls,* cap cells of sense organ; *d,* pyriform sclerite of tympanum; *e,*
muscle process of tympanal capsule; *ISp,* first abdominal spiracle; *IT,* tergum
of first abdominal segment; *Nv,* nerve of sense organ; *3Ph,* part of third
phragma; *PN₃,* lateral part of postnotum of metathorax; *SCls,* sense cells;
Sco, sense rods, scolopes; *SO,* scolopophorous sense organ; *Tm,* tympanum;
u, subtympanal lobe of metathorax; *x,* tympanal capsule; *146,* tensor muscle of
tympanum; *147,* dilator muscle of spiracle; *148,* occlusor muscle of spiracle.

than the front wall, and the plane of the tympanum is, therefore,
oblique, its outer surface being directed outward and posteriorly. The
first abdominal spiracle (*ISp*) is situated in the anterior wall of the
tympanal capsule, and a lobe (*u*) at the lower end of the metathoracic
epimeron (fig. 1) forms the lower lip of the outer opening of the cap-
sule. In the Acridinae the tympanal capsule is much narrower than
in Oedipodinae and Cyrtacanthacrinae.

The tympanum is a thin membrane stretched tightly between the
inner margins of the tympanal depression or capsule (fig. 6 B). A
small apodemal process (*e*) projects ventrally from the lower margin
of the latter and gives insertion to a muscle (*146*) arising ventrally
from a point in the membrane behind the base of the metacoxa laterad

of the first abdominal sternum (fig. 9 A). The dilator muscle of the
spiracle (*147*) takes its origin at the same point. The muscle of the
tympanal frame appears to be a tensor of the tympanum. In the an-
terior part of the tympanum are two small cuticular thickenings that
support the sense organ on the inner surface (fig. 6 B, *SO*). The prin-
cipal support is a wide-angled V-shaped sclerite with a narrow dorsal
arm (B, C, *b*) and a broader ventral arm (*c*) diverging from an apical
knob (*a*). The last is a pitlike invagination of the external surface
of the tympanum, and the major part of the sense organ (B, C) is
attached directly to its ventral surface. The other support is a much
smaller pyriform sclerite (*d*) lying posterior to the angle of the V-
shaped sclerite, to which is attached a small fusiform branch of the
main sense organ (C).

The tympanal sense organ (fig. 6 B, *SO*) is a small oval body com-
posed mostly of a mass of sense cells (C, *SCls*), but in its upper part
is a stratum of elongate parallel cells containing sense rods, or scolopes
(*Sco*), beyond which is a layer of large cap cells (*CpCls*) by which
the organ is attached to the knob (*a*) at the angle of the V-shaped sup-
porting sclerite. A slender posterior branch of the main organ contains
a second smaller set of scolopes, and is attached by a fascicle of slender
cap cells to the pyriform sclerite (*d*). From the ventral end of the
organ the sensory nerve (*Nv*) proceeds to the large composite ganglion
of the ventral nerve cord lying in the metathorax.

Between the tympana of the opposite sides of the body are two large
air sacs given off from the lateral tracheal trunks in the base of the
abdomen. The sacs completely occupy the cavity of the first abdominal
segment above the alimentary canal, and their outer walls are pressed
close against the tympana. The two sacs form such a large air-filled
space in the base of the abdomen of *Dissosteira* that it is possible to
look clear through the body of the insect, *i. e.,* into one " ear " and
out of the other.

The tympanal organ of the Acrididae is usually regarded as a sound
receptor, though little or no evidence of hearing on the part of the
grasshoppers has yet been produced. Few species are capable of mak-
ing sounds, and an auditory " sense " would not seem to be one of great
importance to a grasshopper, but the elaborate mechanical and sensory
structure of the tympanal organs suggest that the latter must subserve
some function of importance in the life of the insect. Perhaps we are
too prone to conceive of insect " senses " as sensory perception of
stimuli. An insect merely reacts through its motor mechanism to
certain stimuli. The reaction to stimuli from a tympanal receptor
organ, therefore, may be something quite different from a general
sensitivity to sound in the audible sense.

THE CERCI

The cerci of Acrididae vary in form and size from simple peglike organs (fig. 33 A, *Cer*) to broader lobes of irregular shape (fig. 35 A), sometimes provided with accessory processes (fig. 36). The cerci of *Dissosteira* are of the simple type; they are longer in the male (fig. 7 B) than in the female (A), but they have the same structure in both sexes. The appendages arise from membranous areas behind the posterior margin of the tenth abdominal tergum between the bases of the epiproct and the paraprocts (B, *Cer*). The base of each cercus has a large irregular lobe (*b*) extending mesally beneath the
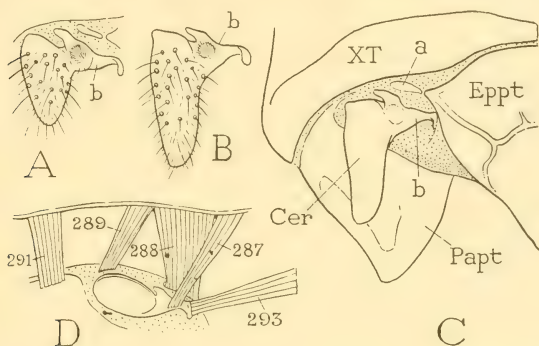
Fig. 7.—The cercus and its associated musculature. *Dissosteira carolina.*

A, left cercus of female, dorsal view. B, same of male. C, left half of terminal part of male abdomen, dorsal view. D, inner view of base of right cercus and its muscles.

edge of the epiproct, but it is not articulated to the surrounding sclerites. The shaft of the organ is clothed with long and short setae, the short setae being more numerous on the apical part. Many of the larger hairs, especially on the proximal half of the cercus, arise from large, conspicuous, rosette-like alveoli with dark scalloped margins. Each cercus is penetrated by a large nerve, and its setae apparently are tactile organs.

Four muscles are intimately associated with each cercus, and are clearly concerned with its movements, though only two of them are inserted directly on the base of the cercus (fig. 7 D). The cerci of the male are erected during copulation and grasp the base of the subgenital plate of the female. The elevation of each appendage is produced by the two muscles, a broad median muscle (*288*) and a smaller

2

lateral muscle (*289*), both arising on the anterior margin of the tenth tergum. The median muscle is inserted on a small sclerite in the membrane behind the tenth tergum before the mesal lobe of the base of the cercus (C, *a*) ; the lateral muscle is inserted in the same membrane very close to the outer angle of the base of the cercus. A third muscle (D, *287*) arises anteriorly on the tenth tergum just mesad of *288,* and is inserted on the posterior margin of the basal lobe of the cercus. This muscle is evidently a depressor of the cercus. The fourth cercal muscle (D, *293*) is an adductor. It arises mesally on the anterior part of the epiproct (fig. 14) and is inserted on the extremity of the basal lobe of the cercus. Because of the oblique plane of the cercal base this muscle produces an adduction of the appendage. It is interesting to note that the cerci, which appear to be appendages of the eleventh segment, have only one pair of muscles (*293*) taking their origins in this segment, and that they have no muscular connections with the paraprocts.

II. THE ABDOMINAL MUSCULATURE

The body muscles are well developed in the abdomen of the grasshopper, particularly in the male, and individual muscles are easily identified. The several groups of muscles in the pregenital segments conform with the classification of the abdominal muscles into *dorsal muscles, ventral muscles, lateral muscles, transverse muscles,* and *spiracular muscles* as given by the writer in an earlier paper (Abdomen, Part I, Smithsonian Misc. Coll., vol. 85, no. 6, 1931). The plan of musculature in the pregenital segments, however, is lost in the genital and postgenital segments, and the muscles of these segments must be studied separately. The series of numerals designating the abdominal muscles follows that of the thorax of *Dissosteira* (Smithsonian Misc. Coll., vol. 82, no. 2, 1929). The transverse muscles are omitted from the descriptions of the segmental musculature and are treated as a separate topic.

MUSCLES OF THE FIRST SEGMENT

The musculature of the first abdominal segment is simpler than that of the following segments because of the elimination of some of the dorsal muscles and most of the lateral muscles.

140. Lateral oblique intersegmental muscle (figs. 5 A, 9 A).—A very slender muscle, observed only in the female, attached ventrally on the apex of the lateral arm of the metasternal apophysis, extending dorsally and posteriorly, mesad of the leg muscles, to the anterior

margin of the tympanal capsule of the first abdominal segment, to which it is attached dorsal to the spiracle. This is the only thoracico-abdominal muscle in the grasshopper.

141. Longitudinal dorsal muscles (fig. 8).—A broad sheet of muscles above the tympanal capsule, arising anteriorly on the first tergum somewhat behind the base of the phragma, inserted posteriorly on the anterior margin of the second tergum.

142a, 142b. Lateral oblique dorsal muscles (fig. 9 A).—Two small muscles arising laterally on the first tergum external to the longitudinals, extending ventrally and posteriorly, close to the tympanal capsule,
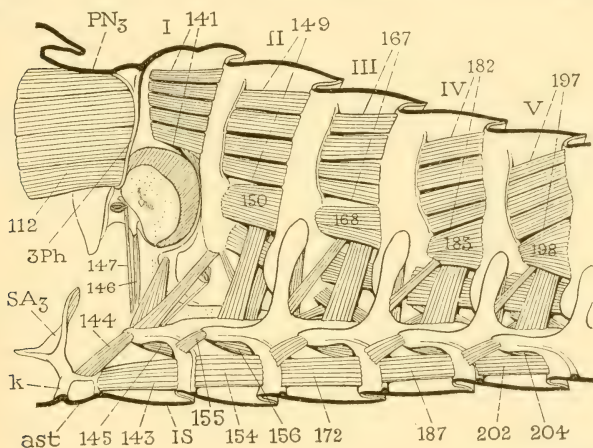
Fig. 8.—Muscles of the right side of the first five abdominal segments of *Dissosteira carolina*, male, together with the dorsal muscles (*112*) of the meta-thorax. (See fig. 10 A for identification of muscles.)

to their insertions behind the latter on the anterior margin of the second tergum.

143. Median internal ventral muscle (fig. 8).—A wide band of intersternal fibers over the lateral half of the sternal surface, arising anteriorly on the antecosta of the first sternum, inserted posteriorly on the anterior margin of the second sternum.

144. Lateral internal ventral muscle (fig. 8).—A cylindrical muscle arising laterally on the antecosta of the first sternum, inserted posteriorly on the anterior end of the apodeme of the second sternum.

145. External ventral muscle (figs. 8, 9).—This muscle is a sternal protractor. It takes its origin laterally on the posterior part of the

first sternum (fig. 9 B), and extends anteriorly and dorsally to its insertion on the under surface of the anterior apodeme of the second sternum. Its contraction separates the two sterna.

146. Tensor of the tympanum (figs. 8, 9 A).—This muscle is the only representative of the lateral muscles in the first abdominal segment of *Dissosteira*. It is a slender muscle arising laterad of the first sternum in the membrane behind the base of the hind coxal cavity, and extends dorsally to its insertion on the ventral process of the tympanal capsule. Its contraction evidently serves to stretch the tympanum.

147. Dilator muscle of the spiracle (figs. 5 A, 8, 9 A).—A very slender muscle arising with *146* in the membrane laterad of the first abdominal sternum, extending dorsally to its insertion on the manubrium of the ventral atrial plate of the first spiracle.

148. Occlusor muscle of the spiracle (figs. 5 A, 9 A).—A very short muscle arising on the anterior part of the tympanal capsule above the spiracle, inserted on the manubrium of the ventral atrial plate opposite the dilator.

MUSCLES OF THE SECOND SEGMENT

The musculature of the second abdominal segment conforms closely with that of the following segments except in the arrangement of the lateral muscles.

149. Median internal dorsal muscles (fig. 8).—A flat band of four more or less distinct groups of longitudinal fibers against the upper part of the tergum within the pericardial cavity. Origins anteriorly on the submarginal ridge of the second tergum, insertions posteriorly on the anterior margin of the third tergum.

150. Lateral internal dorsal muscle (figs. 8, 9 A).—A broad extrapericardial muscle on the lateral part of the tergum above the upper ends of the posterior lateral muscles, inserted in line with the intrapericardial dorsals on the anterior margin of the third tergum.

151. Paradorsal muscle (fig. 9).—This muscle lies against the side of the tergum below the extrapericardial dorsal muscle, external to the internal lateral muscle (*159*). It is inserted posteriorly on the anterior margin of the third tergum.

152, 153. External dorsal muscles.—Two small oblique or transverse muscles lying external to the internal dorsals in the posterior fold of the segment, where they arise on the posterior part of the second tergum. One extends dorsally, the other (fig. 9 B, *153*) ventrally to their insertions on the anterior margin of the third tergum.

These muscles in the second segment are similar to those of the third segment (fig. 10 A, *170, 171*). The external dorsals evidently produce a torsion of the adjoining tergal plates on each other.

154, 155, 156. Ventral muscles (fig. 8).—The ventral muscles of the second segment are the same as those of the first segment and of the segments following the second. They comprise median (*154*) and lateral (*155*) internal ventrals, which are sternal retractors, and an external muscle (*156*) on each side, which is a sternal protractor.

157-164. Lateral muscles (fig. 9).—The lateral muscles of the second segment differ in many respects from those of the segments following. They comprise an outer and an inner series of tergosternal
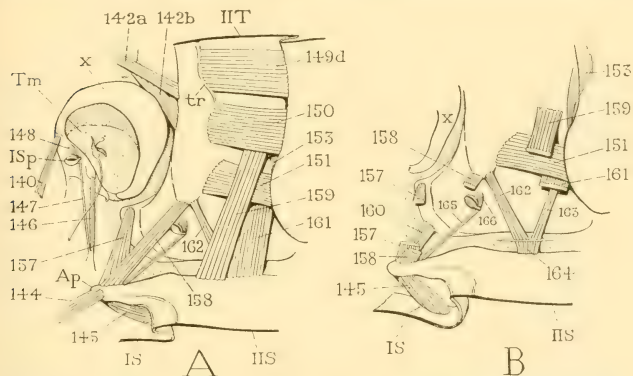
FIG. 9.—Lateral muscles of the first and second abdominal segments of *Dissosteira carolina*, right side, inner view, female.

A, all muscles in place. B, external lateral muscles of second segment (*160, 162, 163, 164*) exposed by cutting and partial removal of overlying muscles.

muscles, a pair of tergopleural muscles, and a sternopleural muscle. The inner series of tergosternals includes three muscles. The first (fig. 9 A, *157*) arises on the anterior lobe of the tergum and is inserted on the anterior apodeme (*Ap*) of the sternum; the second (*158*) arises on the tergum above the spiracle and has the same insertion as *157*. The third (*159*) is a much larger muscle arising on the tergum beneath the edge of the lateral dorsal muscle (*150*) and inserting on the lateral margin of the sternum. The outer series of tergosternals includes a short muscle (fig. 9 B, *160*) from the anterior ventral angle of the tergum to the anterior end of the sternal apodeme, and a broad posterior muscle (A, *161*) arising external to the paradorsal muscle (*151*) and inserted on the edge of the sternum behind

159. The two tergopleural muscles (B, *162, 163*) arise anteriorly and posteriorly on the lower part of the tergum external to *159* and *161,* and converge upon a narrow linear sclerite in the membrane between the tergum and the sternum. In all the other segments the external lateral muscles are attached directly on the sternum. The sternopleural muscle of the second segment is a group of very short fibers (B, *164*) connecting the pleural sclerite with the sternum.

165, 166. Muscles of the spiracle (fig. 9 B).—The dilator of the spiracle (*165*) is a long slender muscle arising on the apodeme of the sternum, the occlusor (*166*) a short muscle arising on the tergum; both are inserted on the manubrium of the movable valve of the spiracular atrium.

MUSCLES OF THE THIRD SEGMENT

The musculature of the third segment presents the typical abdominal musculature of the grasshopper, since its pattern is repeated in segments *III* to *VII* in both sexes, and its dorsal and ventral muscles are duplicated in the second segment.

167. Median internal dorsal muscles (fig. 10 A).—These muscles of the third segment, as those of the second, consist of four flat groups of fibers (*a, b, c, d*) lying within the pericardial chamber, extending from the anterior tergal ridge (*tr*) to the anterior edge of the following tergum. In the succeeding segments they become more oblique (figs. 8, 12, *182, 197, 227*) with their posterior ends dorsal to their anterior ends.

168. Lateral internal dorsal muscle (fig. 10 A).—The lateral dorsal muscle is separated from the median dorsals by the attachments of the transverse muscles of the dorsal diaphragm on the tergum (*td*), and is, therefore, extrapericardial. In the following segments this muscle becomes conspicuously fan-shaped (figs. 8, 12, *183, 198, 228, 243*).

169. Paradorsal muscle (fig. 10 A).—The paradorsal muscle is distinguished from the other lateral dorsal muscle (*167, 168*) by the fact that it lies external to the internal lateral muscles (*175, 176*). It has the same relations in some other insects, though it is a muscle not generally present. In *Dissosteira* it is repeated in the segments *II* to *VII* of both sexes, and in segment *VIII* of the male (fig. 12, *244*). The paradorsal muscle has been termed a " pleural " muscle, but it lies well within the area of the dorsum. Since it occurs in some larval insects lacking tergal plates, the writer here discards the former name of " paratergal " muscle. (Snodgrass, 1931.)

170, 171. External dorsal muscles (fig. 10 A).—External dorsal muscles occur in segments *II* to *VII* of both sexes, and also in segment *VIII* of the male. They take their origins on the posterior parts of the terga within the intersegmental folds, and are inserted on the overlapped anterior margin of the tergum following in each case. The median external dorsal of segment *III* (figs. 10 A, 11 B, *170*) arises

Fig. 10.—Muscles of the third abdominal segment of *Dissosteira carolina*.

A, muscles of the right side, inner view. *167*, median internal dorsals; *168*, lateral internal dorsal; *169*, paradorsal muscle; *170*, median external dorsal; *171*, lateral external dorsal; *172*, median internal ventral; *173*, lateral internal ventral; *174*, external ventral; *175, 176*, internal laterals; *177, 178, 179*, external laterals; *td*, attachment of dorsal transverse (diaphragm) muscles.

B, position of the muscles in cross-section of third segment, diagrammatic. *dil*, lateral internal dorsals; *dim*, median internal dorsals; *DS*, dorsal sinus; *DV*, dorsal blood vessel; *lAp*, lateral apodeme of sternum; *lle*, first external lateral muscle; *li*, internal lateral muscle; *p*, paradorsal muscle; *PvS*, perivisceral sinus; *td*, dorsal transverse muscles (of dorsal diaphragm); *tv*, ventral transverse muscles (of ventral diaphragm); *vil*, lateral internal ventral muscle; *vim*, median internal ventral muscle; *VNC*, ventral nerve cord; *VS*, ventral sinus.

dorsal to the lateral muscle (*171*); the first proceeds dorsally to its insertion, the second ventrally. In the posterior segments the corresponding muscles become much longer; the base of the median muscle has migrated ventrally, that of the lateral muscle dorsally, until the two muscles cross each other obliquely on the side of the tergum. The relations of the two muscles to each other and to the successive terga on which they are attached is best seen when the terga are pulled apart (fig. 11 C). The external dorsals in Acrididae, as already noted,

are evidently torsion muscles, their transverse positions enabling them to give a movement of partial rotation to the terga on each other.

In the generalized condition the external dorsal muscles are longitudinal in position and lie external to the internal dorsals, but they are commonly shorter than the latter ; and have a tendency to become restricted to the posterior part of the segment. In many of the higher insects they become completely reversed in position, since they take their origins on the posterior part of the tergum and extend forward in the intersegmental fold to their insertions on the invaginated anterior margin of the following tergum. They thus become tergal protractors. The position of the external dorsals of the grasshopper is seen to be intermediate between the more primitive condition and that of complete reversal. The external ventral muscles, on the other hand, are reversed and hence function as sternal protractors.

172, 173, 174. The ventral muscles (fig. 10 A).—The ventral musculature of segment *III* is typical of that of all the pregenital segments (figs. 8, 12). The median internal ventrals (fig. 10 A, *172*) are the principal sternal retractors ; the short lateral internal ventral on each side (*173*) arises at the base of the anterior apodeme (*aAp*) just before the angle of the sternal ridge (*sr*), and is inserted on the anterior end of the corresponding apodeme of the following sternum. The lateral external ventral on each side (*174*) is a sternal protractor, being completely reversed in position, with its origin on the posterior part of the sternum and its insertion anterior on the under face of the anterior apodeme of the following sternum.

The lateral musculature is alike in segments *III* to *VII,* there being in each of these segments representatives of the following five muscles of segment *III,* two of which are internal laterals, and three external laterals.

175. First internal lateral muscle (fig. 10 A).—A slender muscle arising dorsally beneath the edge of the lateral dorsal (*168*), extending ventrally and anteriorly to its insertion on the base of the lateral apodeme of the sternum.

176. Second internal lateral muscle (fig. 10 A).—A broad muscle arising on the side of the tergum just behind *175* and also beneath the edge of the lateral dorsal (*168*), extending ventrally to its insertion on the lateral margin of the sternum. The internal laterals are the principal expiratory muscles, since their contraction lifts the sternum and contracts the abdomen in a vertical direction.

177. First external lateral muscle (fig. 10 A).—This muscle arises ventrally on the anterior part of the ventral margin of the tergum,

and goes dorsally to its insertion on the outer face of the lateral apodeme of the sternum (fig. 10 B, *1le*). It is thus a dilator of the abdomen and an inspiratory muscle in respiration, since its contraction separates the sternum from the tergum (fig. 11 F, G).

178, 179. Second and third external lateral muscles (fig. 10 A).— These two muscles arise on the lateral part of the tergum below the
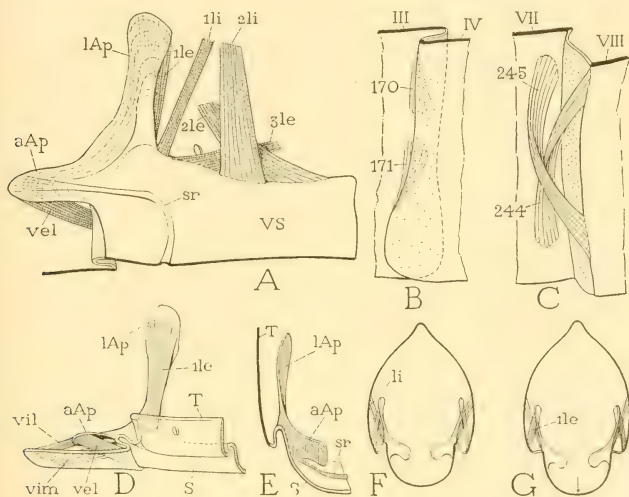
FIG. 11.—Abdominal mechanisms of Acrididae.

A, mechanism of tergosternal movements: tergum and sternum approximated by internal lateral muscles (*1li, 2li*), separated by first external lateral (*1le*), moved lengthwise on each other by oblique second and third external laterals (*2le, 3le*).

B, C, mechanism of torsion, or partial rotary movements of segments, by the transverse external dorsal muscles, best developed in posterior segments (C).

D, mechanism of tergosternal and intersternal movements: dorsoventral dilation produced by first external lateral muscle (*1le*); lengthwise sternal contraction by internal ventrals (*vim, vil*); protraction by external ventral (*vel*).

E, the sternal apodemes, right side, anterior view.

F, G, mechanism of respiration: expiratory movement (F) produced by internal lateral muscles (*li,* see A), inspiratory movement (G) by first external lateral (*1le*).

paradorsal muscle (*169*), and cross each other obliquely, the first going anteriorly, the second posteriorly, to their insertions on the opposite ends of the lateral margin of the sternum (fig. 11 A, *2le, 3le*). The muscles of this pair evidently serve to give forward and backward movements to the tergum and sternum on each other.

180, 181. Muscles of the spiracles.—The spiracular muscles are alike in segments *II* to *VIII,* and the description of those of the second spiracles (*165, 166*) will serve for each of the following spiracles.

MUSCLES OF THE EIGHTH SEGMENT

The muscles of the eighth segment are quite different in the male and the female. The musculature of this segment in the male (fig. 12) conforms with that of the preceding segments except for the reduction of the internal dorsals to a single broad band of fibers on each side (*242*), and in the absence of the first internal lateral. In the female most of the usual muscles are retained in modified form, but there are several muscles pertaining to the ovipositor and the oviducts that have no counterparts in the male. The muscles of the eighth segment of the female are as follows:

242, 243. Internal dorsal muscles (fig. 14).—A transverse series of six longitudinal groups of fibers on each side of the eighth tergum (*VIIIT*), inserted posteriorly on the apodeme and anterior margin of the ninth tergum (*IXT*). The lateral muscle on each side (*243*) is much larger than the others.

244. Paradorsal muscle.—Absent in the eighth segment of the female.

245. Median external dorsal muscle (fig. 14).—A broad muscle arising on the posterior margin of the eighth tergum, the fibers converging anteriorly and mesally to their insertions on the anterior apodeme (*Ap*) of the ninth tergum.

246. Lateral external dorsal muscle.—Absent in the female.

247. Median internal ventral muscle.—A slender muscle arising anterolaterally on the eighth sternum (fig. 13), inserted posteriorly on the median apodemal process of the anterior intervalvula of the ovipositor (fig. 17 D).

248. Lateral ventral muscle.—This muscle arises at the base of the apodeme of the eighth sternum (fig. 13) as in the preceding segments; but it is attached posteriorly in *Dissosteira* on the anterior basal sclerite of the first valvula of the ovipositor (fig. 17 A, B, E), and in *Melanoplus* (fig. 20 C) on the lateral pocket of the genital chamber.

249. External ventral muscle.—Absent in the female, unless represented by the depressor of the first valvula (fig. 17 A, B, *272*).

250. Internal lateral muscle (figs. 13, 14).—A very large triangular muscle arising laterally on the eighth tergum, its fibers spreading ventrally to their insertions along the entire lateral margin of the eighth sternum (fig. 13). This muscle evidently corresponds with the second

internal lateral of the preceding segments, the first being absent in the eighth segment both in the female and the male (fig. 12).

251. First external lateral muscle (figs. 13, 14).—A thick muscle arising in the lower anterior angle of the eighth tergum, inserted anteriorly on the outer face of the apodeme (*Ap*) of the eighth sternum.

252. Second external lateral muscle (figs. 13, 14).—A small muscle arising on the lower part of the eighth tergum below the spiracle, inserted on the base of the apodeme of the eighth sternum.

253. Third external lateral muscle.—Absent in the female.

254, 255. Muscles of the spiracle (figs. 13, 14).—Same as in the preceding segments.
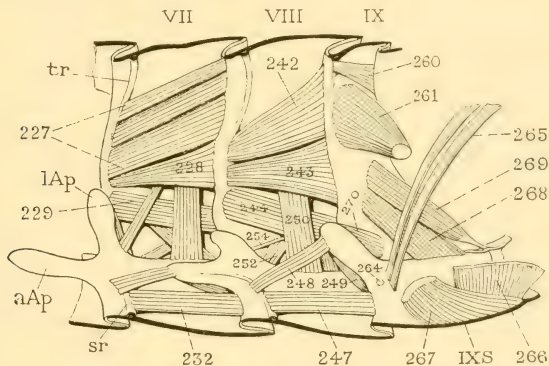
Fig. 12.—Muscles of the seventh, eighth, and ninth segments of the male abdomen of *Dissosteira carolina*, right side, inner view.

The following muscles of the eighth segment of the female have no representatives in the male.

256. Short protractor of the ovipositor.—A short muscle with a broad base arising on the side of the eighth tergum anterior to *250* (figs. 13, 14), inserted anteriorly on the anterior end of the apodeme of the ovipositor (fig. 17 A, C).

257. Anterior muscle of the median oviduct (fig. 13).—A slender muscle arising on the end of the apodeme of the eighth sternum, extending mesally to its insertion on the anterior end of the median oviduct. This muscle is absent in *Melanoplus*.

258. Posterior muscle of the median oviduct (fig. 13).—A long flat muscle arising on the end of the apodeme of the eighth sternum, extending mesally and posteriorly to the posterior end of the median oviduct.

259. The muscular sheath of the oviducts.—The walls of the median oviduct and of the proximal parts of the lateral ducts have a muscular sheath of internal circular fibers and external longitudinal fibers. The longitudinal fibers are continued upon the walls of the calyces, but the circular fibers appear to be absent in these parts of the lateral ducts, and no muscles are present on the anterior glandular parts.

MUSCLES OF THE NINTH SEGMENT

The musculature of the ninth segment differs so much between the male and the female that few muscles can be identified with each other in the two sexes, or homologized with muscles of the pregenital segments. Besides the segmental muscles there are in the female special muscles of the ovipositor, and in the male special muscles of the phallic organs.

In the male grasshopper the following nine muscles take their origins on the segmental plates of the ninth segment.

260. Internal dorsal muscle (fig. 12).—A small band of fibers arising near the mid-dorsal line on the anterior edge of the ninth tergum, the fibers spreading posteriorly and laterally to their insertions on the anterior margin of the tenth tergum. This small muscle is the only representative of the intertergal dorsals in the ninth segment of the male.

261. Retractor of the phallus.—A short, thick, conical muscle arising by a wide base dorsolaterally on the ninth tergum (fig. 12), inserted posteriorly and ventrally on a small oval sclerite in the wall of the genital chamber just laterad of the epiphallus (fig. 25 D).

262, 263. Muscles of the female not represented in the male.

264. Ventral dilator of the rectum.—A fan-shaped muscle arising on the ninth sternum at the base of the sternal apodeme (fig. 12 shows point of origin), the slender fibers spreading dorsally in a longitudinal plane to their insertions on the ventral wall of the rectum (fig. 16 A).

265. Ventral muscles (fig. 12).—A pair of straplike muscles on each side arising laterally on the ninth sternum at the base of the anterior apodeme, going posteriorly and dorsally to the membranous venter of the tenth segment just before the base of the paraproct.

266. Retractor of the aedeagus.—A broad, thin sheet of fibers arising from a median ridge of the ninth sternum (figs. 12, 25 A), attached dorsally to the wall of the genital chamber laterad of the base of the aedeagus (fig. 25 A).

267. Protractor of the aedeagus.—A large, triangular muscle arising by a long base on the median ridge of the ninth sternum, mesad

of *260* (figs. 12, 25 A), the fibers converging dorsally and anteriorly to their insertion on the lateral lobe of the epiphallus (fig. 25 A, D) : its contraction probably elevates the distal part of the phallic apparatus.

268, 269. Internal lateral muscles (fig. 12).—Two large oblique muscles on each side in the position of the second internal lateral of the pregenital segments. The first is inserted ventrally on the lateral margin of the ninth sternum ; the second is inserted by a narrowed stalk at the edge of the ninth sternum between the basal and distal plates of the latter.

270. External lateral muscle (fig. 12).—This muscle clearly corresponds with the first external lateral of the pregenital segments. It arises on the anterior lateral area of the ninth tergum and is inserted on the outer face of the apodeme of the ninth sternum.

In the ninth segment of the female there are the following 10 paired muscles or sets of muscles, including the segmental muscles and the muscles of the ovipositor.

260. Internal dorsal muscles (fig. 14).—A transverse series of five small bands of longitudinal fibers on each side extending from the anterior margin of the ninth tergum to the anterior margin of the tenth tergum.

261. Not represented in the female.

262. Long protractor of the ovipositor.—Origin laterally on the posterior margin of the ninth tergum (figs. 14, 17 C), extends forward to its insertion on the anterior end of the apodeme of the ovipositor (fig. 17 C).

263. Retractor of the ovipositor.—Origin on the anterior margin of the ninth tergum (figs. 14, 17 C) ventrad of *262*, extends posteriorly to its insertion laterally in the base of the dorsal valvula of the ovipositor (fig. 17 C).

264. Ventral dilator of the rectum.—A fan-shaped group of slender fibers arising from the dorsal surface of the apodeme of the ovipositor (fig. 17 B), spreading to their insertions on the ventrolateral line of the rectum (fig. 16 A). If the ventral dilators of the rectum are identical in the male and female, their origins would seem to identify the apodemes of the ovipositor with the anterior apodemes of the ninth sternum in the male.

265-270.—These muscles of the ninth segment present in the male (fig. 12) cannot be identified with any certainty in the female, though it is possible some of them are included in the following musculature of the ovipositor.

271. Levator of the dorsal valvula (fig. 17 A, B, C).—A large thick muscle lying on the dorsal surface of the apodeme of the ovipositor,

attached anteriorly on the latter, and posteriorly on the dorsal margin
of the base of the dorsal valvula.

272. Depressor of the ventral valvula (fig. 17 A, B).—A massive
bundle of fibers arising on the ventral face of the apodeme of the
ovipositor, inserted on the basal plates of the ventral valvula. This
muscle possibly corresponds with the intersternal protractors, or
external ventrals, of the pregenital segments.

273. Adductors of the ventral valvulae (fig. 17 C, D).—A pair of
flat muscles arising anteriorly on the proximal parts of the inner
margins of the apodemes of the ovipositor, the two converging pos-
teriorly to the median apodeme of the ventral intervalvula (f). The
retraction of the intervalvula causes an adduction of the valvulae.

Fig. 13.—Laterodorsal and ventral muscles of the seventh and eighth segments
of the female abdomen of *Dissosteira carolina,* right side, inner view.

274. Adductors of the dorsal valvulae (fig. 17 A, B, C).—Origin
on the proximal part of the dorsal surface of the ovipositor apodemes,
insertion posteriorly on the posterior intervalvula (B, C, *piv*). The
contraction of the convergent muscles of this pair approximates the
valvulae of opposite sides.

275. Muscle of the second valvula (fig. 17 B, C).—A small muscle
arising laterally on the dorsal surface of the anterior intervalvula, in-
serted posteriorly in the distal end of the small second valvula.

276. Dilator of the spermathecal aperture.—A very small muscle
of a few delicate fibers arising on the lateral basal plate of the ventral
valvula (fig. 17 E, a), inserted mesally on the side of the groove in the
dorsal wall of the genital chamber containing the aperture of the
spermathecal duct (fig. 20 D).

277. Muscles of the spermathecal duct.—The entire length of the spermathecal duct is covered by a muscular sheath consisting of outer longitudinal fibers and inner circular fibers.

The following muscles of the ninth segment of the male pertain entirely to the phallic organs and the ejaculatory duct. It is impossible to discover any identity between them and muscles of the female.

278. Epiphallic muscle of the aedeagus (fig. 25 B, C).—A long muscle lying dorsally in the basal fold of the phallus, attached anteriorly on the lateral lobe of the epiphallus (*h*), and posteriorly on the zygoma (*z*) of the aedeagal apodemes.

279. Lateral muscle of the aedeagus (fig. 25 B).—A short muscle arising lateroventrally in the base of the aedeagus, inserted dorsally on the lower edge of the lateral plate (*m*) of the aedeagus.

280. Muscle of the ventral lobe of the aedeagus (fig. 25 B).—A delicate muscle arising within the base of the aedeagus, inserted distally near the apex of the ventral lobe of the latter.

281. Lateral dilator of the endophallus (fig. 25 C, E).—A broad sheet of muscle arising dorsally on the aedeagal apodeme (C, *Apa*), the fibers extending ventrally and anteriorly to the endophallic apodeme (C, E, *w*).

282. Dorsal dilator of the endophallus (fig. 25 F).—A broad flat muscle on the dorsal surface of the endophallic bulb, arising laterally on the inner face of the aedeagal apodeme (*Apa*), inserted mesally on the dorsal edge (*x*) of the lateral plate of the endophallus.

283. Compressor of the endophallus (fig. 25, E, F. G).—An unpaired transverse muscle uniting the endophallic apodemes (*w*), the fibers covering the anterior and anteroventral walls of the endophallic bulb (G). This muscle approximates the endophallic plates and dilates the orifice of the ejaculatory sac.

284. Compressor of the ejaculatory sac (fig. 25 C, E).—A broad sheet of muscle arising internal to *281* (C) on the lateral plate of the endophallus, the fibers converging ventrally to their insertions on the lateral wall of the ejaculatory sac (E, *ejs*).

285. Muscles of the ejaculatory duct (fig. 25 E).—A thick sheath of circular fibers surrounds the ejaculatory duct from the entrance of the mucous glands to the beginning of the ejaculatory sac.

MUSCLES OF THE TENTH SEGMENT

The muscles of the tenth segment have no evident relation to the muscles of the preceding segments. They comprise muscles to the cerci, the epiproct and the paraprocts, dilators of the rectum, and in the female a transverse intrasegmental muscle.

286. Dorsal dilator of the rectum.—A group of slender fibers arising dorsally on the tenth tergum mesad of the other muscles (fig. 14), spreading fanwise ventrally to their insertions laterodorsally on the posterior part of the rectum (fig. 16 A).

287. Depressor of the cercus (figs. 7 D, 14).—A narrow muscle arising anteriorly on the median part of the tenth tergum, inserted posteriorly on the posterior margin of the median basal lobe of the cercus.

288. Median levator of the cercus (figs. 7 D, 14).—A broad muscle arising anteriorly on the tenth tergum laterad of *287*, inserted posteriorly on the small sclerite between the tenth tergum and the basal
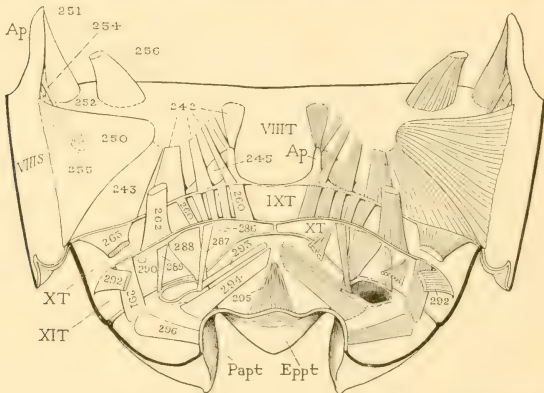
Fig. 14.—Dorsal muscles of eighth, ninth, tenth, and eleventh abdominal segments of female of *Dissosteira carolina,* ventral view.

lobe of the cercus, some of the mesal fibers in some cases inserted on the basal angle of the epiproct.

289. Lateral levator of the cercus (figs. 7 D, 14).—A slender muscle taking its origin on the tenth tergum immediately laterad of *288*, inserted posteriorly in the membrane behind the tenth tergum close to the outer angle of the base of the cercus.

290. Lateral dilator of the rectum.—A fan of fibers arising anteriorly on the lateral part of the tenth tergum (fig. 14, *290*), spreading mesad in a horizontal plane to their insertions along the lateral line of the posterior part of the rectum (fig. 16 A).

291. Ventral muscle of the paraproct (fig. 14).—A broad muscle arising on the anterior margin of the lateral part of the tenth tergum, inserted posteriorly on the base of the paraproct ventrally.

292. Transverse muscle (fig. 14).—An unpaired, straplike transverse muscle, present only in the female, lying dorsal to the base of the ovipositor and attached laterally on the ends of the tenth tergum. (Only the ends of this muscle shown in the figure.)

MUSCLES OF THE ELEVENTH SEGMENT

The musculature of the eleventh segment includes muscles from the epiproct to the cerci and paraprocts, and muscles from the epiproct and paraprocts to the circumanal membrane.

293. Adductor of the cercus (figs. 7 D, 14).—A slender muscle arising anteromedially on the epiproct, inserted on the inner extremity of the basal lobe of the cercus.

294. Adductor of the paraproct (fig. 14).—A large muscle arising medially on the epiproct just behind *293* in the female, extending laterally and posteriorly to its insertion on the upper part of the paraproct behind the base of the cercus. In the male this muscle arises mesad of *293* and underlaps the base of the latter.

295. Dorsal dilator of the anus.—A median unpaired muscle arising centrally on the epiproct (fig. 14), its fibers spreading distally to their insertions on the dorsal part of the circumanal membrane (fig. 16 A).

296. Lateral dilator of the anus.—Origin on the paraproct near the base of the outer wall of the latter (fig. 14) : extends dorsally, mesally, and posteriorly to its insertion ventrolaterally on the rectum just within the anus (fig. 16 A).

THE TRANSVERSE MUSCLES

The transverse muscles of the abdomen comprise *dorsal transverse muscles* (fig. 10 B, *td*) and *ventral transverse muscles* (*tv*). The former are always the muscles of the dorsal diaphragm; the ventral muscles may consist of segmentally individual bundles of transverse fibers, but in the Acrididae they form a continuous muscular sheet, or ventral diaphragm. The muscle uniting the opposite ends of the tenth tergum in the female of *Dissosteira* (fig. 14, *292*) is literally a dorsal transverse muscle, but it evidently does not belong to the series of diaphragm muscles.

III. THE DIAPHRAGMS AND THE DORSAL BLOOD VESSEL

The so-called diaphragms of insects are transverse dorsal and ventral partitions of the body cavity that separate from the axial pervisceral sinus (fig. 10 B, *PvS*) a dorsal sinus, or pericardial cavity (*DS*),

and a ventral sinus, or perineural cavity (VS). Each of the dia-
phragms differs much in the degree of its development in different
insects. The dorsal diaphragm is almost always present in some form,
but the ventral diaphragm is frequently absent; the first is confined
principally to the abdomen, the second may extend into the thorax.
Probably each diaphragm consists of a double peritoneal membrane,
the layers of which are reflected from the walls of the body cavity; but
the membranes enclose between them the dorsal and ventral transverse
muscles, and the muscles become the more important elements of the
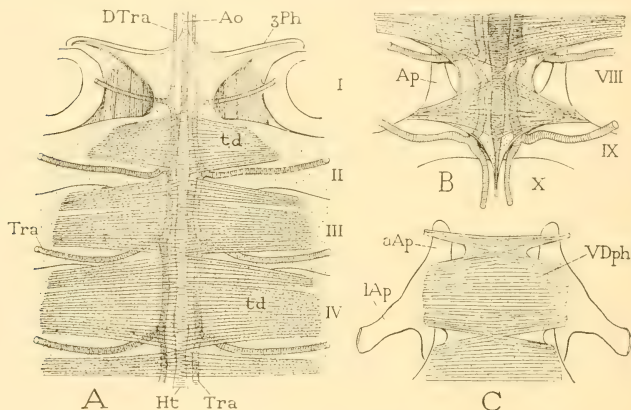
FIG. 15.—The dorsal blood vessel and diaphragms of *Dissosteira carolina*.

A, ventral view of anterior part of dorsal diaphragm extending to lobes of third
phragma (*3Ph*), showing segmental groups of transverse muscles (*td*), and
dorsal blood vessel along median line above the diaphragm. B, posterior part
of dorsal diaphragm and dorsal blood vessel in segments *VIII, IX,* and *X*. C,
dorsal view of part of ventral diaphragm, attached on lateral parts of sterna.

diaphragms, which by the vibratory contractions of the muscles serve
as important adjuncts to the heart in the circulation of the blood.

The dorsal diaphragm of Acrididae extends from the anterior end
of the first abdominal segment to the posterior part of the ninth seg-
ment, and is continued into the metathorax as a narrow membranous
fringe along each side of the aorta. In the first abdominal segment the
broad anterior margin of the diaphragm is attached to the posterior
faces of the lobes of the third phragma (fig. 15 A); the lateral edges
in this segment are free and deeply emarginate. In the following seg-
ments the limits of the dorsal diaphragm are difficult to define in a
ventral dissection, except by the muscle attachments, for the lower

diaphragm membrane appears to be everywhere continuous with a delicate peritoneal covering over the inner surfaces of the somatic muscles lying lateral of the pericardial cavity. The upper membrane of the diaphragm, however, being reflected upon the dorsal pericardial wall, more clearly marks the limits of the diaphragm itself. The two membranes of the diaphragm can be distinguished in whole preparations under the microscope by the two layers of nuclei, one dorsal to the muscle fibers, the other ventral. It is apparent that the two membranes, however, are simply continuations of a peritoneal lining of the perivisceral cavity and of a similar lining of the pericardial cavity, with the transverse muscles between them.

The muscles of the dorsal diaphragm in *Dissosteira* begin in the second segment of the abdomen (fig. 15 A) and end in the ninth segment (B). They consist of a double series of transverse fibers, separated into segmental groups, but for the most part approximately parallel. In all but the second and ninth segments the fibers are slightly divided into secondary anterior and posterior groups. This intrasegmental segregation of the fibers is more accentuated in *Melanoplus* than in *Dissosteira*. The fibers arise laterally on the tergal plates between the median and the lateral longitudinal dorsal muscles (figs. 8, 10). Their median ends branch toward the ventral wall of the heart, on which they break up into fine fibrils, and the fibrils from opposite sides appear to unite in an intricate plexus.

The dorsal blood vessel extends from beneath the brain into the tenth abdominal segment. Ostia and slight segmental enlargements of the tube are present in abdominal segments *II* to *IX* (fig. 15 A, B). Dorsal ampullar enlargements of the aorta occur in the mesothorax, metathorax, and first abdominal segment. Posteriorly the heart terminates in a narrow tapering tube extending into the tenth abdominal segment. For most of its length the dorsal vessel is accompanied by strands of nephrocytes, and the aortic ampullae are capped by dense masses of nephrocytic cells. The pericardial cavity contains also loosely scattered fat cells, and is penetrated by loops of the Malpighian tubules. The dorsal longitudinal tracheal trunks (fig. 15 A, B) lie along the sides of the blood vessel and are connected with the lateral trunks by transverse tracheae in the posterior part of each abdominal segment. It would appear that the blood has entrance into the pericardial cavity only above the free lateral margins of the diaphragm in the first abdominal segment, and at the posterior end of the diaphragm in the eighth and ninth segments.

The ventral diaphragm in *Dissosteira* extends from the head into the seventh (female) or eighth (male) abdominal segment. In the

anterior part of the thorax this diaphragm is merely a very delicate membrane attached laterally on the salivary glands and on masses of fat tissue. Between the widely spreading bases of the metasternal apophyses, however, there begins in the membrane a series of transverse muscle fibers, which continues to the posterior end as the principal tissue of the diaphragm. The fibers are attached in the metathorax to the metasternal apophyses, and in the abdomen on the lateral parts of the sternal plates (fig. 15 C). Most of the fibers go continuously across from one side to the other, but in each segment the anterior and posterior fibers spread somewhat forward and backward to bridge the spaces between the consecutive sternal plates. Posteriorly the ventral diaphragm ends abruptly in a free transverse margin, which in the female crosses the anterior part of the seventh abdominal segment, but in the male is in the anterior part of the eighth segment. In the female the last two ganglia of the ventral nerve cord lie beyond the diaphragm and are dorsal to the spermatheca, the anterior end of which may extend into the ventral sinus. In the male only the last ganglion is not covered by the diaphragm.

IV. THE PROCTODAEUM

The proctodaeum of the grasshopper is a tube of fairly uniform diameter composed of anterior and posterior sections separated by a narrower and usually bent middle section (fig. 16 A), but the relative size of the parts varies much in different specimens according to the distension, or according to the state of contraction of the muscles. The anterior end of the proctodaeum is marked externally by the origins of the Malpighian tubules (*Mal*), which are disposed in 12 groups of about 10 tubules each, arranged in a circle immediately behind the ventriculus (*Vent*). There is no clear anatomical division of the proctodaeum into an anterior intestine and posterior intestine, and there are no specifically developed internal valves, but four fairly well-marked proctodaeal regions may be distinguished by external and internal characters. The first is a short pylorus (*Py*) into which the Malpighian tubules open, the second is a long saclike ileum (*Il*), the third a narrower and usually bent colon (*Cln*), and the fourth is the large rectum (*Rect*) comprising a wide anterior rectal sac and a narrow terminal part extending to the anus.

The muscularis of the proctodaeum consists of external longitudinal fibers and internal circular fibers, the relation of the two sets of muscles on the proctodaeum being thus the same as that of the ventricular muscles (fig. 16 A), though the muscle fibers of these two parts of the alimentary canal are not continuous with each other.

The circular muscles of the proctodaeum begin just behind the bases of the Malpighian tubules, forming here a pyloric sphincter of large fibers (A, B, c), and continue (d) uninterruptedly over the entire length of the rest of the stomodaeal tube. They are particularly strong on the colon. The longitudinal muscles arise as distinct fibers on the anterior end of the proctodaeum in the neighborhood of the Malpighian tubules, but the fibers immediately converge over the pyloric sphincter into six equally spaced muscle bands (e) on the wall of the ileum,
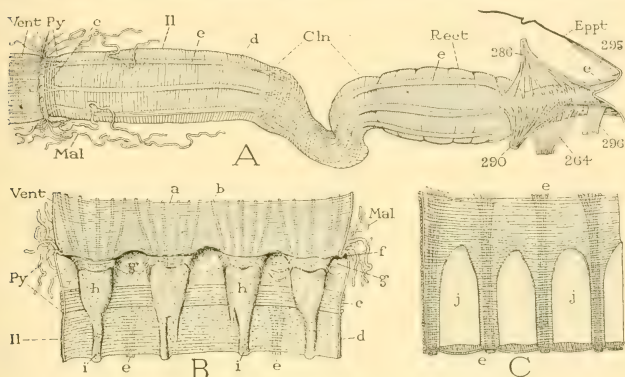
FIG. 16.—The proctodaeum of *Dissosteira carolina*.

A, general view of the proctodaeum, showing its subdivisions, its muscles, and groups of Malpighian tubules given off from anterior end. B, internal view of pyloric region between ventriculus and ileum, with pockets from which the Malpighian tubules arise. C, anterior ends of rectal " glands," inner view of rectal wall.

a, b, circular and longitudinal muscles of ventriculus; *c,* pyloric sphincter; *Cln,* colon; *d,* circular muscles of proctodaeum; *e,* bands of longitudinal proctodaeal muscles; *Eppt,* epiproct; *f,* fold marking terminus of ventricular wall; *g,* Malpighian pockets; *h, i,* internal folds of wall of ileum; *Il,* ileum; *j,* rectal pads; *Mal* Malpighian tubules; *Py,* pylorus; *Rect,* rectum; *Vent,* ventriculus; *264, 286, 290,* ventral, dorsal, and lateral dilator muscles of posterior part of rectum; *295, 296,* epiproctial and paraproctial dilators of the anus (see fig. 14).

and continue thus to the posterior end of the latter. Here each band breaks up into a group of fibers branching on the colon, some of which appear to go beneath the circular fibers to attach on the intima of the proctodaeal wall. On the posterior part of the colon the longitudinal fibers reassemble in six bands that traverse the outer wall of the rectal sac, and then again branch and appear to go beneath the circular muscles to be inserted on the wall of the terminal part of the rectum. Finally the longitudinal fibers appear once more as six short external bands on the terminal part of the rectum, and end with attachments on

the lips of the anus. The colon is the most strongly musculated part of the intestine, and, when in a state of contraction, it often appears as a very short connective between the distended ileal and rectal sacs.

The posterior part of the rectum is provided with fan-shaped dorsal, lateral, and ventral dilator muscles arising on the body wall and inserted on the proctodaeum in line with the longitudinal muscle bands of the latter (fig. 16 A). The dorsal dilators (*286*) arise medially on the tergum of the tenth abdominal segment (fig. 14), and their spreading fibers are inserted on the rectum along the lines of the latero-dorsal longitudinal muscles. The lateral dilators (fig. 16 A, *290*) arise laterally on the tenth tergum (fig. 14), and are inserted in line with the lateral longitudinal muscles of the rectum. The ventral dilators (fig. 16 A, *264*) arise in the male at the bases of the anterior apodemes of the ninth abdominal sternum (fig. 12), in the female on the apodemes of the ovipositor (fig. 17 B), and are inserted in line with the lateroventral longitudinal muscles of the rectum.

The structure of the inner wall of the proctodaeum of *Dissosteira carolina* has been described and figured by Tietz (1923), who shows that the several parts of the intestinal tube present characteristic histological differences. Viewed internally, it is seen that the Malpighian tubules open into 12 pockets of the pyloric region (fig. 16 B, *g*), and that the pockets are somewhat overlapped anteriorly by a circular fold of the enteric wall (*f*). The proctodaeal intima lines the Malpighian pockets and is reflected to the edge of the overhanging fold. It is clear, therefore, that the crest of this fold (*f*) is the true line of separation between the mesenteron and the proctodaeum, and that the Malpighian tubules arise from the proctodaeum. Between the Malpighian pockets the wall of the proctodaeal pylorus forms 12 broad, padlike thickenings (*h*), which are crossed externally by the sphincter muscle (*c*), and which, therefore, may constitute collectively a pyloric closing apparatus between the stomach and the colon. Posteriorly the pyloric pads are narrowed and are either continued as well-marked folds on the wall of the ileum (*i*), or they are broken up into numerous small folds, according to the degree of tension in the ileal wall. The external longitudinal muscle bands of the ileum (*e*) lie between each alternate pair of internal folds. When the folds are accentuated by contraction of the proctodaeal muscles, they extend posteriorly through the colon to the rectum. According to Tietz (1923) the proctodaeal intima has a thickness of .008 mm in the ileum, and of .012 mm in the colon.

The inner wall of the rectal sac presents six long, flat, parallel thickenings lying between the external bands of longitudinal muscles, each

tapering or rounded at the ends, and having sharply defined margins formed by the covering cuticula (fig. 16 C, j). These structures are the so-called " rectal glands." In the grasshopper there is nothing to suggest that they have a secretory function, the surface cuticula being relatively thick, and the epithelium, as shown by Tietz (1923), consisting of simple columnar cells. For the same reasons, also, it does not seem probable that the rectal pads are organs for the absorption of water from the faeces (see Wigglesworth, 1932); in fact, any other part of the rectum would appear to be better adapted to an absorptive function. On the other hand, the hard flat surfaces of the pads, forming six plaques in strong relief on the inner wall of the rectum, suggest that, by contraction of the surrounding circular muscles, the structures may serve to compress the contents of the rectal sac and thus extract water from the faeces.

V. THE OVIPOSITOR AND ASSOCIATED STRUCTURES

The ovipositor of the Acrididae is primarily a digging organ that works by a forcible separation of the short recurved valvulae. It thus differs radically in its action from the usual egg-laying organ of other insects, in which the valvulae are interlocked and move lengthwise on one another. The acridid ovipositor, therefore, has quite a different mechanism from that of the sliding type of ovipositor. Though the prongs of the grasshopper's ovipositor, as shown by their development, are without doubt homologues of the valvulae of other insects, it is apparent that the usual supporting basal plates, or valvifers, are absent, and that the musculature of the acridid organ has little relation to that of an ovipositor in which the muscles of the valvifers are the principal motor elements. A second important function of the acridid ovipositor, however, is that of manipulating the eggs, as the latter issue from the oviducal opening, in such a manner that they may be placed appropriately in the egg cavity for the exit of the young grasshoppers.

STRUCTURE OF THE OVIPOSITOR

The exposed part of the grasshopper's ovipositor consists of a lower and an upper pair of strong, sclerotic, pronglike processes with curved tips turned ventrally and dorsally (fig. 1, Ovp). These processes are respectively the first and third valvulae (fig. 17 A, $1Vl$, $3Vl$). The second valvulae ($2Vl$) are small, and are ordinarily concealed between the others, but they are not rudimentary in the sense of being functionless structures. The ovipositor projects posteriorly at the
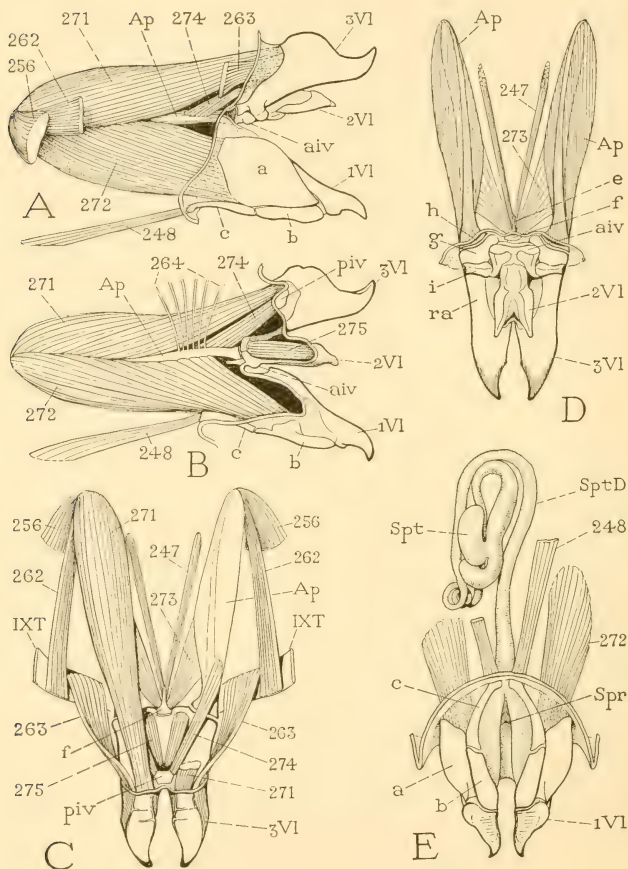
FIG. 17.—The ovipositor and its muscles. *Dissosteira carolina.*

A, ovipositor and muscles, left side. B, median section of ovipositor showing mesal view of right valvulae and muscles. C, dorsal view of ovipositor and muscles. D, ventral view of second and third valvulae, with apodemes, and muscles of anterior intervalvula. E, ventral view of ventral valvulae, dorsal wall of genital chamber with spermathecal aperture, and spermatheca.

a, lateral basivalvular sclerite; *aiv,* anterior intervalvula; *Ap,* apodeme of ovipositor; *b, c,* first and second ventral basivalvular sclerites; *e, f,* apodeme and apodemal sclerite of anterior intervalvula; *g,* base of third valvula; *h,* ventral lip of apodemal invagination; *i,* articular process on ramus of third valvula; *IXT,* lateral parts of ninth tergum; *piv,* posterior intervalvula; *ra,* ramus of third valvula; *Spr,* spermathecal aperture; *Spt,* spermatheca; *SptD,* spermathecal duct; *1Vl, 2Vl, 3Vl,* first, second, and third valvulae.

end of the abdomen (fig. 1) beyond the eighth sternum (*VIIIStn*) from beneath the lobes of the eleventh segment (*Eppt, Papt*), and thus might appear to belong to the ninth and tenth segments; the first valvulae, however, are developed in the nymph from the eighth segment, immediately behind the eighth sternum (fig. 22 A, C, *1Vl*), and the second and third valvulae from the ninth segment (A, C, D). In the adult several basivalvular sclerites are differentiated from the bases of the first valvulae (figs. 1, 17 A, *a, b, c*), which, though partially overlapped by the eighth sternum, are entirely separated from the latter by an inflection of the poststernal membrane that forms the female genital chamber. Between the bases of the dorsal valvulae are anterior and posterior intervalvular sclerites (fig. 17 B, *aiv, piv*); and a pair of large apodemes projects forward in the body cavity from the angles between the bases of the dorsal and ventral valvulae (A, B, D, *Ap*). An important accessory of the acridid ovipositor is the egg guide, a median process of the eighth sternum (fig. 20 A, *eg*).

The first, or ventral, valvulae of *Dissosteira carolina* (fig. 17 A, B, E, *1Vl*) are somewhat elongate lobes, flattened from side to side, ending each in a decurved point. Proximally they are united by the membranous integument between their bases, and their ventral walls are continued into the dorsal wall of the genital chamber (fig. 20 A). Each first valvula is differentiated into a strongly sclerotic terminal lobe (fig. 17 A, *1Vl*), and into a basal part containing a large lateral basivalvular sclerite (*a*) and two narrow ventral sclerites (*b, c*). The upper surface of the terminal lobe (B) is produced proximally as an elongate plate, or ramus, at the end of which is a wide transverse depression that fits closely upon a prominent abutment from the under surface of the basal ramus of the corresponding third valvula (D, *i*). Proximal to this articulation the dorsal wall of the ventral valvula is membranous and shortly ends at the ventral lip of the hollow base of the lateral apodeme (*Ap*). The lateral basivalvular sclerite of the first valvula (A, *a*) is a prominent plate exposed on the side of the abdomen behind the eighth sternum (fig. 1). The posterior ventral sclerite (fig. 17 A, B, *b*) is ordinarily partly exposed behind the eighth sternum, but the anterior ventral sclerite (*c*) is concealed in the dorsal wall of the genital chamber (fig. 20 A), where it flanks a median channel containing the spermathecal aperture (fig. 17 E).

The third, or dorsal, valvulae of *Dissosteira* (fig. 17 A, B, *3Vl*) resemble the ventral valvulae in general form, except that their points are turned upward, but they are larger and stronger than the ventral valvulae, and they have no basivalvular sclerites. Their dorsal surfaces proximal to the upcurved points are broad and flat. The under surface

of each dorsal valvula is prolonged anteriorly in a strong ventral ramus (D, *ra*), the expanded base of which (*g*) is firmly hinged to the dorsal lip of the exposed base (*h*) of the lateral apodeme of the same side. The apodemal bases, therefore, are the fulcral points for the movements of the dorsal valvulae. The ventral valvulae, on the other hand, have their fulcra of movement on the strongly protruding articular ridges (*i*) on the bases of the dorsal valvulae. The dorsal valvulae are united between their bases by a membranous integument containing the anterior intervalvula (D, *aiv*), the bases of the second valvulae (*2Vl*), and the posterior intervalvula (B, C, *piv*).

The second, or intermediate, valvulae (fig. 17 A, B, D, *2Vl*) are short lobes projecting from the membrane between the ventral rami of the dorsal valvulae. The two are adnate mesally for most of their length, but their sclerotic lateral and terminal parts form free lobes enclosing a trough-like depression between them (D). The united bases of the second valvulae are supported on a median process of the anterior intervalvula (*aiv*).

The intervalvulae are small sclerites lying between the bases of the dorsal valvulae, where, because of the position of the latter, they become dorsal and ventral relative to each other. The ventral anterior intervalvula (fig. 17 D, *aiv*) is a transverse sclerite bridging the space between the anterior ends of the ventral rami of the third valvulae, and giving support by a median process to the united bases of the second valvulae. Just before the transverse sclerite is a small, oval, median sclerite (*f*) bearing a short slender apodeme (*e*) on which are attached the muscles of the anterior intervalvula. The posterior intervalvula is a small hexagonal plate lying dorsally between the bases of the third valvulae (B, C, *piv*).

A characteristic feature of the acridid ovipositor is the presence of the pair of long, flat, lateral apodemes (fig. 17 D, *Ap*) extending forward from the angles between the bases of the dorsal and ventral valvulae. These apodemes are well developed also in Tetrigidae and Tridactylidae, but they have no apparent homologues in the ovipositor of other insects. They give attachment to the levator and depressor muscles of the valvulae, to the muscles of the posterior intervalvulae, and to the ventral dilators of the rectum, while the proctractor muscles of the ovipositor are inserted on their anterior ends.

The stalk of each apodeme is hollow, and its base appears as the strongly sclerotic lips of a transverse cleft in the angle between the bases of the dorsal and ventral valvulae, where, as already observed, the ventral ramus of the dorsal valvula is hinged to the dorsal lip of the apodemal invagination. It might be supposed, therefore, that the

apodemes of the acridid ovipositor represent anterior apodemal proc-
esses of the second valvifers in other insects, but it is quite impossible
to reconcile the musculature of the acridid apodemes with that per-
taining to the second valvifers in the usual type of ovipositor. Accord-
ing to Walker (1919) the ovipositor apodemes of *Melanoplus* are
formed in the nymph as invaginations at the angles between the bases
of the valvulae. It is perhaps possible that they are highly developed
anterior apodemes of the ninth sternum (the latter being represented
by the intervalvulae), since the space between the bases of the dorsal
valvulae is bridged by the anterior intervalvula. It is significant that
the ventral dilators of the rectum, which in the male arise anteriorly
on the ninth sternum, take their origins in the female on the ovipositor
apodemes (fig. 17 B, *264*).

The muscles of the acridid ovipositor function as protractors and
retractors of the entire organ, as levators and depressors of the first
and third valvulae, as abductors and adductors of the same valvulae,
and as motors of the second valvulae; but it appears that some of
them may act in more than one capacity. As above noted, it will be
fruitless to attempt to trace any homologies between these muscles
and the usual muscles of the ovipositor in other insects. It should be
observed, however, that with the absence of valvifers in the acridid
ovipositor there is correlated an absence of dorsal muscles correspond-
ing with those ordinarily inserted on the valvifers.

The exsertion of the ovipositor evidently is brought about by two
pairs of muscles inserted on the anterior ends of the lateral apodemes
(fig. 17 A, C, *256, 262*). Of these muscles those of the first pair are
the short protractors (*256*) arising by wide bases on the anterior
lateral parts of the eighth abdominal tergum (fig. 13). The others
are the long protractors (fig. 17 C, *262*) arising laterally on the pos-
terior margin of the ninth tergum (*IXT*). Retraction of the ovi-
positor is accomplished apparently by a pair of ventral muscles of
the first valvulae, by lateral muscles of the third valvulae, and by
muscles of the anterior intervalvula. The retractors of the first val-
vulae arise anteriorly on the eighth sternum (fig. 13, *248*) and in
Dissosteira are inserted on the anterior ventral basivalvular sclerites
(fig. 17 E, *248*). In *Melanoplus*, however, these muscles are inserted
on anterior pockets of the genital chamber (fig. 20 C, *248*). The re-
tractors of the third valvulae are lateral muscles arising anteriorly
on the ninth tergum (fig. 17 C, *263*) and inserted posteriorly on the
lateral margins of the bases of the third valvulae. These muscles would
appear to act also as abductors of the valvulae. The retractors of the

anterior intervalvula (C, D, 247) are a pair of slender muscles arising anteriorly on the eighth sternum (fig. 13) ; they probably assist also in the adduction of the valvulae.

The muscles that open the valvulae dorsoventrally consist of the four huge bundles of fibers arising on the lateral apodemes, one pair dorsally (fig. 17 A, B, 271), the other pair ventrally (272). The dorsal muscles, which are the levators of the third valvulae, are inserted dorsally in the bases of these valvulae; the ventral muscles, or depressors of the first valvulae, are inserted within the bases of the first valvulae on the lateral basivalvular sclerites and on the posterior ventral sclerites (A, E, a, b). These four powerful muscles of the ovipositor produce the movements of the valvulae by which the earth is compressed peripherally in the digging of the egg chamber in the ground.

The closing of the valvulae evidently is produced by muscles of the anterior intervalvula, there being no muscles inserted on the valvulae that directly oppose the opening muscles. The muscles of the anterior intervalvula include the slender retractor muscles (fig. 17 C, D, 247) arising anteriorly on the eighth sternum (fig. 13), and a pair of short, broad muscles (fig. 17 C, D, 273) arising on the ovipositor apodemes. Since the anterior intervalvula lies between the bases of the dorsal and ventral valvulae, a pull on its muscles brings the valvulae together. These same muscles also effect an adduction of the valvulae of opposite sides.

Transverse movements of the valvulae, i. e., movements of abduction and adduction, are not as pronounced as the dorsal and ventral movements, but it can be shown experimentally on a dead specimen that some of the muscles of the ovipositor separate or approximate the valvulae of opposite sides. The only muscles that may serve as abductors of the valvulae are the retractor muscles inserted on the lateral basal margins of the third valvulae (fig. 17 C, 263), which arise laterally on the ninth tergum. The adductors are muscles of the intervalvulae ; a forward pressure on these sclerites brings the valvulae of opposite sides together. The anterior intervalvular muscles comprise the median pair of slender muscles (fig. 17 C, D, 247) arising anteriorly on the ninth sternum (fig. 13), and the lateral pair of wide muscles (273) arising on the inner margins of the basal parts of the lateral apodemes ; both pairs converge to their insertions on the small median apodeme of the anterior intervalvula. The posterior intervalvular muscles consist of a single pair of muscles (B, C, 274) arising on the bases of the lateral apodemes, and converging posteriorly to their insertions on the posterior intervalvula (piv). There

are no tergal muscles in Acrididae corresponding with those inserted
on the intervalvulae in Gryllidae. (See Abdomen, Part II, Smith-
sonian Misc. Coll., vol. 89, no. 8, fig. 17 E, H, *5, 8*.)

The second valvulae are provided with a pair of short muscles aris-
ing anteriorly on the anterior intervalvula (fig. 17 B, C, *275*), and
inserted distally in the free ends of the second valvulae. These small
intermediate valvulae evidently are functional in guiding the eggs
properly between the other valvulae in their passage through the
ovipositor.

An important accessory of the acridid ovipositor is the *egg guide*.
This organ is a small, tapering median process arising from the re-
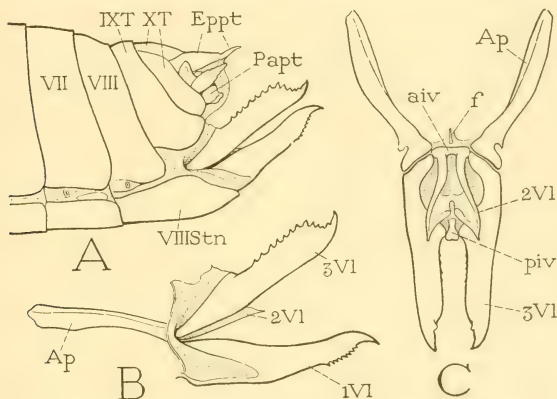
FIG. 18.—End of abdomen and ovipositor of *Tettigidea lateralis*.

A, terminal segments of abdomen, with ovipositor. B, left valvulae and
apodeme of ovipositor. C, ventral view of second and third valvulae, inter-
valvulae, and apodemes of ovipositor.

flected distal end of the eighth sternum (figs. 4, 13, *cg*) directly in
line with the opening of the oviduct (*Gpr*) in the floor of the genital
chamber. The egg guide normally projects between the bases of the
ventral valvulae, and serves to direct the eggs issuing from the gono-
pore upward and into the intervalvular space of the ovipositor. It is
an immovable process developed in the nymph as a median outgrowth
from the posterior margin of the eighth sternum.

The ovipositor of Tetrigidae, as illustrated by *Tettigidea lateralis*
(fig. 18), is of the acridid type of structure in that it is composed of
the first and third valvulae (B), and has a pair of lateral intervalvu-
lar apodemes (B, C, *Ap*) with muscles for opening the valvulae. The

second valvulae are small (C, *2Vl*) as in Acrididae and are supported
by the anterior intervalvula (*aiv*). The first and third valvulae, how-
ever, are longer and slenderer than in the typical acridid ovipositor,
and the apodemes are relatively short. Basivalvular sclerites are ab-
sent in *Tettigidea*, but Walker (1919) describes and figures basivalvu-
lar sclerites associated with the first valvulae in *Acrydium ornatum*,
and Chopard (1920) shows a lateral sclerite (pileolus) at the base
of the first valvula in *Paramastax laeta*. Walker describes also in
Acrydium a sclerite interposed between the base of the third valvula
and the lower edge of the ninth tergum, which he regards as a valvifer.

The ovipositor of the tridactylid genus *Rhipipteryx*, as Walker
(1919) observes, " is remarkably similar to that of the Acridoidea."
The female abdomen of *R. biolleyi* is elongate and slender. The last
unmodified segment is the seventh (fig. 19 A, *VII*). The eighth seg-
ment, which is partly concealed within the seventh, has its tergum di-
vided into two lateral plates by a median membranous area of the
dorsum (A, B, *VIIIT*). The spiracles of this segment lie in the lower
parts of the tergal plates. The tergum of the ninth segment (A, *IXT*)
consists of two widely separated lateral plates (E, *IXT*), the anterior
dorsal angles of which (C, E) are produced into a pair of slender
arms invaginated beneath the dorsal membrane of the eighth segment.
The tergum of the tenth segment (F, *XT*) is broken up into two large
lateral tergites and a group of three small dorsal tergites. The lateral
tergites extend forward between the arms of the ninth tergal plates,
where they are united with each other anteriorly. The eleventh seg-
ment is represented by a shield-shaped epiproct (F, *Eppt*), and two
large projecting paraprocts (*Papt*) bearing each a terminal lobe
(*paptl*). The cerci (*Cer*) arise laterad of the epiproct at the bases of
the paraprocts.

The exposed part of the ovipositor of *Rhipipteryx biolleyi* consists
of four elongate conical processes (fig. 19 A, *Ovp*), which, as in
Acrididae and Tetrigidae, are the first and third valvulae. Each ventral
first valvula (C, *1Vl*) has an accessory tooth on its outer surface and
a large lateral basivalvular sclerite (*a*) at its base. The latter appears
on the side of the abdomen as a prominent plate behind the eighth
sternum (A, *a*). The dorsal third valvulae (C, *3Vl*) are somewhat
longer than the ventral valvulae, and each is supported on the distal
margin of the lateral tergite of the ninth segment (*IXT*), to which
it is articulated ventrally (E) by a condyle of the latter. Below and
between the bases of the dorsal valvulae are two small intermediate
second valvulae (E, *2Vl*), united at their bases by the anterior inter-

valvula (*aiv*). Both anterior and posterior intervalvulae (E, *aiv, piv*) are present in *Rhipipteryx* as in Acrididae and Tetrigidae, and a small median sclerite (*f*) before the anterior intervalvula gives attachment to a pair of convergent muscles (*5*).

The lateral apodemes of the ovipositor of *Rhipipteryx* are long spatulate plates arising between the bases of the valvulae, but each is more specifically connected with the corresponding ventral valvula (fig. 19 D, *Ap*), rather than with the dorsal valvula as in Acrididae. Walker describes the ovipositor apodemes of *R. forcipata* as shelflike extensions of the lower edges of the ninth tergum, having the same
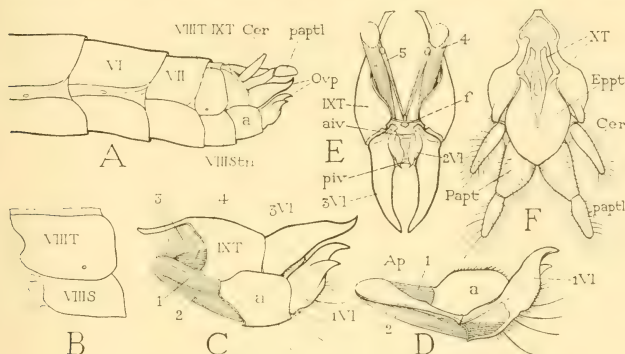
Fig. 19.—Abdomen and ovipositor of *Rhipipteryx biolleyi.*

A, terminal half of abdomen with ovipositor. B, lateral view of eighth segment removed from seventh. C, left view of ninth segment and ovipositor. D, mesal view of right ventral valvula, with right apodeme and muscles. E, ventral view of ninth tergum supporting second and third valvulae. F, dorsal view of tenth and eleventh segments, showing lobes (*paptl*) of paraprocts. (Lettering as on fig. 17.)

relation to the valvulae as the free apodemes of Acrididae. The writer, however, finds no tergal connections of the apodemes in *R. biolleyi,* in which the structures appear to be identical with the intervalvular apodemes of Acrididae. They give attachment to muscles very nearly the same as those of the Acrididae in their distribution to the basivalvulae (fig. 19 C, D, *1*), the ventral valvulae (*2*), the ninth tergum (C, *3*), and the dorsal valvulae (C, E, *4*).

THE FEMALE GENITAL CHAMBER AND THE SPERMATHECAL OPENING

The genital chamber, or copulatory pouch, of the female grasshopper is a flat horizontal invagination of the integument beneath the bases of the ventral valvulae and above the posterior margin of the

eighth abdominal sternum (fig. 20 A, *GC*). The anterior basivalvular sclerites of the first valvulae extend into its dorsal wall (figs. 17 E, 20 A, C, *c*), and in a depression between them is situated the aperture of the spermatheca (*Spr*). The opening of the median oviduct, or gonopore, lies anteriorly in the floor of the genital chamber (fig. 20 A, *Gpr*). A short distance before the spermathecal and oviducal apertures the genital chamber ends as a blind pouch. Here, in *Dissosteira,* a pair of muscles from the eighth sternum have their insertions on the ends of the anterior basivalvular sclerites (fig. 17 E, *248*). In *Melanoplus* the anterior end of the genital chamber is provided with two large lateral pockets (fig. 20 C, *l*), and the muscles (*248*), inserted on the basivalvular sclerites (*c*) in *Dissosteira,* are attached in *Melanoplus* on the walls of the lateral pockets. Similar pockets of the genital chamber in *Anacridium aegyptium* are described as " vésicules oviductaires " by Vardé (1929), who shows from a study of their histology that the pouches are glandular structures in this species.

The female genital chamber of insects generally is usually said to be an invagination between the eighth and ninth abdominal sterna. In the Acrididae, however, it is quite clearly an ingrowth between the eighth sternum and the bases of the first gonopods, which are located behind the sternum. This fact is noted by Nel (1929), who observes that the genital chamber in the female of *Colemania* and *Locustana* is " formed at the hind margin of the eighth sternum by the sternum overgrowing the bases of the anterior ovipositor lobes." The basal sclerites of the first valvulae thus come to lie in the dorsal wall of the genital chamber.

The female gonopore of adult Acrididae, as above noted, is situated on the floor of the genital chamber above the reflected posterior end of the eighth abdominal sternum. It is an elongate median aperture (figs. 4, 13, *Gpr*) between membranous folds that converge and unite posteriorly on the dorsal surface of the base of the egg guide. The oviductus communis (figs. 13, 20 A, *Odc*) extends forward to the seventh segment where it receives the lateral oviducts. The definitive position of the female gonopore in Acrididae, it is claimed by Nel (1929), is not the site of the primary invagination that gives rise to the median oviduct. In late embryos of *Locustana,* Nel says, the common oviduct first appears as an invagination of the conjunctival membrane between the seventh and eighth segments (fig. 20 B, *Odc'*), the aperture of which runs out as a groove on the venter of the eighth segment. In this respect, therefore, the acridid appears to recapitulate a more primitive condition permanently retained in Dermaptera. During the first nymphal stage of the grasshopper, as described by Nel,

the gonopore undergoes a posterior transposition that gives it its definite location behind the eighth sternum. In the early part of the first instar, Nel says, the oviduct opens on the extreme anterior part of the eighth sternum in the groove extending posteriorly from its aperture. During this instar the lips of the groove unite ventrally, the union proceeding from in front backward; the oviduct is thus extended pos-
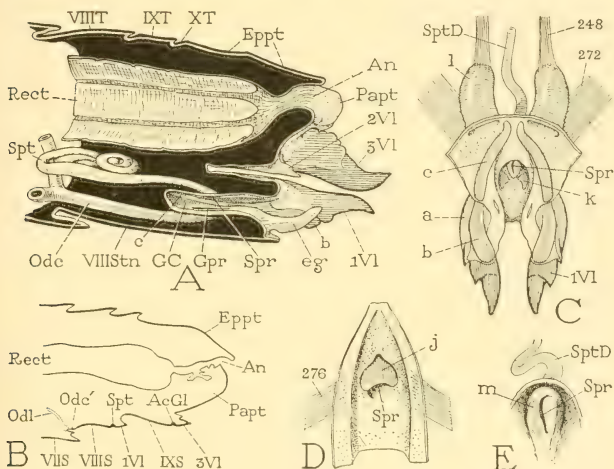
FIG. 20.—Structure and development of the female copulatory apparatus.

A, vertical section of end of abdomen of *Dissosteira carolina* just to left of median plane, showing genital chamber (*GC*) invaginated between bases of ventral valvulae and eighth sternum, with gonopore (*Gpr*) in its ventral wall and spermathecal aperture (*Spr*) in its dorsal wall, the eighth sternum terminating in the egg guide (*eg*). B, diagrammatic section of end of abdomen of first instar nymph of *Locustana* (from Nel, 1929), showing origin of median oviduct (*Odc'*) behind seventh sternum, and spermathecal invagination (*Spt*) at end of eighth sternum. C, ventral view of first valvulae and dorsal wall of genital chamber of *Melanoplus femur-rubrum*. D, spermathecal aperture of *Dissosteira carolina*. E, same of *Melanoplus mexicanus* (structure variable in this species).

teriorly, and its opening, the gonopore, migrates in the same direction, until finally, in the second instar, it takes its definitive position in the newly forming genital chamber behind the eighth sternum.

The typical acridid spermatheca is a long tubular organ extending forward in the ventral sinus of the body cavity beneath the ventral diaphragm (figs. 17 E, 20 A, *Spt*). The middle part is variously coiled, and the tube ends in an enlarged bifid terminal section. The spermatheca of the grasshopper is formed as a median invagination ·in a

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groove of the body wall between the bases of the first valvulae (fig. 20 B, *Spt*), and, therefore, belongs to the eighth abdominal segment. The usual bifid structure of the adult organ in insects suggests that the spermatheca may have been paired in its origin, but one branch is generally the sperm storage chamber, and the other a glandular accessory.

The opening of the spermatheca in the dorsal wall of the genital chamber in adult grasshoppers lies in a median channel of the membranous space between the anterior basivalvular sclerites of the first valvulae (figs. 17 E, 20 C, *Spr*). In *Dissosteira carolina* the aperture is transverse above the posterior margin of a weakly sclerotic heart-shaped sclerite (fig. 20 D, *j*). Structural details associated with the spermathecal opening, however, may be quite different in different acridid species. In *Melanoplus femur-rubrum,* for example, the spermatheca opens through a crescentic longitudinal slit in an oval area or sclerite contained in a median pocket of the genital chamber wall (fig. 20 C, *Spr*). Behind it are two small triangular sclerites (*k*) in the wall of the pocket. In *M. mexicanus* (E) the aperture is a cleft between two lateral lips of a thick oval body (*m*) projecting from a depression in the wall of the genital chamber. It is possible that structural differences in the female spermathecal opening may be found to be correlated with differences in the male intromittent organ, since coition is effected by way of the spermathecal duct.

Accessory genital glands of the ninth abdominal segment are usually not developed in the Acrididae. According to Nel (1929), however, a small median invagination is formed between the ovipositor lobes of the ninth segment in young nymphs of *Locustana* and *Colemania* (fig. 20 B, *AcGl*), which becomes a short tube, but remains vestigial even in the adult. The function of the usual female accessory glands is assumed in Acrididae by a long tubular diverticulum of each lateral oviduct, or more strictly of the oviducal calyx, in which is secreted the frothy material of which the egg pod is formed.

DEVELOPMENT OF THE OVIPOSITOR

It is commonly assumed that the ovipositor of pterygote insects is formed from the limb appendages of the eighth and ninth abdominal segments, that the valvulae are processes of the appendage bases, and that the usual supporting plates, or valvifers, are derived from the limb bases themselves. There is no doubt that the organ is formed from ventral outgrowths and sclerites of the two genital segments, but it is quite a different matter to prove that these parts represent true

segmental appendages. Even the fact that the first rudiments of the valvulae appear in some insects on the embryo in line with vestigial appendages on the pregenital segments is not necessarily evidence that they are homodynamous with the latter, since secondary structures arising in the same relative positions as the true limbs would be very likely to assume the same form in early stages of growth. The best evidence of the origin of the ovipositor from limb structures is furnished by the Thysanura, in which the valvulae are outgrowths of lateroventral plates of the genital segments that are clearly equivalent to the stylus-bearing plates present in some forms on the preceding segments, which plates, there seems little reason to doubt, represent the bases of true abdominal limbs. The ovipositor of Thysanura, therefore, appears to be formed of mesal processes (gonapophyses) of the coxopodites of the appendages of the eighth and ninth abdominal segments, and the fundamental similarity of the ovipositor in Thysanura and Pterygota leads us to conclude that the organ is an homologous structure in all insects in which it occurs.

The facts of the development of the ovipositor in Orthoptera are easy to ascertain and are in general well known. In a young nymph of the cricket *Nemobius* (fig. 21 A) two small conical processes ($1Vl$) project from the membranous ventral part of the eighth segment behind the eighth sternum ($VIIIStn$), entirely free from the latter. These processes are the rudiments of the first valvulae. The valvulae of the ninth segment are not yet in evidence; the sternal region of this segment (IXS) shows no differentiation except two slight rounded swellings of its posterior margin. At a somewhat later stage (B, C), however, a pair of valvular processes is present on each genital segment. Those of the eighth segment (B, $1Vl$) still arise from the membrane behind the reduced eighth sternum ($VIIIStn$). The processes of the ninth segment (C, $3Vl$), on the other hand, which become the third valvulae of the adult, arise directly from a median sclerotization of the ventral wall of the segment, at the sides of which is a pair of small but conspicuous oval lateral sclerites (x). There is thus no sternal plate in the ninth segment distinct from the bases of the valvulae.

The two primary pairs of valvular processes increase in length with successive instars (fig. 21 E), and the rudimentary second valvulae appear ventrally between the bases of the third valvulae (F, $2Vl$), but the relations of the valvulae to their respective segmental areas remain unaltered. Up to a late stage there is no evidence of the presence of valvifers, except for the small lateral sclerites (x) of the ninth segment, which increase in size and become more dorsal in position (F).

In the last nymphal stage of the cricket, as illustrated in *Gryllus* (fig. 21 G), the valvifers appear as weak sclerotizations in the areas previously membranous laterad of the bases of the valvulae. The
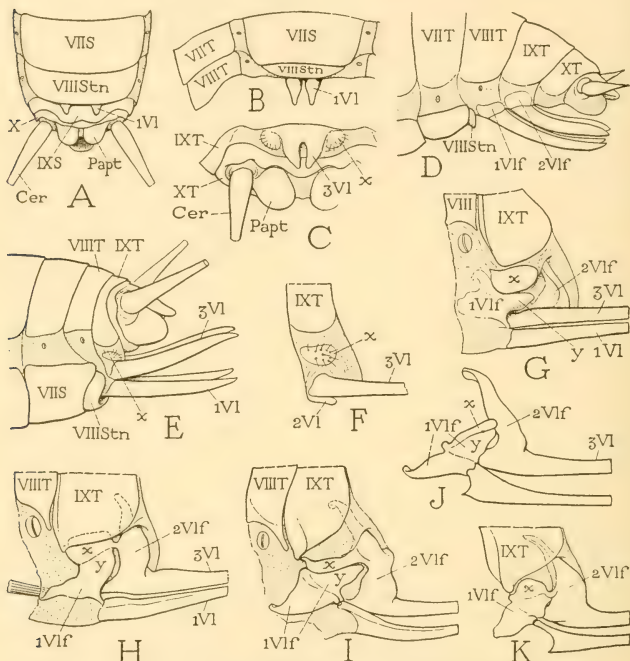
FIG. 21.—Development of the ovipositor of Gryllidae and Tettigoniidae.

A, ventral view of end of abdomen of very young nymph of *Nemobius*. B, seventh and eighth sterna of *Nemobius* at later stage. C, ninth and postgenital segments of same. D, end of abdomen and ovipositor of young nymph of *Neoconocephalus*. E, late instar nymph of *Nemobius*. F, same, lower part of ninth segment and valvulae. G, lower parts of genital segments with base of ovipositor of last nymphal instar of *Gryllus,* showing origin of first valvifer in podial area of eighth segment. H, base of ovipositor of adult *Gryllus assimilis*. I, same of *Orocharis saltator*. J, same of *Neoxabia bipunctata*. K, same of *Cyrtoxipha columbiana*.

first valvifer ($1Vlf$) lies in the ample membrane of the eighth segment behind the small eighth sternum. Ventrally it is connected with the base of the first valvula ($1Vl$), and posteriorly it is prolonged as a prominent lobe (y) inserted between the base of the third valvula and the lateral sclerite (x) of the ninth segment, which latter is now

closely associated with the lower margin of the ninth tergum. The second valvifer (*2Vlf*) is clearly differentiated in the ninth segment, and has essentially the adult form (H, *2Vlf*). Between the bases of the second and third valvulae of opposite sides are formed the small median sclerites that become the intervalvulae of the ninth segment in the adult.

Throughout the development of the gryllid ovipositor, it is to be observed, there is a significant difference in the position of the parts derived from the two genital segments. The first valvulae and the first valvifers are developed from the ventral membrane of the eighth segment entirely behind the eighth sternum. The sternal plate of the eighth segment, therefore, does not contain the limb bases of this segment. The valvifers and valvulae of the ninth segment, on the other hand, arise from the entire ventral region of this segment, except for a small median part from which are formed the intervalvulae. We may presume, therefore, that the apparent sternal region of the ninth segment has a coxosternal composition, as have the usual definitive sternal plates of the abdomen. The median sternal part forms the intervalvulae; the lateral coxal areas give rise to the valvulae and valvifers. In each genital segment the dorsal muscles of the respective valvifers arise on the tergum.

From the above it is evident that the facts of the development of the ovipositor need " interpretation " to make them fit with the theoretical origin of the ovipositor from segmental limbs, but, it should be observed, they are at least not inconsistent with this theory. It is important to note, furthermore, that the first valvulae are the gonapophyses of the first gonopods, while the first formed processes of the ninth segment are the third valvulae, which are elongations of the coxopodites; the second valvulae, or true gonapophyses of the ninth segment, are of later development. This same order of development of the ninth segment processes recurs in most insects with three valvular components in the ovipositor. In Gryllidae, as in Acrididae, the second valvulae remain rudimentary.

The primitive segmental relations of the valvifers in Gryllidae are somewhat confused in the final development of the basal mechanism of the ovipositor. Each first valvifer, as we have seen, in the last nymphal stage of *Gryllus* (fig. 21 G) has a posterior lobe (*y*) interposed between the base of the third valvula (*3Vl*) and the small lateral sclerite of the ninth segment (*x*), which latter has become closely associated with the lower edge of the ninth tergum (*IXT*). In the adult cricket (*H*) the sclerite *x* is solidly fused with the lobe *y* and thus becomes

virtually a part of the definitive first valvifer, by which the latter articulates with the ninth tergum; but the sclerite acquires also a flexible union with the second valvifer (*2Vlf*), which gives the two valvifers on the same side a point of motion on each other. This same structure and mechanism occurs in other members of the same family (I, J, K). In the Gryllidae, therefore, the definitive first valvifer is a composite plate formed of the true first valvifer and of a small dorsal sclerite derived from the coxopodite region of the ninth segment, and thus acquires its secondary articulations with the ninth tergum and with the second valvifer. In the Tettigoniidae the valvifers have a simpler structure, and in the nymph (fig. 21 D) each is a small plate (*1Vlf, 2Vlf*) in its respective segment; those of the first pair are entirely separated from the small eighth sternum (*VIIIStn*).

It will now be of interest to study the development of the ovipositor in a member of the Acrididae in order to discover if possible the nature of the disparity, so evident in the adult structure, between the acridid type of ovipositor and that characteristic of other insects. In a very young nymph of *Melanoplus* (fig. 22 A) the ventral plates of both genital segments are well developed and of approximately equal size. Rudiments of the first valvulae are evident as a pair of flattened lobes (*1Vl*) slightly protruding from behind the sternum of the eighth segment; but the third valvulae (*3Vl*) already have the form of small conical processes arising from the posterior part of the ninth sternum. Here, then, we encounter again the same differences in the relations of the valvulae to the sternal plates as was observed in Gryllidae and Tettigoniidae, namely, the origin of the first valvulae behind the sternum of their segment, and that of the third valvulae directly from the sternal plate. At a later stage in the growth of *Melanoplus* (B, C) the first valvulae have become conical processes, and the small second valvulae (C, *2Vl*) have appeared between the bases of the third valvulae. From this stage to that of the adult but few external changes take place in the ovipositor. The intervalvular sclerites are developed medially before and behind the bases of the valvulae of the ninth segment, the ninth sternal region becomes otherwise reduced, while the eighth sternum increases its length and acquires a small median process on its posterior border, which is to be the egg guide. The valvulae take on the form characteristic of the adult, and those of the first and third pairs become densely sclerotic in the mature insect.

The acridid ovipositor is thus seen to be an organ formed entirely of the valvulae, there being no differentiation of valvifers in the coxopodite areas of either genital segment. In the eighth segment the coxopodite areas must lie in the membrane behind the eighth sternum

(fig. 22 A), but they are never apparent as specific structures. The coxopodites of the ninth segment, on the other hand, are evidently contained in the posterolateral parts of the apparent ninth sternum of the very young nymph (A, *IXS*) ; later they appear as distinct membranous lateral areas (C, *IXCxpd*) from which the third valvulae (*3Vl*) project as direct continuations, and from which the small second valvulae (*2Vl*) arise medially as endite lobes. The coxopodite areas remain membranous in the adult. The true sternal region of
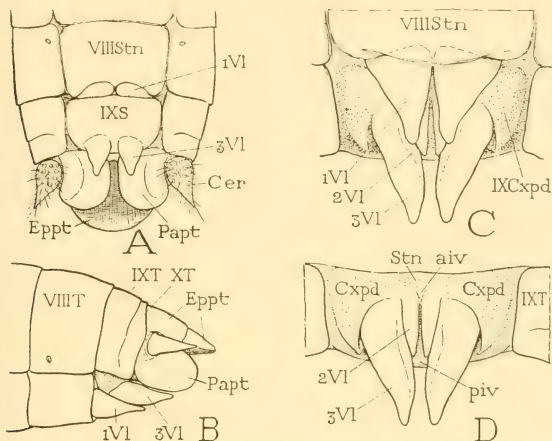
FIG. 22.—Development of the ovipositor of Acrididae.

A, ventral view of end of abdomen of first instar nymph of *Melanoplus*, showing first valvulae as small lobes arising between eighth and ninth sterna, and third valvulae as processes of ninth sternal plate. B, later stage of same, lateral view. C, same as last, ventral view, showing intermediate second valvulae. D, valvulae of ninth segment seen as processes of the coxopodite areas, in which valvifers are not formed in Acrididae.

the ninth segment becomes reduced to a narrow median band between the bases of the valvulae, which includes the areas (D, *aiv, piv*) in which finally will be formed the intervalvular sclerites.

From the above it seems clear that the peculiar feature of the acridid ovipositor is the lack of valvifer sclerites, a conclusion which might be deduced also from the absence of dorsal muscles corresponding with the tergovalvifer muscles of other insects. A different view of the matter, however, has been taken by Nel (1929), who contends that the manner and place of origin of the two first-formed pairs of ovipositor processes leave no doubt that the latter are serially ho-

mologous, while the absence of median lobes between the processes of the eighth segment shows that true gonapophyses are not developed on the gonopods of this segment. Nel concludes, therefore, that the first and third valvulae are developments of the gonocoxae, and that the second valvulae have no morphological equivalents on the eighth segment. As we have seen, however, the valvular processes of the eighth and ninth segments do not have a similar place of origin relative to the sternal regions or plates of their segments, and that a comparison of the development of the ovipositor of Acrididae with that of Gryllidae and Tettigoniidae shows clearly that the elements of the usual ovipositor that are absent in the acridid organ are the valvifers, which are the true representatives of the coxopodites. It may still be difficult to prove that the first valvulae are gonapophyses homodynamous with the second valvulae, and not coxal processes corresponding with the third valvulae; but the identical relations of the first and second valvulae to their respective valvifers in most insects, and the fact that these valvulae constitute the usual blades in the shaft of the ovipositor, to which the third valvulae are mere ensheathing lobes, leaves little basis for questioning the apparent and generally accepted homologies of the ovipositor components. There can be no doubt, at least, that the prongs of the acridid ovipositor correspond with the valvulae of the ovipositor of other insects.

OVIPOSITION

The females of Acrididae lay their eggs in holes made by the ovipositor; most species dig the egg cavity in the ground, a few bore into decayed wood or into the stems of living plants. The ovipositor, therefore, is both an excavating and an egg-laying instrument. In penetrating an even soil the abdomen usually extends downward in a slanting direction from the insect and then turns more or less parallel with the surface of the ground (fig. 23 F); the curvature of the extended abdomen is perhaps attributable to the fact that the protractor muscles of the abdominal sterna (fig. 8, *145-204*) have no dorsal opposition, since the external muscles of the back are transverse in position and give a lateral twist to the segments on one another. The shape of the burrow, however, is subject to much irregularity, especially where ovipositing insects are crowded on a small area, or where obstacles are encountered in the soil. When the abdomen is fully extended it may reach a length two or three times that of its usual retracted condition. The great extension of the abdomen is made possible by the size of the conjunctival membranes ordinarily inflected between the sclerotic parts of the segments (fig. 23 A, E).

The excavation of the egg cavity in the ground and the deposition of the eggs therein have frequently been described in a general way, but the process has been closely studied in the case of *Anacridium aegyptium* by Fedorov (1927), who confined females of this species in cages each having a narrow, glass-walled extension of the floor, 7 mm wide, filled with earth. The diameter of the female's abdomen being 7 mm, the procedure of digging and oviposition could be observed and photographed.

The female grasshopper, according to Fedorov's account, at the beginning of excavation arches her abdomen upward and directs the tip of the ovipositor downward against the soil. The valves of the ovipositor now begin opening and closing, making a hole in the earth, and the ovipositor gradually enters deeper and deeper, while the abdomen extends. The lengthening of the abdomen is accompanied by an unfolding of the conjunctival membranes principally between segments *IV* and *V, V* and *VI,* and *VI* and *VII,* and to a lesser degree of those between segments *III* and *IV,* and *VII* and *VIII.* The segments beyond the eighth do not extend, but are even more closely drawn together than usual. The entire extended abdomen may reach a length of 9 or 10 cm, its ordinary length being about $3\frac{1}{2}$ cm. While digging, the part of the abdomen beyond the sixth segment twists through an angle of 90°, now to one side, now to the other. The entire process of excavating the cavity in suitable earth without special obstacles takes from 1 to $1\frac{1}{2}$ hours. " The whole complex work of digging," Fedorov says, " may be analyzed as consisting of the following simple movements: (1) putting the valves of the ovipositor together, (2) a jerk downward, and (3) opening the valves; apart from that the ovipositor is turned by muscles now to the left, now to the right."

Most observers of ovipositing grasshoppers have been much puzzled to understand the mechanism of the digging apparatus, or particularly the means by which the abdomen is extended to such a great length and apparently with sufficient force to penetrate the earth. Künckel d'Herculais (1894) noted that the fully extended abdomen of *Schistocerca peregrina* has a length of 8 cm, while the retracted abdomen, though filled with eggs, is only 5 cm long. On dissecting specimens with the abdomen protruded at maximum length he found the alimentary canal to contain air; by letting out the air the abdomen could be restored to its ordinary size. Hence he concluded that the digging insects swallow air into the alimentary tract in order to give the abdomen the necessary extension, the surrounding blood serving to regulate the pressure. Contrary to the opinion of most writers,

Künckel d'Herculais says, the muscles play only a secondary rôle in the expansion of the abdomen. It has been suggested also that the abdomen is distended by blood pressure created by a contraction of the thorax, but Grasse (1922) observes that there is no external evidence of any such contraction. A contraction of the tergosternal abdominal muscles might be supposed to extend the abdomen lengthwise, but these muscles could not produce the extreme elongation
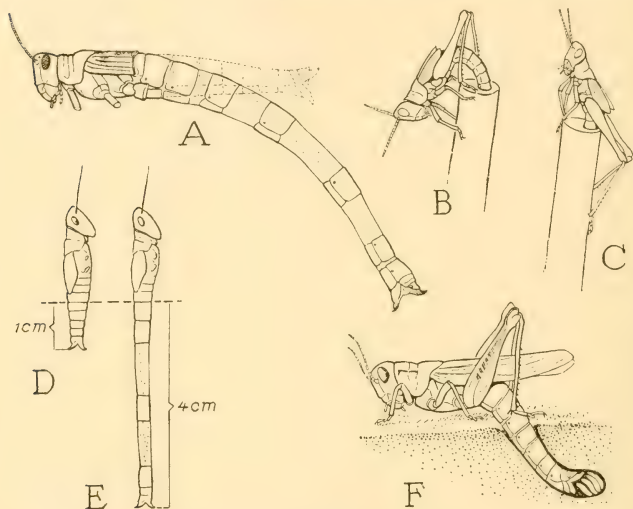
Fig. 23.—Oviposition of Acrididae.

A, *Schistocerca peregrina*, showing extent to which the female abdomen can be pulled out without tearing the conjunctival membranes (from Vosseler, 1905). B, C, two attitudes of *Chrysochraon dispar* ovipositing in cut ends of raspberry stems (from photographs by Ramme, 1927). D, E, diagrams showing relative lengths of retracted and extended abdomen of *Chrysochraon dispar* (from Ramme, 1927). F, grasshopper ovipositing in the ground, showing usual position of abdomen (from Walton, 1916).

attained during the digging process. Grasse maintained that the explanation of Künckel d'Herculais is correct, since he was able to demonstrate the extension of the abdomen by gently inflating the alimentary canal with a pipette inserted into the mouth of the insect and ligatured in the oesophagus through a hole at the back of the head. However, a different explanation of the abdominal extension has been proposed by Fedorov (1927), who says: " When the abdomen is fully extended it becomes obvious that the expansion is due to the air-sacs;

one can see that the rhythmical movements of the abdomen, which apparently facilitate the work of the spiracles, result in the filling of the sacs with air, in their expansion and in the expansion of the abdomen." In his summary Fedorov definitely states: " Inflation of the air-sacs is the cause of the expansion of the abdomen."

Without having made more than casual observations on egg-laying female grasshoppers, the writer, after studying carefully the mechanism of the ovipositor, has no hesitation in saying that the above explanations of the extension of the abdomen during the digging process are not only highly improbable, but are quite unnecessary. It is true that the muscles of the abdomen are entirely inadequate to distend the telescopic abdominal tube to the length observed, and, as we have seen, the protractor muscles that are present are limited to the sternal region. Furthermore, the writer has frequently observed that females of *Dissosteira carolina* taken in late summer and fall have all the muscles of the visceral part of the abdomen in a very lax and apparently semidegenerate condition, contrary to what is found in the male. There is no reason to doubt the observations of Künckel d'Herculais that the alimentary canal contains air during the digging process, or that of Grasse that an inflation of the food tract will distend the abdomen ; nor is there any reason to question the statement of Fedorov that the air sacs become expanded as the abdomen lengthens. It is, however, quite too much to believe that the observed inflation of the alimentary canal or of the air sacs could be the means by which the abdomen is thrust out with sufficient pressure against the ovipositor to drive the latter into the ground. Insects can and do swallow air in sufficient amount to distend the body, as in moulting, but there is no demonstrated mechanism by which they can pump air into the air sacs and distend these delicate vesicles against any considerable opposing pressure.

An examination of the mechanism of the grasshopper's ovipositor shows that the latter is an organ fully competent to dig its own way into the ground ; it is a boring machine, which, once set in motion with its prongs against the soil, must automatically bury itself, and in so doing it will stretch the easily extended abdomen to its full capacity, so long as the insect maintains its hold on the surface of the ground. There is thus no question of the abdomen forcing the ovipositor into the earth ; the ovipositor digs the hole and pulls the abdomen in after it. The extension of the abdomen undoubtedly involves a distention of the air sacs, and is probably facilitated by an active swallowing of air on the part of the insect ; in fact, if the abdomen is actually increased in bulk by the drawing apart of its seg-

ments, it becomes a matter of necessity that there should be a compensation from some source, and the expansion of the air sac would take place automatically as in the inspiratory phase of breathing. The observed filling of the stomach and air sacs with air, therefore, is certainly not the active cause of the elongation of the abdomen; it seems much more probable that the inflation of these organs, followed by a closure of the mouth and spiracles, serves to maintain the extension of the abdomen when the valvulae of the ovipositor are closed, since the latter has then no means of holding its position in the earth.

If we consider the several digging movements of the ovipositor concisely enumerated by Fedorov, we can readily correlate them with muscles in the motor apparatus. The preliminary closing of the valvulae is effected by the muscles of the anterior intervalvula (fig. 17 D, C, *247, 273*); the downward thrust must be produced by the protractors inserted on the ends of the lateral apodemes (C, *256, 262*); the opening of the valvulae is the work of the powerful levators and depressors (A, B, *271, 272*); the twisting movements of the abdomen are accomplished by the transverse outer dorsal muscles between the successive tergal plates (fig. 11 B, C). In addition to these muscles there are the lateral retractors of the dorsal valvulae (fig. 17 C, *263*), evidently capable of pulling the ovipositor back into the genital segments. The muscular equipment of the ovipositor, therefore, is such that there is no need to invoke any other mechanism to account for the operation of the digging apparatus and the stretching of the abdomen than that of the ovipositor itself.

Species of Acrididae known to oviposit in dead wood or in the stems of plants include *Chloealtis conspersa* Harris of North America, and *Chrysochraon dispar* Germ. of Europe. Females of *Dissosteira carolina* are often to be seen along railroad tracks with the end of the abdomen inserted into a decayed part of a tie, though, so far as the writer knows, there is no record of their eggs being deposited in such places.

Chloealtis conspersa is said by Scudder (1874) to select for oviposition short sticks of decaying, charred, or pithy wood, but never to choose upright pieces of timber. " The holes," Scudder says, " are pierced at a slight angle to the perpendicular, away from the insect; they are straight for about a quarter of an inch, then turn abruptly and run horizontally along the grain for about an inch. The eggs (from 10 to 14 in number) are almost always laid in the horizontal portion of the nest." Blatchley (1920) also records observations on the wood-excavating habits of the same species. One female he discovered in

the act of boring a hole in the upper edge of the topmost board of a six-plank fence. " The abdomen," he says " was curved downward, and the toothed forcipate valves of the ovipositor used as pincers with which small pieces of wood were broken off." Within a distance of 30 feet on the top boards of the same fence, which were perfectly sound pine, he found 15 other holes, but none of them contained eggs, the wood apparently being too hard for the proper completion of the borings. Cavities made in stumps and logs, however, were found to have eggs in the horizontal part of each.

The oviposition habits of *Chrysochraon dispar* have been recorded by Ramme (1927), who says that all nests found in the neighborhood of Berlin except one were in stems of raspberry bushes, though other observers report finding them in rotten poplar stumps and in broken stems of *Angelica sylvestris*. Ramme studied the insects in cages, where they were supplied with short pieces of raspberry stems stuck into moist sand. A female about to oviposit, he says, crawls up a stem; reaching the cut top she examines the pith with her antennae, and then climbs over the top and down the opposite side a short distance. As soon as the ovipositor touches the pith it begins digging into the latter, and soon forms a hole in which the end of the abdomen disappears (fig. 23 B); deeper and deeper it sinks until after a half hour or an hour the cavity is completed (C). Woody as well as fresh stems are accepted. When the boring is finished, the abdomen is buried to the fourth or at least to the middle of the fifth segment (E). The length of the abdomen beyond this point is ordinarily only 1 or $1\frac{1}{4}$ cm (D), but during the digging process it may be stretched to a length of 4 cm. In cages Ramme found that the insects were unable to penetrate the stems unless they had access to the cut tops of the latter, from which he concludes that in nature they must use injured or broken canes. In each nest 12 to 30 eggs are deposited, placed obliquely one above the other.

The action of the ovipositor in manipulating the eggs issuing from the oviduct has not received as much attention from students of acridian behavior as have the processes of digging and oviposition. Judging from the anatomical relation of the gonopore to the egg guide and the ovipositor (fig. 20 A), it is clear that an issuing egg must be conducted by the egg guide posteriorly and upward between the bases of the free parts of the ventral valvulae. The eggs are normally so oriented in the oviduct that the anterior pole (the head end of the future embryo) is anterior; the protruding egg, therefore, has its posterior pole directed posteriorly and upward. Riley (1878) says the

newly emerging egg is received between the closed valvulae, and he figures it as being extruded upward and posteriorly from between the dorsal valvulae; at least, he assures us, this is what we should see " if we could manage to watch a female " during oviposition. If the female grasshopper habitually curves the end of her abdomen forward, as shown in Riley's familiar illustration, the eggs extruded in this way would naturally take the proper position in the nest with their anterior ends upward and sloped toward the exit. Most studies of the egg cavity, however, show that the burrow, when unobstructed, extends obliquely downward and backward from the insect. In this case the eggs must be tilted in a direction opposite that of their first position, namely, with the anterior pole upward and forward, if the young grasshopper is to have an easy escape from the nest.

Observations by Giardina (1901) on the extrusion of the eggs by females of *Pamphagus marmoratus*, which oviposited on the bottoms of cardboard boxes in which they were confined, seem to show that each egg is revolved through an angle of 45° as it leaves the ovipositor. Giardina observes that each egg issuing from the oviduct is conducted by the egg guide posteriorly and upward into the ovipositor, where it is at first received and held in this position between the ventral valvulae; but at this time the upper and lower valvulae are wide open, and the prongs of the lower valvulae are somewhat separated. Now, however, the valves suddenly close, and the egg is thrust between the dorsal valvulae, where it remains suspended until the arrival of the next egg, which causes the first to take a horizontal position with the posterior pole directed backward. Finally, with the advent of a third egg, the first, already liberated from the ovipositor, receives another push, which tilts it into a third position in which the anterior pole is directed upward and forward, *i. e.*, obliquely toward the upper wall and the exit of the nest (fig. 23 F).

The issuing eggs are always accompanied by a large amount of viscous frothy material, which soon hardens and forms the much-vacuolated mass enclosing the eggs, known as the " egg pod." The foamy nature of the egg covering is said to be imparted to the liquid fresh substance by movements of the valvulae. The female Acrididae lack the usual accessory glands of the genital apparatus that ordinarily form whatever adhesive or covering material is extruded with the eggs; the substance of the acridid egg pods is produced in long glandular diverticula of the anterior ends of the large calyces of the lateral oviducts, and is discharged with the eggs through the gonopore.

VI. THE EXTERNAL MALE GENITALIA

The external genital structures of the male are so different in the grasshoppers from these organs in other Orthoptera that little attempt will be made here to establish homologies between the acridid organs and the various types of genital structures found in the other orthopteroid families. Walker (1922) has presented a plausible though theoretical scheme for tracing the evolution of the male organs in the Orthoptera, and his ideas will be discussed in a future, more general paper. The acridid genitalia have been but little studied from a comparative standpoint, and only one writer (Hubbell, 1932) has attempted to make use of their characters for taxonomic purposes. The basic structure of the organs is surprisingly alike throughout the family, but there can be no doubt that distinctive specific variations are well marked in many cases.

GENERAL STRUCTURE OF THE MALE GENITALIA IN ACRIDOIDEA

The terminal part of the adult male abdomen in both Acrididae and Tetrigidae is characterized by a great enlargement of the ninth sternum, and by a partial or complete separation of the latter into a proximal part and a distal part that are more or less movable on each other (figs. 27 A, 33 A, 35 A, 36 B, 39 A, *IXS, IXSL*). The proximal sternal plate (*IXS*) may be designated the ninth sternum proper; the distal lobe (*IXSL*) is the male subgenital plate. Styli are absent in all Acridoidea, but if they were present on the ninth abdominal segment they undoubtedly would be carried by the genital lobe of the sternum, and for this reason the lobe is sometimes regarded as representing the united coxopodites of the ninth segment. Since, however, in the young male nymph there is no suggestion of the later division of the ninth sternum, it seems probable that the two sternal plates of the adult are the result of a secondary subdivision of the usual coxosternum of the ninth segment without reference to its more primitive composition.

The subgenital lobe of the ninth sternum is usually turned upward on the end of the proximal plate, and its dorsal margin may be tightly closed against the lobes of the eleventh segment (figs. 29 A, 30 A, 34 A). More generally, however, there is continued forward from the free margin of the subgenital plate a thick membrane, the pallium (fig. 33 A, *Pal*), which presents a rounded or hoodlike dorsal surface closing the space between the upper end of the genital plate and the eleventh segment. Behind the latter the pallium is always deeply inflected to form the posterior wall of the genital chamber (fig. 24 A,

Pal'). In the Tetrigidae the exposed dorsal part of the pallium forms a long valvelike flap containing two elongate plates (fig. 27 A, B, *Pll'lv*). In *Tettigidea* the plates are separated by a median membranous line (B), but in *Acrydium* and *Paratettix,* according to Walker (1922), the pallial valve is armed between the plates with a pair of bars terminating anteriorly in upcurved hooks.

The male genital chamber of the Acrididae (fig. 24 A, *GC*) has the usual relations of the male genital pouch to the ninth and tenth
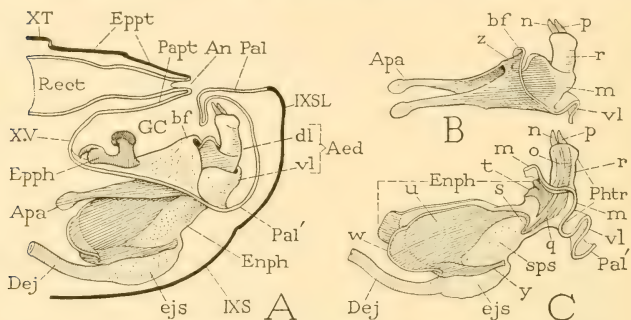
FIG. 24.—Diagrams showing the general structure of the male genitalia of Acrididae.

A, vertical longitudinal section of end of male abdomen somewhat to left of median plane, showing the organs contained in the genital chamber (*GC*), and the endophallus (*Enph*) projecting into the body cavity. B, the aedeagus and its basal apodemes. C, the aedeagus and endophallus.

Aed, aedeagus; *An,* anus; *Apa,* aedeagal apodeme; *bf,* basal fold; *Dej,* ductus ejaculatorius; *dl,* dorsal lobe of aedeagus; *ejs,* ejaculatory sac; *Enph,* endophallus; *Epph,* epiphallus; *Eppt,* epiproct; *GC,* genital chamber; *IXS,* sternum of ninth abdominal segment; *IXSL,* genital lobe of ninth sternum; *Pal,* pallium; *Pal',* inner fold of pallium; *Papt,* paraproct; *Phtr,* pallotreme (external opening of endophallus); *Rect,* rectum; *sps,* spermatophore sac of endophallus; *vl,* ventral lobe of aedeagus; *XT,* tergum of tenth abdominal segment; *X.V,* venter of tenth segment. (For alphabetical lettering see fig. 25.)

abdominal segments—that is, it is an invagination cavity between the end of the ninth sternum and the venter of the tenth segment. Owing to the vertical position of the subgenital plate, however, and the forward extension of the pallium from the latter, the opening of the cavity is dorsal between the eleventh segment and the inflected margin of the pallium. The anterior part of the genital chamber is covered by the ventral walls of the tenth and eleventh segments, the posterior part by the hood of the pallium. The floor of the chamber usually slopes downward posteriorly from the venter of the tenth segment (*X.V*) to the base of the inner pallial fold (*Pal'*).

The phallic organs of the Acrididae consist of a complex of structures arising from the floor of the genital chamber (fig. 24 A), and ordinarily they are entirely enclosed within the genital chamber. Posteriorly is the intromittent organ, or *aedeagus* (*Aed*), which has an upright position and is lodged in the pocket beneath the pallial hood. In front of the aedeagus is a broad sloping area of the genital chamber floor, often rounded and elevated, which rises posteriorly in a prominent transverse *basal fold* (*bf*) that more or less conceals the proximal part of the aedeagus. In the anterior pocket of the genital chamber, seated transversely on the floor of the latter beneath the venter of the tenth abdominal segment, is the *epiphallus* (*Epph*), a large irregular sclerite characteristic of the Acrididae.

The aedeagus (fig. 24 A, *Aed*) is a complex organ, somewhat variable in the relative size and shape of its parts in different genera, but having a constant basic structure that can be recognized in all cases without difficulty. It consists essentially of an irregular dorsal lobe (*dl*), and of a simple ventral lobe (*vl*). Because of the vertical position of the organ the dorsal lobe is anterior and the ventral lobe posterior. These two principal parts of the acridid aedeagus are apparently to be identified with corresponding lobes of the intromittent organ in Tettigoniidae; the ventral lobe is the most constant structural feature of the diverse copulatory apparatus of Blattidae, Mantidae, Tettigoniidae, and Gryllidae, since it always has the form of a soft or partly sclerotized flap projecting below the external genital opening. In the Acrididae the outer genital aperture, or *phallotreme,* is a vertical cleft in the entire length of the ventral (posterior) surface of the dorsal lobe of the aedeagus (figs. 24 C, 37 C, *Phtr*), but the ventral lobe (*vl*) projects beneath its proximal part, and thus has the same relation to the genital opening as has the corresponding lobe in the families above mentioned.

The dorsal lobe of the aedeagus is divided typically into a broad proximal part (fig. 24 B, *m*), and a smaller, usually cylindrical distal part (*r*), from the end of which there project two pairs of apical processes (*n, p*). In some forms, however, the distal part of the aedeagus is small or absent, and in such cases the apical processes are generally relatively large (fig. 31 C) and are carried directly by the proximal part (*m*). The distal part of the dorsal lobe is best developed in the Cyrtacanthacrinae (fig. 37 A). Both the distal and the proximal parts of the dorsal lobe are deeply cleft posteriorly by the phallotreme (figs. 24 C, 37 C, *Phtr*), which invades the extremity of the organ between the apical processes, and extends proximally to the base of the ventral lobe.

5

The lateral walls of the proximal part of the dorsal aedeagal lobe (fig. 24 B, m) are usually strongly sclerotized and are often produced dorsally in a pair of rounded lobes. The lateral sclerotizations are continued anteriorly into a pair of large aedeagal apodemes (Apa) invaginated in deep lateral pockets beneath the basal fold (A, B, bf) that arches over the base of the aedeagus. Within the dorsal part of this fold, in the wall of its ventral lamella, the bases of the apodemes are solidly united with each other by a strong, transverse sclerotic bridge, or *zygoma* (B, z). The aedeagal apodemes are the " endapophyses " of Walker (1922), and the zygoma the " arch of the endapophyses." The aedeagal apodemes give attachment to muscles inserted on the walls of the endophallus.

The ventral lobe of the aedeagus has the form of a broad trough-like fold (fig. 24 A, vl), usually membranous though sometimes more or less sclerotized, extending upward from the floor of the genital chamber at the base of the inner fold of the pallium (Pal'), and closely embracing the base of the dorsal lobe of the aedeagus. It thus conceals the lower part of the phallotreme. The ventral aedeagal lobe is termed the " subventral lobe " by Walker (1922).

The most highly developed and characteristic feature of the acridid phallic apparatus is a large endophallic structure deeply invaginated from the phallotreme into the ventral part of the ninth abdominal segment (fig. 24 A, C, $Enph$). The walls of the *endophallus* are covered by broad plaques of muscle fibers, which give the structure the appearance of a strong muscular bulb (fig. 25 C, E, F). It is necessary to remove these muscles in order to study the skeletal details of the endophallus as presented in the following descriptions.

The long, vertical, slitlike phallotreme opens directly into a laterally compressed cavity of the dorsal lobe of the aedeagus. At the base of the latter this open cleft passes into a short tubular meatus, which leads into a large inner chamber of the endophallus. In each lateral wall of the phallotreme cleft are two elongate parallel sclerites (fig. 24 C, o, q), from the outer ends of which project the external apical processes (n, p). The dorsal (anterior) sclerites (o) end proximally in the meatus, where they are connected with each other by a strong transverse arch (t) in the dorsal wall of the passage. The ventral (posterior) sclerites (q) extend proximally beyond the dorsal sclerites a short distance, where they become much narrowed, and then each makes an abrupt sigmoid flexure (s) dorsally in the lateral wall of the meatus, beyond which it expands anteriorly as a large plate (u) in the lateral wall of the endophallic chamber. The anterior end of each lateral endophallic plate is produced beyond the lumen of the
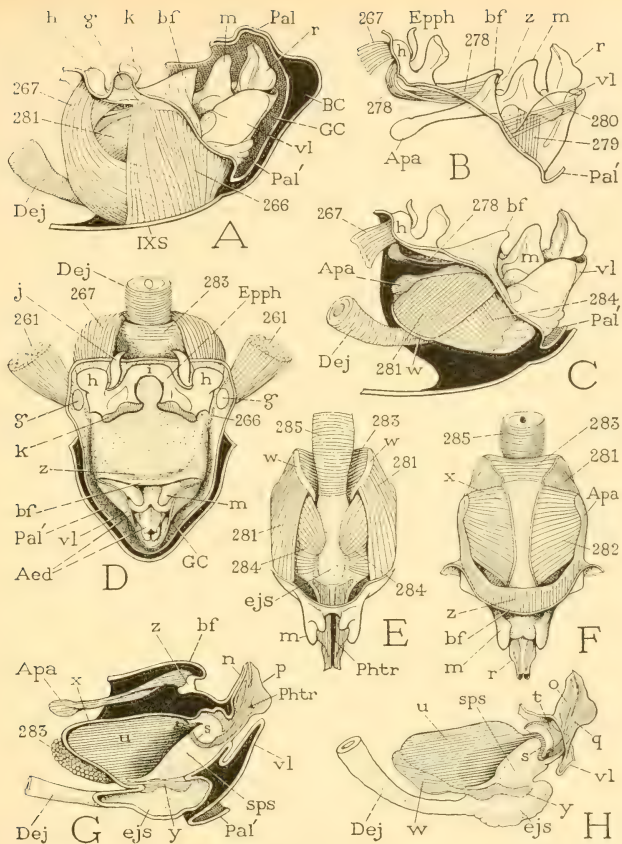
FIG. 25.—Male genitalia of *Dissosteira carolina*.

A, the phallic organs exposed by removal of tenth and eleventh segments and dorsal and lateral parts of ninth segment. B, lateral view of epiphallus and aedeagus with supporting floor of genital chamber. C, lateral view of phallic organs after removal of muscles *266* and *267* (A), showing muscles of endophallic bulb. D, dorsal view of phallic organs and floor of genital chamber. E, aedeagus and endophallic bulb, ventral view. F, same, dorsal view. G, median section of aedeagus and endophallus, with terminus of ejaculatory duct. H, lateral view of endophallus, distal part of aedeagus, and terminus of ejaculatory duct, muscles removed.

For abbreviations, see fig. 24. *g*, sclerites giving insertion to retractor muscles (*261*); *h*, lateral lobe of epiphallus; *i*, bridge of epiphallus; *j*, anterior process of epiphallus; *k*, posterior process of epiphallus; *m*, proximal part of dorsal lobe of aedeagus; *n*, anterior (dorsal) apical process of aedeagus; *o*, anterior (dorsal) lateral sclerite of phallotreme cleft; *p*, posterior (ventral) apical process of aedeagus; *q*, posterior (ventral) lateral sclerite of phallotreme cleft; *r*, distal part of dorsal lobe of aedeagus; *s*, arm of posterior phallotreme sclerite (*q*) continuous with endophallic plate (*u*); *t*, bridge of anterior phallotreme sclerites (*o*); *u*, lateral plate of endophallus; *w*, anterior apodeme of endophallic plate; *x*, dorsal edge of endophallic plate; *y*, gonopore process of endophallic plate; *z*, zygoma of aedeagal apodemes.

65

endophallus as a broad apodeme (w) for muscle attachments. The endophallic plates are the " endoparameres " of Walker (1922), who believes that they are representatives of external or variously invaginated plates or processes ("parameres") of other Orthoptera. By comparison with Tettigoniidae it does appear probable that the endophallus of Acrididae is produced as an invagination of the posterior surface of the dorsal lobe of the aedeagus.

The cavity of the endophallus is mostly a narrow vertical space between the lateral endophallic plates, but its posterior membranous part, somewhat expanded behind the oblique posterior margins of the lateral plates, forms a distinct section of the lumen, and may be designated the *spermatophore sac* (fig. 24 C, *sps*). The ejaculatory duct (Dej) opens into the ventral part of the spermatophore sac through a terminal *ejaculatory sac* (*ejs*). The aperture between the two sacs is the true *gonopore*. Dorsally the spermatophore sac communicates with the phallotreme cleft in the dorsal lobe of the aedeagus through the meatus at the base of the latter. From the lower anterior angle of each lateral endophallic plate a long process (y) projects backward in the membranous connecting wall between the spermatophore sac and the ejaculatory sac. The two processes thus closely embrace the gonopore (fig. 29 E, F, fig. 33 C), and, as will be shown later, by the action of the endophallic muscles they regulate the opening and closing of the gonopore. Lateral vesicles of the ejaculatory sac, such as are present in most other Orthoptera, are absent in the Acrididae.

The curious sclerite known as the epiphallus is a very prominent feature of the acridid genitalia. It is situated on the floor of the anterior pocket of the genital chamber beneath the venter of the tenth and eleventh segments (fig. 24 A, Eph), and is separated from the aedeagus by the sloping surface that culminates posteriorly in the hoodlike fold (bf) covering the base of the aedeagus. The morphological nature of the epiphallus is doubtful, since the sclerite cannot be satisfactorily identified with any part of the phallic structure in other insects. The plate is termed the " pseudosternite " by Walker (1922) and by Ford (1923). It has muscular connections both with the ninth sternum and with the zygoma of the aedeagal apodemes. In form the epiphallus is an irregular transverse sclerite (fig. 31 B) consisting of two expanded lateral lobes (h, h) connected by a narrow median bridge (i). Anteriorly the lateral lobes bear a pair of hooklike processes (j) directed forward, and posteriorly each is produced upward in a large thick irregular transverse process (k). Closely associated with the epiphallus laterally are two small oval

sclerites (*g*) in the floor of the genital chamber (figs. 25 D, 33 B, 35 B), on which are inserted strong muscles (*261*) from the lateral parts of the ninth abdominal tergum.

The aedeagus is ordinarily entirely concealed within the posterior part of the genital chamber beneath the hood of the pallium (fig. 24 A). In the protracted condition, however, the organ is exposed by a retraction of its coverings (fig. 33 B). The genital lobe of the ninth sternum (*IXSL*) is now depressed, and the pallium is turned inside-out, appearing in this condition as a large posterior fold (*Pal*) around the base of the aedeagus, while the basal fold of the genital chamber floor (*bf*) correspondingly embraces the aedeagus anteriorly; the epiphallus (*Epph*) has emerged from its pocket beneath the eleventh segment, and stands boldly exposed on the projected floor of the genital chamber anterior to the ensheathing folds of the aedeagus.

The exsertion of the phallic organs would appear to be accomplished by pressure resulting from a contraction of the pregenital part of the abdomen, since there are no muscles connected with the genital organs capable of producing the protracted condition of the latter (fig. 33 B). The aedeagus apparently is held in the position of retraction by a broad sheet of muscles on each side (fig. 25 A, *260*) arising medially on the ninth abdominal sternum and attached dorsally on the lateral margins of the genital chamber floor. To be exserted, the aedeagus must first be drawn forward from the pocket of the pallium; its release from the latter evidently is effected by the contraction of the strong muscles (D, *261*) inserted on the small sclerites (*g*) at the sides of the epiphallus, which take their origins on the lateral parts of the ninth tergum. The epiphallus itself is provided with a pair of large muscles (A, *267*) arising medially on the ninth sternum, which curve upward around the anterior end of the endophallic bulb and insert on the lateral lobes (*h*) of the epiphallus. It is probable that a contraction of these muscles brings about an elevation of the distal parts of the phallic apparatus, and that pressure from within the abdomen then protrudes the aedeagus. A second pair of epiphallic muscles (B, *278*) arises posteriorly on the zygoma of the aedeagal apodemes and extends anteriorly to the lateral lobes of the epiphallus. The action of these muscles is not clear, but the muscles undoubtedly play some part in the function of the epiphallus in copulation.

The following description of the musculature of the aedeagus and endophallus is based on a study of *Dissosteira carolina*, but a cursory examination of the other species suggests that the musculature and mechanism of the acridid male organs are the same throughout the family.

Two pairs of small muscles lie within the aedeagus, both arising within the base of the latter (fig. 25 B) ; those of one pair (*279*) extend dorsally to the lateral plate (*m*) in the proximal part of the dorsal lobe, those of the other pair (*280*) are attached distally on the ventral lobe. The other muscles of the aedeagus include the epiphallic muscles (*278*) already mentioned, which arise on the zygoma of the apodemes, and muscles that functionally pertain to the endophallus.

The endophallus is mostly ensheathed in broad muscle plaques, which make of the organ a strong muscular bulb, into which opens the ejaculatory duct. The endophallic musculature comprises dilator
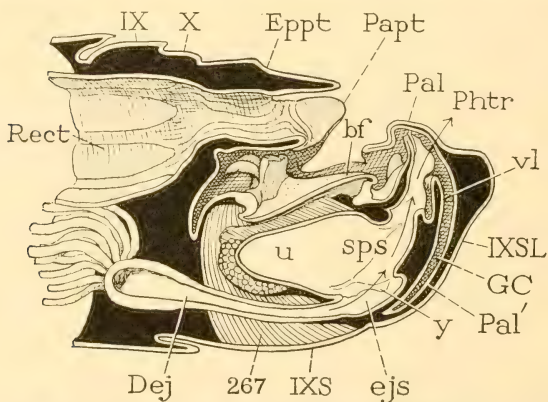
Fig. 26.—Median vertical section of the end of the male abdomen of *Dissosteira carolina* showing the retracted position of the phallic organs.

and compressor muscles of the endophallus, and compressors of the ejaculatory sac. The dilators of the endophallus include a pair of lateral muscles (fig. 25 C, E, *281*) and a pair of dorsal muscles (F, *282*). The lateral dilators are wide sheets of muscle fibers arising dorsally on the aedeagal apodemes (C, *Apa*), and extending ventrally and anteriorly to the outer surfaces of the anterior apodemes of the lateral endophallic plates (C, E, *w*). The dorsal dilators, which likewise are broad sheets of fibers (F, *282*), arise laterally on the inner margins of the aedeagal apodemes and are inserted mesally on the dorsal margins (*x*) of the endophallic plates. The single compressor muscle of the endophallus consists of a thick mass of fibers stretched transversely over the anterior end of the endophallic bulb (E, F, G, *283*)

between the inner faces of the anterior apodemes of the lateral plates. The compressors of the ejaculatory sac are broad plaques of fibers closely applied to the lateral walls of the endophallus (C, E, *284*); each arises on the entire outer wall of the lateral endophallic plate, and its fibers converge ventrally to their insertions on the lateral wall of the ejaculatory sac. In some cases a distinct branch of this muscle takes its origin on the endophallic apodeme (fig. 29 C, *284a*). The ejaculatory duct has a strong sheath of circular fibers (fig. 25 E, *285*) extending to the membranous terminal sac.

The function of the endophallic muscles is to regulate the gonopore, *i. e.*, the aperture of the ejaculatory sac into the spermatophore sac, and to drive the spermatophores through the gonopore, through the spermatophore sac of the endophallus, and through the phallotreme cleft of the aedeagus. If the endophallic cavity is opened from above by cutting its dorsal wall, and the lateral plates are spread apart (fig. 33 C), the slitlike gonopore (*Gpr*) is to be seen in the floor of the spermatophore sac between the posterior ends of the convergent gonopore processes (*y*) of the lateral plates. The gonopore processes are hinged to each other by points of contact just before the anterior end of the gonopore; as a consequence, an approximation of the endophallic plates, produced naturally by a contraction of the muscle between their anterior apodemes (fig. 25 E, F, *283*), results in an opening of the gonopore.

The endophallic mechanism is well illustrated in *Mermiria maculipennis* (fig. 29 E, F). When the lateral plates are separated, as in the ordinary state (E), the gonopore (*Gpr*) is closed to a narrow slit; but when the plates are brought together (F) the gonopore becomes a widely open aperture. Immediately beneath the gonopore is the membranous ejaculatory sac (fig. 25 G, H, *ejs*), which is a terminal enlargement of the ejaculatory duct. The compressor muscles inserted on the lateral walls of the ejaculatory sac (C, E, *284*) probably contract in unison with the compressor muscle of the endophallic plates, and force the spermatophore from the ejaculatory sac through the open gonopore into the spermatophore sac. The passage of the spermatophore through the spermatophore sac is not so easily explained, in the absence of direct observations on the action of the endophallic apparatus, and it seems probable that the endophallic muscles must produce movements of the endophallic walls other than those concerned with the opening and closing of the gonopore and the compression of the ejaculatory sac described above.

The male genitalia of the Tetrigidae, by comparison with the acridid organs, are not only very simple in structure, but, as observed

by Walker (1922), they " are surprisingly unlike those of the Acridi-
dae." The phallus of *Tettigidea lateralis* (fig. 27 D) consists of a
low ovate elevation on the floor of the genital chamber beneath the
pallial valve (C). Sclerites in the lateral walls of the organ converge
and unite anteriorly in a median process armed with small spines.
Between the lateral plates is a large, widely open, membranous cavity,
into the bottom of which the ejaculatory duct opens anteriorly (D,
Gpr). The posterior wall of the cavity is directly continuous with
the inner membranous fold of the pallium (*Pal'*). The ejaculatory
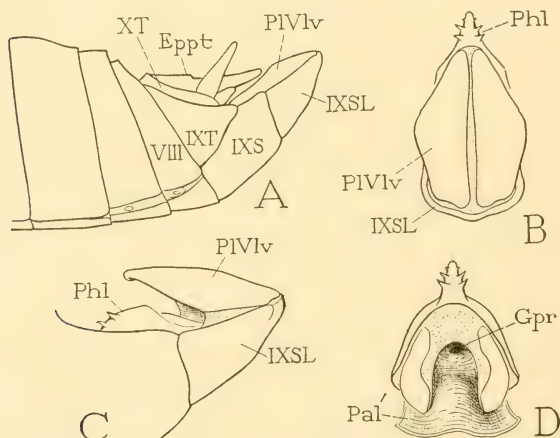
Fig. 27.—Abdomen and male genitalia of *Tettigidea lateralis* (Tetrigidae).

A, terminal part of abdomen. B, dorsal view of pallial valve (*PlVlv*) and
anterior process of phallic organ. C, lateral view of ninth sternum and pallial
valve, with phallic organ exposed beneath the latter. D, the phallic organ, dorsal
view, with base of inner pallial fold.

duct has strongly muscular walls, and groups of muscle fibers arising
on the phallic sclerites are inserted on its terminal part. Coition is
probably effected by evagination of the endophallic sac. According
to Walker the external phallic plates of the tetrigid organ represent
the epiphallus (" pseudosternite ") of the Acrididae; but the attach-
ment of the ejaculatory muscles upon them would make it seem more
probable that they are external representatives of the invaginated
endophallic plates of the Acrididae. These plates, Walker himself
contends, are derived from external plates or processes (" para-
meres ") of other Orthoptera.

It is thus rather curious to find that, while the external parts of the male tetrigid abdomen (fig. 27 A) present the typical acridian characters, the structure of the phallic organs should have so little in common with these organs in the Acrididae. The male organs of Tridactylidae, furthermore, are entirely different from those either of the Tetrigidae or the Acrididae, which fact again is surprising considering the close resemblance of the female ovipositor in all three of these families. The lack of uniformity in the male organs, as compared with the female organs, suggests that the common basic structure of the phallus is something less fundamental than is that of the ovipositor.

COPULATION, AND INSEMINATION OF THE FEMALE

Preliminary to copulation the male grasshopper places himself well forward on the back of the female. With his fore legs he clasps the pronotum of the female, the claws holding at the notch in the anterior margin of the prothorax between the pronotum and the small exposed part of the episternum; the intermediate legs clasp the middle of the female's body; the hind legs are held in various positions and take little part in the copulatory act. The male then lowers his abdomen along the side of the female's abdomen (in pictures almost invariably on the left side, but Boldyrev says, sometimes on the left, sometimes on the right). The genital lobe of the ninth segment of the male is now depressed and the phallic organs protruded, the dorsal lobe of the aedeagus being turned upward and forward. In order to expose the spermathecal aperture of the female, which receives the end of the male organ in copulation, the male, as described by Boldyrev (1929) for *Locusta migratoria*, depresses the subgenital plate of the female with the anterior hooks of the epiphallus. The penis is then introduced into the genital chamber between and beneath the ventral valves of the ovipositor and is inserted into the spermathecal canal. In *Locusta migratoria*, according to Boldyrev, the separation of the lower valves of the ovipositor by the organ of the male stretches the dorsal wall of the genital chamber and pulls back the folds that ordinarily conceal the spermathecal opening; the latter is now " opened wide and the penis is plunged into it right up to its base." The penis, or dorsal lobe of the aedeagus, in *Locusta migratoria* is long, slender, and tapering (fig. 32 B) ; in forms in which the terminal part is short and thick, as in *Melanoplus* (figs. 37, 38, 40), it seems hardly possible that the entire organ can be inserted ; probably in such cases only the apical processes enter the spermathecal orifice. During copulation the cerci of the male are said to grasp the base of the subgenital

plate of the female, while the distal part of the plate is held down by the epiphallus.

Paired grasshoppers remain thus together for a number of hours, or for a day or more, in some cases for more than two days, the duration of copulation apparently being determined by the length of time necessary for the formation of the spermatophore, or spermatophores, and the transference of the latter to the female, or by the number of spermatophores produced. Individuals of each sex may have several successive matings.

It is now well established for the Acrididae that during copulation the spermatozoa are transferred from the male to the female in true spermatophores, which, as defined by Cholodkowsky (1910), are sperm-containing capsules *formed in the genital passage of the male*. In some cases only a single spermatophore is produced at each mating, which, with one end remaining in the genital passage of the male and the other inserted well into the spermathecal duct of the female, forms a conduit from one individual to the other through which the sperm are discharged by the action of the endophallic apparatus of the male; in other cases a number of small spermatophores are injected into the female. The spermatozoa, as in Tettigoniidae and Gryllidae, are united by their head ends in bundles, or spermatodesmata.

The spermatophores of *Locusta migratoria* and their formation have been studied by Iwanowa (1926), Sokolow (1926), and Boldyrev (1929). It appears that normally only one spermatophore is produced by this species at a single mating. Iwanowa reports finding sometimes three or four spermatophores in the receptaculum of the female, but Boldyrev gives evidence that insemination is accomplished properly with one spermatophore, and that if the male attempts to insert a second into the spermathecal orifice the process is not natural and cannot result in the discharge of the spermatozoa.

A spermatophore of *Locusta migratoria*, as described and figured by Boldyrev (fig. 32 D), is an elongate structure with transparent walls, consisting of a proximal sac constricted into two bladderlike compartments, and of a long slender distal tube. The length of the entire spermatophore is usually 25 to 27 mm, but it may reach 29 or 30 mm. The spermatophore thus greatly exceeds the length of the intromittent organ (fig. 32 B), since the latter measures not more than 5 or 6 mm from the gonopore at the bottom of the spermatophore sac of the endophallus (*sps*) to the tips of the apical processes of the aedeagus. Only the distal tubular part of the spermatophore is introduced into the spermathecal canal. The extrusion of the tube,

Boldyrev says, requires an hour or more, and the discharge of the sperm is not completed until $5\frac{1}{4}$ to 18 hours after copulation begins, the time apparently being dependent on the temperature. On opening the genital organs of males killed during copulation, Boldyrev found that the first bladder of the spermatophore is held in the ejaculatory sac (fig. 32 B, *ejs*), while the second lies in the membranous part of the endophallic cavity here termed the spermatophore sac (*sps*). The long spermatophore tube extends through the phallotreme cleft and protrudes forward from the distal end of the aedeagus between the bases of the anterior apical processes (C) ; in copulation it is deeply inserted into the spermathecal duct. During mating the two sexes are thus united by a tubular conduit through which the sperm are driven by the action of the endophallic apparatus from the male into the female. At the end of copulation the spermatophore tube is not drawn out of the female, but is broken off near its base. The detached tube is retained a long time in the spermathecal canal; the basal part of the spermatophore is soon rejected from the male.

With *Anacridium aegyptium,* as shown by Fedorov (1927), insemination of the female is accomplished by the introduction of from 6 to 30 spermatophores into the spermatheca, the usual number being from 12 to 18. In this species, however, the spermatophores are of relatively small size, about 1 mm in length. Each capsule is a hyaline body, broader at the anterior end, which bears a small appendage easily broken off. The spermatophores are formed in the beginning of the ejaculatory duct, but they do not attain their final shape until they reach the terminal part of the aedeagus. Fedorov believes that the spermatophores are all prepared during copulation, and that this accounts for the length of the copulatory period—$1\frac{1}{2}$ or 2 hours being necessary for the completion of one capsule and its transference to the female. He finds thus that 6 to 12 spermatophores correspond with 18 to 24 hours of copulation, 18 to 24 with 36 hours, and 30 with 60 hours. In about 4 to 6 hours after the beginning of copulation, Fedorov says, a milky-white jellylike mass containing the empty spermatophores that have been ejected from the spermatheca collects between the lower valves of the ovipositor where it becomes brittle and yellow as it dries, and after a few hours is lost, leaving no evidence of the insemination that has taken place.

EXAMPLES OF THE MALE GENITALIA OF ACRIDIDAE

The following descriptions of the male genitalia of representative species of the several acrid subfamilies will serve to illustrate the nature of specific variations in the form of the organs, and will show the fundamental unity of structure throughout the family.

Chorthippus bicolor Charp.—The Acridinae (Tryxalinae) have the typical acridid structure of the male genital organs, except that the distal part of the dorsal lobe of the aedeagus is suppressed, and the apical processes, which have the form of four long, closely appressed prongs, arise directly from the proximal part (figs. 28 E, 29 C).

The structure of the male genital organs of *Chorthippus bicolor* is shown in figure 28. The aedeagus (E, *Aed*) includes a dorsal lobe (*dl*) and a ventral lobe (*vl*), but the former consists principally of the usual proximal part of the dorsal lobe (*m*), which bears directly
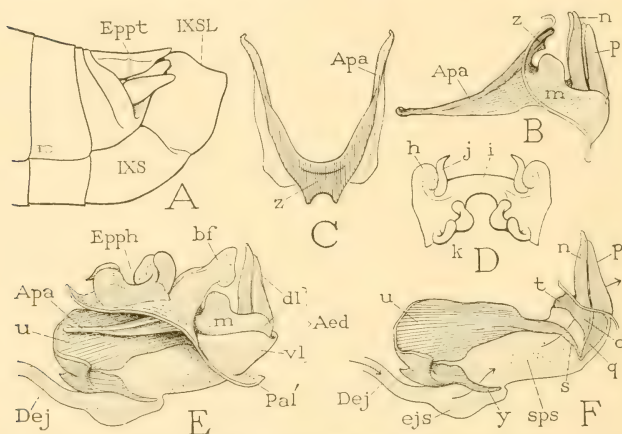
FIG. 28.—Male genitalia of *Chorthippus bicolor* (Acridinae).

A, end of abdomen. B, dorsal lobe of aedeagus and lateral apodeme, left side. C, aedeagal apodemes, dorsal view. D, epiphallus, dorsal view. E, phallic organs and floor of genital chamber, lateral view. F, endophallus and distal part of aedeagus.

the four large apical processes above noted (B, *n, p*). The aedeagal apodemes are well developed as long tapering arms extending forward from the base of the aedeagus (B, *Apa*) in deep invaginations beneath the basal fold (E) ; their proximal parts are united by a strong zygoma (C, *z*) in the under surface of the basal fold (B). From each of the apical processes of the aedeagus (F, *n, p*) a sclerite extends proximally in the inner wall of the endophallic meatus (*o, q*). Here the extremities of the dorsal pair of sclerites are united by a wide dorsal bridge (*t*), while the tapering ends of the ventral sclerites are sharply bent upward (*s*) and then gradually expanded anteriorly to

form the large lateral plates (u) of the endophalic walls. The ejaculatory sac (ejs) opens ventrally into the spermatophore sac of the endophallus (sps) between the gonopore processes (y) of the lateral plates, and the spermatophore sac discharges through the wide meatus and the phallotreme.

The epiphallus is a large sclerite of the usual type of structure (fig. 28 D) seated on the floor of the genital chamber (E, $Epph$) at the anterior end of the surface that forms the fold (bf) overlapping the base of the aedeagus.
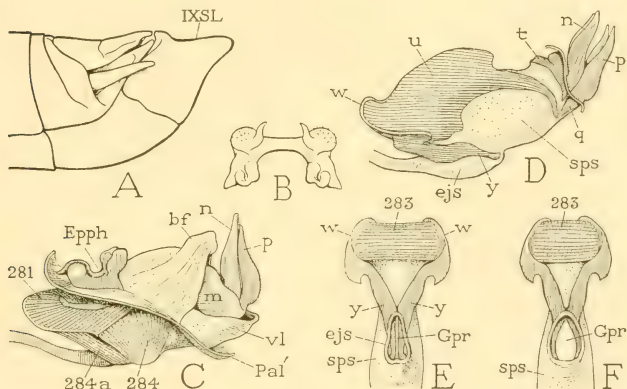
FIG. 29.—Male genitalia of *Mermiria maculipennis* (Acridinae).

A, end of abdomen. B, epiphallus. C, phallic organs with floor of genital chamber and muscles of endophallic bulb. D, endophallus and distal part of aedeagus. E, regulator mechanism of the gonopore, ventral view, closed. F, same, gonopore open.

Mermiria maculipennis Bruner.—The only differences in the male genitalia between this species and the last are in details of form and relative size of the parts (fig. 29). The epiphallus (B, C, $Epph$) has the usual shape; the basal fold (C, bf) forms a large hoodlike covering over the base of the aedeagus. The four large apical processes of the aedeagus, in the retracted condition, project dorsally from the supporting proximal part (m) of the dorsal lobe; the ventral lobe (vl) projects like a trough beneath the latter. The endophallus is large (D), but its lateral plates (u) with their apodemes (w) and gonopore processes (y) are of typical form. The closing and opening mechanism of the gonopore is easily studied in this species (E, F).

Camnula pellucida (Scudder).—There is little in the structure of the male genitalia to distinguish this oedipodine species (figs. 30, 31) from the acridine species just described, though there are many differences to be noted in details of form and relative sizes of the
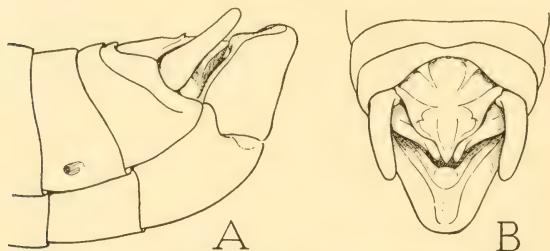
Fig. 30.—End of the male abdomen of *Camnula pellucida* (Oedipodinae).
A, lateral view. B, dorsal view.
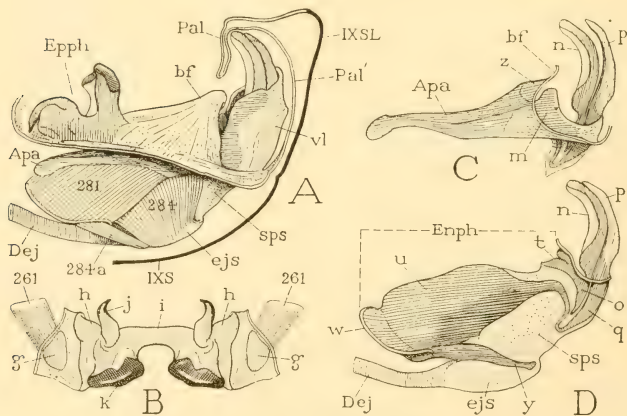
Fig. 31.—Male genitalia of *Camnula pellucida* (Oedipodinae).

A, the phallic organs situated on floor of genital chamber, and muscles of endophallic bulb. B, epiphallus, dorsal view, and associated retractor muscles. C, dorsal lobe of aedeagus and lateral apodeme, left side. D, endophallus and apical processes of aedeagus.

parts. The epiphallus is large and strongly developed (fig. 31 A, *Epph,* B). The basal fold (A, *bf*) covers the base of the aedeagus in the usual manner. The dorsal lobe of the aedeagus consists of a small proximal part (C, *m*) bearing two strong apodemal arms (*Apa*), and of four long curved apical processes (*n, p*). The ventral

lobe (A, *vl*) is unusually large and ensheaths much of the dorsal lobe. The endophallus has the typical form (D, *Enph*), with well-developed apodemes (*w*) and gonopore processes (*y*).

Locusta migratoria L.—The aedeagus of *Locusta migratoria* is quite different in shape from that of the other species here described, but its peculiarities may be seen as an exaggeration of the structure in *Camnula*. The ventral lobe is very large and, in the retracted position
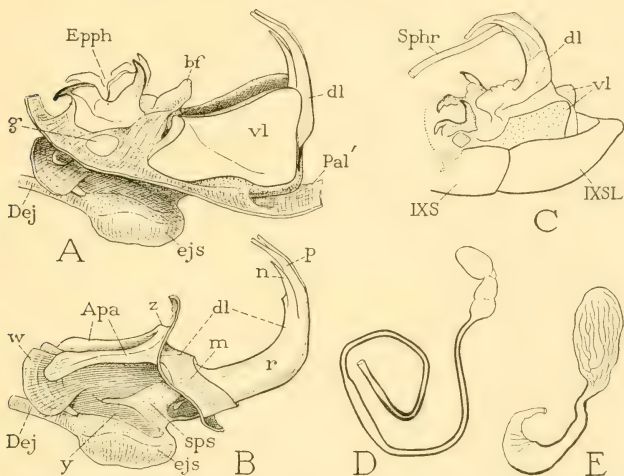
FIG. 32.—Male genitalia of *Locusta migratoria* (Oedipodinae), and acridid spermatophores.

A, phallic organs on floor of genital chamber, with endophallus and ejaculatory sac beneath the latter. B, dorsal lobe of aedeagus, with aedeagal apodemes and endophallus exposed by removal of floor of genital chamber and ventral lobe of aedeagus. C, aedeagus in protracted position, with protruding spermatophore (*Sphr*). D, spermatophore of *Locusta migratoria*. E, spermatophore of *Calliptamus italicus*. (C, D, E from Boldyrev, 1929.)

of the phallic organs (fig. 32 A), completely conceals all but the terminal parts of the dorsal lobe. Its upturned lateral walls contain each a large quadrate plate (*vl*) lying in a vertical plane at the side of the base of the dorsal lobe; ventrally the two plates are united by a median membranous area of the lobe. When the ventral lobe is removed (B) the dorsal lobe of the aedeagus (*dl*) is seen to have the form of a long, tapering tube, curved upward and ending in four slender apical processes. The organ, however, is not literally tubular, since the posterior wall is deeply cleft to its base; the opening is the

phallotreme, and in its inner walls are the usual phallotreme sclerites
ending distally in the apical processes (n, p). The proximal part
of the dorsal lobe (B, m) is small, but is quite distinct from the
cylindrical distal part (r) and bears the two aedeagal apodemes (Apa).
The phallotreme cleft leads through the meatus in the neck of the
endophallus into the endophallic cavity. The spermatophore sac of the
latter is small (sps), but the ejaculatory sac (cjs) is unusually large;
the two communicate by the gonopore, which lies between the gono-
pore processes (y) of the lateral endophallic plates.
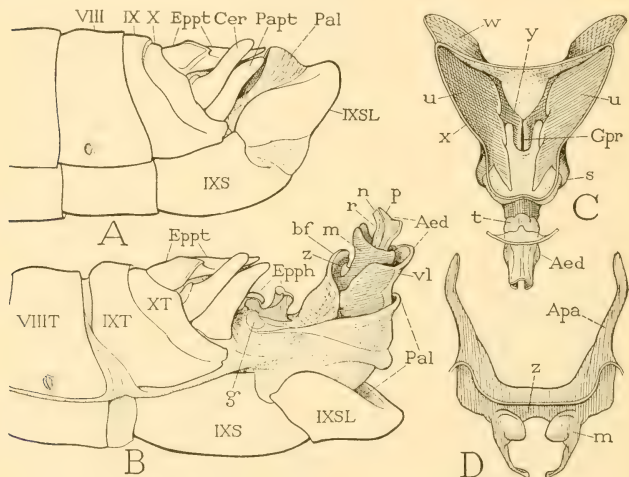
FIG. 33.—Male genitalia of *Dissosteira carolina* (Oedipodinae).

A, end of abdomen with phallic organs concealed in genital chamber. B,
same, with phallic organs protracted. C, endophallic chamber opened from above,
showing gonopore situated in its floor. D, proximal lobes of aedeagus (m)
and aedeagal apodemes with basal zygoma, dorsal view.

In the position of protraction (fig. 32 C), as shown by Boldyrev
(1929), the ventral lobe of the aedeagus is depressed and the dorsal
lobe is projected upward with its apical processes turned forward.
The spermatophore $(Sphr)$ issues anteriorly from the upper end of
the phallotreme cleft between the bases of the anterior processes.

Dissosteira carolina (Linn.).—The end of the male abdomen of
Dissosteira is obtusely pointed (fig. 33 A) because of the conical form
of the genital lobe of the ninth sternum $(IXSL)$. The lobe is movable
on the anterior sternal plate (IXS) by a wide membranous area sepa-
rating the two. From its dorsal margin the pallium (Pal) is continued

forward as a hoodlike fold that meets the lobes of the eleventh segment, and is then reflected inward to form the posterior wall of the genital chamber (fig. 26). The genital chamber and the contained phallic organs are thus ordinarily entirely concealed beneath the tenth and eleventh segments in front, and the pallial hood behind. If the pallium is pulled back from the eleventh segment it is to be seen that the epiphallus occupies an anterior pocket of the genital chamber beneath the venter of the tenth segment, and that the aedeagus is contained in a posterior pouch lined by the inflected fold of the pallium (*Pal'*), which latter extends inward and ventrally to the base of the ventral lobe of the aedeagus (*vl*). The floor of the genital chamber laterally slopes downward from in front (fig. 25 A), where the epiphallus is seated upon it, to the base of the inner fold of the pallium, but medially, between the epiphallus and the aedeagus, it presents a broad, smooth, rounded surface (D), the posterior margin of which forms the basal fold (A, D, *bf*) overlapping the proximal part of the aedeagus. The epiphallus is a large irregular sclerite, consisting of two lateral lobes (D, *h, h*) connected by an arched bridge (*i*), and provided with the usual hooked anterior processes (*j*) and broad, strong posterior processes (*k*) having a vertical position. Just laterad of the epiphallus, in the wall of the genital chamber, are to be seen the small oval sclerites (*g*) that give insertion to the large retractor muscles (*261*) from the lateral parts of the ninth abdominal tergum.

The structure of the aedeagus is well shown in the protracted condition (fig. 33 B), in which the organ projects dorsally from a basal sheath formed of the everted pallium (*Pal*) and the basal fold (*bf*) of the genital chamber floor. The two parts of the dorsal lobe of the aedeagus (*r, m*) are quite distinct, the narrow distal part (*r*), ending in the small apical processes (*n, p*), being exserted from between the lobate lateral walls of the proximal part (*m*). The ventral aedeagal lobe (*vl*) embraces the dorsal lobe posteriorly, and between the two is a deep cavity into which opens the vertical slitlike phallotreme in the posterior wall of the dorsal lobe. The aedeagal apodemes (D, *Apa*) project downward and forward from the base of the dorsal lobe beneath the basal fold (B, *bf*), and their proximal parts are united by a wide zygoma (D, *z*) in the under side of the fold (B, *z*).

The phallotreme is a deep cleft in the dorsal lobe of the aedeagus; in its lateral walls are the usual two pairs of sclerites (fig. 25 H, *o, q*). The sclerites of the dorsal (anterior) pair end in the meatus, where they are united with each other by a transverse bridge (*t*) in the dorsal wall of the latter; the ventral (posterior) sclerites are continuous by narrow upcurved arms (*s*) with the lateral plates (*u*) of the en-

6

dophallic bulb. The posterior angle of each endophallic plate is armed internally by a free spinelike process (G), below which the margin of the plate extends obliquely downward and forward to the base of the gonopore process (y). Between the gonopore processes, as already shown, lies the gonopore, or true genital aperture (fig. 33 C, *Gpr*), by which the ejaculatory sac (fig. 25 G, H, *ejs*) communicates with the spermatophore sac (*sps*) of the endophallus.

Romalea microptera (Beauvois).—The distal lobe of the ninth sternum in this species shuts close against the epiproct and paraprocts, so that the pallium is not exposed and the end of the abdomen has a
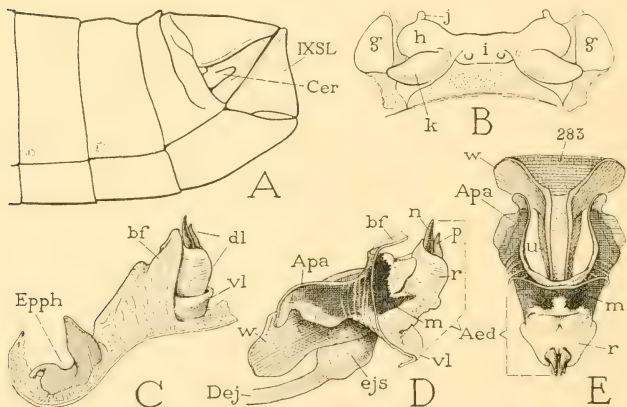
FIG. 34.—Male genitalia of *Romalea microptera* (Cyrtacanthacrinae).

A, end of abdomen. B, epiphallus, dorsal view. C, epiphallus and aedeagus on floor of genital chamber, lateral view. D, aedeagus and endophallus, lateral view. E, same, dorsal view.

truncate form (fig. 34 A). The epiphallus is deeply sunken in the anterior end of the genital chamber, and the basal fold rises steeply against the anterior surface of the aedeagus (C), concealing most of the basal parts of the latter. The dorsal lobe of the aedeagus has a well-developed cylindrical distal part (D, r) from which project two pairs of apical processes (n, p). The proximal part (m) bears a pair of short but very wide lateral apodemes (D, E, *Apa*). The endophallus is relatively small, but the anterior apodemes (w) of its lateral plates are large and widely divergent (E).

Schistocerca americana (Drury).—The elongate subgenital plate of the ninth abdominal sternum of this species has a broad, deeply emargi-

nate extension projecting far beyond the origin of the pallium from its dorsal lamella (fig. 35 A, B, *IXSL*). The exposed part of the pallium (*Pal*) forms a thick, transversely corrugated fold against the paraprocts. When the tenth and eleventh segments are removed (B) the genital chamber is exposed from above, and there are to be seen on its floor the phallic structures lying anterior to the aedeagus, the latter being still concealed beneath the pallial hood. The epiphallus consists of large lateral lobes (*h, h*) connected by a narrow median bridge; anterior processes are absent, but the posterior processes are present
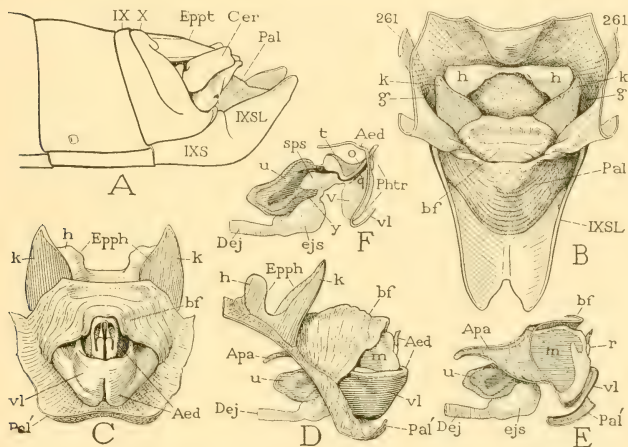
Fig. 35.—Male genitalia of *Schistocerca americana* (Cyrtacanthacrinae).

A, end of abdomen. B, dorsal view of genital lobe of ninth sternum, pallium, and anterior part of genital chamber, exposed by removal of tenth and eleventh segments. C, phallic organs, posterior view. D, same, lateral view. E, aedeagus with apodeme, endophallus, and ejaculatory sac. F, endophallus and apex of aedeagus.

in the form of large triangular plates (*k, k*). Between the bases of the latter the floor of the genital chamber presents a deep transverse groove, the part behind the groove terminating in the basal fold (*bf*). The aedeagus is small (C, D, *Aed*), but its ventral lobe (*vl*) is relatively large. The principal part of the dorsal lobe is formed of the usual proximal subdivision (D, E, *m*), the distal part (E, *r*) being much reduced and ending in a small spoutlike terminal lobe without apical processes. The aedeagal apodemes (E, *Apa*) are short but broad at their bases. The endophallus (F) has the usual structure, but has characteristic features. The phallotreme sclerites (*o, q*) are

very slender; those of the dorsal pair are united by an arched bridge
(t) in the dorsal wall of the meatus; each sclerite of the ventral pair
bears a large, thin, oval plate (v) in the lateral wall of the phallotreme
cleft. The ejaculatory sac (ejs) is relatively large and is separated
from the spermatophore sac (sps) by strong gonopore processes
(y) of the lateral endophalic plates.

Melanoplus differentialis (Thomas).—The ninth sternal lobe is
short in this species (fig. 36, $IXSL$), and from its dorsal margin the
exposed part of the pallium (B, Pal) rises like a dome behind the
eleventh segment. The phallic organs (fig. 37 A) are somewhat
crowded in the rather small genital chamber. The epiphallus ($Epph$)
is large but weakly sclerotized, and is deeply sunken into the folded
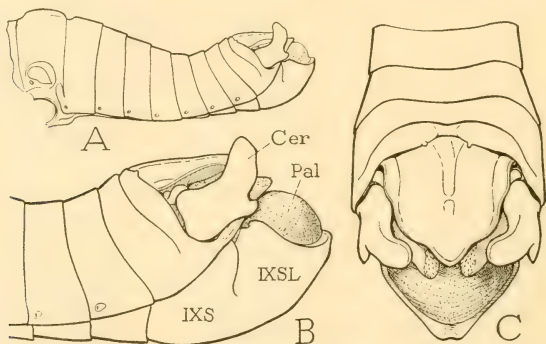
FIG. 36.—Male abdomen of *Melanoplus differentialis* (Cyrtacanthacrinae).
A, entire abdomen. B, end of abdomen, lateral view. C, same, dorsal view.

floor of the genital chamber. The basal fold (bf) is bilobed. The
dorsal lobe of the aedeagus is distinctly divided into a proximal part
(A, B, m) bearing the aedeagal apodemes (B, Apa), and a large cylin-
drical distal part (r). The ventral lobe (A, vl) is relatively small.
From the distal end of the aedeagus there projects only one pair of
apical processes (A, B, C, D, n), which are the usual anterior dorsal
processes continuous from the dorsal sclerites of the phallotreme cleft
(D, o). The ventral processes are present, but they are concealed
within the phallotreme cleft (C, p), since they arise deeply from the
walls of the latter and do not project from the apex of the aedeagus.
The endophallus (D) has the usual structure, though the sperma-
tophore sac (sps) is much reduced, and the ejaculatory sac (ejs) is
turned upward against its posterior wall.
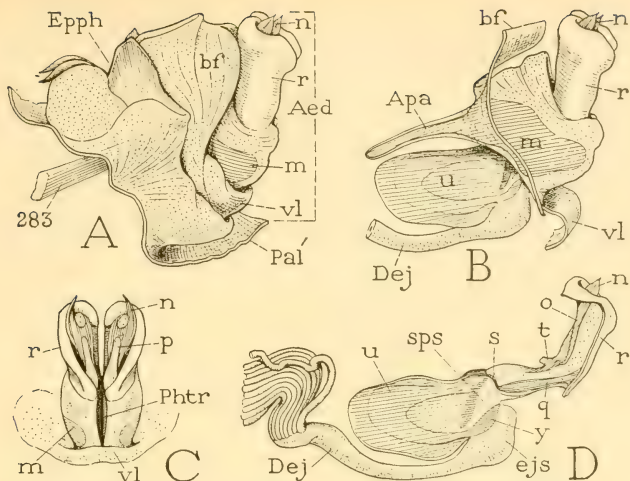
FIG. 37.—Male genitalia of *Melanoplus differentialis* (Cyrtacanthacrinae).

A, the external phallic organs on floor of genital chamber. B, aedeagus and endophallus. C, dorsal lobe of aedeagus, posterior view, showing phallotreme (*Phtr*) and apical processes (*n, p*). D, endophallus with apex of aedeagus, and ejaculatory duct.
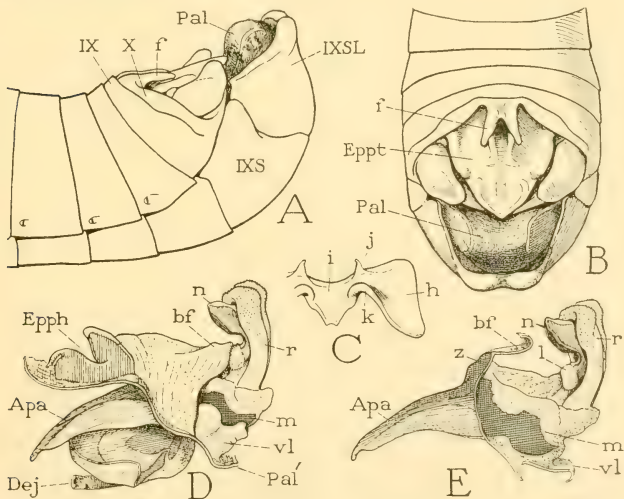
FIG. 38.—Male abdomen and genitalia of *Melanoplus mexicanus* (Cyrtacanthacrinae).

A, end of abdomen, lateral view. B, same, dorsal view. C, right half of epiphallus. D, external and internal phallic organs, with floor of genital chamber. E, aedeagus and apodeme, right side.

83

Melanoplus mexicanus (Sauss.).—The general features of this species are sufficiently shown in figure 38. The distal part of the dorsal lobe of the aedeagus is unusually long (D, E, *r*) and is produced into two terminal lobes laterad of the phallotreme cleft. The dorsal apical processes (*n*) thus come to project anteriorly below the summit of the terminal lobes. With the base of each of these processes there is connected a soft padlike lobe (E, *l*). The ventral apical processes are concealed within the phallotreme cleft as in the last species.

Melanoplus femur-rubrum (Degeer).—The exposed characters of the male abdomen of this species are shown in figure 39. The phallic organs are entirely concealed in the usual manner within the genital chamber (fig. 40 B). The epiphallus (A, B, *Epph*) is very large, especially as to its lateral lobes. Behind the epiphallus the genital
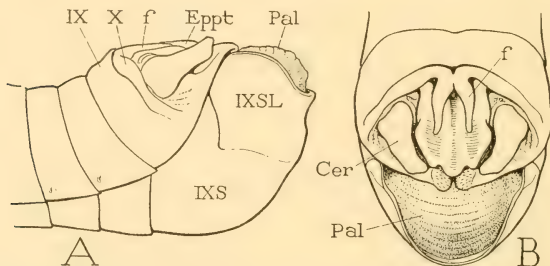
FIG. 39.—End of the male abdomen of *Melanoplus femur-rubrum* (Cyrtacanthacrinae).

A, lateral view. B, dorsal view.

chamber floor is elevated in a large cushionlike structure, the anterior part of which rests against the posterior epiphallic lobes, while the deeply cleft posterior part forms a thick bilobed basal fold (*bf*) covering the basal part of the aedeagus. The aedeagus (B, *Acd*) consists of an irregular dorsal lobe, and of a simple relatively small ventral lobe (*vl*). The dorsal lobe shows the usual subdivision into a proximal part (*m*) and a distal part (*r*), the latter bearing a single pair of large apical processes (*n*), which, as in other species of *Melanoplus*, are the usual anterior dorsal processes. Connected with the base of each of these processes is a soft, flat accessory lobe (C, *l*) lying on the dorsal surface of the base of the aedeagus. The ventral processes, as appears to be characteristic of *Melanoplus*, arise deeply within the phallotreme cleft (fig. 41 B, *p*) and only their tips appear externally before the bases of the dorsal processes (A, *p*). The phallo-
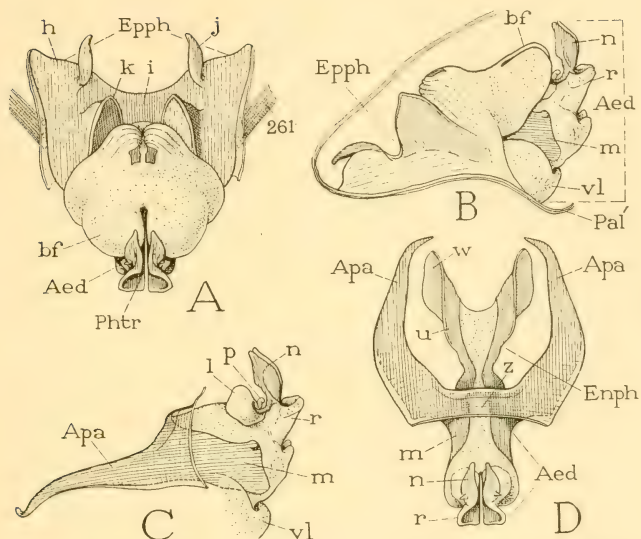
FIG. 40.—Male genitalia of *Melanoplus femur-rubrum* (Cyrtacanthacrinae).

A, the external phallic organs, dorsal view. B, same, lateral view, with part of genital chamber wall. C, aedeagus and apodeme, left side. D, aedeagus with apodemes, and endophallus, dorsal view.
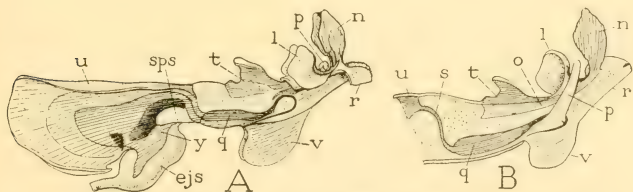
FIG. 41.—Male genitalia of *Melanoplus femur-rubrum* (Cyrtacanthacrinae).

A, endophallus and apical part of aedeagus. B, diagrammatic median section of distal part of aedeagus, exposing right inner wall of phallotreme cleft and meatus of endophallus, showing accessory lobe (*l*) of dorsal apical process (*n*), and internal origin of ventral apical process (*p*).

treme sclerites (B, o, q) extend forward in the walls of the phallo-treme cleft from the bases of their respective processes (n, p). Anterior to the phallotreme a tubular meatus (A) leads into the cavity of the endophallus, and the ejaculatory sac (ejs) opens between large gonopore processes (y) into the small spermatophore sac (sps). The phallotreme cleft in the proximal part of the dorsal lobe of the aedeagus has its lateral walls strengthened by a pair of thin oval plates (fig. 41 A, B, v).

The foregoing studies of three species of *Melanoplus* suggest that the phallic structures will be found to be more variable and more specialized among the Melanopli than in the other acridid groups.

ABBREVIATIONS USED ON THE FIGURES

aAp, anterior sternal apodeme.
Aed, aedeagus.
AcGl, accessory genital gland.
acs, antecostal suture.
aiv, anterior intervalvula.
AN, alinotum.
An, anus.
Ap, apodeme.
Apa, apodeme of aedeagus.
ast, acrosternite (precostal lip of sternum).
atg, acrotergite (precostal lip of tergum).

bf, basal phallic fold.
Bs, basisternum.

Cer, cercus.
Cln, colon.
CpCls, cap cells of sense organ.
CxC, coxal cavity.
Cxpd, coxopodite (limb basis).
Dej, ductus ejaculatorius.
dil, lateral internal dorsal muscles.
dim, median internal dorsal muscles.
dl, dorsal lobe of aedeagus.
DMcl, longitudinal dorsal muscles.
DS, dorsal sinus.
DV, dorsal blood vessel.

eg, egg guide.
ejs, ejaculatory sac.
Enph, endophallus.
Epm, epimeron.

Epph, epiphallus.
Eppt, epiproct.
Eps, episternum.

GC, genital chamber.
Gpr, gonopore.

Il, ileum.
IXSL, genital lobe of ninth abdominal sternum.
lAp, lateral sternal apodeme.
lc, external lateral muscles.
li, internal lateral muscles.
lst, lalterosternite.
ltg, laterotergite.

Nv, nerve.

Odc, oviductus communis.
Odl, oviductus lateralis.
Ovp, ovipositor.
Pa, postalar arm of postnotum.
Pal, pallium.
Pal', inner fold of pallium.
Papt, paraproct.
paptl, lobe of paraproct.
Ph, phragma.
Phl, phallus.
Phtr, phallotreme.
piv, posterior intervalvula.
Pl, pleuron.
PlS, pleural suture.
PlVlv, pallial valve.
PN, postnotum.

Prcx, precoxal pleural sclerite.
PvS, perivisceral sinus.
Py, pylorus.

Rect, rectum.

S, definitive sternum.
sa, external pit of sternal apophysis.
SCls, sense cells.
Sco, scolops (sense rod).
Sl, sternellum.
SO, sense organ.
Sp, spiracle.
Sphr, spermatophore.
spn, external pit of sternal spina.
Spr, spermathecal aperture.
sps, spermatophore sac of endophallus.
Spt, spermatheca.
SptD, spermathecal duct.

sr, sternal ridge.
Stn, primitive sternum.

T, tergum.
td, dorsal transverse muscles.
Tm, tympanum.
tr, tergal ridge.
tv, ventral transverse muscles.

Vent, ventriculus.
vil, lateral internal ventral muscles.
vim, median internal ventral muscles.
Vl, valvula.
vl, ventral lobe of aedeagus.
Vlf, valvifer.
VNC, ventral nerve cord.
VS, ventral sinus.

WP, pleural wing process.

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A NEW AND IMPORTANT
COPEPOD HABITAT

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CHARLES BRANCH WILSON
State Teachers College, Westfield, Mass.

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In addition to forming an integral portion of the plankton of both fresh and salt water, copepods have also been found in several unique situations. Some species inhabit damp moss in the Black Forest of Germany and other European woodlands long distances from any body of water. Other species live within the branchial chambers of land crabs, which enter the ocean only during their spawning season, once a year. Copepods have also been found in the rain water which accumulates inside the cup formed by the tightly sheathed leaves of certain epiphytic Bromeliads saddled on the limbs of tropical trees far away from the water. But these are simply distribution freaks, likely to occur in any animal or plant group, and confined to so few species as to be worthy only of passing notice.

There has recently been discovered, however, a new copepod habitat of vastly more importance and claiming as its tenants a sufficient number of genera and species to constitute an important group. According to their habits and mode of life, copepods have hitherto been divided into three well-known groups: free-swimmers, commensals, and parasites. The dwellers in this new environment will constitute a fourth group, which may be designated as terraqueous copepods because they actually live in both water and sand or mud. Brief mention has already been made [1] of this group, and the name benthonic was suggested for them. But that term has already come into general use to designate the fauna and flora of the sea bottom as opposed to the plankton. Certain of the free-swimming copepods live close to the bottom and move about in the water or among the vegetation above the bottom. They are the forms which should be designated as benthonic, whereas these terraqueous copepods actually penetrate the sand or mud, and hence can never be captured by towing. They are not free-swimmers, therefore, and are neither commensal nor parasitic in their habits, but must form a new group.

The discovery of these sand and mud dwellers was first made by the late Dr. N. A. Cobb, government specialist on nematodes. While

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[1] U. S. Nat. Mus. Bull. 158, p. 6, 1932.

washing out some of his nematodes from the sand of the bathing beach at Woods Hole, he found copepods among them. Further examination revealed that the sand of that beach and other beaches along Cape Cod and on the neighboring islands was fairly teeming with copepods. Many more could be washed out of the sand than could be obtained by towing along the shore.

During the following summer the same was found to be true of the sand beaches around Mount Desert Island on the Maine coast. And since every sand beach yielded its quota of copepods, the search was extended to the mud flats, the mussel beds, and the tide pools—in fact, to all kinds of localities where the beach was not composed of solid rock. Let it be remembered that the exceptional tides (12 to 16 feet) of the region lay bare immense areas of shore at low water. Every locality examined yielded at least one or more copepod species, usually more, and a few localities as many as 20 or 25. In the mussel beds they were found in the sand or mud beneath the upper layer of living mussels; in areas covered with seaweed they were in the soil beneath the plants; in the tide pools they were washed out of the sand or mud covering the bottom of the pool.

These copepods not only live in the sand and mud while it is covered by the tide, but remain there after the tide has ebbed and left the beach uncovered. As some of them are found as far up on the beach as the average high water mark, the time during which their habitat is covered by the ocean water is very much shorter than the interval during which it is left uncovered. And yet such conditions do not seem to be at all disadvantageous, to say nothing of being inimical. Sand that had remained uncovered at least 10 hours and had become rather warm in the hot sunlight, yielded living and active copepods when washed out in the laboratory.

Nor are the copepods confined to the beach between tide marks, but are found everywhere in the sand and mud constantly beneath the water down to moderate depths. Portions of the sea bottom brought up on the flukes of anchors or in a dredge usually yield some copepods on being washed out and strained. Many such species have been obtained in dredging and have been described and figured by various authors without the knowledge that they were really sand dwellers. It is of course impossible to tell whether a dredged specimen comes from above or beneath the surface of the ocean bottom. The descriptions and figures, however, show just such modifications in size, shape, and structure as appear in these sand dwellers.

Upon reflection it will appear that two conditions are requisite in order to induce the copepods to penetrate the sand or mud and remain

there for any length of time. There must be plenty of food and the environment must be such as to allow the copepods more or less freedom of locomotion. The former is readily explained by the presence in the sand or mud of such organisms, especially diatoms, as ordinarily serve for copepod food. This would constitute a sort of cold storage supply amongst which the copepods could browse with much less danger from outside interference. But can the copepods move about in the sand or mud with anything like freedom of locomotion? Consider the sand first.

What is commonly designated as sand may be derived from several sources, and its constituent grains may vary greatly in size, with considerable resultant differences in the sand itself. If derived from the geologic weathering and erosion of crystalline rocks, the sand is made up very largely of rounded grains of quartz. Such is the sand of Cape Cod and the Maine coast, and it cannot be compressed sufficiently to obliterate or even greatly diminish the interstices between the grains. These open spaces make an ideal forage ground for copepods small enough to move about within them, and there is little danger of being crushed. Such sand always contains copepods even on exposed beaches like those of the south shore of Marthas Vineyard, where a heavy surf breaks almost continuously. Such sand also frequently collects in the tide pools along the Maine coast and often contains a good assortment of copepods. One pool at Sea Wall on Mount Desert Island, about the size of a small room, yielded more than 20 copepod species, including calanids, harpactids, and cyclopids.

If the sand is largely made up of broken shells, as it often is in the Tropics, its grains are not spherical but more or less flattened, and when the flattened surfaces come together, which is the usual tendency, the interstices are entirely obliterated. Any minute organism that tried to live in such sand would be in constant danger of being crushed. This kind of a sand beach never contains copepods, and the bathing beach on the eastern shore of Mount Desert Island just south of Bar Harbor is an excellent example. Two-thirds of the sand of that beach is broken shells, and it is the only sand beach examined on the island that yielded no copepods.

A third source of sand is coral disintegration, and this is the prevalent kind of sand beach everywhere in the Tropics. The coral rock is so soft that the resultant grains tend to become extremely small and to vary considerably in size. Here again the interstices between the grains can be practically obliterated by pressure, and if any are left they become so small and irregular as to be uninhabitable. Only rarely

and in exceptional localities would any copepods be found in this sort of sand.

In view of these considerations the final answer to the question whether copepods can move about freely in sand is in the affirmative if it is quartz sand, and in the negative if it is shell or coral sand. The fact also that both the shell and the coral sand are calcareous may have some influence upon the copepods.

As to the mud, its composition is also the most important factor in determining whether it is to be inhabited or not. If it is dense clay there will be no chance of finding copepods within it, and on the other hand if it be sandy the probability of its being inhabited by copepods will become greater as the percentage of sand it contains increases. The upper layers of ordinary mud are more or less flocculent, that is they are made up of small flattened flakes or floccules. These are to a certain extent buoyant in water and are so irregular in form that they do not pack together closely but leave sufficient open spaces for the copepods to move about freely. Many of the floccules are also so small and light that they can be easily pushed aside by the copepods during their progress, and so soft that contact with them is not likely to be at all harmful. Consequently, in the mud there is not the same restriction in size that prevails in the sand, and the larger copepods can move about as freely as the smaller ones, possibly with even greater facility.

Such a life as this, moving about all the time within the confines of the sand and mud, is just as different from that of the typical free-swimming forms that frequent the open water as are the lives of the commensal and parasitic copepods. The investigations carried on in these last two groups have already revealed numerous modifications resulting from their habits and mode of life. It is reasonable to suppose that these terraqueous copepods would also exhibit modifications similar in their interpretation but differing in their details, and such we find to be the case.

The first of these modifications is shown in the restricted size of the fully developed adult. In the other groups we find great variations in size up to 200 mm in a few parasitic forms. Here there is great uniformity in size, from a minimum of a quarter of a millimeter to a maximum of half a millimeter in the sand dwellers, and a maximum of slightly more than a millimeter in the mud dwellers.

A second modification is one of shape; it is evident that a linear form will have greater freedom of motion under the restrictions of the sand and mud than a rotund or corpulent form. The terraqueous copepods all exhibit a more or less pronounced slenderness, the length

being many times the width of the body. The accompanying figures of
four different genera of sand-dwelling copepods show their typical
linear form, which is admirably suited to their mode of life (figs. 1
and 2).
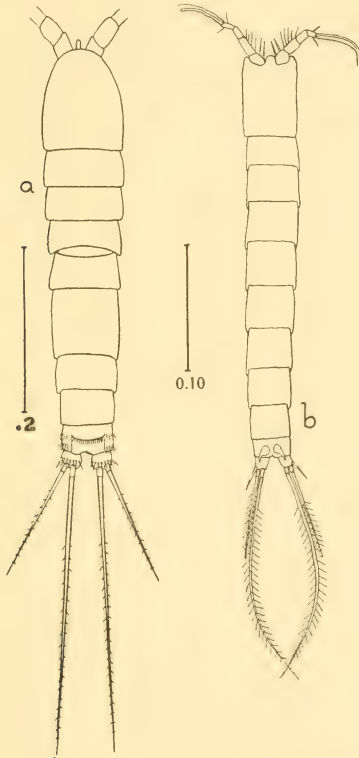
FIG. 1.—*a*, dorsal view of a female *Nitocra chelifer*, a sand
dweller; *b*, dorsal view of a male *Arenosetella spinicauda*, a sand
dweller.

A third modification results in increased flexibility; mere slender-
ness of body would contribute but little to freedom of motion unless
accompanied by flexibility. In the jointed body of the ordinary cope-
pod only one of the articulations is really movable, all the others being
more or less rigid and incapable of motion. In these copepods there

is much freedom of motion in every one of the articulations, and the body can be flexed considerably upward or downward, to the right or to the left, as may be necessary. This increased flexibility enables the copepod to realize fully all the advantages of its modified size and shape. If one of these copepods is put in an aquarium with sand
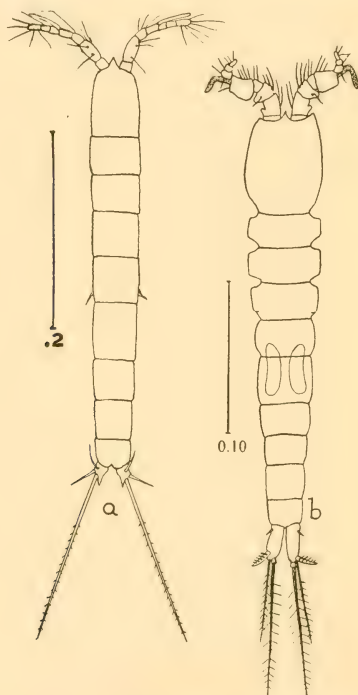
FIG. 2.—*a*, dorsal view of a female *Paraleptastacus brevicauda-tus*, a sand dweller; *b*, dorsal view of a male *Emertonia gracilis*, a sand dweller.

at the bottom, it quickly buries itself in the sand, and during the process gives abundant evidence of its great flexibility.

Another useful modification is an increase in tactile equipment and sensibility. These terraqueous copepods are compelled to move about more or less in the dark, where their eyesight can be of little use for guidance. At the same time the space within which they move is so

restricted that the demand for some sort of guidance is greatly en-
hanced and becomes imperative. This demand is met by a greatly in-
creased tactile sensibility in the first antennae, which here become
" feelers " in the fullest sense of the term. The normal copepod usu-
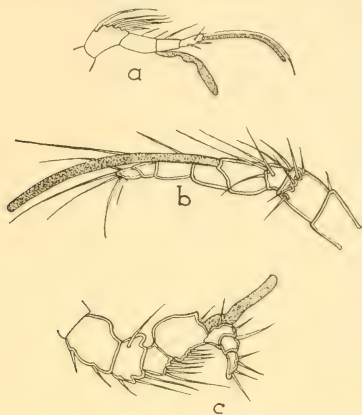
Fig. 3.—*a*, first antenna of a male *Arenosctella spinicauda*, with
two large aesthetasks; *b*, first antenna of a male *Nitocra chelifer*,
with a single long and stout aesthetask; *c*, first antenna of a male
Emertonia gracilis, with a single enlarged aesthetask.
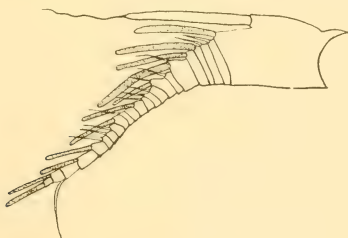
Fig. 4.—First antenna of *Arenocalanus tumidus*, female, a new
genus of sand-dwelling calanids, showing an exceptional increase
in the number of aesthetasks.

ally carries a single sensory club or aesthetask on each of the first
antennae. In these terraqueous copepods the size and length of the
aesthetasks may be considerably increased, as happens more often
in the males (fig. 3). In the females either the number of aesthetasks
is multiplied as in figure 4, or they are supplemented by thick finger-

like processes, carrying along one or both sides a row of coarse spines
as in figure 5. There are sometimes six or eight such processes on each
antenna, projecting in all directions and giving the appendage a de-
cidedly bizarre appearance. Nothing of this sort has ever been reported
upon free-swimming copepods, and hence it may be regarded as a
special modification for a special mode of life. Furthermore, the first
antennae are short and curve around the front of the head in such a
way as to offer least resistance to forward progress. At the same time

FIG. 5.—*c,* first antenna of a female *Rathbunula curticauda,* a
sand dweller; *d,* first antenna of a female *Echinocornus pectinatus,*
a sand dweller.

the frontal margin is thereby furnished with a highly sensitive arma-
ture admirably suited for guidance.

Of course these copepods cannot indulge in free-swimming, since
there is no room for it within the sand and mud, and the copepods
come out into the open water very seldom, if at all. We therefore
find, as would be expected considerable modification of the swimming
legs in some of the species. The long plumose setae, so useful in
swimming, partially or wholly disappear and are replaced by stout
spines. In figure 6 all the first four pairs of legs are modified in this
way, and it is quite evident that they are thus made more serviceable

for crawling about in sand and mud. There is also sometimes a re-
duction in the number and size of the endopod segments until in a
few species the entire endopod is reduced to a mere knob, of no use
except to show that the leg is still biramose.

Another modification is concerned with the external ovisacs, which
in the free-swimming copepods hang loosely from the genital segment
and often diverge considerably from the body. The eggs themselves
are of moderate size and fairly numerous, and may be carried in one
or two ovisacs, or even extruded singly into the water without being
carried at all. In the parasitic copepods a large number of eggs seems
to be the primal requisite. When the eggs are arranged in a single
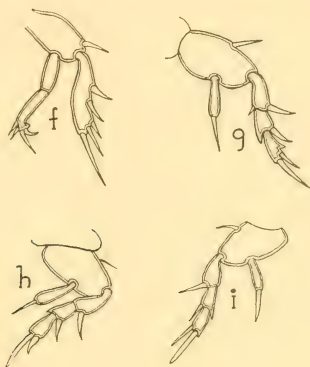
FIG. 6.—*f* to *i*, first, second, third and fourth leg of *Emertonia
gracilis,* showing substitution of spines for plumose setae.

row, as in the Caligidae, the increase in number is obtained by length-
ening the ovisacs, which sometimes become several times as long as
the entire body. When the eggs are multiseriate, the diameter of the
ovisac is increased and the size of the egg is at the same time dimin-
ished. As a result, the number of eggs in some copepods parasitic upon
deep-sea fish may reach 10,000 or more in each ovisac. In the com-
mensal copepods there are often no ovisacs, the eggs being gathered
into a brood sack situated in the dorsal portion of the thorax.

In contrast with these three groups, the ovisacs of the terraqueous
copepods are nearly always flattened and closely appressed to the
surface of the genital segment and abdomen. Sometimes the fifth
legs are enlarged and modified to cover the anterior ends of the ovisacs
and thus partially protect them. The number of eggs is reduced, and

at the same time the size is increased, so that each ovisac contains very few eggs, in some instances only two as shown in figure 7, an harpactid, or a few more as in figure 8, a cyclopid.

In addition to the modifications in structure exhibited by these sand and mud dwellers, there are also such differences in habits and mode of life as would be expected from their habitat. Free-swimming copepods maintain nearly perpetual motion; as they are heavier than water,
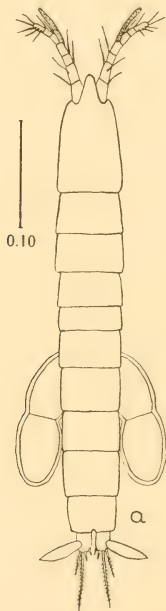
Fig. 7.—Dorsal view of female *Goffinella stylifer,* a sand dweller, showing the peculiar ovisacs and large eggs.

this is necessary to keep them suspended and prevent their sinking to the bottom. When they wish to rest, some species are able to suspend themselves from the surface film of the water, but all the others must find some support. For those that live near the bottom, the vegetation and the debris that collects on the bottom afford the requisite support, but it is quite different with those that live in the open ocean. For them, unless there happens to be something floating to which they can cling, it becomes the simple problem of sink or swim.

A great deal of motion and very little rest therefore constitutes the essential mode of life of a free-swimmer.

The great majority of the parasitic copepods, when once they are securely fastened to their hosts, do not move at all but may be, and usually are, carried long distances by their hosts. In early life all these parasitic forms are free-swimmers during their nauplius, met-anauplius, and often their copepodid stages. And of course during those periods they must maintain a great deal of motion and enjoy but
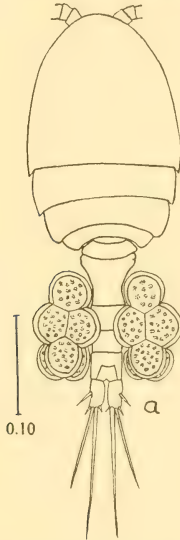
Fig. 8.—Dorsal view of female *Cyclopina agilis,* a dweller in sandy mud, with large eggs closely appressed to the body.

little rest. But in adult life this is exactly reversed even for such species as continue to practice more or less the free-swimming of early life. They may leave their hosts and move about freely in the water, but this is not continued for any length of time, and they quickly return to their hosts.

The commensal copepods spend their entire lives inside the body of their hosts, and hence they never swim freely except in so far as it is possible within such narrow confines. A great deal of rest and very little motion, therefore, are the characteristics of their mode of life.

These terraqueous copepods form a new group intermediate between the others and differing from them in many ways. There is no necessity for swimming in order to prevent them from sinking, and wherever they may stop when moving about will provide a convenient resting place. Their chief concern is to obtain an adequate food supply, and in doing this they scurry about freely in the sand or mud. They have much more freedom of motion than the commensal forms but not nearly as much as the free-swimmers; they may well be called free-movers but scarcely free-swimmers. In all probability their time is much more evenly divided between motion and rest than it is in the other groups.

Again, the free-swimmers, in consequence of their protracted movements, cover a considerable area and may even be carried long distances by currents or drifts. In this way they are widely distributed, and it is not uncommon to find some of the species in nearly every ocean on the globe. The same thing is true of the parasitic copepods, for here the females, and often both sexes, are carried about by the hosts, and if the latter are fish or other animals capable of extended migration, the parasites are thereby widely scattered.

On the contrary, most commensal copepods live within ascidians, holothurians, tunicates, and similar animals, which move about but little if at all. And since the movements of the copepod adults are also restricted, the species have only a limited distribution. Their chance for dissemination lies in the escape of the larvae from their host and the ability to swim about during their development stages.

Similarly, in these terraqueous copepods the distance covered by the locomotion of the adults is so limited that the distribution of the species is seriously handicapped. The presence of a given species in the sand or mud of one beach is no indication that it will be found in neighboring beaches. We may go farther and say that the component parts of the same beach are very likely to yield different species of copepods. In short, isolation is as much an accompaniment of dwelling in the sand or mud as is wide distribution a result of swimming freely in the open ocean.

A final consideration is concerned with reproduction and is also intimately associated with distribution. Among the free-swimmers the female carries her eggs about with her in external ovisacs or extrudes them singly at intervals into the water. In the former case the eggs are kept together until they hatch, in the latter case they are widely scattered, since the female is constantly moving about while extruding them. Similarly, when the eggs in the ovisac hatch, the nauplii do not all emerge at the same time, but there is a considerable interval between

the bursting of the first and the last egg shell. Here also the female copepod is moving about constantly while the nauplii are emerging, so that the latter are just as widely separated as when the eggs were deposited singly. Such a scattering of the larvae must contribute greatly to a wide distribution of the species, but we are chiefly concerned here with the separation of parent and offspring. It is quite evident that among these free-swimmers no inference of relationship can be drawn from a mere association of adults and larvae.

In the commensal copepods, on the contrary, every step in the process of reproduction from the preliminary mating to the final moult into the adult form takes place within the body of the host. If there were a single male and female at the outset it would be fairly certain that all the larvae were their offspring, and we would have a genuine copepod family from a genetical point of view. Relationship can be argued here from association of adults and larvae and might possibly continue through more than one generation.

The terraqueous copepods appear to occupy an intermediate position between the two extremes just noted. Compared with the free-swimmers they move about very little, compared with the commensals they have greater freedom of locomotion. It is highly probable, however, that the area covered by a female during the hatching of her eggs is very limited. As a result the emerging nauplii are not far removed from their parent and may be more or less closely associated with one another. The relationship of adults and larvae found together is not at all impossible, but neither is it as probable as among the commensal copepods.

The considerations here discussed show very clearly that these terraqueous copepods constitute a fourth group fully as well defined as either of the three already accepted. And they open up to the investigator an entirely new field of research along several interesting lines. Not only will a comparatively large number of the specimens obtained in the sand and mud prove to be new species and genera, but also they will exhibit some remarkable adaptations to their environment. The habitat is entirely new and one of the last to be suspected as a resort for copepods, and the mode of life is unique and entirely unlike that of other copepods. Such a combination ought to prove genuinely attractive and, supplemented by the abundant supply of working material, ought to yield important results.
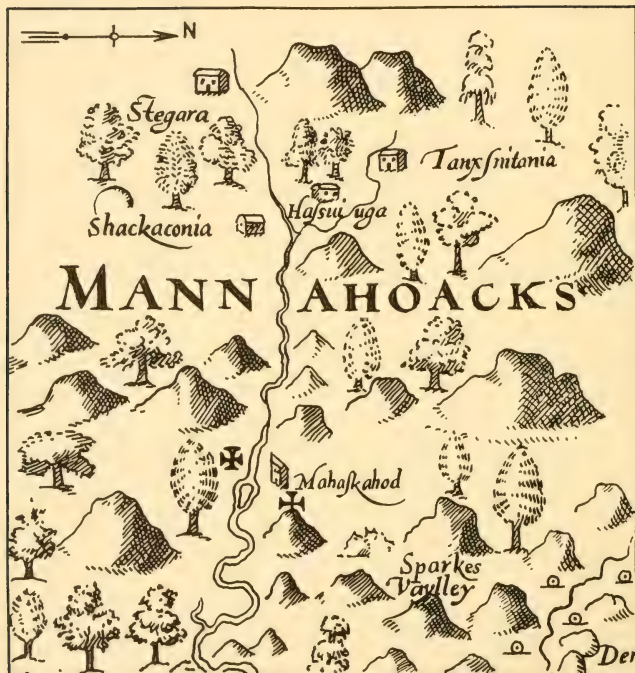
SECTION OF THE SMITH MAP, 1624

The two crosses indicate the farthest points reached by the colonists when they ascended the Rappahannock in August 1608. The large island is just below Mahaskahod. An aerial photograph of the island as it now appears is reproduced in plate 2.

THE MANAHOAC TRIBES IN VIRGINIA, 1608

(WITH 21 PLATES)

BY
DAVID I. BUSHNELL, JR.

CONTENTS

ILLUSTRATIONS

PLATES

THE MANAHOAC TRIBES IN VIRGINIA, 1608

By DAVID I. BUSHNELL, JR.

(With 21 Plates)

INTRODUCTION

At the beginning of the seventeenth century the greater part of the piedmont section of Virginia was occupied by Siouan tribes. The villages of the Monacan were then standing on the banks of the James and Rivanna Rivers and dominated the surrounding country.[1] Northward, along the course of the Rappahannock and of the tributary Rapidan, were the scattered settlements of the various tribes that formed the Manahoac confederacy. The restricted area between the eastern boundary of the lands then claimed by the Manahoac tribes, which extended to the vicinity of the falls of the Rappahannock, and the right[2] bank of the Potomac was occupied by Algonquian groups, some of whom belonged to the Powhatan confederacy, others being in alliance with tribes then living on the opposite side of the Potomac, a region soon to become part of the " Province of Mary-land ".

For many years after the establishment of Jamestown the Manahoac tribes constituted one of the most important groups in the colony. But between the English settlements and the land claimed and occupied by the Manahoac were the many Algonquian villages, dominated first by Powhatan and later by Opechancanough, hostile to the English and ever enemies of their Siouan neighbors. These served as a barrier and prevented intercourse between the colonists and the tribes then living beyond the falls of the Rappahannock.

Although the English encountered many of the Manahoac for a single day during the summer of the year following the settlement of the colony, there is no known record of a European having visited a village of the confederacy or of having had other contact with the tribes in the region they had occupied in 1608. Evidently the English did not enter the country west of the falls until after the native

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[1] Bushnell, David I., Jr., The Five Monacan towns in Virginia, 1607. Smithsonian Misc. Coll., vol. 82, no. 12, 1930.

[2] When using the terms " right bank " and " left bank ", the observer is considered to be facing downstream.

villages had been abandoned and the people dispersed; consequently, very little is known of the manners, customs, and beliefs of this ancient Siouan group.

The region now to be considered, part of the ancient country of the Manahoac, extends westward from the falls of the Rappahannock at Fredericksburg, up the valley of the Rappahannock to Kellys Ford, and along the Rapidan from its mouth to near Mortons Ford.

The description of the various camp and village sites and of the material found scattered over the surface of many of them, which is presented in the following pages, is based on data gathered during short visits to the different localities. It was not planned to conduct a thorough examination of the region, but rather to make a reconnaissance in the endeavor to locate sites that might have been occupied by the Manahoac in 1608, and to discover, if possible, additional evidence of an earlier period of occupation.

At this time I desire to express my appreciation to Capt. H. K. Baisley, Army Air Corps, stationed at Bolling Field, D. C., by whom the aerial photographs (except pl. 2) were made; to H. B. Collins, Jr., my companion on many trips; and to F. M. Aldridge, of Fredericksburg, and G. G. Harris, of Stevensburg, for assistance in locating sites and material.

ARRIVAL OF THE ENGLISH AT THE FALLS OF THE RAPPAHANNOCK, AUGUST 1608

During the summer of 1608 colonists from Jamestown, led by Capt. John Smith, made two successful exploring trips to the islands and shores of Chesapeake Bay in the endeavor to learn more about the nature of the country in which their new home had been established. They entered many streams, up which they went as far as possible, and discovered Indian villages never before visited by Europeans, in turn being the first white men to be seen by the majority of the native inhabitants. Both trips proved to be of the greatest interest and importance, and brief accounts of them have been preserved, but only that portion of the narratives will now be considered that treats of the exploration of the Rappahannock which brought the English into contact with the Manahoac tribes.[2]

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[2] Quotations are from the narratives of " What happened the second Voyage in discovering the Bay . . . . Written by Anthony Bagnall, Nathanaell Powell, and Anas Todkill ", in *The Generall Historie of Virginia,* by Capt. John Smith, 1624. All references to Smith's writings are taken from the English Scholar's Library edition, edited by Edward Arber, Birmingham, 1884.

The information concerning the Manahoac gathered during the brief stay of Smith and his party in the vicinity of that people constitutes the major part of our knowledge of the manners, customs, and beliefs of members of that group of tribes, and its importance cannot be over-estimated. The names of four native settlements, two on the banks of the Rapidan and two on the Rappahannock, were told at that time by Amoroleck, a Manahoac Indian from Hassininga, who had been wounded and taken captive by the English.

The second expedition left Jamestown July 24, 1608, and returned early in September. Late in August, after having explored much of the bay to the northward, they reached the mouth of the Rappahannock and continued up the river to the village of Moraughtacund. This was shown on the 1624 map as being on the left bank of the river, and is thought to have occupied a site near a small creek, about 1½ miles above the mouth of Corrotoman River, in the present Lancaster County, Virginia. Here a few years ago, scattered over an area of some 60 acres, were vast quantities of oyster shells, the deposits having a maximum depth of about 4 feet. A greater amount of fragmentary pottery and a larger number of chipped boulders and pebbles, chips of stone, crudely made axes, and other objects of native origin are said to have been found here than on any other site yet discovered on the banks of the Rappahannock, indicating the location of a large native settlement.

At Moraughtacund the colonists met their " old friend *Mosco,* a lusty Salvage of *Wighcocomoco* upon the river of *Patawomek* ", who was destined to serve them as guide and interpreter during their trip up the river. Continuing up the stream, the English had a serious encounter with the Rapahanocks, whose village, designated at Toppahannock, is shown on the 1624 map on the left bank of the river. It may have occupied a site on the bank of the Rappahannock in the present Richmond County, immediately opposite the town of Tappahannock, which stands on the right bank of the river in Essex County.

Thus far, only Algonquian tribes had been encountered.

The day following the skirmish with the Indians the English continued up the stream as far as their boat could be taken, where the channel became obstructed by the rocks below the large island. Here they went ashore to explore the country. They did not go far from the boat but, as indicated by the position of the small cross on the map, appear to have ascended the high ground on the right bank of the river opposite the upper end of the island, beyond which lay the country of the Manahoac.

THE MANAHOAC

Soon after the English had landed in the vicinity of the falls of the Rappahannock they were attacked by Indians. The fight lasted about half an hour, when the latter " vanished as suddenly as they approached. *Mosco* followed them so farre as he could see us, till they were out of sight." One of the Indians was found severely wounded and was taken to the boat, where Mosco attempted to attack him. " In the meane time we contented *Mosco* in helping him to gather up their arrowes, which were an armefull; whereof he gloried not a little."

The wounded Manahoac soon recovered from the shock (p. 427) :

he looked somewhat chearefully, and did eate and speake. . . . . Then we desired *Mosco* to know what he was, and what Countries were beyond the mountaines; the poore Salvage mildly answered, he and all with him were of *Hassininga,* where there are three Kings more, like unto them, namely the King of *Stegora,* the King of *Tauxuntania,* and the King of *Shakahonea,* that were come to *Mohaskahod,* which is onely a hunting Towne, and the bounds betwixt the Kingdome of the *Mannahocks* and the *Nandtaughtacunds,* but hard by where we were.

We demanded why they came in that manner to betray us, that came to them in peace, and to seeke their loves; he answered, they heard we were a people come from under the world, to take their world from them.

We asked him how many worlds he did know, he replyed, he knew no more but that which was under the skie that covered him, which were the *Powhatans,* with the *Monacans,* and the *Massawomeks* that were higher up in the mountaines.

Then we asked him what was beyond the mountaines, he answered the Sunne: but of any thing els he knew nothing; because the woods were not burnt.

These and many such questions wee demanded, concerning the *Massawomeks,* the *Monacans,* their owne Country, and where were the Kings of *Stegora, Tauxsintania,* and the rest. The *Monacans* he sayd where their neighbours and friends, and did dwell as they in the hilly Countries by small rivers, living upon roots and fruits, but chiefly by hunting. The *Massawomeks* did dwell upon a great water, and had many boats, and so many men that they made warre with all the world. For their Kings, they were gone every one a severall way with their men on hunting. But those with him came thither a fishing till they saw us, notwithstanding they would be all together at night at *Mahaskahod.*

For his relation we gave him many toyes, with perswasions to goe with us: and he as earnestly desired us to stay the comming of those Kings that for his good usage should be friends with us, for he was brother to *Hassininga.* But *Mosco* advised us presently to be gone, for they were all naught; yet we told him we would not till it was night. All things we made ready to entertaine what came, and *Mosco* was as diligent in trimming his arrowes.

The night being come we all imbarked; for the river was so narrow, had it beene light the land on the one side was so high, they might have done us exceeding much mischiefe. All this while the King of *Hassininga* was seeking the rest, and had consultation a good time what to doe. But by their espies seeing we were gone, it was not long before we heard their arrowes dropping on every side the Boat; we caused our Salvages to call unto them, but such

a yelling and hallowing they made that they heard nothing, but now and then we shot off a peece, ayming so neare as we could where we heard the most voyces. More than 12 myles they followed us in this manner; then the day appearing, we found our selves in a broad Bay, out of danger of their shot, where wee came to an anchor, and fell to breakfast. Not so much as speaking to them till the Sunne was risen.

Being well refreshed, we untyed our Targets that covered us as a Deck, and all shewed our selves with those shields on our armes, and swords in our hands, and also our prisoner *Amoroleck*. A long discourse there was betwixt his Countrimen and him, how good wee were, how well wee used him, how wee had a *Patawomek* with us, who loved us as his life, that would have slaine him had wee not preserved him, and that he should have his libertie would they be but friends; and to doe us any hurt was impossible.

Upon this they all hung their Bowes and Quivers upon the trees, and one came swimming aboord us with a Bow tyed on his head, and another with a Quiver of Arrowes, which they delivered our Captaine as a present: the Captaine having used them so kindly as he could, told them the other three Kings should doe the like, and then the great King of our world should be their friend; whose men we were. It was no sooner demanded but performed, so upon a low Moorish poynt of land we went to the shore, where those foure Kings came and received *Amoroleck*: nothing they had but Bowes, Arrowes, Tobacco-bags, and Pipes: what we desired, none refused to give us, wondering at every thing we had, and heard we had done: our Pistols they tooke for pipes, which they much desired, but we did content them with other Commodities. And so we left foure or five hundred of our merry *Mannahocks,* singing, dauncing, and making merry, and set sayle for *Moraughtacund.*

Thus ended the first intercourse between the English and chiefs of several Manahoac tribes. Other colonists may have entered the country above the falls of the Rappahannock, but not until after the native villages had been abandoned and the Indians had left the valleys are explorers and settlers known to have traversed the ancient territory of the Manahoac and to have left records of their journeys into the wilderness, now the piedmont section of Virginia.

In " The Description of Virginia ", 1612, Captain Smith [4] wrote: " The third navigable river is called *Toppahanock.* (*This is navigable some 130 myles.*) At the top of it inhabit the people called *Manna-hoackes* amongst the mountaines, but they are above the place we describe." It will be remembered that Smith and his party did not enter the Manahoac country, and that all their knowledge of the position of the different tribes whose villages then stood in the valleys of the Rapidan and Rappahannock was evidently obtained from the wounded Manahoac Indian, Amoroleck, through the Algonquian interpreter, Mosco. Many of the native settlements were indicated on the map of Virginia, issued in 1624, and their apparent accuracy is

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[4] Op. cit., Arber edition, p. 52.

very remarkable. Smith, in describing the map, wrote: " In which Mappe observe this, that as far as you see the little Crosses on rivers, mountaines, or other places, have been discovered; the rest was had by information of the *Savages,* and are set downe according to their instructions." Two such crosses appear near the falls of the Rappahannock, one on the left bank below the island, the second on the right bank just above the island. These indicate the most distant points reached by the English in August 1608.

When referring to the several tribes Smith wrote (p. 71) :

Upon the head of the river of *Toppahanock* is a people called *Mannahoacks.* To these are contributers the *Tauxsitanias,* the *Shackaconias,* the *Outponcas,* the *Tegoneaes,* the *Whonkentyaes,* the *Stegarakes,* the *Hassinnungas,* and diverse others; all confederats with the *Monacans,* though many different in language, and be very barbarous, living for most part of wild beasts and fruits.

A paragraph very similar to the preceding, written by Smith, occurs in the Strachey manuscripts,[5] but the spelling of the names differs, and there are other variations. Strachey[6] wrote (p. 104) :

Beyond the springs of the river Tappahanock (the second from Powhatan's) is a people called Mannahoaks; to these are contributory the Tanxsnitanians, the Shackaconias, the Outpankas, the Tegoneas, the Whonkentias, the Stogaras, the Hassinugas, and divers others, all confederates with the Monacans, though many of them different in language and very barbarous, living for the most part upon wild beasts and fruicts, and have likewise assisted the Monacans, in tymes past, against Powhatan, and maie also by us be dealt withall and taken into friendship, as opportunity and meanes shall affourd.

In describing the country, Strachey had previously written (p. 37) : " the third navigable river by the Naturalls of old was called Opis-

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[5] Strachey, William, The historie of travaile into Virginia Britannia. Hakluyt Society, London, 1849.

[6] William Strachey was the first Secretary of the Colony and remained in Virginia several years, but very little is known of his life and career. He does not appear to have visited the country of the Manahoac and may have had very little intercourse with the Indians. The statements by Smith and Strachey are so similar that it's evident one was quoted from the other, and on the assumption that Smith's work was prepared before the compilation of the two Strachey manuscripts, it should be considered the source of much of Strachey's material.

It is the belief of the writer that the William Strachey who resided in Virginia, the first Secretary of the Colony, did not actually prepare the two manuscripts now preserved in London and Oxford, but that he probably sent notes to England, where they were combined with ample quotations from the writings of Smith to form the manuscripts, which were thus prepared by another. More than one William Strachey, possibly related to the Virginia adventurer, lived in England during the early years of the seventeenth century. Brief references to the Strachey family of that period are to be found in the introduction to the Hakluyt Society publication.

catumeck, of late Toppahanock, and we the Queen's River; this is navigable some one hundred and thirty miles. At the top of yt inhabite the people called Mannahoacks, amongst the mountaynes, but they are above the place described in Captain Smithe's mappe." This was the present Rappahannock, the old Indian name of which was Opiscatumeck.

Although it is to be regretted that more information about the manners and ways of life of the Manahoac tribes is not available, it is gratifying to realize how much was gathered and preserved as a result of the brief contact of colonists and Indians in August 1608. But for the willingness of one wounded native, even that would not have been recorded.

MANAHOAC SITES INDICATED ON THE 1624 MAP

As previously mentioned, only five Manahoac sites are indicated on the 1624 map, one being that of the " hunting Towne ", a temporary camp, the other four probably being the names of the chiefs whom the English met during the morning after the encounter near the falls. In addition to these, three others were mentioned in the text but not shown on the map; these were Outponcas, Tegoneaes, and Whonkentyaes. There is nothing to suggest where they may have been situated—whether on the Rappahannock or the Rapidan.

Concerning the true significance of the eight names, it is not known whether they were place names that would have been applied to settlements through a long period of years or the names of chiefs, who in 1608 were recognized and acknowledged by others and whose people dominated a region that corresponded with the position of the name on the map. Amoroleck, the Manahoac Indian, once referred to himself as " brother to Hassininga " who was later mentioned as " the King of Hassininga ". Evidently Amoroleck was a brother of a chief named Hassininga, whose village then stood on the banks of the Rappahannock just above its junction with the Rapidan. If this hypothesis is correct, it should be assumed that the eight names were primarily those of individuals rather than of places. The names may have been provided by the four chiefs themselves, who at the same time would probably have indicated the relative positions of their villages as later recorded on the map.

The five sites will be considered separately in the endeavor to determine where they may have stood in the year 1608. However, there is no record of any of the native villages having been visited by a European, their actual existence and approximate position having

been revealed to the English by the Indians after the encounter below the falls. The names were undoubtedly recorded by the English as given them by their Algonquian guide and interpreter, Mosco.

As yet it has not been possible to translate the names as given by Smith or Strachey. They were undoubtedly in some Siouan dialect and were told to the English by an Algonquian Indian. The latter appears to have attempted to translate the Siouan word into his own language, and this resulted in the names as recorded by the English being a combination of Siouan and Algonquian, making it difficult, if not impossible, ever to learn their true meaning.

Traces of many native settlements have been discovered on the banks of the Rapidan and the Rappahannock above the falls, some of which were undoubtedly occupied in 1608, but it will probably never be possible to determine the exact position of any one of the eight villages that were mentioned in the early narratives.

MAHASKAHOD

Mahaskahod was the name applied to a camp, possibly of a temporary nature as distinguished from a permanent settlement. It was described as " a hunting Towne ", where several hundred Indians from four or more distant villages of the Manahoac were gathered in August 1608.

This large encampment, if it really existed as described at the time of the first visit of the English to the region, must have stood on the banks of the Rappahannock some distance above the upper end of the large island. The colonists, as suggested by the position of the small cross placed at that point on the 1624 map, reached a locality on the right bank of the river opposite the island. They probably ascended the cliff that rises from the river bank at the end of the dam just above the island, from which they would have had a view up the valley. This point is clearly shown in plate 2. But the narrative did not mention an Indian encampment in the vicinity, nor did the English encounter any natives at that time.

HASSUIUGA

The position of Hassuiuga can be identified with a greater degree of certainty than any other site on either the Rapidan or the Rappahannock. It evidently occupied the banks of the Rappahannock a short distance above the mouth of the Rapidan, at a crossing of the river now known as Richards Ford, where traces of a native village occur, and where, according to local tradition, an Indian town once stood. This corresponds with the position of the name on the 1624 map.

TANXSNITANIA

This name appears on the 1624 map far up the stream that corresponds to the present Rappahannock River. The region so vaguely indicated on the map was settled during the early years of the eighteenth century. " In a grant of 1717, relating to lands above the mouth of Great Run, there is mention of a ' poison field where an Indian town had formerly stood.' This was doubtless the Manahoac town laid down on Capt. John Smith's map as Tanxsnitania." [7] The " poison fields " were identified as the area adjoining the Fauquier White Sulphur Springs. The site would be between 2 and 3 miles above the mouth of Great Run, which joins the Rappahannock on the left bank; Great Run is some 5 miles above the mouth of Hazel River.

SHACKACONIA

As indicated on the 1624 màp, Shackaconia was the first settlement on the Rapidan above its mouth. The exact position may never be known, but the village probably occupied one of the sites later to be described.

STEGARA

Stegara may have stood on the banks of the Rapidan in Orange County, a mile or more east of the Greene County line. However, that would have been a long distance from the falls, near which the " King of Stegora " was met by the English in August 1608. Such long journeys, however, were often undertaken by an entire village, and, as will be told later, dugout canoes were used by Indians on the Rapidan as late as 1682, when they went from the foothills of the Blue Ridge to visit the English outpost at the falls of the Rappahannock.

One of the most extensive level tracts in the valley of the Rapidan borders the right bank of the river at the locality mentioned, and when partly covered with timber, as it probably was until cleared for cultivation, would have been a beautiful site for a native settlement.

Part of a large burial mound that belonged to the village is still standing on the immediate bank of the stream. The mound was partially examined by Fowke[8] and found to contain many burials. Quantities of arrowpoints, axes, and other objects of native origin have been discovered scattered over the surface in the vicinity of the mound,

[7] Harrison, Fairfax, Landmarks of Old Prince William, vol. 1, p. 202. Privately printed, Richmond, 1924.

[8] Fowke, Gerard, Archeologic investigations in James and Potomac Valleys. Bull. 23, Bur. Amer. Ethnol., 1894.

and in many respects the entire site resembles that of the ancient Saponi village, Monasukapanough, on the banks of the Rivanna some 15 miles away.

DISPERSING OF THE NATIVE TRIBES FROM THE RAPIDAN-RAPPAHANNOCK AREA

The English reached the falls of the Rappahannock in August 1608 and there came in contact with the Manahoac tribes whose lands lay to the westward, but the first journey into the country beyond the falls, of which a record is known to have been preserved, was not made until the year 1670. Great changes had taken place, however, during the interval between 1608 and 1670, and although there had been a relatively large population living in camps and villages along the courses of the streams at the beginning of the century, by the year 1670 the country was practically deserted.

During the summer of 1670 the German traveler, John Lederer, of whom so little is known, traversed the wilderness as far as the Blue Ridge. Earlier in the year he had visited several Monacan villages in the valley of the James, and in the brief account of his " Third and last expedition. From the Falls of Rappahanock River in Virginia, due west to the top of the Apalatean Mountains ", referred to his journey through the region that had so short a time before been the home of the scattered Manahoac tribes. Small groups of Indians may have remained in the vicinity, but they were not mentioned and may not have been encountered. Describing this last expedition Lederer wrote in part:[9]

On the twentieth of August 1670, Col. Catlet of Virginia and my self, with nine English horse, and five Indians on foot, departed from the house of one Robert Talifer, and that night reached the falls of Rappahanock river, in Indian *Mantapeuck.*

The next day we passed it over where it divides into two branches north and south, keeping the main branch north of us.

The three and twentieth we found it so shallow, that it onely wet our horses hoofs.

The four and twentieth we travelled thorow the Savanae amongst vast herds of red and fallow deer which stood gazing at us; and a little after, we came to the Promontories or spurs of the Apalataean-mountains.

A crudely drawn map of the region accompanies the narrative, a section of which is reproduced in figure 1. This shows the Rappahannock and the Rapidan uniting some miles above the falls, and

[9] Lederer, John, The discoveries of. . . . . Begun in March 1669, and ended in September 1670. London, 1672. Reprint 1902.
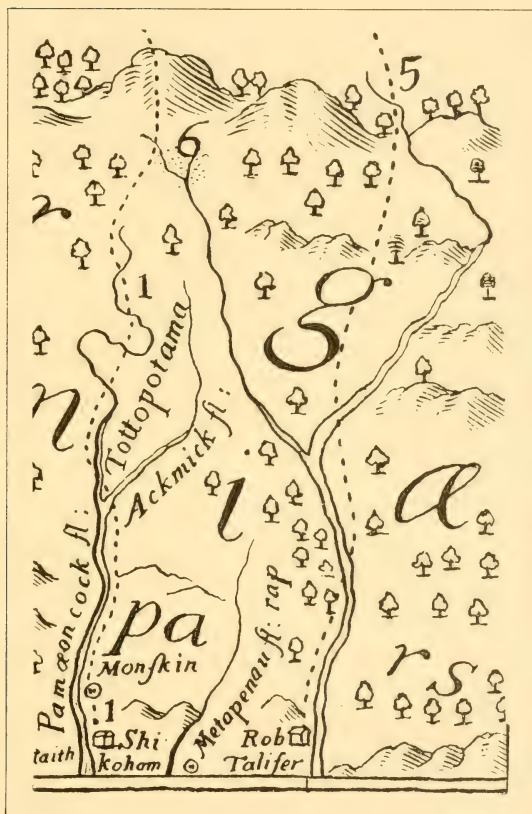
Fig. 1.—Section of the Lederer map, 1670. The stream on the right is the Rappahannock. The broken line indicates the trail followed by Lederer, "from the house of one Robert Talifer."

a broken line indicates the route of the party westward. They undoubtedly followed an Indian trail, which may have been about the course of the road that leads west from Falmouth, on the left bank of the Rappahannock at the falls, and crosses the river at Richards Ford, about 1 mile above the mouth of the Rapidan.[10]

The name Manahoac was not used by Lederer when referring to the native tribes, although it had been employed in the earlier records, but it is believed the names Mahoc and Mahock of his narrative were other forms of the word that were used at the later day.

As so often told in history, sometime before the spring of 1656 a large number of Indians, probably an entire village with all of their possessions, " sett downe neer the falls of James river, to the number of six or seaven hundred ".[11] They had come as friends to seek a new home, not as enemies, and desired peace, not war. Later they were attacked by the colonists in the endeavor to expel them from the colony. The English had as allies Totopotomi and his Pamunkey warriors. In the encounter that ensued the English suffered great losses and their allies were routed and driven back.[12] The Indians against whom the combined attack had been directed probably retired up the James and were lost to history, but Mohawk Creek, on the right bank of the James a mile or more south of the present Goochland, is believed to perpetuate their name.

Some 15 years after the disastrous encounter Lederer mentioned it and wrote in part: " a great Indian king called Tottopottoma was heretofore slain in battle, fighting for the Christians against the Mahocks and Nahyssana." [13] The latter were from far up the James, and it is now believed the Mohocks, who had come from a distance,

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[10] The road as it was used at the beginning of the last century was shown on the Bishop James Madison map, first issued in 1807 and again in 1818; also on the Nine Sheet Map, 1827. The road from Falmouth crossed the Rappahannock at Richards Ford, then continued to Stevensburg and beyond, as it does at the present time.

[11] Hening, William Waller, The statutes at large . . . . of all the laws of Virginia, vol. 1, New York, 1823.

[12] The exact date of the engagement is not known, but it occurred subsequent to March 27, 1656, when it was enacted by the General Assembly " That the two upper countyes, under the command of Coll. Edward Hill, do presently send forth a party of 100 men at least and that they shall first endeavour to remoove the said new come Indians without makeing warr if it may be, only in case of their own defence. . . . ." (Hening, vol. 1, pp. 402-403). And it was probably between April 23 and June 4, 1656, as is suggested by brief references to early Council and General Court records. (Virginia Hist. Mag., Virginia Hist. Soc., vol. 8, no. 2, p. 164, Richmond, 1900.)

[13] Lederer, op. cit.

were a village or group of Manahoac who had been forced to abandon their country to the northward, along the Rappahannock and the Rapidan.

The pressure exerted by enemy tribes from the north undoubtedly caused the dispersal of the Manahoac from the region they had occupied in 1608. The movement may have begun soon after the middle of the century, at a time when the Iroquois were waging relentless war against the Erie, thus leaving the tribes to the south of them free to act on the offensive.

The difficulties that were being experienced by the colony along the frontier at that time were expressed in several reports recorded by Hening,[14] one of which is quoted, and although this is dated March 1661-2, it refers to events and happenings that had transpired sometime before. It reads in part:

Upon the report of the committee appointed for the Indian affaires it appearing that the Susquehannock and other northern Indians, in considerable numbers frequently come to the heads of our rivers, whereby plain paths will soone be made which may prove of dangerous consequence, and alsoe affront the English and destroy their stocks and gett the whole trade from our neighbouring and tributary Indians; *it is ordered by this assembly* that for prevention and of other injuries to the English from the Marylanders for the future, that the honourable governour cause by proclamation a prohibition of all Marylanders, English and Indians (which they have alreadie done to us) and of all other Indians to the Northward of Maryland from trucking, tradeing, bartering or dealing with any English or Indians to the southward of that place, and that by commission from the governour collonel Wood be impowered to manage the said businesse.

The falls of the Rappahannock were at that time beyond the frontier of the colony, and it is easily conceived that " the Susquehannock and other northern Indians " had, during their southern raids, traversed the region to the westward, entered the valley of the Rappahannock, and thus caused the native tribes to disperse and seek new homes elsewhere.

The historic " Carolina Road ", which may not have acquired its name until about the middle of the eighteenth century, followed the course of more ancient trails that led from north to south. It crossed the Potomac at the mouth of the Monocacy, reached the Rappahannock in the vicinity of the present Kellys Ford, thence to the left bank of the Rapidan which was probably crossed at or near Fox Neck.[15] The crossing may once have been at a very old, long-abandoned

[14] Hening, op. cit., vol. 2, p. 153.
[15] Harrison, Fairfax, Landmarks of Old Prince William. Privately printed. 2 vols., Richmond, 1924.

ford about 1 mile above Fox Neck, just below the mouth of a small stream now known as Sissens Run, but designated as Fleshman's R. on the Nine Sheet Map, 1827.

Leaving the Rapidan, the trail continued southward to the crossing of the James at the present town of Goochland. On the opposite or right bank of the James, above the ferry, is the mouth of Mohawk Creek. It is evident the Manahoac, or rather some part of them, moved southward from the valley of the Rapidan or the Rappahannock over the old route and arrived at the James, where they may have remained before continuing down the river to the falls. Their camp was probably at the mouth of the creek, to which their name was soon applied.

The name of another creek suggests the identity of the Manahoac tribe that had " sett downe neer the falls of James river, to the number of six or seaven hundred ".

On the 1624 map the village of Shackaconia is indicated on the right bank of the Rapidan a short distance above the mouth of the stream, and it is assumed to have occupied a site on or near Fox Neck, or possibly at the present Skinkers Ford, where traces of an extensive settlement have been discovered. No one of the sites would have been more than a few miles from the trail that led southward from the Rapidan to the James.

The camping place of the Indians who had come from afar and had settled near the falls of the James was on, or in the vicinity of, the headwaters of Shaccoe Creek, which flows into the James within the City of Richmond. A manuscript map in the " Byrd Title Book ", in the collections of the Virginia Historical Society, dated early in the year 1663, shows the creek bearing the legend : " Shaccoe Creek formerly Called Chyinak ". It is now suggested that the new name Shaccoe was derived from that of the Indians who had a few years before settled nearby, believed to have been from the village of Shackaconia on the banks of the Rapidan. Until their coming the creek had evidently been known by the name Chyinak. If this belief is correct it was the Shackaconia tribe of the Manahoac confederacy, the Mahocks of Lederer, who defeated the colonists and their Pamunkey allies in one of the most important encounters between the English and Indians recorded in the annals of the colonies. This was the last great fight in Virginia between Siouan and Algonquian tribes.

After the defeat of the English the Mahocks may have returned to the vicinity of the mouth of Mohawk Creek. Although this is thought to have been the site of the Monacan village of Massinacack

in 1607, the name of the ancient settlement was in no way associated with that of the stream.

During the year 1676 a fort was erected " at or neare the ffalls of Rapahanack river ", and soon the country that lay beyond the forks became better known to the colonists. In 1682 Cadwalader Jones, then commander of the Rappahannock Rangers, explored far westward, traversed the region previously mentioned by Lederer, where were to be found " vast herds of red and fallow deer ", and may have crossed the Blue Ridge. Among his companions was John Taliaferro, who some years later testified that he had been with Jones in 1682 and said in part:

> We traviled up the South river till we came to sev[ll] small mountains & so to the North River. In our travills we were sev[ll] times on the North River and went up the South River to the great Mountains where we discovered the South River's Springs to head into the Mountains. All our Judgm[ts] was the South river to be the bigest and were inform'd so by all the Indians y[t] was our Pilotts; and saw an Indian y[t] made a periauger at the mountain and brought her down to the Garison with Skins and venison, where the said Jones Commanded.[16]

In this statement South River referred to the present Rapidan, and North River was that part of the present Rappahannock above the mouth of the Rapidan. " Periauger " was the name then applied to a dugout canoe, made of a single log.

The brief quotation from Taliaferro's testimony proves of much interest, as it contains the only reference known to the writer of the actual use of a dugout canoe by Indians in piedmont Virginia. It also indicates that long journeys were made in such craft from the foothills of the Blue Ridge, down the Rapidan, and on to the fort near the falls of the Rappahannock, then on the frontier of the colony.

EVIDENCE OF INDIAN OCCUPANCY

As already stated, the region now being considered extends up the Rappahannock River from the falls just above Fredericksburg to Kellys Ford, and along the Rapidan from its junction with the Rappahannock to the vicinity of Mortons Ford. The supposed site of Stegara on the Rapidan, and of Tanxsnitania on the Rappahannock, are beyond these limits and consequently will not be included in the present narrative.

It is interesting to discover traces of Indian occupancy on nearly every acre of cleared or cultivated land along the river banks, wher-

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[16] Harrison, op. cit. The quotation was made from the manuscript of Taliaferro's testimony, document 5 : 1315, in the Colonial Office, London.

ever it is possible to examine the surface carefully. Often it is liter-
ally a trace—an arrowpoint, a bit of pottery, or a flake of stone.
Again, the occurrence of a large accumulation of material within a
rather restricted area will indicate the location of an extensive village,
or of a site that had been frequented by small groups at intervals
during a long period. But all the fragmentary pottery and objects of
stone encountered in the region must not be attributed to the Siouan
tribes who claimed the country at the beginning of the seventeenth
century. They had been preceded by other groups, many of whose
weapons and implements may now be intermingled with those of the
later people.

A large part of the land above the falls remains heavily timbered,
and some interesting sites may be hidden beneath the tangled mass of
vegetation bordering the streams. But some tracts that were once cul-
tivated are now overgrown; some such areas may be distinguished in
the photographs taken from the air. Springs of clear cold water
occur throughout the region. Game was abundant, and much may
still be found.

The depth of water in the rivers varies greatly, and freshets and
droughts often follow in quick succession, as during the summer and
early autumn of 1934. In some places the banks of the rivers are
of sufficient height to confine the streams at all times, but the flats
are frequently overflowed. Strange as it may seem, the greater part
of the material found has been recovered from land that has often
been covered by water.

Many sites have been examined along both rivers and will be de-
scribed separately, beginning at the falls and continuing up the Rappa-
hannock to Kellys Ford, then along the Rapidan from its mouth
to near Mortons Ford. The distances between the places mentioned
are: From the falls to the junction of the two streams, in a direct
line, about 8 miles, thence to Kellys Ford about 13 miles. From the
mouth of the Rapidan in a direct line to Mortons Ford is approxi-
mately 17 miles. The distances between the same points by the me-
andering courses of the rivers would be at least twice as great.

All sites mentioned in the text are indicated on the map of the
region, figure 2.

THE ISLAND AND VICINITY

The waters flowing past the large island, and the rapids both above
and below, appear to have been favorite fishing places for all who
had occupied or frequented the region since it was first known to

man. It was near the island that several hundred Manahoac Indians, the last of the native tribes to claim the country, had gathered early in August 1608, when some were met by the English who had ascended the Rappahannock, and it is easily conceived that it had served as a gathering place for others through centuries. As related by Amoroleck, the Manahoac man who had been wounded and taken captive, the English were not discovered by the Indians until he and " those with him came thither fishing ".

Fish traps may have extended across the rocky bed of the river, below the island, in the year 1608 as some do at the present time. Those still existing have been used in recent years, but by whom they were originally constructed will never be ascertained. Traps similar to these, however, had undoubtedly been made by the Manahoac, as well as by others who had preceded them in the region. They resemble the traps in the James River at Richmond, described by Beverley more than two centuries ago.

Fragments of pottery found a few years ago on the right bank of the Rappahannock opposite the middle of the large island are illustrated in plate 3. The site, which was cultivated when the discoveries were made but is now in grass, is shown in plate 2, on the extreme left above and adjoining the circular track.[17]

The 12 sherds belong to several types of ware that differ in texture and decoration. The nine pieces above are parts of rims of vessels. The three on the right, *a,* are of a light yellowish-gray color and are very hard. They were made of a fine, clean clay and contain no particles of stone. Although very hard, they are extremely porous, owing to the disappearance of the tempering material. Evidently a vegetal substance had served as the tempering material; possibly stems of grass or bits of wood had been reduced to the proper size and mixed with the clay. A fresh fracture through the lowest of the three specimens revealed particles of carbon filling small cavities, but the greater part of the material, after having been carbonized, had leached away, leaving the many small cavities. The fragments are decorated with incised lines.

The three specimens *b* are fragments of rims of large vessels. All are black, hard, and compact, and are tempered with finely pulverized quartz.

The two pieces *c* may have belonged to the same vessel, and resemble in texture specimens *a.* The fracture at the bottom of the lower speci-

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[17] All specimens shown in plates 3 and 4 were collected by F. M. Aldridge, Fredericksburg, Va., by whom the pottery has been presented to the U. S. National Museum.
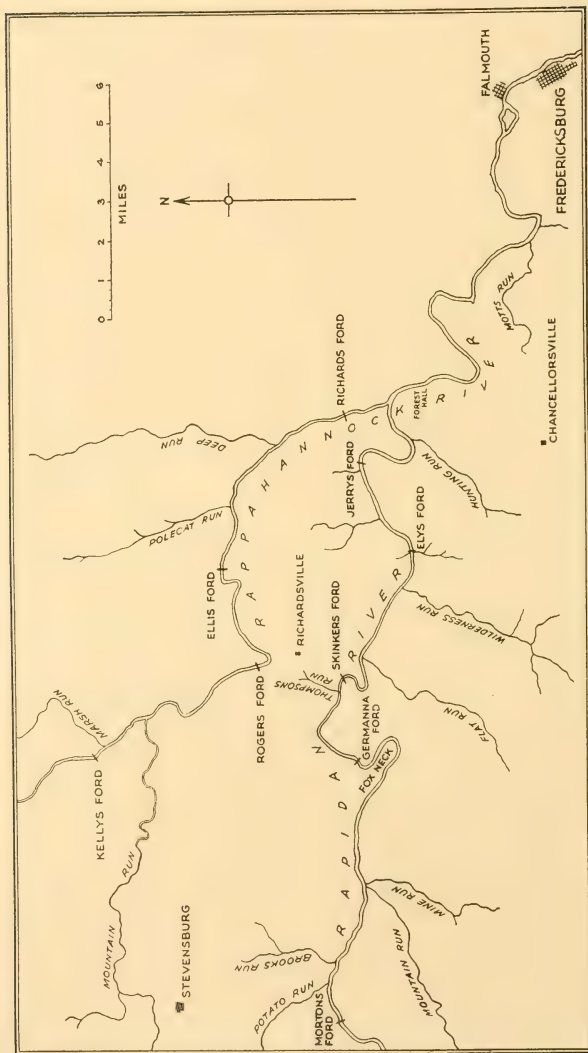
Fig. 2.—Map of the country above the falls of the Rappahannock at Falmouth.

Photograph U. S. Army Air Corps.

LOOKING UP THE RAPPAHANNOCK OVER THE FALLS AND THE ISLAND
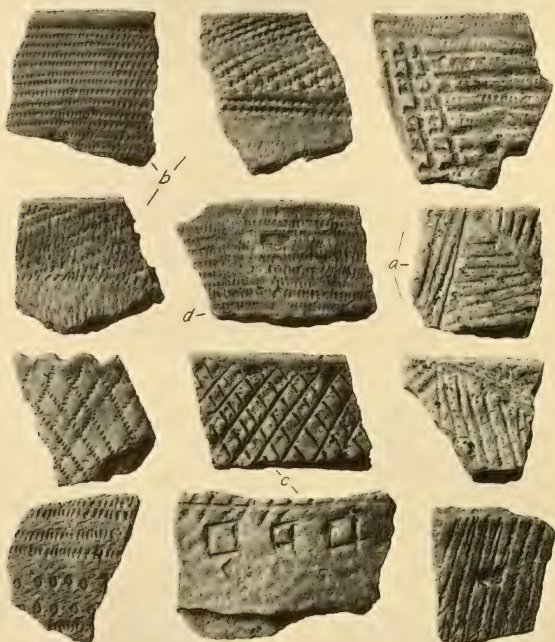
SPECIMENS FOUND ON THE RIGHT BANK OF THE RAPPAHANNOCK, OPPOSITE THE LARGE ISLAND

½ natural size. Pottery, U.S.N.M. no. 373778.

MATERIAL FROM OPPOSITE THE ISLAND AND FROM NEAR MOTTS RUN

Above, specimens from the vicinity of Motts Run. Below, two chalcedony scrapers, from right bank of the Rappahannock opposite the island at the falls. Upper figure ½ natural size; lower figure natural size.
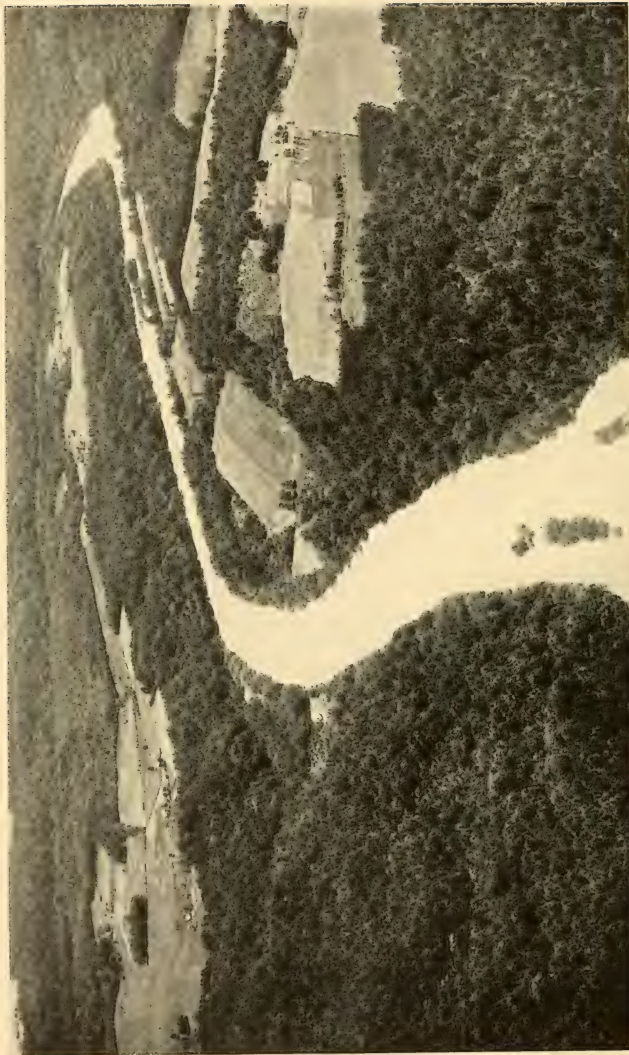
Photograph U. S. Army Air Corps.

LOOKING DOWN THE RAPPAHANNOCK FROM OVER THE MOUTH OF THE RAPIDAN

Forest Hall site on right.

SPECIMENS FROM THE FOREST HALL SITE SHOWN IN PLATE 5

½ natural size. Arrowpoints, U.S.N.M. no. 373780. Four implements, U.S.N.M. nos. 373787-90.
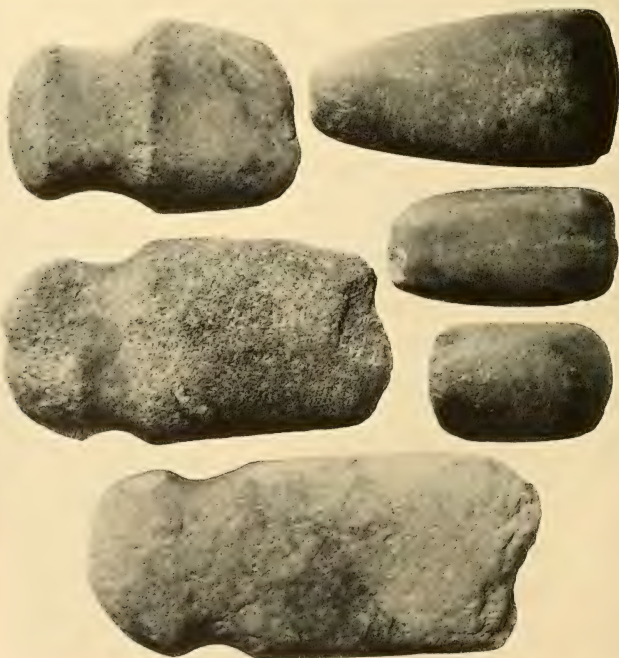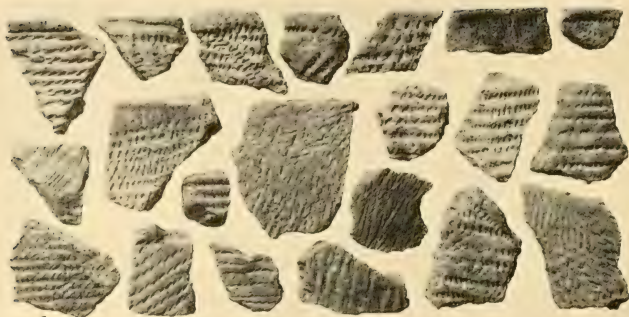
SPECIMENS FROM THE FOREST HALL SITE SHOWN IN PLATE 5

½ natural size. Pottery, U.S.N.M. no. 373779. Celts, axes, U.S.N.M. nos. 373781-6.
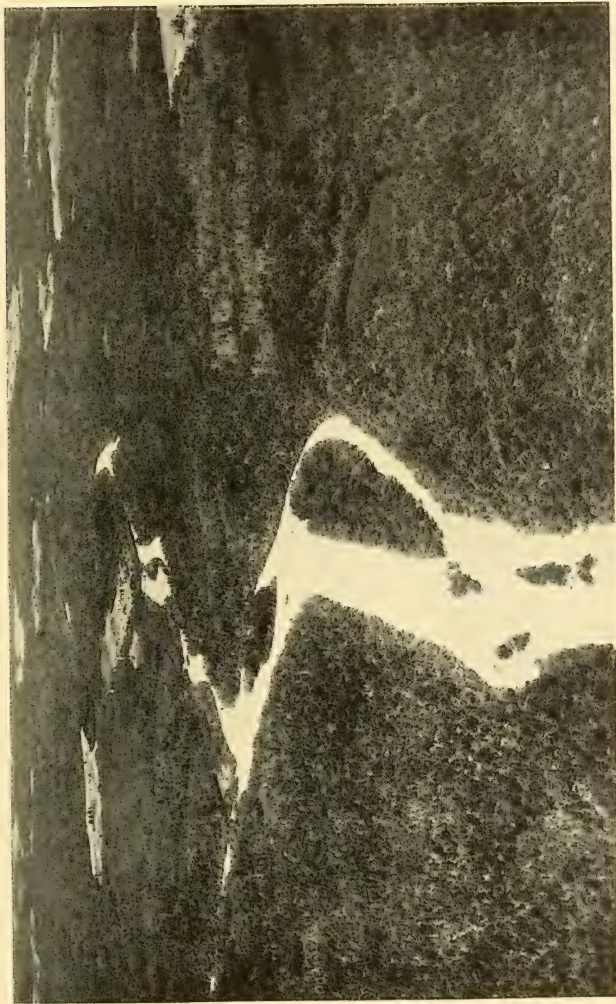
Photograph U. S. Army Air Corps.

LOOKING UP THE VALLEY OF THE RAPPAHANNOCK

Mouth of the Rapidan on the left and Richards Ford beyond.

Photograph U. S. Army Air Corps.

1. RICHARDS FORD ON THE RAPPAHANNOCK, ABOUT 1 MILE ABOVE
THE MOUTH OF THE RAPIDAN

The cultivated land is on the right bank of the river.

2. FRAGMENTS OF POTTERY FROM RIGHT BANK OF THE
RAPPAHANNOCK AT RICHARDS FORD

½ natural size. U.S.N.M. no. 373791.

men follows the line of contact of two strips or coils of clay used in the construction of the vessel but which had not been closely blended.

Specimen *d* is yellowish brown in color, very hard and fine-grained. It does not show evidence of the use of tempering. The impression on the outer surface is the imprint of a rigid, coiled basket. This represents probably the oldest type of pottery found on the site.

The polished grooved ax, plate 3, is a beautiful example, being very symmetrical and carefully finished. The material is a diabasic rock.

Two flakes of chalcedony, plate 4, found on the site, had served as scrapers or cutting instruments. The edges of both are very sharp and in places have been finely serrated through use.

During a visit to the island in the spring of 1933 several small pieces of pottery, a few broken arrowpoints made of quartz and quartzite,
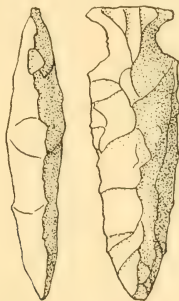
FIG. 3.—Projectile point made of brown chert. Natural size. U.S.N.M. no. 373776.

and a quantity of flakes of quartz, quartzite, chert, and diabase were found on the surface near the extreme western end of the cultivated fields on the upper part of the island. The area is shown in plate 2. This had probably been the site of a fishing camp, and as parts of the island rise high above the greatest freshets, it would have been a place well suited for a native settlement.

When Captain Smith wrote regarding the fishing customs of the Virginia Indians, he said in part: " They use also long arrowes tyed in a line wherewith they shoote at fish in the rivers." Such a method may have been followed by some from the shores of the island, and one projectile point found on the surface may at one time have been attached to an arrow shaft used in shooting fish. The point is sketched in figure 3. It is made of brownish chert, a material seldom encountered in the locality, and is of uniform width and thickness, which

would have been about the same as the diameter of the shaft to which it was fastened.

Many white quartz arrowpoints are found in the vicinity of the island. These will not be mentioned in detail, as they are similar to others found throughout the Rapidan-Rappahannock area, typical examples of which will later be described.

VICINITY OF MOTTS RUN

A small stream bearing the name Embrey Run enters the right bank of the Rappahannock about 3 miles above the falls, a little west of north of old Salem Church. About half a mile beyond, also on the right bank of the river, is the mouth of Motts Run. Between Embrey Run and Motts Run there is a sandy flat several hundred feet in width extending from the river bank to the foot of the rising ground.
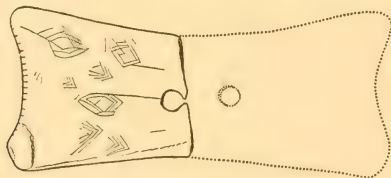
Fig. 4.—Perforated tablet found near Motts Run. ½ natural size.

Although the area has been cultivated for many years and frequently has been covered by the waters of the Rappahannock, a vast amount of fragmentary pottery and many arrowpoints and other objects of stone are still to be found scattered over the surface. This may have been the site of Mahaskahod, the " hunting Towne ", in August 1608.

The pottery recovered from the area is similar to that occurring farther up the river at the Forest Hall site, examples of which are shown in plate 7. Only very small pieces were found, and in many instances the markings of the cords had been practically obliterated, worn away through exposure and contact with sand and water for three centuries or more. A single sherd was discovered that bore deeply incised lines and closely resembles specimens *a*, plate 3. The fragment is very porous but extremely hard.

A piece of a perforated tablet, made of a dark talc schist, was found on the surface near Motts Run. It is a material thought to occur locally. The specimen is sketched in figure 4, one half natural size. On one side are various simple designs formed of straight, incised

lines, but the reverse is smooth. Its maximum thickness is about
$\frac{3}{8}$ inch. There are several specimens of like form in the collections of
the National Museum, one having been discovered in a burial mound
on the Kanawha River, near Charleston, W. Va., and others in the
valley of the Miami, in Ohio. The latter pieces were made of slate.
All, including the fragment from the site on the Rappahannock, may
have been of Siouan origin.

Several small flakes of jasper and chert were found that had served
as scrapers or blades.

As elsewhere, innumerable arrowpoints, most of them made of
white quartz, have been collected from the surface of the low grounds
extending up the river from Embrey Run. Some of these are assumed
to represent the work of the Manahoac and different tribes who fre-
quented the region in later times, but others are thought to have be-
longed to a much earlier period. Some interesting examples are illus-
trated in plate 4. The specimens *a* are made of a diabasic rock with
the surfaces greatly weathered. A small chipped ax, made of the
same material and with the surface equally weathered and worn, was
found about midway between the two runs. This and the points just
mentioned should undoubtedly be attributed to the same early period.
Other pieces included in the plate are made of quartzite, argilite, and
chert.

Shallow sandstone mortars, hammerstones, and roughly flaked
pieces that had probably served some purpose about the camp have
been recovered from the surface. As the first extensive low ground
above the falls begins at Embrey Run, it is readily conceived that it
would have been an important and long frequented camping ground
and as such was probably occupied the day the English reached the
falls a few miles below.

Large boulders, and pebbles of diabase and diabasic rocks, are found
in and near the bed of Embrey Run, and these served the Indians as
raw material for their stone implements. For a hundred yards or
more from the left bank of the run, and some distance from the
river, the surface is strewn with a vast quantity of fractured pebbles
and flakes, and often a piece of more specialized form—evidence of
the fact that this was a site where much work had been done and many
objects made. With few exceptions the fractured surfaces are altered
to the same degree as the ax and projectile points already mentioned,
but others have changed little in appearance since they were struck
from the mass.

FOREST HALL SITE

The aerial photograph of which a part is reproduced in plate 5 was made from high over the mouth of the Rapidan, with the camera pointing a little east of south. It is looking down the Rappahannock, as the stream bears to the left in the distance. On the right is the Synam farm—part of the old Forest Hall plantation—a mile or more below the junction of the two streams. The dwelling and barns, far to the right in the picture, stand on land some 40 or 50 feet higher than the Rappahannock. The flats bordering the river bank, where once stood a native village, are mostly cultivated and are very rich and productive. This is the first cleared ground on the Rappahannock below the mouth of the Rapidan, in the midst of a thickly timbered area that has changed little in appearance since the days when it was claimed by the Manahoac tribes. Here the river banks are rather high, with islands both above and below, and although when the photograph was made (Sept. 17, 1934) the river was unusually high, the waters had not spread over the bordering fields. This was a most desirable site for a native settlement, one which had evidently been occupied from the earliest times.

The entire surrounding country is of much historical interest, and less than a mile west of the Synam house are the remains of the iron furnace constructed by Governor Alexander Spotswood in 1727, the first furnace erected in North America for the exclusive manufacture of pig iron. This became known as the " Tubal Works ".

The large field on the right bank in the bend of the river proved to be of interest when visited late in the summer of 1934. Much of the surface was strewn with pottery, all small fragments, broken and ground by the plow during the many years the land has been cultivated. Some arrowpoints, a few entire but the majority fractured, were likewise found, together with innumerable flakes of quartz, quartzite, and diabasic rocks. In addition to the material discovered on the site at that time, other objects were obtained that had been collected during the past few years, all tending to indicate the location of an extensive native settlement. This may have been one of the Manahoac villages occupied in 1608, but some of the specimens appear to be much older than others, suggesting more than one period of occupancy by different tribes, the last of which ended about the middle of the seventeenth century. Material from the site is shown in plates 6 and 7.

Many of the projectile points and other small chipped objects found on the site are made of white quartz, and for that reason there is no difference in the surface appearance of the specimens, although some

may be centuries older than others. Typical examples are illustrated in plate 6. One triangular point with a concave base, made of black chert, was found near the river bank. It is known that quantities of points of many types and sizes have been found scattered over the surface during past years, and the same is true of larger objects. Undoubtedly one or more burial mounds once stood nearby.

The four stone artifacts also illustrated in plate 6 are believed to have been made and used during an early period of occupancy. The surfaces of all are deeply weathered and have become so worn and smoothed that it is often difficult to distinguish where flakes had been
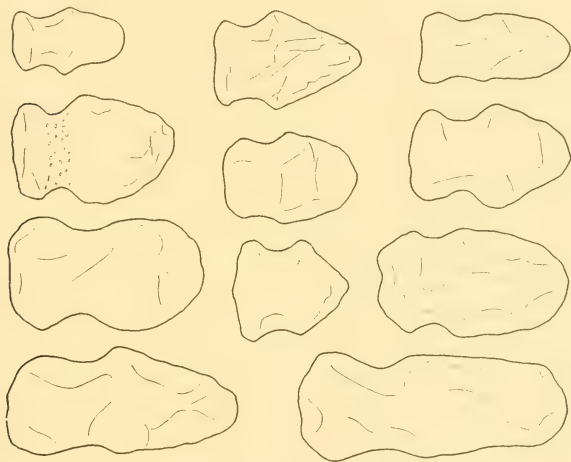
Fig. 5.—Specimens from the Forest Hall site. ⅓ natural size.

removed. Specimens of this class have been very numerous on the site, and the outlines of 11 examples are given in figure 5. These vary greatly in size and must necessarily have served different purposes—some as weapons, others as implements. Some larger and others smaller than any illustrated have been found. All are made of diabasic rocks.

Examples of grooved axes and celts found on the site are shown in plate 7. These resemble more closely the artifacts found on sites along the Potomac than those usually encountered west of the falls of the Rappahannock. All are attributed to a later period, and the difference between these and the four specimens illustrated in plate 6 is very apparent.

A fragment of a thin ornament, possibly a perforated tablet, made of schist was found near the center of the field. The surface is smooth and has not become altered through exposure.

The fragmentary pottery found on the site, characteristic examples of which are shown in plate 7, is very uniform in texture and decoration. Little if any tempering material had been added to the clay of which the vessels were made. Some sherds reveal a small amount of crushed quartz, but this may have been natural. The fragments on the top row are bits of rims of vessels. Some specimens were cord-marked, others appear to have been decorated by the use of a narrow roulette. As shown in the illustration, the cords that had been impressed upon the soft clay varied greatly in size; some were no thicker than a heavy thread, others were very coarse. The impression on the small specimen *a* resembles that of a rigid coiled basket, closely woven and very regular.

Only very small fragments of pottery were discovered on the surface; consequently, it is not possible to determine either the size or the form of the vessels.

RIGHT BANK OF THE RAPPAHANNOCK FROM THE MOUTH OF THE RAPIDAN TO RICHARDS FORD

The junction of the two streams, however large or small they may have been, was always a desirable location for a native settlement. In a densely forested country, trails often followed the banks of streams, and where it was possible to use canoes, the streams themselves served as lines of communication. Consequently, the junction of two water courses afforded three distinct routes that led away from the camp, or by which it could be approached. Fishing may also have been better at or near the mouth of a tributary stream.

In plate 8 is reproduced an aerial photograph made from high over the Forest Hall site, looking up the Rappahannock, with the camera pointing about due north. The mouth of the Rapidan is on the left, and the farm on the right bank of the Rappahannock (on the left in the view, which is looking up the river) is at Richards Ford, about 1 mile above the mouth of the Rapidan. The small, rocky, V-shaped island seen in the foreground may also be distinguished in plate 5, and had the water not been so very high, other islands and ledges would be visible in the channel of the river. It will be observed how great a part of the country remains heavily timbered, although a section of it now overgrown may, long ago, have been cleared and cultivated.

A small clearing can be seen between the two rivers at the mouth of the Rapidan. This was cultivated a few years ago, but when visited

during the autumn of 1934, it was overgrown, and the surface could not be examined. However, along the margin of the higher ground, facing the Rappahannock and less than 20 feet from it, fragments of pottery and several quartz points were discovered in a stratum about 1 foot below the present surface. This indicates the exposed surface at one period of occupancy; the superstratum of sand was deposited by the river during some great freshet. The level area is not more than 2 acres in extent, bounded by the rivers and a cliff, and this, when carefully examined, should prove of exceptional interest.

Cliffs face the Rappahannock from Richards Ford and beyond to the mouth of the Rapidan. They reach the right bank of the river just above the ford, but a short distance below the crossing the low ground, between the foot of the cliff and the river bank, is about 250 feet wide. Much of the low ground is not visible in the photograph, plate 8, as it is screened by a fringe of trees and brush along the bank, overhanging the water.

A vertical aerial view of the river and adjacent land at the ford is reproduced in plate 9, figure 1. Several large islands in the river just above the ford are not included in the picture. The house near the upper left corner is on a plateau some 50 feet higher than the river, but the cultivated field, on the right bank of the Rappahannock and extending beyond the area shown in the photograph, rises only a few feet above the normal stage of the river and was under water during the flood of September 1934. The fragmentary pottery shown in plate 9 was found on the surface of the field a few days after the waters had receded, and may be briefly described:

Specimen *a* appears not to be a fragment of a vessel, but suggests a piece of wet clay that had been accidentally pressed on a woven bag or a piece of matting. It is flat on both sides, very porous, and of a light reddish color. The textile, as restored, is shown natural size in figure 6. The long elements resemble a grass or some other vegetal fiber that had not been twisted, and these were held together by tightly twisted cords.

Three specimens, *b*, bear the impression of nets. That on the largest fragment is clearly defined, and a double impression of the net appears on part of the surface. The meshes were about one quarter inch square, knotted at the crossing of the cords. The nets used on the other two specimens had much smaller meshes, and the impressions are less distinct. The two pieces *c* were probably similar to the three preceding, but the surfaces have become smoothed, either intentionally or as the result of use and wear. The color of all is brownish. The very small quantity of crushed quartz intermixed with the clay may

have been added as tempering. The five fragments just mentioned have the appearance of greater age than the majority of specimens recovered from the site, and may have belonged to an early period of occupancy.

The decoration on the small fragment *d* is more difficult to understand. It appears as four parallel lines of cord marks, less than one-quarter inch apart. Of these the first and second, and the third and fourth, are joined by similar impressions so placed as to form rows of squares, but no indications of knots are visible. It suggests the use of a net made of finely twisted cords, impressed upon the plastic clay, with the connecting lines between two rows of the mesh smoothed away.
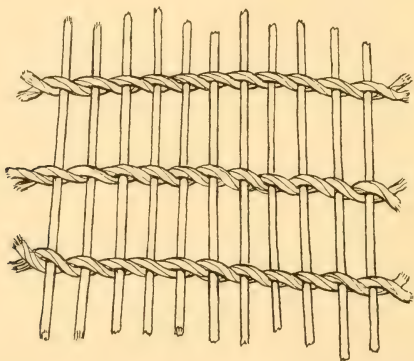
Fig. 6.—Textile, restored, from Richards Ford. Natural size.
U.S.N.M. no. 373791.

Many of the fragments reveal the use of the roulette, and others are cord-marked. The impression on *c* was produced by either a textile or basketry, the surface is greatly worn. No examples of incised decorations were discovered on the site. The three specimens to the right in the top row are fragments of rims of vessels.

A few arrowpoints made of white quartz were found scattered over the surface of the fields, and near the center of the plowed area shown in the vertical photograph were several diabase boulders from which pieces had been struck, with a quantity of small flakes nearby. The surfaces of the flakes are only slightly altered, although they have been exposed to the action of the elements for three centuries or more. The finding of flakes in this condition indicates that some work had been done on the site at a comparatively late day.

As mentioned when reference was made to the probable location of the five settlements indicated on the 1624 map, Hassuiuga is assumed to have stood on the banks of the Rappahannock in the vicinity of the present Richards Ford. Lederer undoubtedly followed an Indian trail when making his memorable journey in 1670. On August 21, the day after leaving the falls, he and his party crossed the Rappahannock " where it divided into two branches north and south, keeping the main branch north of us ", obviously at the ford later to be known as Richards Ford. A very old road not more than 6 feet in width, and probably following the course of a still more ancient trail, ascends from the river bank to the plateau at the edge of the line of trees on the southern boundary of the clearing in which the house stands. This may be traced in the vertical view, and it was undoubtedly the trail over which Lederer passed " due west to the top of the Apalataean Mountains."

<center>QUARRY-WORKSHOP</center>

Evidence of a quarry-workshop was discovered on the left bank of the Rappahannock just below a small branch known as Polecat Run, approximately midway between Ellis Ford and the mouth of Deep Run. The site proved to be of much interest and may be rather extensive, but during our brief visit its extent could not be ascertained.

The low ground continues for some distance along the stream and is here about 300 feet wide, from the river bank to the beginning of the rising ground. But it was probably too low ever to have been occupied by a permanent village, although it would have been a temporary camping ground for those seeking material at the quarry. A small ax of the early form, with its surface greatly altered through long exposure, was found on the surface near the foot of the cliff, and several quartz and quartzite points were discovered nearby. A few bits of pottery were recovered from the surface some distance from the river bank.

During September 1934 the Rappahannock was unusually high, and the waters washed away the soil to a depth of several feet for a distance of from 50 to 100 feet back from the normal bank of the river. The quarry-workshop was exposed along the face of the newly eroded surface, where boulders, and fractured pieces of diabasic rocks, quartz, and quartzite, had been uncovered by the flood. Intermingled in the mass of sand and rock were numerous flakes that had been removed during the process of shaping weapons and implements.

3

Typical examples of the material from the site are illustrated in figure 7. Specimens *a*, *b*, and *d* are diabase; *c* is a flake of dark brownish shale. All are altered through exposure.
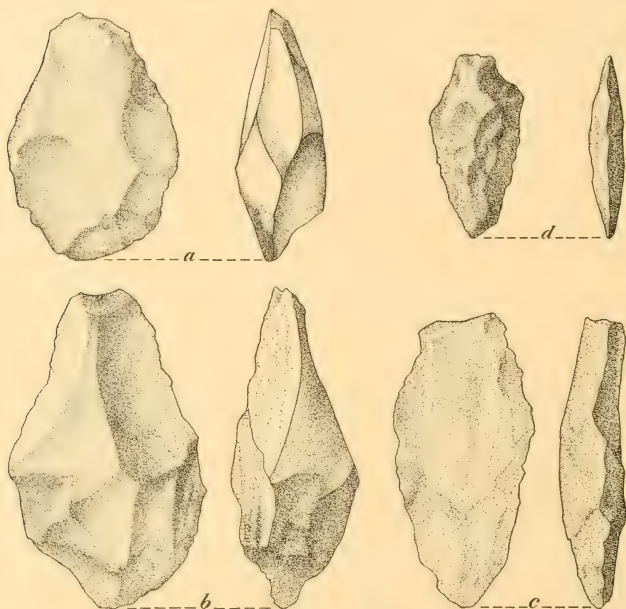
FIG. 7.—Workshop material from left bank of the Rappahannock about 1 mile above Deep Run. ½ natural size. U.S.N.M. no. 373777.

ROGERS FORD

Rogers Ford is a crossing of the Rappahannock just above a great bend of the river. In a direct line it is 2¼ miles north of Skinkers Ford on the Rapidan, where once stood a large native settlement. The sandy bottoms bordering the right bank of the river at Rogers Ford are extensive and become much wider above than below the ford, where the rising ground soon reaches to near the water. The entire area was inundated during the flood of September 1934, but the fields were not gullied, and the only erosion occurred for a space of not more than 50 feet back from the normal bank, where the surface was lowered 2 feet or more. The land on the opposite side of the stream appears to be somewhat higher but it could not be reached.
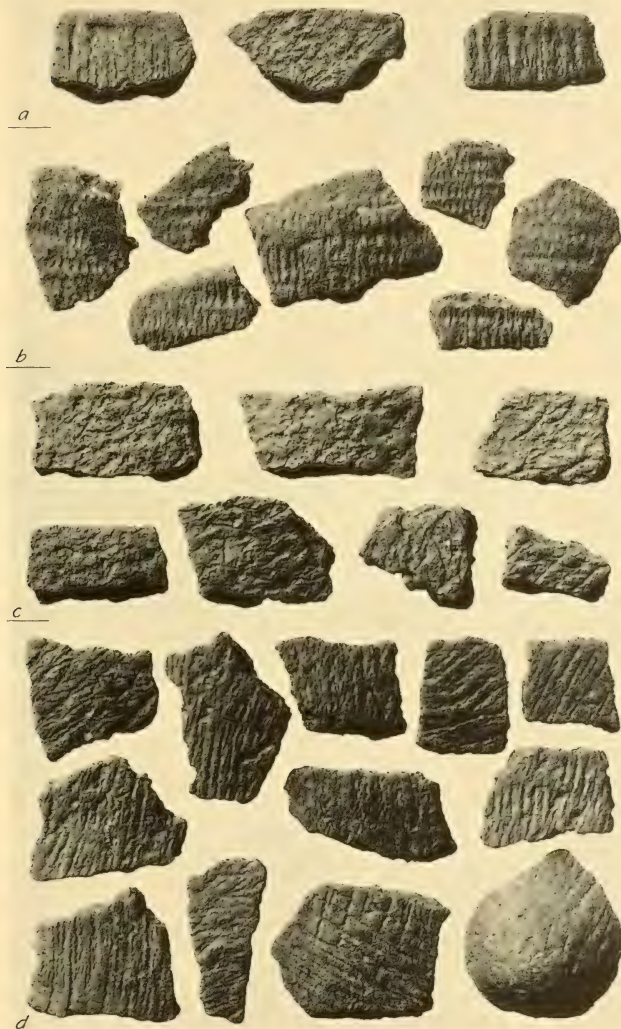
**FRAGMENTS OF POTTERY FROM RIGHT BANK OF THE RAPPAHANNOCK
AT ROGERS FORD**

½ natural size. U.S.N.M. no. 373792.
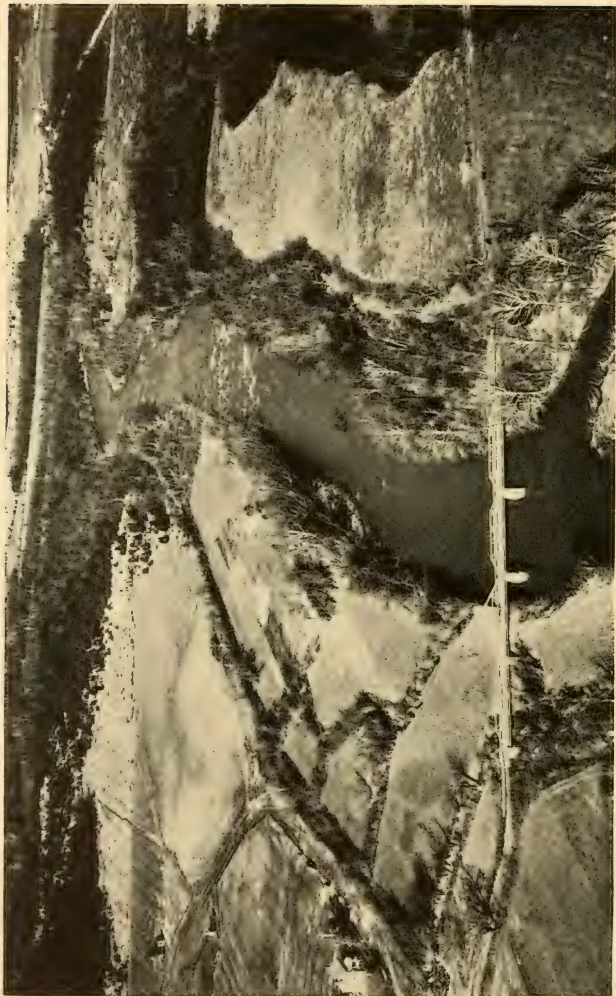
Photograph U. S. Army Air Corps.

LOOKING UP THE VALLEY OF THE RAPPAHANNOCK FROM KELLYS FORD

Photograph U. S. Army Air Corps.

1. DOWN THE VALLEY OF THE RAPPAHANNOCK FROM KELLYS FORD
Mouth of Marsh Run on left.
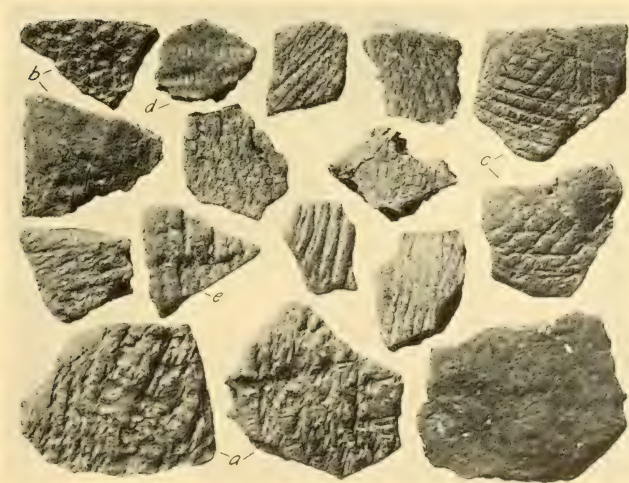
2. FRAGMENTS OF POTTERY FROM THE RIGHT BANK OF THE
RAPPAHANNOCK AT KELLYS FORD
½ natural size. U.S.N.M. no. 373793.
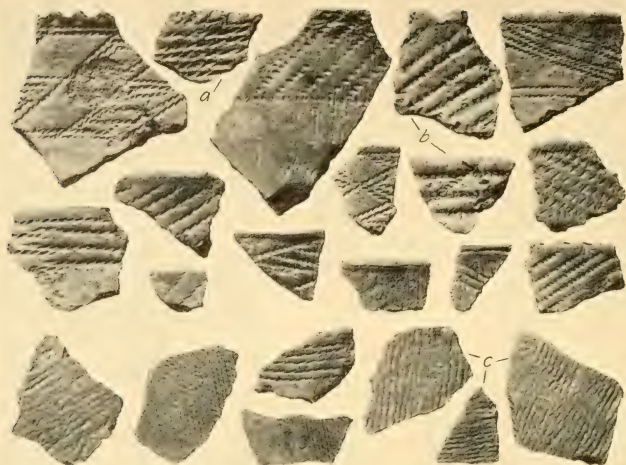
1. FRAGMENTS OF POTTERY FROM JERRYS FLATS, ON LEFT BANK OF THE RAPIDAN ABOUT 2 MILES ABOVE ITS MOUTH

½ natural size. U.S.N.M. no. 373794.

2. POINTS ATTRIBUTED TO EARLY PERIOD

a, pentagonal point found north of Elys Ford. Two Folsom type points: *b*, from near Orange; *c*, found near bank of the Rappahannock about 15 miles below Fredericksburg. Natural size.

A number of arrowpoints were found on the cultivated surface several hundred yards above the ford. Many were broken, but they proved to be of interest as the majority were triangular forms, some having very deep concave bases. Several were made of black flint, others of quartz and quartzite. No examples were discovered, however, of the more common types made of white quartz, such as were found on the Forest Hall site and which occur throughout the piedmont. It is difficult to believe they are not to be found on the site. One small flake of black flint that had served as a scraper or blade was found. Scattered over the same cultivated area were innumerable fractured pebbles, and quantities of flakes of diabase, some of which were greatly altered. Many small pieces of white quartz that showed evidence of working, were likewise found. It is evident that much work had been done here, and possibly some interesting specimens could be discovered beneath the surface.

A large number of fragments of pottery were encountered on the surface near the river bank, a hundred yards or more above the ford. They had evidently been exposed when the soil washed away, probably during the freshet of last autumn, and all appear to be equally old. Examples are shown in plate 10. Three specimens, *a,* at the top of the plate, are fragments of rims of vessels, representing two forms of decoration, as will be mentioned later. Below are seven pieces, *b,* all of which are thought to bear the impression of basketry. The specimen on the extreme left is more than ⅜ inch in thickness and contains some very large pieces of crushed quartz, which had been added to the clay. Next below are seven fragments, *c,* some of which may have belonged to the same vessel. The impressions on the surfaces were made by a loosely woven, rather coarse textile, possibly similar to that later to be mentioned in connection with material found at Skinkers Ford. The rim fragment in the middle of the top row is an example of this ware. A small amount of crushed quartz, some being rather coarse, had been added as tempering material.

The fragments included in *b* and *c* are bits of roughly made vessels, all of which must have been large. The pieces are now of a light brownish color and are very hard. All are examples of coiled ware as revealed by some fragments that have separated at the line of contact of the coils, a feature clearly illustrated by the specimen shown on the left, bottom row, in group *c.*

Eleven examples of cord marked sherds are reproduced in *d,* some of which undoubtedly belonged to the same vessel. The two rim fragments at the ends of the top row are the same type of ware. This differs from that included in *b* and *c ;* it is somewhat thinner, is of

a reddish color, and the paste of which it was made was of a finer texture. A small amount of fine sand contained in the paste may have been added as a tempering material, although it could have occurred naturally in the clay. The walls of the vessels had been carefully made, and no indications of the coils remain.

The conical bottom of a large coiled vessel is shown in the lower right corner of the plate, and is also sketched in figure 8. The fragment is more than $\frac{1}{2}$ inch thick in the middle, and in color and texture it resembles the cord-marked ware previously mentioned. It is broken at the line of contact of the coils; the end of one is clearly shown and reveals how they had been added, spirally, to form the wall of the vessel. This suggests an Algonquian type. The conical base was devised to hold the vessel in place when in use.

One of the drawings made by John White in 1585 bears the legend: " Their seetheynge of their meate in earthen pottes ", and although

Fig. 8.—Conical base of a large vessel. Coiled ware, with the end of a coil exposed on the right. The edges of the fragment are smoothed and worn away. Natural size. U.S.N.M. no. 373792.

this is intended to represent a group of Algonquian Indians living in northeastern North Carolina a generation before the settlement of Jamestown, the description would have applied equally well to people who occupied villages in the Rapidan-Rappahannock area early in the seventeenth century. It reads in part as follows:

Their woemen know how to make earthen vessells with special Cunninge and that so large and fine. . . . . After they have set them uppon an heape of erthe to stay them from fallinge, they putt wood under which being kyndled one of them taketh great care that the fyre burne equallye Rounde abowt. They or their woemen fill the vessel with water, and then putt they in fruite, flesh, and fish, and lett all boyle together.[18]

This had been the custom through generations.

The site at Rogers Ford is one of much interest, and the material, although not plentiful, indicates a connection between it and the village that stood so short a distance southward, on the left bank of the Rapidan at Skinkers Ford. Both may have been occupied long before the coming of the Manahoac.

[18] Hariot's Narrative. Quaritch reprint, 1893.

SITE AT KELLYS FORD

Traces of an ancient native settlement were encountered on the right bank of the Rappahannock above the bridge at Kellys Ford. The site was probably one of importance, as this is believed to have been near the crossing place of the old Carolina Road, already mentioned in connection with the movement of the Manahoac southward. If this belief is correct, it is evident that the area had been visited by members of many tribes in addition to those of the historic Siouan group, whose camps may at different times have occupied both banks of the river, both above and below the ford. Fragmentary pottery with other evidence of occupancy was found scattered over the surface of the cleared and cultivated area reaching to the river bank and extending to the foot of the rapids. This is shown on the left in the photograph reproduced in plate 11, a view up the valley, with the camera pointed about due north.

A short distance below the bridge, on the left bank of the Rappahannock, is the mouth of Marsh Run, a small, sluggish stream that flows through a famed hunting ground of past generations. Beyond this are Elk Run and Elk Marsh, suggestive names that have come down from the days of the colonists. A view down the valley, showing the mouth of Marsh Run on the extreme left, is reproduced in plate 12, figure 1.

Sand has been removed to a depth of 2 or 3 feet from an acre or more of the site; the excavation thus made can be seen just below the rapids, on the left, in the view looking up the river.

The sherds illustrated in plate 12, figure 2, were discovered on the sandy surface adjoining the excavations, nearer the bridge. These may be described briefly:

Specimens *a* are two pieces that evidently belonged to the same vessel, the specimen on the left being part of the rim. It is coiled ware, hard and black throughout, except where it is weathered to a light brownish on the exposed surfaces. A small amount of crushed quartz, some of which is very coarse, was used as tempering material. The fragment is $\frac{3}{8}$ inch in thickness near the rim. The surface bears the impression of very coarse cords, but no indications of a woven fabric.

Specimens *b* are the only fragments of this type of ware encountered on the site, and both may have belonged to the same vessel. The texture and color of the ware, as well as the impression on the surface, are the same as in specimen *b* discovered at Skinkers Ford on the Rapidan and figured in plate 17.

Specimens c are fragments of a very heavy coiled vessel with coarse quartz tempering and bearing the impression of rather fine twisted cords.

Specimen d is a small fragment bearing the impression of what is believed to have been a rigid basket. Crushed rock, including a small amount of quartz, was added as tempering material. It is very hard, is reddish brown in color, and has an average thickness of ⅜ inch.

Specimen e is a small sherd bearing the impression of a very coarse textile formed of twisted cords, evidently an example of wrapped weaving.

No fragments with incised decorations were found on the site.
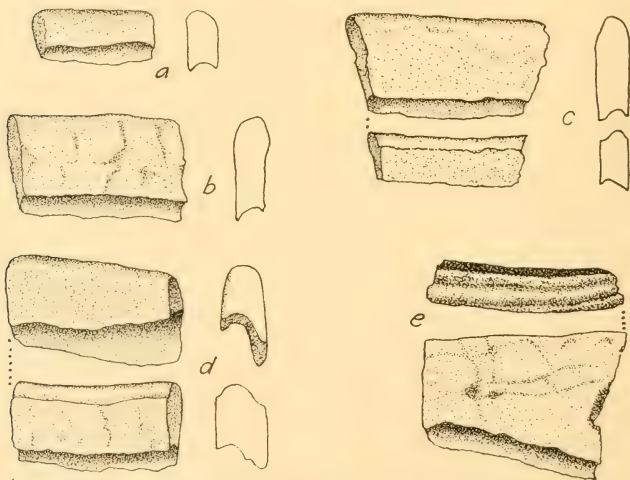
FIG. 9.—Fragments of pottery revealing the use of coils in the construction of the vessels. Natural size. U.S.N.M. no. 373793.

A large number of sherds from this interesting locality reveal clearly the method of using coils of clay in building up the walls of a vessel. Fragments have separated at the line of contact of two bands, thus showing not only the size of the coils so employed, but also the manner in which they had been placed in succession, horizontally, one upon another, after which they were worked together in the endeavor to make the mass compact and uniform. In many instances, however, as shown by these fragments, the two bands of clay did not become closely united although the newly applied coil had been rubbed down over

the sides of the one below it. This process caused the bottom of a coil or band of clay to become concave in section, and the top of the one upon which it rested to remain convex. Sketches of specimens from the site illustrating this feature are shown in figure 9.

Large numbers of arrowpoints, mostly made of white quartz and of the types found throughout the region, have been discovered on the site and in the nearby country. Several points made of black chert were likewise found on the site. Flakes of yellow jasper and of dark chert were encountered near the sand pits; one of the former had evidently been used as a scraper or blade, as the edges had become serrated from use. Chipped axes of the early form and other objects of stone are known to have been recovered from the surface of the site in past years, but little now remains to mark the position of the ancient settlement.

A few bits of pottery, including one small fragment similar to plate 12, *d,* and several arrowpoints, were found near the right bank of the Rappahannock opposite and just below the mouth of Marsh Run. Traces of a camp were discovered a mile farther down the river at the mouth of Mountain Run.

The flats in the vicinity of Kellys Ford, and especially those opposite the mouth of Marsh Run, have frequently been flooded, and it is evident that the surface has been reduced since it was first cleared and cultivated; consequently few traces of Indian occupancy can now be found.

JERRYS FLATS

As already mentioned, Richards Ford is a crossing of the Rappahannock a mile or more due north of the mouth of the Rapidan. About the same distance from the ford, a little south of west, is a wide turn in the Rapidan some 2 miles above its junction with the Rappahannock. Here, on both sides of the Rapidan, are extensive low grounds known as Jerrys Flats, with a good ford across the river. A small stream enters the Rapidan on the left bank just above the ford, and this, according to local tradition, was the site of a large Indian village.

Persons living in the vicinity relate that a burial mound formerly stood near the left bank of the small stream 100 feet or more from the Rapidan. This was destroyed some 40 years ago at the time of a great freshet, and it is also related that when the waters had receded, quantities of human remains were found exposed on the surface. Pottery vessels and other objects are remembered to have been found at that time near the skeletal remains, but everything discovered has been lost or scattered.

The position of the mound, the existence of which is well authenticated, undoubtedly indicates the location of one of the Manahoac towns in 1608. The low grounds between the foot of the cliffs and the left bank of the Rapidan was probably occupied by part of the village, which may have bordered both banks of the river. The low grounds have been cultivated for many years and have often been overflowed, as they were during the late summer of 1934.

A slight rise is believed to indicate the former location of the mound, and possibly the lower part of it has never been disturbed. A large amount of fragmentary pottery was found scattered over the surface of the rise and on the adjacent ground. Some of the sherds appeared to have been only recently exposed, probably by the high water early in September, a few weeks before the site was visited.

Examples of the pottery found in the vicinity of the mound are illustrated in plate 13, figure 1. The 15 sherds in the upper part of

Fig. 10.—Fragment of pottery with incised decoration. Found at Jerrys Ford. Natural size. U.S.N.M. no. 373794.

the figure are fragments of rims of vessels showing the variety of cord markings and also how greatly the cords varied in size. Several of the pieces were decorated with the roulette. Many of the rims are smooth and flat, but others were decorated by pressing the plastic clay at intervals to form a fluted edge, as is clearly shown in the photograph. In some instances the depressions extended obliquely across the rim, and specimen *a* is a good example of this form of decoration. Thick twisted cords were impressed in the plastic clay before the vessel was fired. The greater part of the ware is very hard, well made, and contains a very small amount of tempering material.

The two specimens *b* differ from the majority, being rather more porous and containing a greater amount of tempering material, either sand or crushed quartz.

Among the numerous fragments of pottery found on the site were some that were exceptionally thin and of a very fine texture. Examples of the thin ware are shown in the lower part of the illustration. The three specimens *c* are not more than $\frac{1}{8}$ inch in thickness, and some

pieces are even thinner. All appear to have been parts of rather large vessels, possibly as much as 8 or 10 inches in diameter. No rim fragments of the thin ware were discovered.

One small piece of earthenware (fig. 10) bearing an incised decoration was found near where the mound had stood. This is a fragment of a fluted rim, probably of a small vessel.

A few arrowpoints made of white quartz, and many flakes of quartz and quartzite, were found on different parts of the low grounds, and these, together with the fragments of pottery already described, were all that could be discovered to indicate the position of a native village that was occupied three centuries or more ago.

ELYS FORD

A bridge now spans the Rapidan at the old crossing place which still bears the name Elys Ford. This is about midway between the mouth of the river and Skinkers Ford and was evidently on the route of Indian trails long before the settlement of the colony. Although the flats on both sides of the river at the bridge have often been covered by water, sand has been deposited in some places, and on other sections the surface soil has been washed away, but nevertheless, traces of Indian occupancy are still to be found. Small fragments of pottery, arrowpoints made of white quartz and flakes and masses of the same material from which pieces had been struck, together with several chipped axes of diabase were found on the surface near the right bank of the river just above the bridge. The axes are of the early form, with surfaces greatly altered; the small bits of pottery are weathered and worn, but are unusually hard and compact and reveal the use of finely crushed quartz as tempering material. Although the evidence is scant, it suggests that this was the site of a very ancient settlement.

Points of the recognized Folsom type (pl. 13, fig. 2, *b* and *c*) have been discovered just outside the area now being considered,[19] one in the vicinity of Orange, another a short distance below Fredericksburg in King George County, but none is known to have been found between these localities. However, a specimen of a different form (pl. 13, fig. 2, *a*), but which may be equally old, was discovered on the high land, east of the road, about a quarter of a mile north of Elys Ford. It is made of a dark, slightly mottled yellow jasper. Its dimensions are: length from tip of point to middle of base, $2\frac{1}{8}$ inches; width, $1\frac{3}{16}$ inches; greatest thickness, $\frac{3}{16}$ inches.

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[19] Literary Digest, June 9, 1934.

This must be accepted as a highly specialized form, and until a name is supplied, it may be referred to as a pentagonal type of point, or blade, attributed to an early culture. Very few examples have thus far been recorded. Like the Folsom points, however, they may be widely scattered east of the Mississippi, although not numerous in any one locality. Examples have been discovered in the northwestern part of Louisiana, in a region where many Folsom points have like-wise been found, but the relation of the two types, if any actually exists, has not been determined. To learn the distribution of the pentagonal type would be of interest in connection with the study of the Folsom points.[20]

SITE AT SKINKERS FORD

Skinkers Ford is an old crossing of the Rapidan between 2 and 3 miles down the river from all that remains of Governor Spotswood's settlement at Germanna, adjoining Fox Neck and Indian Town, which will later be described. The ford is near the middle of a great bend in the river, and immediately below it is an ancient fish trap that oc-cupies the entire stream bed from bank to bank. This will be termed the lower trap, to distinguish it from the upper trap, which extends across the river a little more than half a mile above.

The site gives the impression of being very extensive and of having been occupied and reoccupied by different tribes through generations. When in its native state, with dense forests covering cliffs and ravines and reaching to the river banks, it would have been one of the most desirable locations for a native settlement in the entire valley of the Rapidan. Fish were undoubtedly plentiful, as suggested by the pres-ence of the traps, and wild game was always to have been encountered in the surrounding wilderness. Although an additional water supply was of no great importance, because of the proximity of the river, several springs of sufficient size to supply the wants of many people flow from beneath the cliffs that border the low ground.

Both sides of the Rapidan had been occupied, but only that part of the site on the left bank of the river, extending between the two fish traps, will be described at this time. However, the entire area is worthy of careful examination, and possibly the right bank, being the higher, would prove to be the more interesting.

The entire site is shown in plate 14. This is a view up the river, the camera being pointed about northwest. At the time the photo-

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[20] The specimen just described is in the private collection of F. M. Aldridge, Fredericksburg, Va.
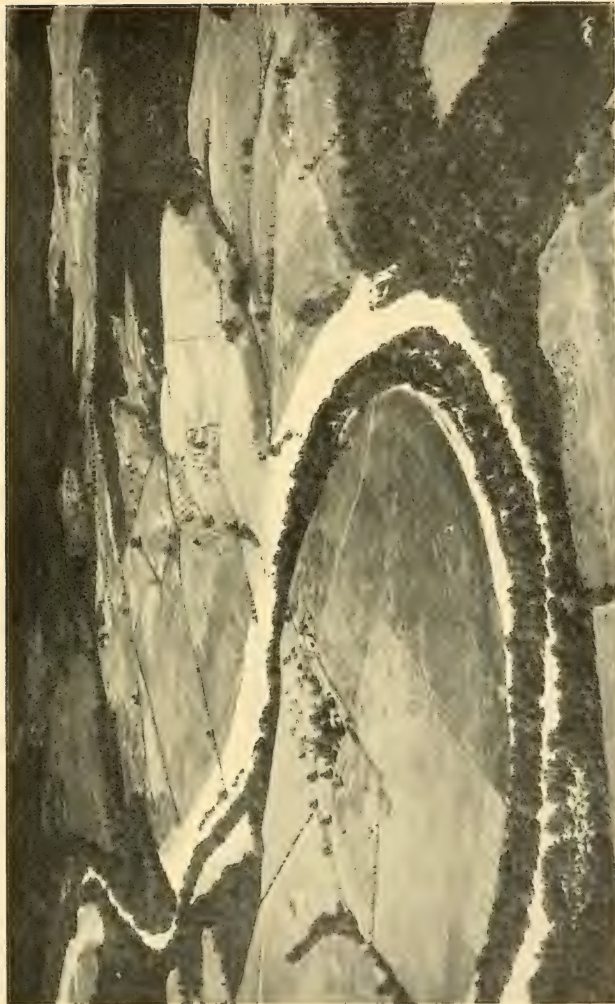
Photograph U. S. Army Air Corps.

SITE AT SKINKERS FORD ON THE RAPIDAN

Looking up the valley.

Photograph U. S. Army Air Corps.

1. SITE AT SKINKERS FORD ON THE RAPIDAN

Looking down the valley.

Photograph U. S. Army Air Corps.

2. SITE AT SKINKERS FORD ON THE RAPIDAN

Looking down the river and showing the position of the lower fish trap.

SPECIMENS FROM SITE AT SKINKERS FORD ON THE RAPIDAN

Above, various small objects, $\frac{1}{2}$ natural size. Below, eight jasper blades and scrapers, natural size. U.S.N.M. nos. 373795-6.
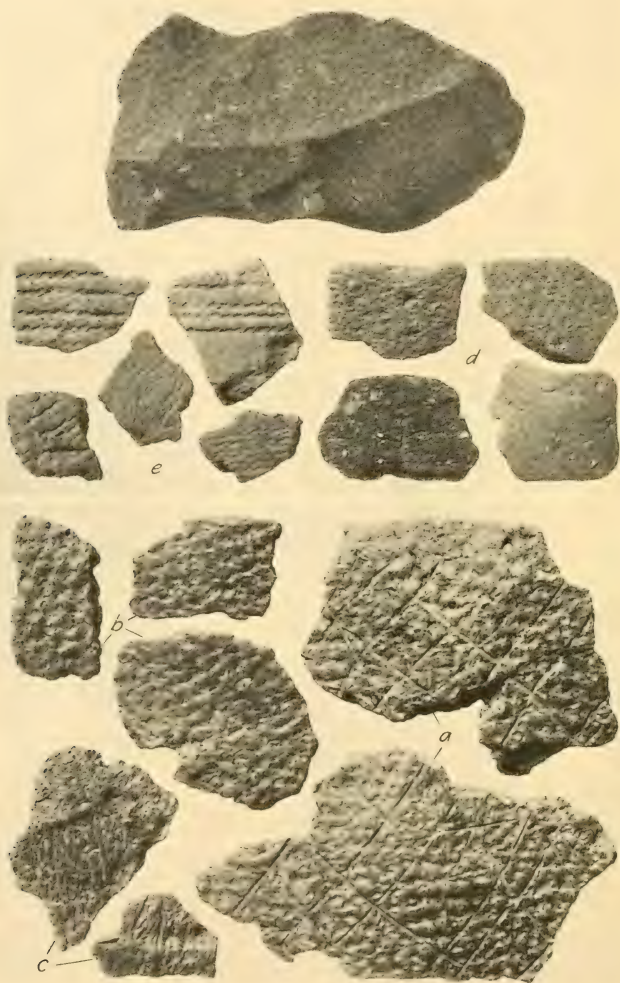
SPECIMENS FROM SITE AT SKINKERS FORD ON THE RAPIDAN

Above, implement attributed to the early period. Below, fragments of pottery.
½ natural size. U.S.N.M. no. 373797.

graph was made, the river was higher than it had been for years, and much of the low ground was flooded. A road can be distinguished running from a group of barns near the left center of the picture to the river on the right. This is lost in the fringe of timber, but leads down to the ford, which here crosses to the left bank of the river near the cluster of trees. This is just above the lower fish trap, which cannot be distinguished by reason of the depth of the water, which likewise covers much of the low ground on the left bank of the river between the two traps. The second or upper trap crosses the river at the far end of the low ground, just below the heavy mass of timber that reaches the bank of the river where it begins to bear to the right. Nothing of the history of the traps is known to the present occupants of the adjoining farms. The traps have existed in their present condition as long as can be remembered and have never been used.

A view down the river over the ford, showing the position of the lower fish trap, is reproduced in plate 15, figure 2.

A sketch of the lower trap is shown in figure 11. This was not made to scale, no actual measurements having been taken, but it is sufficiently accurate to reveal the several peculiar features. The river at this point is approximately 25 yards in width. The two lines of boulders touch the banks and extend down the stream approaching to within 6 or 7 feet near the middle of the channel. The two walls then continue for about 10 feet, roughly parallel. Logs extending transversely are still remaining, both above and below the opening, under water and partly covered by sand and gravel. The ends of these are held in place on the right by a long log, extending with the current, and this in turn is held down by a large flat boulder. Probably a similar log, likewise held in place by a boulder, once stood on the opposite side. The upper trap is said to be of similar construction, but viewed from the left bank of the river, it appears to be rather more massive and to be better preserved.

Although it is well known that traps of this general form were constructed by Indians in prehistoric times, it is difficult to accept these two examples as having existed in their present condition for more than a century. But their history is unknown and consequently nothing definite can be told of their origin—when and by whom they were constructed. As previously mentioned, traps similar to these occur in the Rappahannock just below the large island at the falls.

Undoubtedly, innumerable objects of native origin were once scattered over the surface of the site or accumulated in refuse heaps, but little can now be found. However, considering the number of years the land has been cultivated and the frequent floods that have

covered parts of the site, it is all the more interesting to find some traces of what may have been an extensive native village, possibly one of the Manahoac settlements mentioned in 1608.

Many arrowpoints have been found on the site and on the adjacent lands. The great majority are made of white quartz and are of the forms so plentiful throughout piedmont Virginia, similar to those
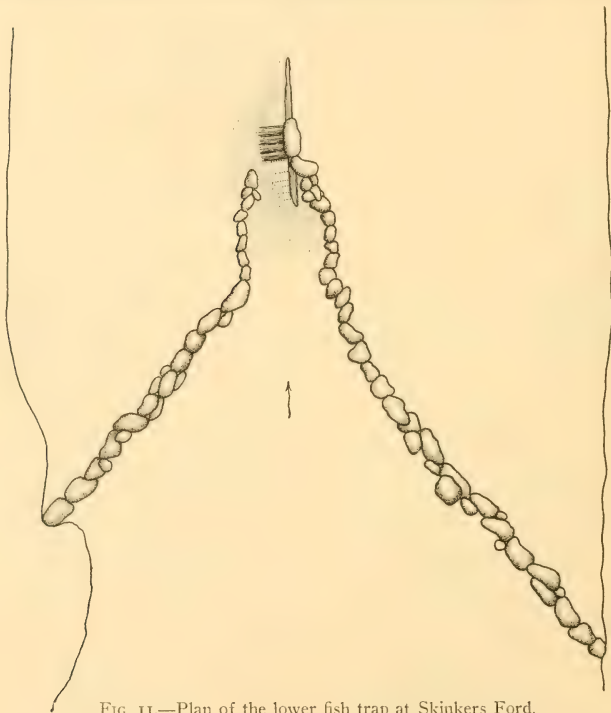
Fig. 11.—Plan of the lower fish trap at Skinkers Ford.

figured from the Forest Hall site and from the vicinity of Potato Run. Axes of the early form, roughly chipped and weathered, likewise occur on the site, and a few fragments of cord-marked pottery have been found on both sides of the Rapidan, but other material has been recovered that is rather unusual.

Small jasper scrapers and blades were found on the surface, within a very limited area, not far from the normal bank of the river, and

although this spot was under water when the photograph shown in plate 14 was made, it is clearly defined in the view reproduced in plate 15, figure 1. It is the slight rise to the right and just beyond the sharp turn in the line of brush and trees that marks the course of a small stream that joins the Rappahannock far to the left in the picture. Eight specimens are shown natural size in plate 16. The one in the lower left is made of a mottled purplish jasper; all others are of a brownish-yellow color. The material was probably found as pebbles or boulders in the stream bed.

In addition to the great number of quartz arrowpoints that have been found scattered over the surface, some examples of triangular points made of black flint have been discovered. Three of the latter are illustrated in plate 16, together with various small flaked objects which, for want of better terms, may be called scrapers, knives, and perforators.

Chips of different kinds of rock are scattered over the surface— evidence that implements and weapons were made on the site. These are numerous near the rise on which the jasper scrapers and blades were discovered, and at one place, within a space of a few feet, were many thin flakes of diabase from 2 to 3 inches in length. These are so greatly weathered and altered that it is often impossible to distinguish the natural from the flaked surfaces. Nearby was found the specimen shown in the upper left corner of plate 16, probably a cutting implement, made of diabase, the surface being deeply weathered.

Very little pottery was recovered from the site, but undoubtedly much remains to be discovered. However, fragments that had belonged to three different vessels were found on the left bank of the river, near the water, and these proved to be of much interest. The location is clearly shown in plate 15, figure 2, in the brush just beyond the edge of the cultivated ground. The area was under water during the September freshet. These specimens are illustrated in plate 17, and may be described briefly:

The two fragments, *a,* belonged to a vessel that would have measured between 20 and 22 inches in diameter and probably about 10 inches in depth. Having a thickness of only $\frac{1}{4}$ to $\frac{5}{16}$ inch, it would necessarily have been rather fragile. The ware is porous in places, but hard. It is of a light reddish brown, and as a result of unequal firing is a more brilliant red in some places than in others. The unusual feature of the vessel is the mixture of large pieces of crushed quartz with the clay, some of the pieces being more than $\frac{3}{8}$ inch in length. Several of the pieces extend through the wall of the

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vessel and are visible on both the inside and outside. The outer surface bears the impression of what appears to have been a textile, probably a material woven of cords of buffalo hair similar to that known to have been made in early historic times by tribes in the Mississippi Valley. Deep lines were incised on the surface before the vessel was fired, as a decoration, and are easily distinguished in the photographs. Narrow vertical impressions about ½ inch apart and the same in length appear on the inside of the rim at the top; otherwise the rim of the vessel is plain and straight.

Specimen *b* was similar in many respects to the preceding. It is the same color and texture, and the textile impression on the outer surface is the same, but the incised lines were not added on either the outside of the vessel or the inside of the rim. The tempering is sand or small pieces of crushed quartz, differing in this respect from the very coarse material occurring in *a*. The second piece from the left is a fragment of the rim. The sherds are small, and consequently it is more difficult to estimate the diameter of the vessel, but it was probably smaller than *a*, although the thickness is about the same.

Small fragments found on the site at Kellys Ford, already described, plate 12, figure 2, *b*, belonged to a vessel similar in texture, color, and decoration to the preceding.

Many small fragments of vessel *c* were found close together near the fragments of *a* and *b*. In texture, color, and tempering it closely resembles *b*. The outer surface bears the impression of tightly twisted cords from $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter. Many of the cords are parallel and in some instances overlap, but there is no impression of a textile. Cords had probably been bound over a paddle, or some hard material, and then applied to the plastic surface.

The three specimens *a, b,* and *c* are examples of coiled ware. The four specimens *d* were found in sand deposited on the river bank near the end of the lower fish trap. The surfaces of all are worn away through exposure to the elements. The remaining five pieces, *e*, came from the vicinity of the upper trap. These show clearly the impressions of cords, some of which were very coarse and appear to have been tightly twisted.

FOX NECK AND VICINITY

Fox Neck is a narrow peninsula, bordered by the left bank of the Rapidan where the river makes a sharp bend. It is a high, rolling tract some 12 or 14 miles above the mouth of the river and was included in lands granted to Governor Alexander Spotswood early in the

Photograph U. S. Army Air Corps.

FOX NECK, BORDERED BY THE LEFT BANK OF THE RAPIDAN

Germanna ford just to the right is point where road crosses the river in upper right-hand part of picture. Camera pointing about northwest.

Photograph U. S. Army Air Corps.

1. LOOKING DOWN THE RAPIDAN WITH PART OF FOX NECK ON THE LEFT

Camera pointing about southeast.
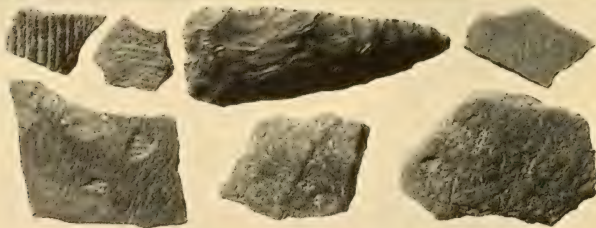
2. MATERIAL FROM THE RIGHT BANK OF THE RAPIDAN, OPPOSITE FOX NECK

½ natural size. U.S.N.M. nos. 373798-9.

SPECIMENS FOUND ON THE LEFT BANK OF THE RAPIDAN BETWEEN POTATO RUN AND BROOKS RUN

½ natural size. Arrowpoints, U.S.N.M. no. 373800. Three implements, U.S.N.M. nos. 373801-3.
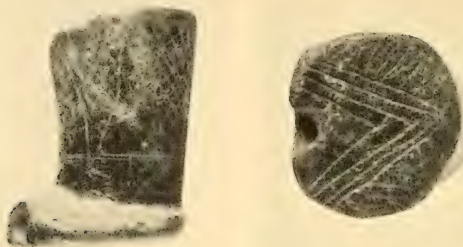
1. PIPE MADE OF STEATITE

Found on the supposed site of Stegara, Orange County. Natural size.

2. TWO PIPES MADE OF CHLORITIC SCHIST

Found in Orange County. Upper pipe, finished and much worn from use. Lower pipe, unfinished. Both $\frac{2}{3}$ natural size.

eighteenth century. Here, in April 1714, were seated the German colonists who had been induced by agents of Spotswood to come to Virginia, where they were to work the iron mines about to be developed. The name Germanna, then applied to the settlement, has persisted, although the settlement itself has long since disappeared, and only scant traces of it remain.

In the year 1730, as told in a County Court record: "William Bohannon came into court and made oath that about twenty-six of the Sapony Indians that inhabit Colonel Spotswood's land in Fox's neck go about and do a great deal of mischief by firing the woods . . . . and that he verily believes that one of the Indians shot at him the same day . . . . that the Indian after firing his gun stood in a stooping manner very studdy so that he could hardly discern him from a stump. . . . ."[21] Whether these Indians had formerly been at Fort Christanna or had always lived in the valley of the Rapidan is not known, but the presence of a native settlement on the neck in 1730 suggests that it was the site of one of the more ancient Manahoac towns occupied in 1608. Shackaconia may have stood nearby.

When gathered at Fort Christanna, the groups of Indians were known to the English as the "Sapponi nation". This fact was mentioned in 1728 by Col. William Byrd.[22] He wrote (p. 88):

All the grandees of the Sapponi nation did us the honour to repair hither to meet us. . . . . This people is now made up of the remnants of several other nations, of which the most considerable are the Sapponies, the Occaneches, and Stoukenhocks, who not finding themselves separately numerous enough for their defence, have agreed to unite into one body, and all of them now go under the name of the Sapponies. Each of these was formerly a distinct nation, or rather a several clan or canton of the same nation, speaking the same language, and using the same customs. But their perpetual wars against all other Indians, in time, reduced them so low as to make it necessary to join their forces together.

Consequently, the term "Sapony Indians" would have been applied to the natives who occupied Fox Neck in 1730, even though they may not have descended from the Saponi group. Mount Pony, a few miles west of Stevensburg, probably derived its name from that of the "Sapony Indians" who lived nearby.

An aerial view of Fox Neck and surrounding country is reproduced in plate 18. The camera was pointed about northwest and is looking up the valley of the Rapidan on the left. The road

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[21] Scott, W. W., A history of Orange County, Virginia, p. 56. Richmond, 1907.
[22] Byrd, William, The Westover manuscripts: containing the history of the dividing line . . . . Petersburg, Va., 1841.

on the right crosses the river over the recently completed Germanna bridge, and the ancient ford, one of the most historic spots in all Virginia, is less than 100 yards below. To the left of the bridge, on this side of the river, stand the chimneys that belonged to a house erected by Governor Spotswood, the site rising high above the water.

As much of the surface of Fox Neck and of the low grounds on both sides of the Rapidan has been cultivated, worked over, and occupied for more than two centuries, and with rains and floods changing the land, scant traces of Indian occupancy can now be found. But it is not to be doubted that a native settlement once stood nearby. A few fragments of pottery and stone objects were recovered from the cultivated field on the right bank of the river (pl. 19, fig. 2). The site itself is shown in the lower right quarter, near the middle, of plate 19, figure 1. When making this photograph, the camera was pointed southeast. The site may also be distinguished on the extreme left, middle, in the view looking up the valley.

The few fragments of pottery are of a reddish-brown color, hard, and all contain bits of crushed quartz that had been added for tempering. All are cord-marked. The ware resembles certain sherds discovered at Jerrys Flats some miles below.

Projectile points made of white quartz, similar to those occurring throughout the valley, have been found here, but only a few examples, some of superior workmanship and representing the rarer types, together with a blade made of yellow jasper, are shown in plate 19. Quartz is so easily fractured that perfect specimens are seldom found on land that has been cultivated for many years, and one prong is missing from the triangular point shown fourth from left, which had a deep concave base. The second from the left is a form seldom found in the Rapidan-Rappahannock area, but all that have been discovered are equally well made, symmetrical, and finely flaked on the edges. They may not have been arrowpoints, but may have served another purpose. The jasper blade is of particular interest, as other objects made of the same material have been encountered on various sites throughout the area.

THE RAPIDAN ABOVE FOX NECK

Mortons Ford is an airline distance of between 6 and 7 miles up the Rapidan from Germanna. From the ford down to the great bend that forms Fox Neck the course of the river is comparatively straight. Extensive flats border the left bank with much higher ground on the opposite side. A great part of the surface that was

exposed several centuries ago, and on which would have stood the native camps and villages, has now been covered with deep deposits of sand, and other sections have been washed away. As a result of these radical changes, traces of Indian occupancy are seldom encountered, and no indications were discovered during two visits made to the section. The floods of September 1934 had left much of the low ground covered with a new deposit of sand, and the same condition is said to prevail throughout the region.

Potato Run enters the left bank of the Rapidan about 1 mile below Mortons Ford, and about half a mile farther down, on the same side, is the mouth of Brooks Run. The G. G. Harris farm is between the two small runs. During an unusual freshet some years ago a number of axlike implements or weapons were exposed at the foot of the rising ground, on the edge of the flat, between the Harris house and the river. These may indicate the site of an ancient camp or village, or the specimens may have been part of a cache. Three of the pieces are illustrated in plate 20, together with examples of white quartz arrowpoints found on different parts of the farm. The three specimens are made of a diabasic rock, are greatly altered, and have changed to a light greenish color. The arrowpoints are the types so plentiful in the surrounding region.[23]

Traces of many camps and villages, together with much material that belonged to different periods of occupancy, may remain hidden beneath the deposits of sand along the river banks, to be revealed from time to time as were the objects on the Harris farm. And it is believed that much of this material, should it be discovered, will prove to have belonged to a time long before the coming of the Manahoac and other historic tribes to the valleys of the Rapidan and Rappahannock.

The paucity of objects makes it desirable to refer to three specimens from farther up the valley of the Rapidan, but still within the limits of Orange County. These are three tobacco pipes, shown in plate 21, and which might well have been found on any one of the sites previously mentioned.[24] They may be briefly described: The small specimen, plate 21, figure 1, was found on the supposed site of Stegara, on the bank of the Rapidan in the extreme western part of Orange County. It is made of a dark grayish steatite and shows the effect of long use. The entire surface is decorated with incised

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[23] All specimens illustrated in plate 20 have been presented by G. G. Harris to the U. S. National Museum.

[24] The specimens are in the private collection of J. P. Thompson, Cedar Mountain, Rapidan Station, Va.

lines, and the design suggests that appearing on several fragments of pottery illustrated in plate 3. The two pieces in the lower part of the plate are made of a greenish chloritic schist and were found near the Rapidan a short distance below Orange. The smaller is worn and smoothed from use. The perforation is very regular, as shown in the drawing of the section. The larger specimen was not completed, and although it had been carefully shaped and polished, the perforation had been made for less than $\frac{1}{2}$ inch in the bowl, and no start had been made in drilling the stem. A solid drill had been used.

In August 1608, on the morning following the encounter between the English and the Indians near the falls of the Rappahannock, in Smith's words: " foure Kings came and received *Amoroleck:* nothing they had but Bowes, Arrowes, Tobacco-bags, and Pipes." And the same statement would undoubtedly have been applicable to a great majority of those who had gathered on the banks of the river. The pipes and such arrowpoints as were made of stone would have remained to the present time, but all else would have disappeared.

Pipes were made of both stone and clay, and although they must have been numerous in all the camps and villages on the banks of the Rapidan and Rappahannock, no example was discovered on any of the sites examined. This suggests the probability that pipes were buried with their owners, but nothing is known of the burial customs of the ancient Manahoac tribes.

COMPARATIVE STUDY OF MATERIAL FROM THE RAPIDAN-RAPPAHANNOCK AREA

In the year 1608 the native tribes whose settlements stood on the banks of the Rapidan and Rappahannock pursued the manners and customs and practiced the arts of the Stone Age, thus representing the last of the Stone Age in piedmont Virginia. It is readily agreed that other tribes or groups had preceded them, and that certain sites may have been occupied and reoccupied through many centuries.

During the periods of occupancy many objects were lost or abandoned, and these often accumulated with other material in heaps in the vicinity of the habitations. Once deserted, the site soon became covered with vegetation, which often served to protect the surface of stone or pottery from exposure to the elements. Later the land was cleared and cultivated, the heaps of refuse leveled, and the broken pottery and other traces of native occupancy scattered over the surface, where much remains to the present day. But to separate

the material and determine the period to which the various specimens should be attributed proves to be difficult and in many instances impossible. Such are the conditions encountered in the valleys of the Rapidan and Rappahannock.

Very few specimens of any sort are now found on the sites except axes, projectile points, and fragments of pottery vessels, although other objects, including shallow mortars, long cylindrical pestles, hammers, discoidal stones, and pipes, are frequently described as having been discovered in the past, only to be lost again or scattered.

AXES

Axes, and axlike implements and weapons of two distinct types, have been discovered in the ancient Manahoac country and are thought to represent different periods of occupancy. The first, and undoubtedly the older, are the crudely flaked specimens of which the surfaces are weathered and worn away as a result of long exposure to the elements. Typical examples are shown in plates 6 and 20. They are numerous in the valleys of the Rapidan and Rappahannock and represent forms encountered over a wide area northward to New England and southward through Virginia. Specimens from one site often vary greatly in size as is indicated by the outlines given in figure 5, and for that reason they are thought to have served various purposes as weapons and implements. Those discovered in the Rapidan-Rappahannock area appear to be very old; they are uniformly altered and must have belonged to an earlier culture than that represented by the historic Siouan tribes. This belief is substantiated by a specimen discovered in the autumn of 1928 on the supposed site of Stegara, near part of a large burial mound on the right bank of the Rapidan in Orange County. Although the site is beyond the bounds of the region being considered in the present narrative, this single specimen must, nevertheless, be mentioned at this time. It is a flaked axlike object made of diabase. After it was used and later abandoned or lost, the surface became greatly weathered through exposure. Centuries elapsed before it was found, the edges rechipped, and it was again used. But the surface exposed by the removal of the flakes during the later process of reshaping has become only slightly altered, although the object in its present condition has been exposed to the elments for not less than two and one-half centuries. This is conclusive evidence of at least two distinct, long-separated periods of occupancy in piedmont Virginia.[25]

[25] Bushnell, David I., Jr., Evidence of Indian occupancy in Albemarle County, Virginia. Smithsonian Misc. Coll. vol. 89, no. 7, 1933.

The crudely made objects found on the sites along the Rapidan and
Rappahannock are assumed to have belonged to the earlier of the two
periods indicated by the flaking on this interesting specimen.

Polished grooved axes and celts are thought to have been of much
later origin than the preceding. Excellent specimens have been
found on the Rappahannock sites below the mouth of the Rapidan,
but no examples were encountered above the junction of the streams,
although they doubtless occur in some localities. Several are illus-
trated in plates 3 and 7. Similar forms are numerous on sites along
the Potomac, within the territory occupied by the historic Algonquian
tribes in 1608, by whom they had probably been made and used.
The specimens discovered in the vicinity of the falls of the Rappa-
hannock, and a short distance above, may have been of Algonquian
rather than Siouan origin, and obviously should be attributed to the
recent, or later, period. Many of the earlier, cruder forms previously
mentioned also occur on the Potomac sites, the majority being made
of quartzite, whereas a large proportion of those discovered in the
Rapidan-Rappahannock area are made of diabase or related rocks.

The collection from the Potomac sites were described and figured
by Holmes [20] some years ago, and much of the information presented
at that time will apply equally well to the region now being con-
sidered.

If the crudely fashioned implements found on sites above the falls
belonged to a time before the coming of the Siouan tribes, the
interesting question is presented as to what type of axes, or of axlike
implements or weapons, was used during the later period. Possibly
the Manahoac tribes had not been in the country for many years
before they were discovered in 1608, and if this is true, only a small
part of the specimens now found would have been made and used
by the last of the native tribes to claim the region. Bone, antler, and
wood may have been used extensively, just as the same perishable
materials were employed by other Siouan tribes at a much later day
in the country beyond the Mississippi. All traces of objects made
of any one of the three would long since have disappeared, and
this may, in part, explain the small number of artifacts now en-
countered on many sites.

PROJECTILE POINTS AND OTHER SMALL FLAKED OBJECTS

Innumerable projectile points, and many small flaked objects, the
use of which is often difficult to determine, have been found on sites
along the Rapidan and Rappahannock Rivers; others are frequently

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[20] Holmes, W. H., Stone implements of the Potomac-Chesapeake Tidewater
Province. *In* 15th Ann. Rept. Bur. Ethnol., 1897.

discovered away from the camp and village sites, among the hills and valleys where they had probably been lost by hunters when in quest of game.

Arrowpoints found in the region now being studied vary greatly in age, and when attempting to ascertain the period to which a specimen should be attributed and the tribe or group of tribes to which its maker may have belonged, three factors must be considered: the shape, the material of which it was made, and the condition of the surface.

As stated on a preceding page, the crudely flaked specimens made of a dark diabasic rock, now altered and changed to a brownish color through long exposure to the natural elements, are thought to be the earliest form of axlike implements or weapons encountered in the Rapidan-Rappahannock area. They have been discovered throughout the region, and without exception are so deeply weathered that it is often difficult, if not impossible, to distinguish the surface from which flakes had been removed. They are assumed to have belonged to a culture that preceded, possibly by centuries, the coming of the historic Siouan and Algonquian groups who claimed the country in 1608.

Arrowheads and spearheads made of the same diabasic rock as the preceding, crudely flaked and equally weathered, have been found on sites with the axes, and it is reasonable to assign them to the same early period. The axes and points should be attributed to the same culture. Six examples of the points are illustrated (pl. 4, *a*), and other specimens in the same illustration, although made of chert, quartzite, and argilite, may likewise be of very early origin. Certain of these resemble in form and size pieces found by Harrington in the upper Tennessee valley [27] and ascribed by him to the earliest of three distinct periods of occupancy, the last being that of the historic Cherokee. Some specimens were made of flint, others of quartz and quartzite, and typical examples were figured by Harrington, plate 48.

Points are often discovered on the surface that differ in shape and material from the characteristic specimens of the region. They had probably been made in some distant locality, to be carried by hunters or warriors and lost near where they are now found. It is impossible to determine, even approximately, the place of origin of many specimens thus encountered, but later, when greater attention is

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[27] Harrington, M. R., Cherokee and earlier remains on Upper Tennessee River. Mus. Amer. Indian, New York, 1922.

devoted to the small flaked objects, their value in tracing the move-
ments of tribes will become more readily understood and appreciated.

Triangular points—some of which are found in the Rapidan-
Rappahannock area—are classed with those of indeterminable origin
just mentioned. They are rather few in number, and the majority
are made of a dark or black flint, others of a fine yellow, brown, or
gray quartzite. On some the base is straight or only slightly concave,
others are very deeply concave. Excellent specimens were found
at Rogers Ford, some of which may have been made there. Examples
from other sites are shown in plates 4, 16, and 19.

Quantities of triangular points occur on the Potomac sites, and
they are even more numerous in certain localities away from
Virginia. Many have been discovered in Maryland and northward;
others found in the mountainous country of Tennessee and Carolina
are considered by some to be the characteristic point of the ancient
Cherokee. Many of the scattered specimens now encountered in the
vicinity of the Rappahannock and Rapidan are thought to have been
made far away from the country of the Manahoac.

The great majority of points found scattered over the surface
are made of white quartz, and are similar to others widely distributed
throughout piedmont Virginia. The various forms, some of which
are very distinctive, are illustrated in plates 6 and 20. As the
material of which they are made is not affected by long exposure
there is no change in the appearance of the surface that would
suggest, or aid in determining, the relative age of the different
specimens. Some were made and used by the Manahoac after the
year 1608, others belonged to an earlier period, but all now appear
equally old.

Small blades and scrapers made of jasper and chalcedony were
discovered on several sites and may be plentiful in the area. A
greater number were found in the vicinity of Skinkers Ford than
elsewhere, and here, as already mentioned in the description of the
site, they occur only in a very limited space. Other examples were
found on the surface near Motts Run, also at Rogers Ford, and
larger specimens have been recovered from the site opposite the
large island at the falls. All are very interesting, but it is not possible
to determine to which period of occupancy they should be attributed.

Part of what may have been a projectile point found at Skinkers
Ford was made of the same yellow jasper, as was also the pentagonal
point found north of Elys Ford. The latter specimen should, it is
believed, be assigned to an early period, to which the small pieces
from the vicinity of Skinkers Ford may likewise have belonged.

The beautiful blade from opposite Fox Neck was made of the same light yellow jasper.

Many flakes and small bits of the same material that do not reveal evidence of use have been discovered on various sites, as at Kellys Ford, Motts Run, and Skinkers Ford.

The jasper had undoubtedly been obtained in the form of pebbles from the stream beds, but although large pieces of red jasper were encountered at several places, neither implements nor flakes of it were discovered.

<center>POTTERY</center>

The fragmentary pottery, occurring on many sites along the banks of the Rapidan and the Rappahannock, differs greatly in texture, decoration, and apparent age.

As yet no undisturbed refuse heap has been encountered in which it would be possible to discover successive strata that would represent the several periods of occupancy of a site and thereby make it possible to determine the sequence of the various types of ware. Some such heaps may remain hidden beneath masses of vegetation, but others have been reduced by the plow and their contents scattered over the leveled surface, resulting in the intermingling on the same site of sherds representing more than one culture. Therefore, in the endeavor to determine the relative age of the fragments and the periods to which they may have belonged, they were compared with other pieces that had been discovered under more favorable conditions in other localities.

What is believed to be the earliest pottery found in the Middle Atlantic region will be considered first. Harrington,[28] when exploring in Loudon County, Tenn., discovered traces of very early occupancy of the upper valley of the Tennessee. He distinguished evidence of three distinct cultures that had followed in succession, the oldest of which was designated that of the " Round Grave people," because of their curious form of burial. The characteristic pottery associated with the burials—only sherds being discovered—was " marked with parallel corrugated indentations quite different from anything seen in the Cherokee deposits." The latter were more recent. Examples of the crude ware were figured (Harrington, pl. 47), and b in the illustration appears to be similar to a small fragment found on the site at Kellys Ford on the Rappahannock (pl. 12, d), as well as to another piece discovered a short distance down the river, about

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[28] Harrington, op. cit.

opposite the mouth of Marsh Run. Crushed stone had served as
tempering material in both specimens from the Rappahannock, which
are very hard and of a reddish-brown color. The " parallel corrugated
indentations " appear to have resulted from the use of a basket in
forming the vessel, thus preserving on the outside of the pottery
vessel the impression of the inside of the rigid basket.

When the surface of a bit of pottery has become partly worn
away, it is difficult to distinguish between the markings made by a
roulette and the impressions caused by contact of the plastic clay
with woven textiles or the surface of a basket. Coiled baskets are
thought to have been unknown to the historic Siouan and Algonquian
tribes of Virginia, but they had evidently been made and used by
others who had preceded them, by whom the early earthenware vessels
had likewise been fashioned.

Two fragments of pottery found on the right bank of the Rappa-
hannock below the mouth of the Rapidan bear the impressions of
basketry, appearing to have been of the coiled variety. Of these, the
specimen found opposite the falls, shown in plate 3, d, is the more
interesting. Although the surface has become considerably worn and
smoothed the impression left by the basketry in the plastic clay
remains clearly defined. The second of the two examples (pl. 7, a)
was found a few miles up the river on the Forest Hall site. This at
first glance suggests the impression of a roulette, but it is believed
to be that of a basket. Several very good examples of similar ware
discovered farther up the Rappahannock at Rogers Ford are likewise
believed to have belonged to a period that preceded the coming of the
historic Siouan tribes to the Rapidan-Rappahannock area.

Fragments of ware that bear on the surface clearly made im-
pressions of coiled basketry have been discovered on the Anacostia
site in the District of Columbia. Other examples have been found in
North Carolina, in the vicinity of Albemarle Sound in the northeastern
part of the State, in Carteret County (U.S.N.M. No. 140929)
midway down the coast, in New Hanover County just north of the
mouth of Cape Fear River,[29] and in Granville County near the
Virginia line. Farther south, fragments of pottery bearing similar
impressions have been reported from near the mouth of the Santee
River, midway down the coast of South Carolina; in the vicinity of
Montgomery, Ala.; and in Clarke County (U.S.N.M. 331027) and
Oktibbeha County (U.S.N.M. 369327), Miss., both in the eastern

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[29] Bushnell, David I., Jr., Notes on the archaeology of New Hanover County.
In Cape Fear Chronicles, by James Sprunt, Raleigh, N. C., 1914.

part of the State, the former being bounded on the east by the
Alabama line.

Similar material must occur on many sites along the coast as well
as in the interior, and its distinctive feature makes it easily recognized.
As previously mentioned, this appears to be one of the earliest types
of earthenware encountered in the Middle Atlantic and Southeastern
areas, and the extreme limits of the region in which it is found
should be determined.

Parts of three vessels found on the left bank of the Rapidan at
Skinkers Ford closely resemble material from southwest Virginia
figured and described by Holmes.[30] Several specimens were illustrated
(Holmes, pl. 133) and described as " Potsherds with textile markings,
New River Valley, Virginia." The textile impression is exactly like
that on plate 17, *a* and *b*, from Skinkers Ford on the Rapidan, and
plate 12, *b*, from Kellys Ford on the Rappahannock. Examples were
also found at Rogers Ford, also on the Rappahannock and less than
2¼ miles from Skinkers Ford. It is interesting ware, and Holmes
wrote regarding it (p. 150) : " The people concerned may have
belonged to the Algonquian stock, for Algonquian features decidedly
prevail, but there is a possibility that they were Siouan." The same
question of identity is presented by the pieces from the Rapidan-
Rappahannock region, an area which, although claimed by the
Manahoac in 1608, may earlier have been the home of Algonquian
tribes. In this connection it is interesting to record that a conical
base of a vessel was found in contact with the fragments at Rogers
Ford, this form of base being suggestive of Algonquian pottery.

A small fragment of similar ware, of a reddish color and bearing
the same impressions as on specimens *b*, from the sites at Kellys
Ford and Skinkers Ford (pl. 12, fig. 2 ; pl. 17), and also from Rogers
Ford (pl. 10), was found at Anacostia, in the District of Columbia,
some distance from the country occupied by Siouan tribes at the
beginning of the seventeenth century. Other small sherds found at
Anacostia show the same impression on the surface but contain
rather large pieces of crushed quartz as tempering, in this respect
again resembling certain pottery fragments from the site on the
Rapidan.

The impression of nets are more readily distinguished, and the
meshes are often clearly defined. Several good examples of pottery
so decorated were found at Richards Ford, on the Rappahannock, a

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[30] Holmes, W. H., Aboriginal pottery of the Eastern United States. *In* 20th
Ann. Rept. Bur. Amer. Ethnol., 1903.

mile above the mouth of the Rapidan, and are figured in plate 9. It was to this type of ware that Holmes referred when he wrote (pp. 154-155) : [31] " This pottery is found in more or less typical forms intermingled with the ordinary varieties of ware on sites extending from the Yadkin to the Delaware." He was then describing a sherd discovered in the great shell heap at the mouth of Popes Creek, on the left bank of the Potomac, some miles below Washington, D. C., and had previously written, when comparing the latter with fragments found near the Yadkin, in North Carolina : " The materials are the same, the shape, size, degree of rudeness, treatment of surface, and decoration are the same, even the netting and the practice of partially obliterating the net impressions on the whole or a part of the vessels are the same." It is interesting to find at Richards Ford specimens on which the net impressions had likewise been partially obliterated, but in some instances this may have been caused by the wearing away of the surface during long use of the vessel.

Later discoveries seem to extend the net-marked ware still farther south. An illustration in the account of the partial examination of the great mound on Stalling's Island, in the Savannah River near Augusta, Georgia,[32] shows one fragment of pottery that appears to bear the impression of a net (Claflin, pl. 27), but it is not described, nor are any dimensions given.

As shown by comparison with material from other localities, the fragments of pottery from the Rapidan-Rappahannock area, which have already been mentioned, represent types of ware and forms of decoration that are widely distributed, though not very plentiful, and which have, in some instances, been discovered under conditions that prove their comparatively great age. It is now believed that all such ware encountered on sites along the Rapidan and Rappahannock should be attributed to a tribe, or tribes, who had inhabited the region before the coming of the historic Siouan and Algonquian groups, and who extended over a wide region both north and south from Virginia. Obviously, other pottery found on the same sites belonged to a much later period of occupancy.

There is a remarkable similarity between certain sherds shown in plate 3, from the site on the right bank of the Rappahannock facing the falls, and many pieces found at Stalling's Island. The same form of decoration was employed at both sites, and in some instances the roulette, punctate, and incised designs were used in

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[31] Holmes, op. cit.

[32] Claflin, William H., Jr., The Stalling's Island Mound, Columbia County, Georgia. Papers Peabody Mus., Harvard Univ., vol. 14, no. 1, 1931.

similar combinations on the surface of a vessel. It is also interesting to consider the similarity of the two sites, both being at the falls of large streams. All this suggests more than a mere coincidence.

Many of the fragments that may be attributed to the later period are of rather heavy ware, cord-marked and with straight rims. But pieces of vessels of a superior quality were discovered on the site at Jerrys Ford, examples of which are illustrated in plate 13. Some of this is thought to have come from the burial mound that formerly stood near where the sherds were found. Among the pieces recovered were fragments of many very thin, fragile vessels, some being less than ⅛ inch in thickness, cord-marked, and beautifully made. Typical specimens are shown at the bottom of plate 13. The outer surface of the thin ware is a light brownish color, but the inner surfaces are a lustrous black, which undoubtedly resulted from a process employed in the endeavor to make the vessel impervious to water.

Many customs were probably practiced in common by the potters of the different eastern tribes. Years ago, while among the Cherokee in the mountains of Carolina, Mooney met a woman who knew the art of pottery making. Later, during the summer of 1906, Harrington visited the Cherokee in North Carolina, and learned from the same old woman—Iwi Katalsta, by name—the secrets of her art.[33] It is an interesting narrative, from which the following is quoted (p. 226):

" In order to be good for cooking, these pots should be smoked," she said. " If this is not done the water will soak through." So she dropped a handful of bran in each one while they were still almost red-hot, stirred it with her stick, tipped the pots this way and that, and finally, turning out the now blazing bran from each in turn, inverted the vessels upon it. In this way the inside was smoked black and rendered impervious and this without leaving any odor of smoke in the vessels when they became cold. Generally, Iwi told me, crushed corn-cobs were employed for this purpose, but she always used bran when cobs were not available.

This may explain the cause of the black inner surface of the thin vessels from Jerrys Ford. Small fragments of similar ware were found on the nearby site at Richards Ford, and it is reasonable to believe the two settlements existed at the same time.

The only example of incised decoration discovered above Motts Run was found at Jerrys Ford, a small piece sketched in figure 10. No evidence of a looped handle, nor of a projection of any sort on the outside of a vessel, was encountered on any site.

[33] Harrington, M. R., The last of the Iroquois potters. New York State Mus. Bull. 133, 1909.

Much of the later ware was undoubtedly the work of the Manahoac tribes, and some of the vessels may have been made and used after the year 1608.

Many of the vessels thought to have been made during the recent, or later, period were decorated by pressing cords into the plastic clay. Simple designs were thus produced—always straight lines, which usually extended only a short distance below the rim. Specimens of pottery decorated in this manner were found on various sites, but the majority of the more interesting pieces were discovered on Jerrys Flats; examples of these are shown in plate 13. The cords thus used varied greatly in size from that of a coarse thread to others more than ⅛ inch in diameter.

It is evident that the Indians of Virginia, at the beginning of the seventeenth century, made a variety of cords to serve different purposes. This was referred to by Captain Smith[34] soon after the settlement of the colony when he wrote:

> Betwixt their hands and thighes, their women use to spin the barks of trees, deare sinews, or a kind of grasse they call *Pemmenaw;*[35] of these they make a thred very even and readily. This thred serveth for many uses, as about their housing, apparell; and also they make nets for fishing, for the quantity as formally braded as ours. They make also with it lines for angles.

This readily explains the difference in size and appearance of the many impressions of cords that appear on the surface of the fragments of vessels. As to the materials used in making the cords, some were probably formed by twisting the bark of a milkweed as described by Colonel Byrd[36] more than two centuries ago. The milkweed was the Indian hemp of the early settlers, and is thought to have been the plant mentioned by Byrd as " silk grass ", known to many persons in Virginia at the present time as silk weed. On November 10, 1728, Colonel Byrd described certain customs of the Saponi, a Siouan tribe related to the Manahoac, and wrote in part (p. 81): " The Indians use it in all their little manufactures, twisting a thread of it that is prodigiously strong. Of this they make their baskets and the

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[34] *Op. cit.,* Arber edition, p. 69.

[35] Rather than being the name of " a kind of grasse " this may be an Algonquian word for some cord, rope, or thread. Strachey in "A Dictionarie of the Indian Language ", gave the following " Penninaugh, *a rope* ", and " Peymmata, *threed* ".

[36] Byrd, William, The Westover manuscripts : containing the history of the dividing line . . . . Petersburg, Va., 1841.

aprons which their women wear about their middles, for decency's sake." The plant mentioned by Colonel Byrd may have been the *Asclepias pulchra*. Undoubtedly, the Manahoac likewise made extensive use of the plant, which would have been found growing throughout their country.

Finely twisted sinew was used, as related by Captain Smith, but the larger, coarser cords were probably formed of the wool or hair of wild animals. Buffalo must have been known to the people by whom the pottery was made, as it is evident they were to have been encountered within a few miles of the falls of the Rappahannock only 6 years after the settlement of Jamestown. To quote from Purchas, when he wrote concerning conditions in Virginia (p. 759) : [37]

> Master *Whitaker* in his letter and book from Henrico 1612, testifieth the health and welfare of the Colonie. *Samuel Argall* in the yeare 1613, affirmed likewise that he found the state of Virginia farre better then was reported. In one voyage they had gotten one thousand and one hundred bushells of corne : they found a slow kinde of Cattell, as bigge as Kine, which were good meate.

Buffalo alone among the beasts encountered in Virginia could have been so described. But they may never have been very numerous, which would account for the lack of references by other writers of the period.

Cords made of the wool and hair of the buffalo were undoubtedly woven into a textile such as was impressed on the surface of large vessels, fragments of some of which were discovered on the site at Skinkers Ford. Bags would have been made of the same material, similar to specimens collected in the Mississippi Valley in the eighteenth century and now preserved in European museums.

The native tribes of the Rapidan-Rappahannock area may also have followed a custom practiced by the Indians of Carolina of using the hair or wool of the opossum as mentioned by Lawson [38] who wrote, when referring to the opossum (p. 121) : " Their Fur is not esteem'd nor used, save that the Indians spin it into Girdles and Garters."

CONCLUSION

The material discovered during the recent examination of sites on the banks of the Rapidan and Rappahannock Rivers indicates two, and possibly more, distinct periods of occupation, which may have been separated by centuries.

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[37] Purchas, Samuel, Purchas his Pilgrimage. . . . . Second ed., London, 1614.

[38] Lawson, John, History of Carolina, London, 1714.

No stratified mass of camp refuse was encountered to reveal the sequence of the different types of pottery, and consequently it was necessary to compare the sherds with others of similar ware that had been discovered elsewhere under such conditions as would determine their relative age. Sherds bearing the impression of basketry are believed by the writer to be one of the earliest types of earthenware found in the Middle Atlantic and Southeastern areas and one which should be attributed to a very early culture. Fragments of this ware have been recovered from sites in the Rapidan-Rappahannock area, and other similar sherds occur far southward on the Atlantic Coast, thence westward to near the Mississippi, proving its widespread distribution. This early period of occupancy of the valleys of the Rapidan and Rappahannock is believed to have preceded by centuries the arrival of the historic Siouan groups, but the direction from which the ancient tribes first entered the region has not been determined, although it is the belief of the writer that it was from the north. Fragments of other vessels found on many sites undoubtedly represent the work of the historic Siouan and Algonquian tribes, and many of the vessels may have been made and used even after the settlement of Jamestown.

Stone implements likewise suggest two clearly defined periods, the earlier being represented by the crudely flaked objects, altered through long exposure, the later by the polished celts and grooved axes, much fewer in number.

The discovery of points of the recognized Folsom type, specimens of superior workmanship, presents a problem that may be difficult to solve. One example was found near the Rapidan a short distance west of the region now being considered, another was discovered near the banks of the Rappahannock some 15 miles below Fredericksburg. The Rapidan-Rappahannock area, therefore, must have been traversed, if not occupied, by the makers of this highly specialized form of point. Other objects of stone were necessarily made and used during the same period, and possibly some of the oldest of the numerous flaked implements were the work of the makers of the Folsom points; however, that is another question that remains to be answered.

Thus it is evident that the country beyond the falls of the Rappahannock, the Rapidan-Rappahannock area, has been occupied or frequented by man through the centuries, but floods and other forces of nature have so changed the surface of the narrow valleys that scant traces of the native camps and villages remain.

Thomas Lincoln Casey Fund

REVIEW OF THE
GENUS CHLAENOBIA BLANCHARD
(COLEOPTERA : SCARABAEIDAE)

BY
EDWARD A. CHAPIN
Curator, Division of Insects, U. S. National Museum

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REVIEW OF THE GENUS CHLAENOBIA BLANCHARD (COLEOPTERA: SCARABAEIDAE)[1]

By EDWARD A. CHAPIN

Curator, Division of Insects, U. S. National Museum

The tribe Rhizotrogini of the scarabaeid subfamily Melolonthinae is represented in the New World by about 450 known species, distributed among what are usually considered as five genera. Somewhat more than three-fourths of these species are assigned to *Phyllophaga* Harris (*Lachnosterna* Hope). One species is the sole member of the genus *Chirodines* Bates. *Listrochelus* Blanchard and *Phytalus* Erichson together number about 100 species. *Chlaenobia* Blanchard, as defined in the present paper, contains 15 named forms, of which 2 are given but subspecific rank.

In describing *Chlaenobia,* Blanchard allied it to certain genera which are grouped about *Macrodactylus* Latreille. Lacordaire followed Blanchard's suggestion in this matter. Bates, the first to have an adequate series of specimens for study, recognized the genus as Rhizotrogine and not Macrodactyline and so treated it in the Biologia Centrali-Americana. Dalla Torre returned to the views of Blanchard and Lacordaire in the Junk Catalog, but there is ample evidence to show that this work is not at all critical. The present treatment of the genus follows Bates.

Arrow, in 1920, suggested that the American genus *Phytalus* Erichson and the Asiatic genera *Brahmina* Blanchard and *Holotrichia* Hope should be abandoned and their species placed in *Lachnosterna* Hope (*Phyllophaga* Harris). If this is necessary, it is also necessary to add those species now contained in *Chlaenobia,* for that genus is certainly intimately connected with *Phytalus.* *Chirodines* is also very close to *Phytalus,* and when its female is known, it may seem best to add this genus to *Phyllophaga* also. On the other hand, a study of the Rhizotrogini may show that an entirely new grouping of the

species along lines other than those at present used will result in more clean-cut genera. There is a greater diversity of structure displayed among the species of *Phyllophaga* than between those of *Phytalus* and *Chlaenobia*.

Pending a reinvestigation of the whole complex, the five genera of Rhizotrogini known to occur in the New World may be separated as follows:

1. Claws of front and middle legs simple, those of hind legs cleft
                                            Chirodines Bates.
    All tarsal claws toothed, cleft, pectinate or serrate......................2.
2. Tarsal claws cleft...3.
    Tarsal claws toothed, pectinate or serrate..............................4.
3. Prothorax somewhat narrowed at base; female pygidium usually profoundly modified; tarsi usually with dense pubescence on plantar surfaces
                                            Chlaenobia Blanchard.
    Prothorax wider across basal angles than across anterior angles; female pygidium not modified; tarsi without dense pubescence on plantar surfaces
                                            Phytalus Erichson.
4. Tarsal claws strongly bipectinate or feebly serrate, sometimes with a more or less well developed subapical tooth on one or both of the claws of a foot ....*Listrochelus* Blanchard.
    Tarsal claws neither pectinate nor serrate, with a more or less strongly developed tooth which may be subbasal, median, or subapical in position
                                            Phyllophaga Harris.

CHLAENOBIA Blanchard

Blanchard, 1850, Cat. Coll. Ent. Paris, Coleopt., vol. 1, p. 116; Lacordaire, 1856, Gen. Coleopt., vol. 3, p. 265; Bates, 1888, Biol. Céntr.-Amer., Coleopt., vol. 2, pt. 2, p. 166; Arrow, 1933, Ann. Mag. Nat. Hist., Ser. 10, vol. 11, p. 146.

Type species.—*Chlaenobia ciliatipes* Blanchard 1850 (monobasic; also by subsequent designation of Arrow 1933).

KEY TO THE SPECIES OF CHLAENOBIA BLANCHARD 1850

MALES

1. Antenna nine-segmented ....2.
    Antenna ten-segmented ....3.
2. Spurs of posterior tibia short, straight, and tapering.........*aegrota* Bates.
    Spurs of posterior tibia somewhat spatulate and twisted, the spur more remote from the insertion of tarsus strongly hooked at apex...*arrowi* n. sp.
3. Metasternum sparsely set with bristles, the portion adjacent to the median line glabrous or nearly so...4.
    Metasternum moderately hairy to very densely pilose, with never more than a small spot on median line glabrous; plantar surface of second segment of anterior tarsus pilose; pronotum unicolorous.......................5.

4. Plantar surface of second segment of anterior tarsus bare, its margins fimbriate with long hairs; pronotum bicolored (not always distinctly so in greasy specimens), disk castaneous and flanks testaceous; body form unusually broad for genus.................................*panamana* n. sp.
   Plantar surface of second segment pilose; pronotum unicolorous; body form normally slender ....*vexata* Horn.

5. Clypeus deeply concave, the anterior third or more strongly reflexed; second segment of anterior tarsus about twice as long as broad.....*latipes* Bates.
   Clypeus shallowly concave, only the marginal fifth reflexed; second segment of anterior tarsus at least three times as long as wide...................6.

6. Hind tibia gradually but distinctly widened from base to apex; lower half of inner face finely engraved and bounded beneath by a knife-edge margin ....7.
   Hind tibia not evenly expanded from base to apex; lower half of inner face without fine engraving, not bounded beneath by a knife-edge margin....8.

7. Outer apical angle of middle tibia produced outward; inner acute margin of hind tibia starting near base.......................*colimana* Arrow.
   Outer apical angle of middle tibia not outwardly produced; inner margin of hind tibia acute in apical half only....................*dissimilis* n. sp.

8. Spurs of hind tibia dissimilar in shape, the inner broader than the outer and twisted ....*aequata* Bates.
   Spurs of hind tibia slender, straight, and similar..........................9.

9. Pronotum less densely punctured on disk than on flanks; fifth visible abdominal sternite without median patch of asperities..........*scabripyga* Bates.
   Pronotum less densely punctured on flanks than on disk; fifth visible sternite with median patch of asperities from which long hairs arise
                                                                   tumulosa Bates.

Note: The males of the following species are unknown to the writer: *ciliatipes* Blanchard, *rodriguezi* Bates, *personata* n. sp.

FEMALES

1. Antenna nine-segmented ....2.
   Antenna ten-segmented ....5.

2. Pygidium with a deep, subconical excavation on apical half which is connected with the basal margin by a broad and rather deep groove
                                                                   arrowi n. sp.
   Pygidium without a deep, subconical excavation near apex..............3.

3. Pygidium with a median longitudinal groove; third and fourth segments of antenna equal...*ciliatipes* Bl.
   Pygidium without a median longitudinal groove; fourth segment longer than third ....4.

4. Clypeus deeply concave, the anterior third strongly reflexed; lateral marginal bead of pronotum wider near anterior and posterior angles than at middle; apical portion of pygidium with shallow, vaguely defined depression ....*rodriguezi* Bates.
   Clypeus not deeply concave, anterior fifth reflexed; lateral marginal bead of pronotum uniformly narrow throughout length; apical portion of pygidium with deep, well-defined depression...................*aegrota* Bates.

5. Apical margin of sixth visible abdominal sternite more or less produced at
   middle, the projection usually seated in a broad and very shallow
   emargination ....6.
   Apical margin of sixth sternite broadly, deeply and evenly emarginate, not
   at all produced on median line.......................................11.
6. Pygidium bicallose, the callosities separated more or less completely by a
   median longitudinal groove..7.
   Pygidium not bicallose..8.
7. Callosities of pygidium well separated, the median longitudinal groove pass-
   ing between them and very nearly attaining the basal margin
                                                          latipes Bates.
   Callosities approximate, coalescing above, the median longitudinal groove
   short, not passing completely between them..............*dissimilis* n. sp.
8. Pygidium with a single median callosity near base, the remaining portion
   shallowly concave, floor of the concavity with a pronounced median groove
                                                          colimana Arrow.
   Pygidium broadly, shallowly, and transversely excavate in apical half, the
   floor of the excavation not grooved...................................9.
9. Pygidium subacutely angulate at apex, with a single low median callosity
   on the upper margin of the subapical excavation; pronotum unicolorous
                                                          vexata Horn.
   Pygidium broadly rounded at apex, without a callosity on the basal portion
   above the excavation; pronotum bicolored as in the male sex.........10.
10. Pronotum strongly narrowed basally, as wide across anterior angles as
    across base; pygidium moderately coarsely and very sparsely punctured
                                                          panamana n. sp.
    Pronotum not strongly narrowed basally, width across anterior angles much
    less than across base; pygidium coarsely and rather densely punctured
                                                          personata n. sp.
11. Pygidium subapically with a large hemispherical cavity which is bounded
    laterobasally by two low and poorly defined callosities and apically by a
    sharp protruding margin...............................*tumulosa* Bates.
    Pygidium virtually simple, without modification other than a shallow and
    inconspicuous median impression near apex..............*aequata* Bates.

Note: The female of *ciliatipes* Blanchard is known to the writer only by
description. The female of *scabripyga* Bates is unknown to him.

DESCRIPTION OF SPECIES

CHLAENOBIA CILIATIPES Blanchard

Chlaenobia ciliatipes Blanchard, 1850, Cat. Coll. Ent. Paris Coleopt., vol. 1,
p. 116; Lacordaire, 1856, Gen. Coleopt., vol. 3, p. 266.

Head black, punctate, clypeus rufotestaceous, margin reflexed and
feebly emarginate. Body entirely testaceous, upper parts glabrous
and somewhat shining, underparts sericeous. Antenna nine-segmented,
with the third and fourth segments elongate and equal. Pronotum
transverse, widest anteriorly, sides obtusely angulate, uniformly and

densely punctured. Elytra with discal costae hardly perceptible. Propygidium very large and only partly covered by elytra, pygidium moderately convex, with a median longitudinal groove (female?). Anterior tibia obtusely bidentate.

Length.—13 to 14 mm.

Type locality.—Not stated in original description; by Lacordaire as Brazil.

Type.—In the Paris Museum.

This species is known to me only from the descriptions of Blanchard and Lacordaire. The above diagnosis is made up from the statements of these authors. Following Lacordaire's suggestion that the specimens available to him are females, the species has been inserted in that part of my key.

CHLAENOBIA AEGROTA Bates

Chlaenobia aegrota Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 167, pl. 10, fig. 1.

Head moderately coarsely and most densely punctured on upper portion of frons, vertex and lower portion of frons sparsely punctured, frons slightly concave, clypeofrontal suture moderately impressed and bisinuate, clypeus more coarsely and sparsely punctured, deeply concave, the outer third strongly reflexed, margin feebly sinuate at middle. Antenna nine-segmented. Pronotum transverse, side margins obtusely angulate just before the middle, lateral margin feebly sinuate near posterior angle as viewed from side, viewed from above anterior and posterior angles narrowly rounded; punctures coarse, very sparsely placed on disk, more densely on flanks. Scutellum equilateral, side margins curved, with a few punctures along sides. Elytra with sutural margins broadly tumid, each with two faintly indicated costae, the one nearer the suture a little better defined; punctures a little less coarse but more densely placed than on pronotum, epipleura narrow, disappearing before the extreme apex. Metasternum moderately coarsely and most densely punctured, rather densely clothed on median portion with moderately long erect hairs.

Male.—Antennal club one-fifth longer than second to sixth segments combined. Fifth sternite without special hair tuft, sixth sternite with a shallow median longitudinal groove, its free margin transverse, very feebly produced at middle. Pygidium strongly convex, coarsely, sparsely and irregularly punctured, sparsely set with erect hairs, transversely grooved just before apex, floor of this groove impunctate, apical margin strongly reflexed. Anterior tibia bidentate with a trace
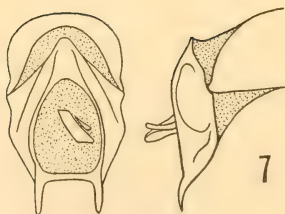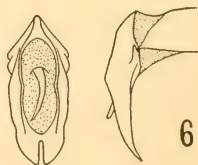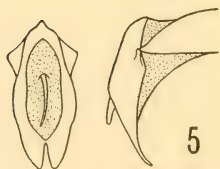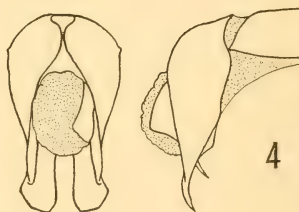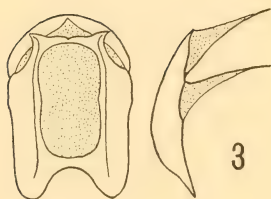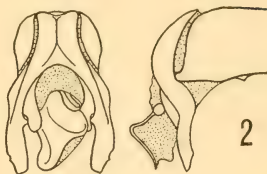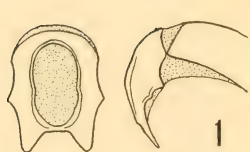
FIGS. 1-12.—En face and lateral views of aedeagus.

1. *Chlaenobia aegrota* Bates. Mexico? British Museum.
2. *Chlaenobia arrowi,* n. sp. Venodio, Sinaloa, Mexico. Paratype.
3. *Chlaenobia latipes* Bates. Cordoba, Vera Cruz, Mexico.
4. *Chlaenobia panamana,* n. sp. Cano Saddle, Gatun Lake, Canal Zone. Type.
5. *Chlaenobia vexata* (Horn). Brownsville, Texas.
6. *Chlaenobia unituberculata* Bates. North Yucatan, Gaumer. British Museum.
7. *Chlaenobia colimana* Arr. Colima Volcano, Mexico.
8. *Chlaenobia dissimilis,* n. sp. Venodio, Sinaloa, Mexico. Type.
9. *Chlaenobia aequata* Bates. Costa Rica. British Museum.
10. *Chlaenobia chiapensis,* n. subsp. Chiapas, Mexico. Type.
11. *Chlaenobia scabripyga* Bates. Juquila, Mexico. British Museum.
12. *Chlaenobia tumulosa* Bates. Palin, Guatemala.

of a third tooth. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 1.

Female.—Antennal club as long as second to sixth segments combined. Sternites not modified, free margin of sixth rather strongly produced. Pygidium somewhat as in male but with all characteristics greatly accentuated, the punctures coarser and more densely placed, the transverse groove enlarged and deepened and with apical margin produced into a liplike structure. Anterior tibia tridentate with upper tooth small.

Length.—14 mm.

Type locality.—Jalapa, Mexico (as here restricted).

Type.—In the British Museum.

Material examined.—Three males and one female from Jalapa, Mexico, Hoege, probably paratypes; one male and four females from Cordoba, V. C., Mexico, F. Knab; one male from Mexico, D. F., J. R. Inda. Three of the Jalapa specimens were loaned for study by the British Museum, the fourth was received some years ago as a gift from the same source.

CHLAENOBIA RODRIGUEZI Bates

Chlaenobia rodriguezi Bates, 1889, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, supplement, p. 399.

Head very coarsely and closely punctured except just above the impressed bisinuate clypeofrontal suture, outer or marginal third of clypeus gradually reflexed, the central portion tumid, the anterior margin broadly and shallowly notched at middle. Antennae nine-segmented. Pronotum transversely oblong, side margins obtusely angulate before the middle, lateral margin strongly bisinuate as viewed from side, viewed from above the anterior and posterior angles are obtuse and rounded; punctures coarse, sparsely and irregularly distributed. Scutellum equilateral, lateral margins curved, surface with a few punctures near margins. Elytra with sutural margins tumid to apices, where the extreme margins are sharply carinate, discal costae not evident, punctures coarse and more densely placed than on pronotum, epipleura very narrow and failing to reach sutural angle. Metasternum coarsely and rather densely punctured at sides, with a few scattered punctures in median portion.

Male.—Unknown to the writer.

Female.—Antennal club as long as second to sixth segments combined. Sternites not modified, finely punctured and sparsely set with short hairs. Pygidium broadly triangular, convex basally from side

to side, apical portion flattened and set off from basal portion by two very faintly indicated callosities. Anterior tibia tridentate with basal tooth poorly developed. Anterior tarsus with slender, parallel-sided segments.

Length.—14 mm.

Type locality.—Capetillo, Guatemala.

Type.—In the British Museum.

Material examined.—A female from the type locality, collected by Rodriguez and apparently a paratype, loaned for study by the British Museum.

CHLAENOBIA ARROWI, n. sp.

Head coarsely and moderately densely punctured on frons, vertex virtually impunctate, clypeofrontal suture sharply impressed and bi-sinuate, clypeus concave, the marginal fifth sharply reflexed, coarsely and very sparsely punctured, margin feebly sinuate at middle. Antenna nine-segmented. Pronotum transverse, side margins obtusely angulate just before the middle, lateral margin straight near posterior angle as viewed from side, viewed from above anterior and posterior angles obtuse, bluntly rounded, equal; punctures more coarse than those of head, sparsely and irregularly placed. Scutellum with base longer than a side, sides evenly curved, with a few scattered punctures. Elytra with sutural margin broadly tumid and each with a single, faintly indicated discal costa, punctures less coarse but more densely placed than on pronotum, epipleura very narrow, terminating just before extreme apex. Metasternum finely and densely punctured on median area, coarsely and more sparsely punctured laterally, clothed with rather short erect hairs. Sternites, especially first and second, with short, fine bristlelike setae on median portion.

Male.—Antennal club one-fourth longer than second to sixth segments combined, fourth segment much longer than third. Sixth sternite with a median longitudinal depression, its free margin transverse. Pygidium strongly and evenly convex, sparsely and moderately coarsely punctured and sparsely hairy, the extreme apical margin sharply reflexed and produced at middle. Anterior tibia bidentate. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 2.

Female.—Antennal club as long as second to sixth segments combined. Sixth sternite without depression, its free margin moderately strongly produced at middle. Pygidium very sparsely punctured, with a deep, nearly hemispherical depression at middle, which is connected with the basal margin by a deep groove, half as wide as the

pit itself. Apical margin strongly produced in an acute, reflexed lip. Anterior tibia tridentate.

Length.—13 to 14.5 mm.

Type locality.—Venodio, Sinaloa, Mexico.

Type.—U.S.N.M. no. 51041.

Material examined.—Type (male) and 35 paratypes of both sexes collected at the type locality June 10-15, 1918, Kusche, donated to the National Museum by B. P. Clark; one male paratype from Sinaloa, Mexico, without further data.

In the 37 specimens before me, 3 show a partial division of the fourth antennal segment into two segments on one or both sides of the insect. In no case is the division complete on both sides of the same specimen and in the other specimens both antennae are without doubt nine-segmented.

CHLAENOBIA LATIPES Bates

Chlaenobia latipes Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 167.
Chlaenobia bicallosa Bates, 1888, loc. cit., p. 168.

Head rather densely and moderately coarsely punctured on frons, region adjacent to the feebly impressed but strongly bisinuate clypeofrontal suture more sparsely punctured. Frons slightly convex. Antenna ten-segmented. Pronotum transverse, side margins obtusely angulate well before the middle, lateral margin sinuate just before posterior angle as viewed from side, viewed from above anterior angles narrowly rounded, posterior angles acute and slightly produced; punctures a little coarser than those of head, rather sparsely and irregularly distributed. Scutellum equilateral, sides curved, with a few scattered punctures. Elytra with sutural margins strongly tumid, discal costae feebly indicated; punctures finer and more densely placed than on pronotum, epipleura very narrow, obsolete toward apex. Metasternum moderately coarsely and densely punctured, vestiture moderately long and suberect.

Male.—Clypeus deeply concave, rather coarsely and densely punctured, subtrapezoidal, anterior margin feebly emarginate. Antennal club half again as long as second to seventh segments combined. Sixth sternite broadly and shallowly impressed, its free margin broadly rounded and slightly produced. Pygidium transverse, slightly convex, median area slightly impressed, apex transverse, slightly lipped. Anterior tibia slender, bidentate, second segment of anterior tarsus broadly oval, less than twice as long as wide. Aedeagus, figure 3.

Female.—Clypeus feebly concave, coarsely, densely and somewhat confluently punctured, biarcuate with median indentation shallow.

Antennal club a little shorter than second to seventh segments combined. Sixth sternite with its free margin rather strongly produced in a broad lobe. Pygidium transverse, median line sharply impressed, with a conical boss on either side of median line at middle of length, apical third shallowly excavate, apical margin subtransverse and sharply reflexed. Anterior tibia tridentate.

Length.—13.5 to 15 mm.

Type locality.—Teapa, Mexico (*latipes*) ; Tomatlan and Tuxtla, Mexico (*bicallosa*).

Types.—In the British Museum.

Material examined.—Two males from Cordoba, determined as this species by Arrow but previously determined by Bates as *aegrota;* one female, apparently a paratype of *bicallosa,* from Tomatlan; seven males and nine females from Cordoba, V. C., Mex., May 12-June 9, Fred. Knab; one male and one female from Chiapas, Mexico, in collection of L. W. Saylor.

Two males and a female were taken by Knab on May 12 and again on May 16. It seems unlikely that these sexes are not of the same species. The males compare favorably with the two specimens determined by Arrow, and one of the females has been compared by Arrow with the type of *bicallosa.* The original description of the female of *latipes* is not materially different from that of *bicallosa.*

CHLAENOBIA PANAMANA, n. sp.

Head densely and moderately coarsely punctured on frons, vertex and region adjacent to clypeofrontal suture, which is deeply impressed and strongly biarcuate, very sparsely punctured. Frons evenly and slightly convex. Clypeus shallowly concave, its outer portion not sharply reflexed, margin distinctly indented at middle. Antenna ten-segmented. Pronotum transverse, side margin obtusely angulate just before the middle, lateral margin strongly sinuate just before the posterior angle as viewed from the side, viewed from above anterior angle subacute, posterior angle acute and slightly produced ; punctures coarse, densely placed on disk, more sparsely so on flanks. Scutellum equilateral, rather sparsely punctured. Elytra with sutural margins narrowly tumid, each with two feebly indicated discal costae, of which the first (from suture) is more developed than the second ; punctures as coarse and a little more densely placed than on disk of pronotum, epipleura very narrow, not well defined beyond middle of the length. Metasternum moderately coarsely and very sparsely

punctured, the median area puncture-free; vestiture moderately long but sparse.

Male.—Antennal club about one-fifth longer than second to seventh segments combined. Abdominal sternites not noticeably modified, sixth with the free margin slightly produced at middle. Pygidium moderately strongly convex in basal half, which is rather coarsely but not densely punctured, apical half less convex, shining, nearly puncture-free, the extreme apex not strongly reflexed. Anterior tibia long and slender, bidentate with a feeble indication of a third tooth, second segment of anterior tarsus narrow, about four times as long as wide. Aedeagus, figure 4.

Female.—Antennal club as long as second to seventh segments combined. Abdominal sternites convex, not modified, the sixth with its free margin produced at middle in a small triangular process. Pygidium with a moderately deep, transversely oval depression covering almost the entire apical three-fifths, the apical margin slightly produced, basal portion sparsely and moderately coarsely punctured. Anterior tibia short and broad, distinctly tridentate.

Length.—13.5 to 15 mm.

Type locality.—Cano Saddle, Gatun Lake, Canal Zone.

Type.—U.S.N.M. no. 51042.

Material examined.—Type (male) and three paratypes (males and females) from the above locality, collected May 8-12, 1923, R. C. Shannon; one paratype (female) from Barro Colorado Island, Panama, June 25, 1933, J. D. Hood.

This broad species, when fresh and without grease, has a very distinctive appearance due to the bicolored pronotum. In greasy specimens the disk of the pronotum appears nearly black, while the flanks and elytra are moderately dark brown.

CHLAENOBIA PERSONATA, n. sp.

Head coarsely and densely punctured except on vertex, clypeo-frontal suture deeply impressed, bisinuate, frons with a short median impressed groove extending backward a short distance from the clypeofrontal suture, outer third of clypeus gradually reflexed, anterior margin broadly and shallowly emarginate at middle. Antenna ten-segmented. Pronotum transverse, side margin obtusely angulate just before the middle, lateral margin feebly sinuate near posterior angle as viewed from side, viewed from above the anterior angles are obtuse and rounded, the posterior angles subacute, surface moderately coarsely and rather irregularly punctured. Scutellum equilateral, side margin curved, surface sparsely and rather coarsely

punctured. Elytra with sutural margins tumid to apices, discal costae not evident, punctation similar to that of pronotum, epipleurae very narrow but complete. Metasternum coarsely punctured, very densely at sides and less densely at middle.

Male.—Unknown to the writer.

Female.—Antennal club as long as the second to seventh segments combined. Sternites moderately coarsely and densely punctured, sparsely hairy. Sixth sternite very coarsely punctured. Pygidium broad, not angulate, convex basally from side to side ; apical portion with a shallow excavation, the floor of which is virtually devoid of punctures, rest of surface coarsely and rather densely punctured. Anterior tibia tridentate, basal tooth well defined. Anterior tarsus with slender, parallel-sided segments.

Length.—15.5 mm.

Type locality.—Mexico.

Type.—In the British Museum.

Material examined.—A single specimen, number 21975, from the Frye Collection. The specimen bears the pin label " Liogenys personata Reiche—Mexico ".

CHLAENOBIA VEXATA (Horn)

Phytalus vexatus Horn, 1885, Trans. Amer. Ent. Soc., vol. 12, p. 120.
Phytalus cavifrons Linell, 1896, Proc. U. S. Nat. Mus., vol. 18, p. 729.

Head moderately coarsely and densely punctured on frons. Clypeofrontal suture deeply impressed, biarcuate. Clypeus coarsely but less distinctly punctured than frons, very slightly elevated at middle, the outer third abruptly reflexed, anterior margin feebly indented. Antenna ten-segmented. Pronotum transverse, broadest across middle, side margins very broadly angulate, lateral marginal carina slightly sinuate near posterior angle as viewed from side, viewed from above anterior and posterior angles subacute ; punctures slightly less coarse and much less densely placed than those on frons, irregularly distributed. Elytra with sutural margins tumid, discal costae faintly indicated ; punctures slightly finer but about as densely placed as those on pronotum ; epipleura narrow. Metasternum polished and sparsely punctured at middle, coarsely and more densely punctured at sides, vestiture short and sparse.

Male.—Antennal club a little longer than second to seventh segments combined. Second to fifth sternites polished at middle with a very few scattered punctures. Sixth sternite feebly depressed at middle. Pygidium convex, moderately coarsely and very sparsely

punctured, apex rounded and lipped. Anterior tibia with three teeth, the upper not strongly developed. Second segment of anterior tarsus elongate with parallel sides, about four times as long as wide. Aedeagus, figure 5.

Female.—Antennal club a little shorter than second to seventh segments combined. First to fifth sternites unmodified, sixth sternite convex, with a broad shallow emargination behind. Pygidium strongly convex in basal half, shallowly and transversely excavated apically, with a single, low, median callosity. Anterior tibia strongly tridentate. Second segment of anterior tarsus elongate, parallel-sided, about three times as long as wide.

Length.—11 to 13.8 mm.

Type locality.—Texas.

Types.—In the Academy of Natural Sciences, Philadelphia (*vexatus* Horn) ; in the United States National Museum, no. 574 (*cavifrons* Linell).

Material examined.—One female from Texas in the Philadelphia Academy (type of *vexatus* Horn) ; two males and one female from Brownsville, Tex., May 24–June 11, C. H. T. Townsend (type and paratypes of *cavifrons* Linell) ; five males and one female from same locality, May 15–Aug. 17, C. Schaeffer (Brooklyn Museum Collection, U.S.Nat.Mus.) ; one male from Texas, Fry Collection 1905-100 (British Museum).

This species is unusual in the genus in having a moderately well defined third tooth on the anterior tibia of the male.

CHLAENOBIA VEXATA subsp. UNITUBERCULATA Bates

Chlaenobia unituberculata Bates, 1889, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, supplement, p. 399.

Very similar to the typical form of the species. The punctation of the head and pronotum is a little coarser in *unituberculata* than in *cavifrons.* The aedeagus offers the only sure means of identification. In the present subspecies (fig. 6) the apical portion of the organ narrows sharply from a point at about the level of the terminus of the median fissure.

Type locality.—Temax, N. Yucatan (Gaumer).

Type.—In the British Museum.

Material examined.—A pair, probably paratypes, from the type locality, loaned for study by the British Museum and a pair from Rin Antonio, Oaxaca, Mexico, F. Knab, collector.

CHLAENOBIA COLIMANA Arrow

Chlaenobia colimana Arrow, 1933, Ann. Mag. Nat. Hist., ser. 10, vol. 11, p. 145.

Head rather sparsely and moderately densely punctured on frons, median line, vertex and along the lightly impressed and feebly sinuate clypeofrontal suture almost free of punctures. Frons almost plane. Clypeus not concave, its outer margin slightly reflexed and very feebly indented at middle. Antenna ten-segmented. Pronotum transverse, side margins very obtusely angulate before the middle, lateral margin strongly sinuate just before the posterior angle as viewed from side, viewed from above anterior and posterior angles acute; punctures coarse and rather sparse on disk, finer and sparser on flanks. Scutellum equilateral, with a few coarse punctures along side. Elytra with sutural margin broadly tumid at middle of length, narrowed basally and apically, discal costae almost completely effaced; punctures a little finer and as densely placed as those on pronotal disk, epipleura very narrow, disappearing just before the extreme apex. Metasternum very finely and densely punctured on median portion, more coarsely and sparsely at sides, vestiture short and erect, absent from a minute spot at center.

Male.—Antennal club half again as long as second to seventh segments combined. Abdominal sternites short and crowded along median line, sixth sternite as long, along median line, as fourth and fifth combined, its median portion flattened and with a poorly defined longitudinal groove. Pygidium strongly convex, apical half sparsely hairy, apical margins transverse and slightly lipped. Anterior tibia slender, bidentate with a trace of a third tooth, second segment of anterior tarsus elongate oval, about three times as long as wide. Aedeagus, figure 7.

Female.—Antennal club very slightly longer than second to seventh segments combined. Abdominal sternites somewhat flattened along median line but not concave, sixth sternite long, with its free margin bisinuate. Pygidium with a single well-developed median tubercle on basal half, apical two-thirds cut away and with a deep, narrow median groove extending from below the tubercle toward apex. Apical margin with two small processes which fit into the sinuations at apex of sixth sternite; concave portion sparsely hairy. Anterior tibia slender, tridentate.

Length.—13.5 to 16.5 mm.

Type locality.—Colima, Mexico.

Type.—In the British Museum.

Material examined.—Six males and three females from Colima Volcano, Jalisco, L. Conradt. Specimens from this lot have been compared with the type by Arrow.

CHLAENOBIA DISSIMILIS, n. sp.

Head moderately coarsely and densely punctured near eyes, rest of frons, vertex and clypeus sparsely punctured. Clypeofrontal suture feebly impressed and biarcuate. Clypeus flat with outer fourth gradually reflexed, its anterior margin feebly and broadly indented. Antenna ten-segmented. Pronotum transverse, side margins obtusely angulate well before the middle, lateral marginal carina weakly sinuate just before the posterior angle as viewed from the side, viewed from above anterior and posterior angles acute, not produced; punctures a little more coarse than those of head, sparsely placed on disk, very sparsely on flanks. Elytra with sutural margins strongly tumid, discal costae obsolete; punctures almost as coarse as those on pronotum and a little more densely placed; epipleura very narrow, obsolete toward apex. Metasternum coarsely and densely punctured at sides, very finely and very densely at middle except for the small median area, which is puncture-free; vestiture sparse at sides, very dense at middle.

Male.—Antennal club about one-third longer than second to seventh segments combined. Abdominal sternites each with a median patch of short, fine and dense hairs, sixth with a shallow median longitudinal impression, its free margin transverse, not noticeably produced. Pygidium strongly convex, rather sparsely punctured, apex sub-transverse and slightly lipped. Anterior tibia moderately stout, bidentate. Second segment of anterior tarsus oval, about two and one-half times as long as wide. Aedeagus, figure 8.

Female.—Antennal club a little shorter than second to seventh segments combined. First and fifth abdominal sternites convex, not modified, sixth sternite with a broad and rather deep pit on either side of the median line, its free margin strongly tumid and sinuous. Pygidium with a pair of strong, conical bosses on basal half which are confluent basally, apical half excavate, apex transverse. Punctures sparse on basal half, almost wanting on apical half. Anterior tibia short, distinctly tridentate.

Length.—14.5 to 16 mm.
Type locality.—Venodio, Sinaloa, Mexico.
Type.—U.S.N.M. no. 51043.

Material examined.—Type (male) and three paratypes (males and females) from above locality, collected from June 10–July 30, Kusche.

The extremities of this species are unusually pilose in the male, the posterior femora at base and posterior tibia at apex bear dense brushes of long hair on their inner margins. All tarsi are also exceedingly pilose.

CHLAENOBIA AEQUATA Bates

Chlaenobia aequata Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 168.

Head coarsely punctured, densely so on vertex and upper portion of frons, moderately densely so on clypeus and very sparsely so on lower part of frons in the region of the clypeofrontal suture which is strongly impressed and bisinuate; clypeus with marginal fourth reflexed, the central portion nearly flat, the margin slightly notched at middle. Antenna ten-segmented. Pronotum transverse, side margins strongly angulate at middle, lateral margin strongly sinuate near posterior angle as viewed from side, viewed from above, the anterior angles are obtuse and rounded, basal angles prominent and subacute; punctures coarse, more sparsely placed on disk than on flanks where their density is similar to those on clypeus. Scutellum equilateral, the side margin curved, surface sparsely and rather finely punctured near margins. Elytra with sutural margins broadly tumid except at apex where the extreme margins are sharply carinate, discal costae not evident, punctures less coarse but as densely placed as on flanks of pronotum, epipleura very narrow. Metasternum moderately coarsely and very densely punctured at sides, a little more sparsely so in median portion.

Male.—Antennal club almost as long as all the remaining segments combined. Fifth sternite with a sparse patch of hair at middle, arising from a patch of asperities, sixth sternite tumid with a central depression surrounded by a few very coarse punctures or pits, free margin with a broad and not very prominent process. Pygidium uniformly and strongly convex, coarsely and sparsely punctured, a little more densely so toward base; apical margin sharply and narrowly reflexed. Anterior tibia bidentate with a faint indication of a third tooth. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 9.

Female.—Antennal club as long as second to seventh segments combined. Sternites not noticeably modified. Pygidium elongate triangular, basal half evenly convex from side to side, apically

flattened with indications of two broad callosities just above the flattened portion. Anterior tibia tridentate.

Length.—12 mm.

Type locality.—Chontales, Nicaragua and Costa Rica.

Type.—In the British Museum.

Material examined.—A pair (of which the female is probably a paratype) from Costa Rica, loaned for study by the British Museum; one female from Tuis, C. R., 2,400 feet, C. H. Lankester.

CHLAENOBIA AEQUATA subsp. CHIAPENSIS, n. subsp.

Similar in most respects to the typical subspecies but differing in the slightly coarser punctures of the head and pronotum and in the conformation of the aedeagus. The lateral appendages of the aedeagus in the typical subspecies are short and extend about half-way from their insertion to the apex of the conjoined lateral lobes. In the subspecies *chiapensis* (fig. 10) these appendages are considerably longer, almost reaching the level of the apex of the lobes.

Type locality.—Chiapas, Mexico.

Type.—U.S.N.M. no. 51044.

Material examined.—Type (male), three paratypes (males) and two paratypes (females) from the Pacific slope of the Cordilleras, altitude 800 to 1000 meters, state of Chiapas, L. Hotzen, 1919.

CHLAENOBIA SCABRIPYGA Bates

Chlaenobia scabripyga Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 167.

Head coarsely punctured, moderately densely so on clypeus and frons, sparsely so on median portion of vertex, clypeofrontal suture deeply impressed and strongly biarcuate, with the median cusp prolonged a short distance onto the frons as a median impressed line, clypeus with margin more or less following the curvature of the clypeofrontal suture, feebly reflexed, central portion nearly flat. Antenna ten-segmented. Pronotum transversely oblong, sides obtusely angulate at middle, lateral margin nearly straight throughout its length as viewed from side, viewed from above both anterior and posterior angles are obtuse and rounded; punctures similar in size to those on frons, moderately densely placed except along the lateral margins and on median portion of disk, where they are slightly less dense. Scutellum equilateral with side margins curved, surface moderately coarsely and densely punctured. Elytra with sutural margins broadly and strongly tumid, discal costae not well defined,

punctures about as coarse and as densely placed as on disk of pronotum, epipleura very narrow. Metasternum moderately coarsely and rather evenly punctured, median portion set with rather long erect hairs.

Male.—Second to fourth sternites each with a dense median patch of short erect hairs, fifth sternite with surface generally uneven but without asperities or hair patch at middle. Sixth sternite with median area slightly depressed, its posterior margin not noticeably sinuate. Pygidium strongly convex in its upper (basal) half, which is coarsely and densely punctured, the lower half is more flattened, coarsely wrinkled and convoluted, apical margin sharply and narrowly reflexed. Anterior tibia feebly tridentate, the upper tooth at some distance from the middle tooth. Second segment of anterior tarsus narrow with parallel sides, about four times as long as broad. Aedeagus, figure 11.

Female.—Unknown to the writer.

Length.—12 mm.

Type locality.—Juquila, Mexico.

Type.—In the British Museum.

Material examined.—A male, probably a paratype, from the type locality, loaned for study by the British Museum. Unfortunately, both of the antennal clubs are missing.

CHLAENOBIA TUMULOSA Bates

Chlaenobia tumulosa Bates, 1888, Biol. Centr.-Amer., Coleopt., vol. 2, pt. 2, p. 168.

Head rather densely and moderately coarsely punctured except for a small area on vertex which is free of punctures. Clypeofrontal suture moderately sharply impressed and not strongly sinuate. Clypeus evenly, densely, and moderately coarsely punctured, slightly convex at middle, and with outer third gradually reflexed, anterior margin moderately strongly indented at middle. Antenna ten-segmented. Pronotum transverse, broadest across middle, side margins broadly rounded, lateral marginal carina rather strongly sinuate near posterior angle as viewed from side, viewed from above anterior and posterior angles subacute, the latter slightly produced; punctures as coarse but less dense than those on frons, irregularly distributed. Elytra with sutural margins tumid, discal costae faintly indicated; punctures about as dense and coarse as those on pronotum; epipleura very narrow. Metasternum very finely and densely punctured at middle, more coarsely and sparsely at sides, vestiture fine and dense at middle.

Male.—Antennal club one-fifth longer than second to seventh segments combined. Second to fourth abdominal sternites each with a

median patch of fine, short hair. Fifth sternite with a transverse patch of asperities along the posterior margin from which arise moderately long, fine hair. Sixth sternite with a median longitudinal groove. Pygidium convex, coarsely and rather densely punctured on basal half, very sparsely punctured on apical half, apex subtransverse and slightly lipped. Anterior tibia slender, bidentate, second segment of anterior tarsus elongate oval, about three times as long as wide. Aedeagus, figure 12.

Female.—Antennal club a little shorter than second to seventh segments combined. First to fifth sternites unmodified, sixth sternite with a broad semicircular emargination on free margin. Pygidium conical with apex replaced by a deep hemispherical cavity bounded at sides by blunt crests, below by an acute and somewhat produced margin. Anterior tibia stout, tridentate.

Length.—14 to 15 mm.

Type localities.—British Honduras, R. Sarstoon; Guatemala, near city, Duenas, Capitillo.

Type.—In the British Museum.

Material examined.—Two specimens, male and female, from Guatemala (Sallé), apparently paratypes, loaned for study by the British Museum; three males and four females from Palin, Guatemala, May 1924, W. M. Mann; three males and one female from Tegucigalpa, Honduras, May–June, 1917, F. J. Dyer; one male from Finca Gibraltar, Mexico, September 1910, in collection of L. W. Saylor.

In the Honduras specimens noted above, the aedeagus differs from the Guatemala type in that the triangular tooth at the middle of the outer margin of each lateral lobe is somewhat accentuated. A separate name for each race does not seem necessary.

I also refer to this species a single female from Cacos, Trece Aguas, Alta Vera Paz, Guatemala. The specimen is evidently abnormal, as the head is very asymmetrical, the clypeus projecting forward nearly twice as far on the right side of the head as on the left. The pygidial characters are like those of the other female specimens but are less accentuated.

Roebling Fund

SOLAR RADIATION AND WEATHER STUDIES

(With Three Plates)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

(Publication 3339)

CONTENTS

ILLUSTRATIONS

PLATES

TEXT FIGURES

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SOLAR RADIATION AND WEATHER STUDIES

By C. G. ABBOT

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(With Three Plates)

INTRODUCTION

Many years ago the late Secretary Langley expressed the hope that the studies of the Astrophysical Observatory on the intensity of the sun's radiation would lead to long-range weather forecasting. His hopes were encouraged when in 1903 our studies seemed to indicate a considerable change in the sun's output of radiation [1] associated with a marked drop of temperature over the Northern Hemisphere. This, which now seems to have been a chance coincidence, led to a campaign of " solar constant " determination which is still in progress. It has involved the establishment of observing stations at high altitudes in 10 different localities, 5 in the United States, 2 in Chile, 1 each in South-West Africa, Algeria, and Egypt. Three of these are now in occupation. Part of the expense of these observing stations was borne by the Government, but a considerable fraction was defrayed by grants from Mr. John A. Roebling and from the Hodgkins Fund of the Smithsonian Institution. The National Geographic Society also made a large grant which supported the establishment and continuation of 5 years of the station in South-West Africa.

After an excellent series of nearly daily solar-constant observations of 12 years length became available, analysis showed that what at first sight seemed chance variations of the sun's output really comprised a summation of at least seven [2] regular periodicities. Although these were of the order of only 1 percent or less, it seemed advisable to see if they appeared to be associated with weather changes of significance. A study of this question was made by the aid of the long-term records of temperature and precipitation contained in " World Weather Records," published recently by the Smithsonian Institution with the assistance of Mr. John A. Roebling.

[1] See Ann. Rep. Smithsonian Inst. 1903, pp. 81-84, 1904; and Astrophys. Journ., vol. 19, pp. 305-321, 1904.

[2] In the latest analysis, given below, covering the years 1920-1934, 12 periodicities are found in solar variation.

Analysis of weather records appears to show that each of the various solar periodicities above referred to influences both temperature and precipitation to a significant degree. At least five (perhaps six) other periodicities in weather elements, closely associated in length with the original seven, are also significant. Inasmuch as all of these 12 or 13 periodicities are very nearly aliquot parts of 23 years, it follows that their combined effect produces in the weather a large number of features more or less pronounced during a period of 23 years. Succeeding intervals of 23 years tend to bring repetitions of these features. For some of these periodicities, however, 46 years appears to be the critical interval. Hence there is a somewhat closer correspondence at some times and some stations between weather features 46 years apart. Owing to certain modifying influences in the sun itself, to which reference will be made below, and to the complexity of the terrestrial agencies through which the solar influences act, these repetitions of weather features are subject to moderate displacements in time, and to modifications in amplitude. Actual reversals of phase, as will be shown, sometimes occur after 23-year intervals. Nevertheless, special weather features remain recognizable in many instances by comparison of successive 23-year curves.

Based on these grounds it becomes possible to make forecasts of weather conditions for years in advance which appear to be significantly more representative than normal values. The modifying factors referred to above detract as yet greatly from the accuracy of such forecasts, but further study may lead to greater perfection. The following paper gives the evidences for these statements.

The evidence to be presented being extensive and complex, and certain parts of it—as, for instance, the studies of periodicities in the temperature of Berlin—being apt to prove tiresome to some and controversial to others, it is suggested that high spots of the demonstration may be picked out as follows:

1. Turn to captions 3 and 4, pages 6 and 10, and note the results expressed by figures 4, 6, 7, and 8.

2. Turn to captions 14-Ba, 14-Bb, and 15, pages 35, 38 and 53, and note the results expressed by figures 15, 16, 17, 19, and 23.

3. Turn to captions 17 to 25, pages 56 to 75, and note at least a part of the results expressed in figures 24 to 37, inclusive.

4. Finally, with these results in mind, read the Summary, pages 88 and 89.

In this way it is hoped that the reader will obtain briefly such a view of the more remarkable parts of the investigation as will arouse his curiosity to pursue the entire course of the demonstration.
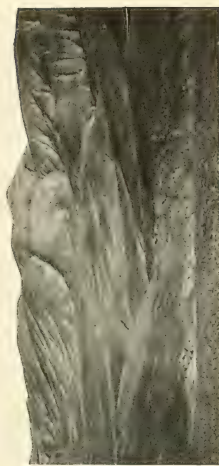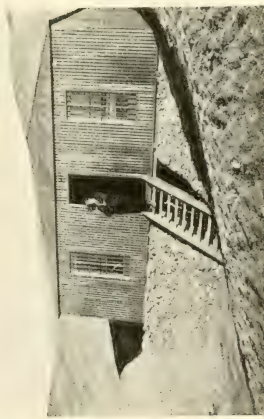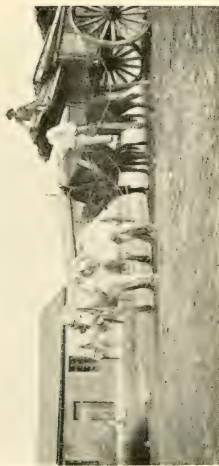
SMITHSONIAN SOLAR RADIATION STATION, MONTEZUMA, CHILE

Upper left, coelostat and pyrheliometric apparatus; upper right, hauling materials from Calama for the solar observing station; lower left, dwelling house at the solar observing station; lower right, peak on which the observing station is located.
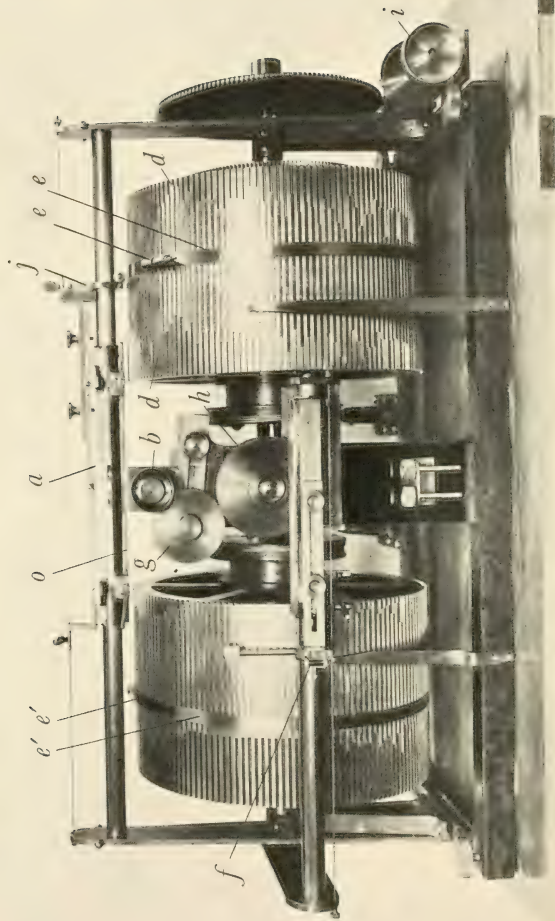
THE PERIODOMETER. AN INSTRUMENT FOR DETECTING AND EVALUATING PERIODICITIES
IN LONG SERIES OF DATA

I. SOLAR RADIATION MEASUREMENTS[3]

1. Objects and Stations

We measure at the earth's surface the total intensity of solar radia-
tion, its spectral distribution, the losses its various rays meet in travers-
ing the atmosphere; and we compute its intensity and spectral dis-
tribution outside the atmosphere, and the variations of its intensity
from day to day as they occur in the sun itself before the rays enter
the atmosphere. At present, the Smithsonian Institution carries on
these measurements at three high-altitude desert stations chosen for
their cloudlessness and other favorable conditions. They are Table
Mountain, Calif.; Montezuma, Chile; and Mount St. Katherine,
Egypt. Their respective altitudes are 7,500, 9,000, and 8,500 feet,
approximately. Other Smithsonian stations formerly occupied have
included Washington, D. C.; Hump Mountain, N. C.; Mount Wilson
and Mount Whitney, Calif.; Mount Harqua Hala, Ariz.; Bassour,
Algeria; and Mount Brukkaros, South-West Africa. Plate 1 shows
the station at Mount Montezuma. Besides these terrestrial stations,
a self-recording instrument for measuring total solar radiation was
raised by sounding balloons from Omaha, Nebr., July 1914, to a
level of over 15 miles. It made good records of the intensity of solar
radiation at that high level where only 1/25 of the atmospheric pres-
sure remained above. The mean value of the solar constant of radia-
tion as computed from mountain stations is 1.94 calories per square
centimeter per minute. Balloon pyrheliometry indicated 1.84 calories
at 15 miles elevation. Correction of balloon pyrheliometry for loss
in the highest atmosphere gives 1.88 calories, which agrees with moun-
tain solar-constant results within the experimental error of the balloon
observations.

2. Instruments and Methods

For measuring total solar radiation at the earth's mountain surface
we have hitherto depended[4] on the silver-disk pyrheliometer and the
water-flow pyrheliometer. The former is a secondary instrument
whose readings are converted into absolute units (calories per square
centimeter per minute) by comparisons with the water-flow pyr-
heliometer.[5] These instruments are shown diagrammatically in figures

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[3] This section is for the most part abbreviated from vols. 1-5, Annals of the
Astrophysical Observatory of the Smithsonian Institution.

[4] We are now (1935) introducing the Ångström electrical compensation pyr-
heliometer as a cooperating instrument.

[5] See improved water-flow pyrheliometer as described in Smithsonian Misc.
Coll., vol. 87, no. 15, 1932, and vol. 92, no. 13, 1934.
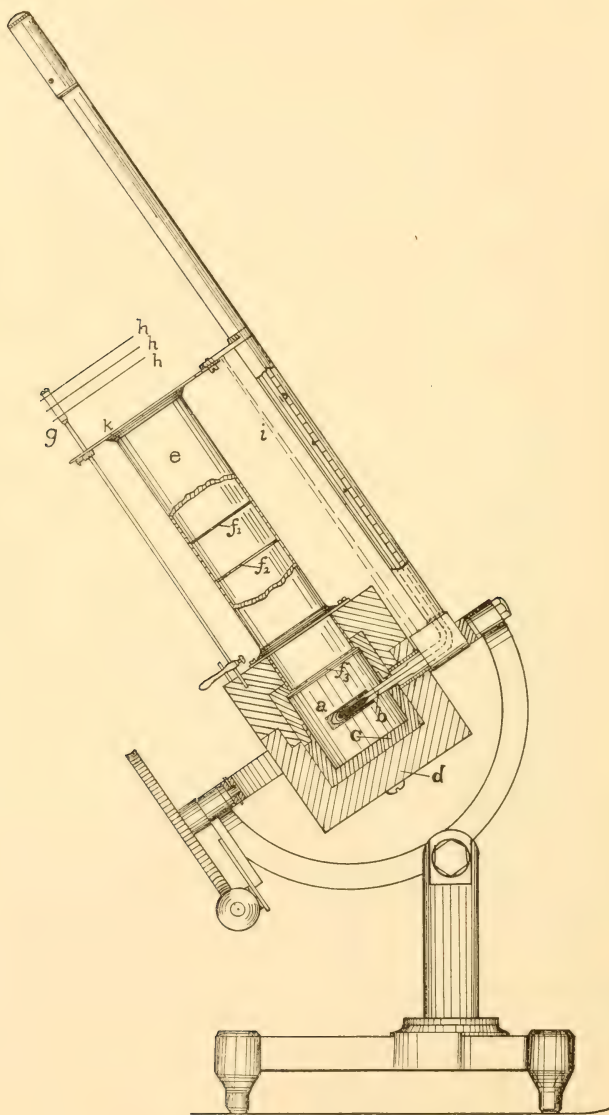
Fig. 1.—Diagram of silver-disk pyrheliometer.

1 and 2. Their sources of error, corrections to their direct readings, and other details regarding them are published in volumes 2, 4, and 5 of the Annals of the Smithsonian Astrophysical Observatory and in papers nos. 3182 and 3288 of the Smithsonian Miscellaneous Collections. Intercomparisons of silver-disk pyrheliometers made at intervals over a period of about 20 years indicate that the scale of observing has not changed appreciably. These intercomparisons are
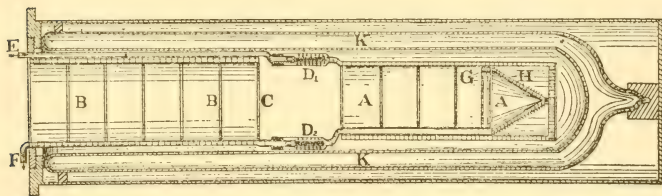
Fig. 2.—Diagram of water-flow pyrheliometer.

Solar rays are mainly absorbed on the cone in A, but some are scattered about the walls of AA. Their heat is given up to water which flows in a spiral channel about the cone and tube AA. The rise of temperature of the water due to solar heating is measured by the electrical thermometer D_1D_2. Test quantities of electrical heat introduced at G or H may be measured as a check.

published extensively in the Annals, volume 4, pages 94-97, and volume 5, pages 139-145. Table 1 gives one typical example.

TABLE 1.—*Long-continued Series of Intercomparison of Pyrheliometers S.I. 1 with A.P.O. 8$_{bis}$*

Year	1911	1911	1912	1913	1915	1916 [a]	1917	1917	1920
Ratio	1.0357	1.0246	1.0268	1.0324	1.0343	1.0119	1.0360	1.0330	1.0352

[a] It is believed that owing to maladjustment S.I. 1 was not properly exposed on this occasion.

The distribution of energy in the solar spectrum before it enters the atmosphere approximates roughly that of the perfect radiator at 6,000° K. Hence, nearly all of its energy is contained between wave lengths 0.3 and 3.0 microns. Rays beyond 0.3 micron in the ultraviolet are almost wholly cut off by ozone in the higher atmosphere, and those beyond 3.0 microns in the infrared by water vapor in the lower atmosphere. Between these limits not only these and other atmospheric vapors, but also dust and even the permanent gaseous molecules of the air, absorb or scatter the sun's rays both selectively and generally, so that the solar beam is both changed in spectral distribution and generally weakened during its passage through the atmosphere. In order to evaluate these losses, energy spectral measurements are re-

quired. These are made at our stations several times on each observing day by means of the spectrobolometer. This instrument, shown diagrammatically in figure 3, is explained in the Annals. Plate 3 shows a group of successive solar spectrobolometric observations made at Montezuma, Chile, July 7, 1924. The relative losses of radiation suffered at different wave lengths in transmission through the spectrobolometer are measured and allowed for as described in the Annals, volume 2, pages 50-52, and volume 3, pages 27-29.

Knowing the sun's altitude, and thereby the length of path of the sun rays in the atmosphere compared to the length of a vertical path therein, taken as unity, these several curves may fix the atmospheric transmission coefficients at all wave lengths. Thereby the spectral energy curves can be reduced in form and height to what they would have been if observed outside the atmosphere. This reduction is explained in the Annals, volume 2, page 56, and volume 3, page 28. The total area included under such a spectral energy curve is proportional to the total energy of the solar beam as it would be observed with the pyrheliometer. Hence, the ratio of areas included under two spectral energy curves, one computed as of outside the atmosphere, and the other observed as at the earth's surface, is the factor by which the pyrheliometer measurement is to be multiplied to yield the intensity of the sun's radiant energy outside the atmosphere. Including also, as a factor, the square of the ratio of the earth's actual solar distance to its mean value, we arrive at the " solar constant of radiation."

In the year 1919 it was discovered that a mere measurement of the brightness of the sky surrounding the sun could be made to yield closely enough the coefficients of atmospheric transmission at all wave lengths. This measurement is made with the instrument called the pyranometer. It thus becomes possible to make five solar-constant determinations in one morning and reduce them within the time formerly occupied with one determination. The method as now developed is explained in the Annals, volume 5, pages 110-120.

3. The Variation of the Sun's Radiation

Figure 4 shows superposed in the form of 10-day means the solar-constant results obtained at Montezuma, Table Mountain, and Mount Brukkaros from 1925 to 1930. The order of excellence of the stations is the order just given. This is indeed plain from the relative smoothness of the three curves of figure 4. But though differing in details, the three stations agree in showing in common certain principal trends, and thereby indicate a real variation of the sun.

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w_2 w_1 Ω Ψ Φ $\rho\sigma\tau$ A B C F H K

Infra-red —————— × —————— Visible —————— × —— Ultra-violet →

BOLOGRAPHS OF THE SOLAR ENERGY SPECTRUM

Observed at Montezuma, Chile, July 7, 1924. Precipitable water, 0.03 cm.
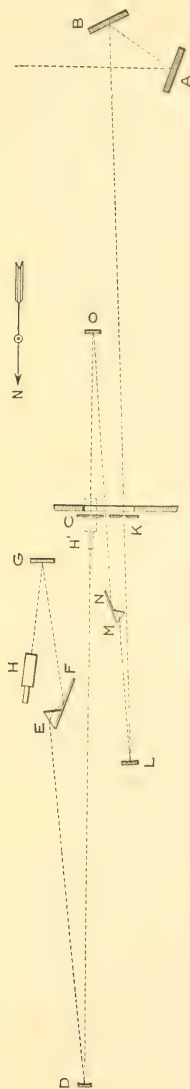
FIG. 3.—Diagram of spectrobolometer.

In daily observing, the sun ray is reflected directly from B through the slit C, is analyzed into the spectrum at EF; and a selected ray falls on the bolometer H. The double spectroscope, as shown, is used occasionally to measure the transmission of the optical train CDEFG.
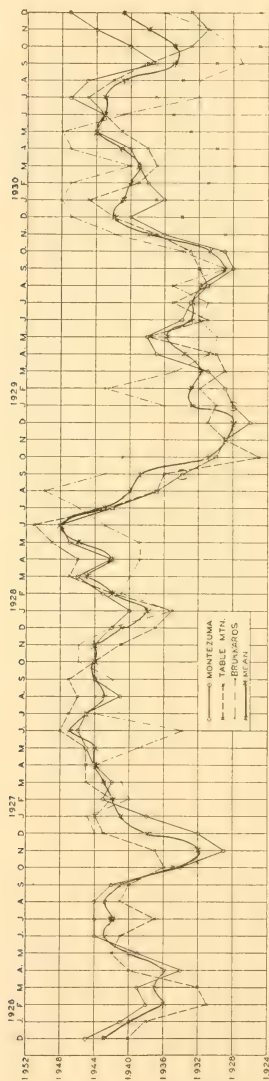
Fig. 4.—Solar-constant values, three stations, 1925-1930.
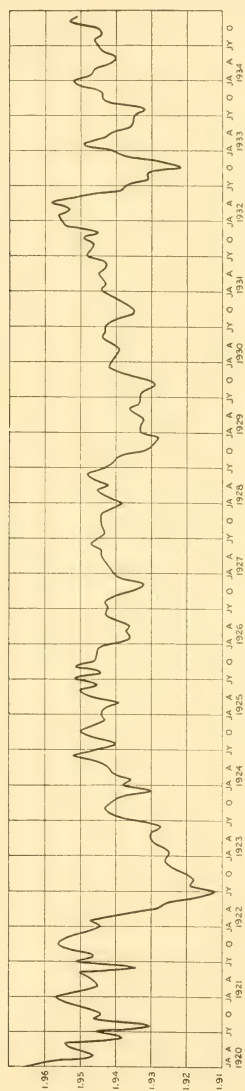
Fig. 5.—March of solar variation, 1920-1934.

Figure 5 illustrates the mean result of all the evidence from 1920 to 1934, inclusive. It depends on observations at Calama and Monte-zuma, Chile; Mount Harqua Hala and Table Mountain in the United States, and Mount Brukkaros, Africa.[6]

The range of variation of solar radiation as indicated by the 10-day mean values of the solar constant is given by table 2.

4. PERIODICITIES IN SOLAR VARIATION

To casual inspection the solar variation is irregular. More careful inspection discloses an 8-month periodicity. Eleven other periodicities have also been found and evaluated. As successively discovered, they have been removed by subtraction, one by one, from the numerical record so as to simplify the search for other solar periodicities. The process of evaluating and removing periodicities is illustrated for an 11-month period by table 3 and figure 6. Plate 2 shows a machine capable of doing the same thing.[7, 8]

The reader will note that this computation of the 11-month solar period is separated into several parts nearly similar to each other whose mean result is to be repeated consecutively and added to consecutive repetitions of other periodicities to produce the second curve in fig-ure 7. The partial mean curves computed in table 3 are seen to differ somewhat in form and amplitude, but to agree fairly closely as to the phases of maximum and minimum values of solar radiation. These independent determinations at different epochs, all yielding 11-month periodicities in nearly the same phase, seem to strongly support the veridity of the 11-month solar period. The third group, indeed (1930-1934) shows about 3 months lag in phase. As will be shown in sections 14B and 25 below, there is some reason to anticipate a change of phase of some of the periodicities about January 1934. Possibly this is the cause of the observed phase-shift. Later observations will settle it.

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[6] The values given in fig. 5 and table 2 are provisional for the years 1931-1934 and may be altered in revision.

[7] See The Periodometer, Smithsonian Misc. Coll., vol. 87, no. 4, 1932.

[8] In the analysis of curves, most investigators employ developments of Fourier's methods. That is, they represent the observed curve as a summation of a number of arbitrary harmonic curves of integral periodic relationships. These constituent harmonic curves have the periods $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, . . . $1/n$ of the entire unit length of the curve analyzed. In such a case as that of a harmonic analysis of the sun-spot numbers, none of the constituent harmonics have any independent physical significance whatever. Nor is it to be supposed that the harmonic form itself represents at all closely the march of any physical quantity connected with the phenomenon. It has seemed to me preferable to discard this tedious and arbitrary procedure, and to compute the actual mean forms of the solar periodicities as illustrated by table 3 and fig. 6.

5. Analysis of the Solar Variation

The curve of solar variation contains, however, not only a number of regular periodic constituents, but also accidental errors of nearly as great amplitudes as the periodic terms themselves. These various constituents, accidental and periodic, are confused together, and mutu-
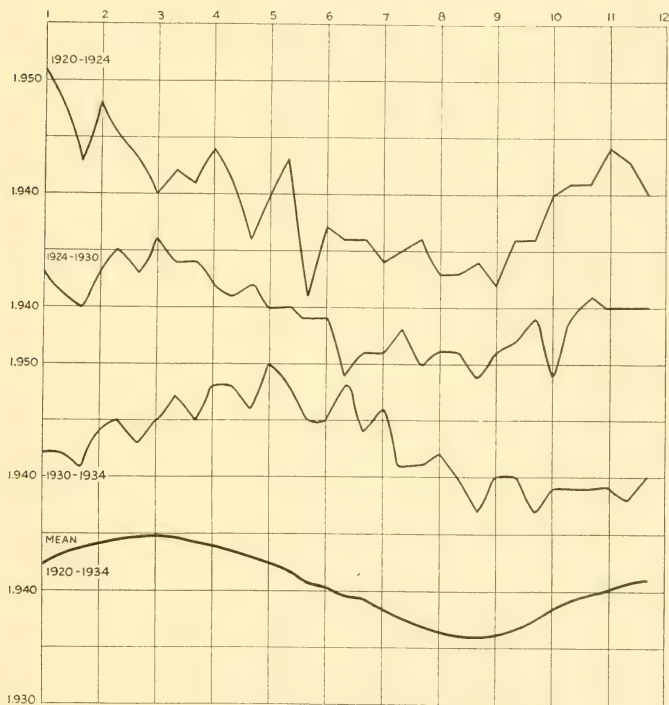
Fig. 6.—The 11-month periodicity in solar variation.

ally influence the graphic expressions of each other in the observed curve. For the purpose of simplification it has seemed best to remove the several periodic terms one by one, beginning with those of shortest period. In the presence of confusing variations from other causes, these short-period curves may be the most accurately investigated of any because they present the largest numbers of cases which may

2

TABLE 2.—*Preferred Solar Constants, Ten-day Mean Values, Collected and Adjusted from Observations at Several Stations*

Date (decade)	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Jan. 1	1.968	1.964	1.938	1.934	1.936	1.945	1.939	1.940	1.037	1.929	1.935	1.944	1.959	1.046	1.055
2	1.967	1.956	1.945	1.924	1.940	1.939	1.940	1.939	1.932	1.933	1.938	1.944	1.952	1.046	1.959
3	1.959	1.959	1.948	1.918	1.941	1.947	1.934	1.937	1.037	1.932	1.936	1.943	1.954	1.035	1.959
Feb. 1	1.958	1.942	1.944	1.925	1.936	1.941	1.035	1.939	1.044	1.933	1.934	1.942	1.953	1.052	1.960
2	1.954	1.954	1.949	1.934	1.935	1.949	1.041	1.944	1.940	1.027	1.940	1.945	1.002	1.046	1.043
3	1.956	1.954	1.948	(1.915)	1.937	1.940	1.930	1.042	1.941	1.930	1.943	1.941	1.952	1.040	1.043
Mar. 1	1.959	1.939	1.947	1.925	1.944	1.041	1.938	1.936	1.047	1.029	1.049	1.932	1.944	1.047	1.044
2	1.948	1.954	1.941	1.930	1.941	1.940	1.939	1.943	1.046	1.939	1.937	1.945	1.454	1.040	1.043
3	1.932	1.939	1.932	1.930	1.939	1.036	1.934	1.943	1.045	1.931	1.939	1.948	1.953	1.038	1.951
Apr. 1	1.948	1.942	1.930	1.933	1.939	1.041	1.930	1.044	1.943	1.932	1.941	1.948	1.959	1.039	1.959
2	1.956	1.945	1.929	1.925	1.943	1.045	1.935	1.047	1.939	1.940	1.938	1.948	1.960	1.049	1.943
3	1.952	1.946	1.925	1.931	1.044	1.046	1.040	1.945	1.042	1.037	1.939	1.938	1.954	1.034	1.938
May 1	1.959	1.959	1.923	1.027	1.943	1.046	1.938	1.946	1.042	1.038	1.942	1.936	1.052	1.037	1.942
2	1.961	1.949	1.932	1.930	1.946	1.050	1.943	1.942	1.049	1.934	1.942	1.948	1.948	1.034	1.942
3	1.050	1.959	1.924	1.934	1.947	1.054	1.943	1.945	1.046	1.935	1.942	1.947	1.942	1.038	1.938
June 1	1.043	1.927	1.930	1.918	1.951	1.043	1.939	1.050	1.046	1.035	1.945	1.043	1.935	1.037	1.948
2	1.034	1.939	1.915	1.932	1.953	1.043	1.945	1.944	1.951	1.032	1.944	1.948	1.036	1.036	1.945
July 1	1.938	1.936	1.912	1.932	1.953	1.048	1.941	1.945	1.043	1.932	1.940	1.046	1.042	1.032	1.938
2	1.945	1.952	1.900	1.934	1.946	1.052	1.941	1.948	1.043	1.933	1.944	1.954	1.043	1.933	1.042
3	1.049	1.953	1.913	1.928	1.950	1.054	1.944	1.945	1.040	1.932	1.950	1.049	1.932	1.937	1.042
Aug. 1	1.951	1.948	1.923	1.944	1.943	1.047	1.941	1.946	1.040	1.934	1.934	1.943	1.937	1.035	1.046
2	1.930	1.944	1.917	1.942	1.959	1.049	1.943	1.943	1.941	1.931	1.931	1.949	1.932	1.027	1.046
3	1.927	1.957	1.919	1.940	1.940	1.041	1.941	1.940	1.034	1.932	1.944	1.932	1.933	1.032	1.047
Sept. 1	1.032	1.937	1.921	1.941	1.930	1.042	1.942	1.942	1.038	1.930	1.941	1.043	1.928	1.036	1.047
2	1.031	1.959	1.921	1.945	1.941	1.056	1.941	1.941	1.041	1.928	1.946	1.030	1.030	1.938	1.045
3	1.044	1.957	(1.915)	1.943	1.950	1.046	1.938	1.941	1.935	1.928	1.948	1.035	1.035	1.941	1.046
Oct. 1	1.044	1.959	1.919	1.940	1.946	1.959	1.943	1.948	1.923	1.932	1.941	1.945	1.029	1.043	1.041
2	1.942	1.955	1.926	1.942	1.950	1.942	1.936	1.945	1.929	1.931	1.937	1.951	1.021	1.044	1.044
3	1.951	1.961	1.921	1.942	1.950	1.949	1.937	1.943	1.932	1.033	1.937	1.945	1.999	1.045	1.051
Nov. 1	1.038	1.953	1.914	1.939	1.949	1.946	1.931	1.941	1.932	1.930	1.938	1.947	1.939	1.943	1.054
2	1.952	1.958	1.928	1.934	1.947	1.944	1.932	1.943	1.927	1.932	1.938	1.946	1.926	1.948	1.954
3	1.948	1.952	1.925	1.943	1.949	1.948	1.939	1.943	1.925	1.935	1.939	1.941	1.929	1.040	1.959
Dec. 1	1.957	1.955	1.920	1.941	1.944	1.944	1.932	1.943	1.929	1.949	1.935	1.956	1.936	1.951	1.947
2	1.957	1.959	1.925	1.942	1.942	1.944	1.935	1.944	1.926	1.941	1.943	1.953	1.939	1.040	1.054
3	1.049	1.948	1.930	1.922	1.939	1.946	1.935	1.938	1.032	1.939	1.939	1.946	1.939	1.050	1.952

TABLE 2.—*Preferred Solar Constants, Ten-day Mean Values, Collected and Adjusted from Observations at Several Stations*

Date (decade)	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Jan. 1	1.968	1.964	1.938	1.934	1.936	1.945	1.939	1.940	1.937	1.929	1.935	1.944	1.959	1.946	1.955
2	1.967	1.956	1.945	1.924	1.940	1.939	1.940	1.939	1.932	1.933	1.938	1.944	1.952	1.942	1.950
3	1.959	1.950	1.948	1.918	1.941	1.947	1.934	1.937	1.937	1.932	1.936	1.943	1.954	1.935	1.950
Feb. 1	1.958	1.942	1.944	1.925	1.936	1.941	1.935	1.939	1.944	1.933	1.934	1.942	1.953	1.952	1.960
2	1.954	1.954	1.948	1.934	1.935	1.949	1.941	1.944	1.940	1.927	1.940	1.945	1.962	1.946	1.943
3	1.956	1.954	1.948	(1.915)	1.937	1.940	1.939	1.942	1.941	1.930	1.943	1.941	1.952	1.946	1.943
Mar. 1	1.959	1.939	1.947	1.925	1.944	1.941	1.938	1.936	1.947	1.929	1.940	1.932	1.944	1.947	1.944
2	1.948	1.939	1.941	1.930	1.941	1.936	1.939	1.943	1.946	1.939	1.937	1.945	1.954	1.940	1.943
3	1.932	1.942	1.932	1.930	1.939	1.941	1.934	1.943	1.945	1.931	1.939	1.948	1.953	1.938	1.951
Apr. 1	1.948	1.949	1.939	1.933	1.939	1.945	1.939	1.944	1.943	1.932	1.941	1.948	1.959	1.939	1.959
2	1.956	1.945	1.939	1.925	1.943	1.950	1.935	1.947	1.939	1.940	1.938	1.948	1.960	1.949	1.943
3	1.952	1.946	1.945	1.931	1.944	1.946	1.940	1.945	1.942	1.937	1.939	1.938	1.954	1.934	1.938
May 1	1.950	1.950	1.923	1.927	1.943	1.946	1.938	1.946	1.942	1.938	1.942	1.936	1.952	1.937	1.942
2	1.961	1.949	1.932	1.939	1.946	1.950	1.938	1.942	1.945	1.934	1.942	1.948	1.948	1.934	1.942
3	1.950	1.959	1.924	1.934	1.947	1.954	1.943	1.945	1.946	1.935	1.942	1.947	1.942	1.938	1.938
June 1	1.943	1.927	1.920	1.918	1.951	1.943	1.939	1.950	1.946	1.935	1.945	1.943	1.935	1.937	1.948
2	1.934	1.939	1.915	1.932	1.953	1.943	1.945	1.944	1.951	1.932	1.944	1.948	1.936	1.936	1.945
3	1.938	1.936	1.912	1.932	1.953	1.948	1.941	1.945	1.945	1.932	1.949	1.943	1.942	1.932	1.938
July 1	1.945	1.952	1.900	1.934	1.946	1.952	1.944	1.948	1.943	1.933	1.944	1.954	1.943	1.933	1.948
2	1.940	1.953	1.913	1.928	1.950	1.954	1.944	1.945	1.939	1.932	1.959	1.949	1.932	1.937	1.942
3	1.951	1.948	1.923	1.944	1.943	1.947	1.941	1.945	1.940	1.934	1.946	1.943	1.937	1.935	1.942
Aug. 1	1.939	1.944	1.917	1.942	1.950	1.949	1.943	1.943	1.941	1.931	1.944	1.948	1.933	1.932	1.046
2	1.927	1.957	1.919	1.940	1.940	1.941	1.941	1.940	1.934	1.932	1.944	1.949	1.932	1.936	1.047
3	1.932	1.937	1.921	1.941	1.930	1.942	1.942	1.942	1.938	1.930	1.941	1.946	1.928	1.936	1.045
Sept. 1	1.951	1.959	1.921	1.945	1.941	1.956	1.941	1.941	1.941	1.928	1.939	1.946	1.930	1.938	1.046
2	1.944	1.957	(1.915)	1.943	1.950	1.946	1.938	1.941	1.935	1.928	1.934	1.948	1.935	1.041	1.041
3	1.944	1.959	1.919	1.940	1.946	1.950	1.943	1.948	1.923	1.932	1.941	1.945	1.929	1.043	1.041
Oct. 1	1.942	1.955	1.926	1.942	1.950	1.942	1.936	1.945	1.929	1.931	1.937	1.951	1.021	1.044	1.044
2	1.938	1.961	1.921	1.942	1.949	1.949	1.937	1.943	1.932	1.933	1.937	1.945	1.915	1.045	1.951
3	1.952	1.953	1.914	1.939	1.950	1.946	1.931	1.941	1.927	1.939	1.938	1.951	1.929	1.043	1.954
Nov. 1	1.948	1.958	1.928	1.934	1.947	1.944	1.932	1.943	1.925	1.932	1.938	1.947	1.930	1.941	1.954
2	1.943	1.955	1.920	1.941	1.944	1.944	1.932	1.943	1.930	1.940	1.935	1.941	1.929	1.040	1.959
Dec. 1	1.957	1.959	1.925	1.942	1.942	1.936	1.935	1.944	1.929	1.941	1.940	1.956	1.936	1.051	1.947
2	1.957	1.959	1.922	1.949	1.947	1.945	1.934	1.938	1.926	1.939	1.943	1.953	1.939	1.949	1.954
3	1.949	1.948	1.930	1.922	1.939	1.046	1.935	1.938	1.932	1.939	1.939	1.946	1.939	1.050	1.952
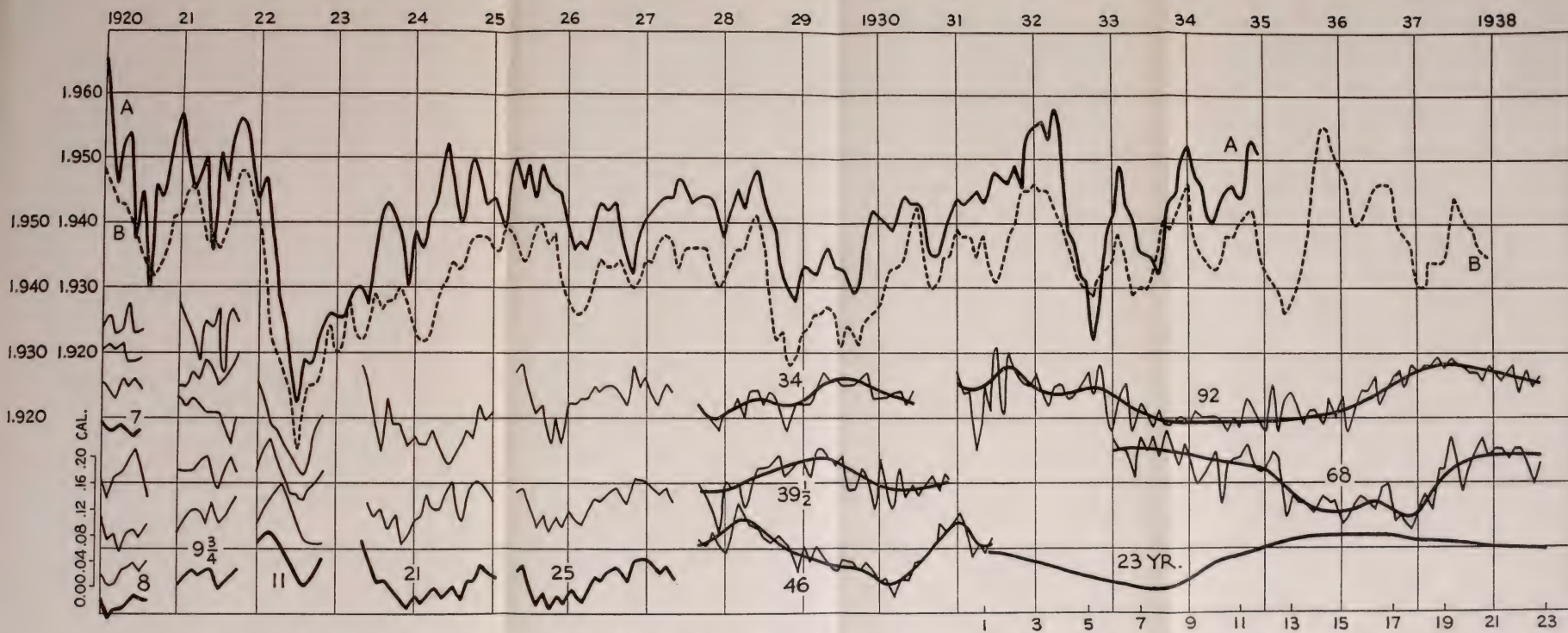
Fig. 7.—Analysis and synthesis of solar variation 1920-1934. The synthetic curve B is drawn below the observed curve A to avoid confusion. Successive derivations of the shorter periodicities precede their general mean. The 23-year periodicity presents as yet only 15 years of its course and is partly estimated.

be combined to determine their mean forms. Interferences from other periodicities and from accidental errors are largely eliminated when occurring in different phases in so many independent cases.

As stated above, an 8-month periodicity in solar variation was seen by the first inspection, and this was first determined. Then the original curve was modified by subtracting from its ordinates a sufficient num-

TABLE 3.—*The 11-month Periodicity in Solar Variation* [a]

Jan. 1920–July 1924					Mean	Aug. 1924–Jan. 1930						Mean	Feb. 1930–Aug. 1934					Mean	General Mean [b]
68	59	58	28	43	51	47	52	37	44	45	30	43	36	44	54	33	42	42	1.9421
67	57	51	24	40	48	38	54	43	41	42	30	41	43	43	50	28	44	42	1.9431
60	48	53	16	40	43	29	48	41	44	44	31	40	46	42	44	29	43	41	1.9437
60	62	50	29	41	48	39	51	42	50	43	30	43	43	40	59	37	41	44	1.9441
57	53	48	26	41	45	49	44	44	45	49	38	45	39	44	53	41	48	45	1.9445
58	48	47	22	39	43	45	44	41	46	45	35	43	39	41	55	41	39	43	1.9446
60	41	38	27	34	40	50	57	41	48	44	36	46	42	32	55	46	49	45	1.9447
49	53	45	22	42	42	51	46	39	45	49	33	44	40	45	65	41	46	47	1.9447
34	54	49	29	39	41	50	49	40	47	45	34	44	41	47	55	34	48	45	1.9443
50	54	46	32	39	44	47	40	39	45	44	35	42	42	46	47	50	55	48	1.9441
56	38	52	21	38	41	49	47	37	43	39	33	41	41	45	56	45	51	48	1.9435
51	40	50	16	21	36	45	46	42	44	40	33	42	41	37	53	46	51	46	1.9431
48	46	46	24	36	40	44	45	36	42	39	33	40	43	36	60	47	62	50	1.9424
58	43	42	33	40	43	50	48	38	41	32	32	40	43	49	62	40	46	48	1.9418
48	45	34	15	42	31	41	44	32	47	36	35	39	40	48	56	37	46	45	1.9407
42	50	32	25	38	37	46	42	32	43	39	33	39	44	45	52	37	47	45	1.9404
33	49	30	29	38	36	39	43	30	41	34	35	34	50	51	47	46	45	48	1.9306
38	51	24	28	39	36	46	44	33	41	22	32	36	45	49	41	32	51	44	1.9389
45	29	21	30	45	34	39	37	37	44	29	29	36	42	57	33	37	60	46	1.9384
39	42	29	23	42	35	47	39	37	43	33	28	38	41	51	35	35	45	41	1.9376
49	38	22	30	41	36	40	33	37	43	28	31	35	39	43	42	39	40	41	1.9371
27	53	19	27	41	33	42	35	41	42	25	29	36	39	49	43	39	42	42	1.9365
25	54	14	30	43	33	36	42	39	36	29	31	36	35	51	32	39	41	40	1.9362
31	50	12	35	43	34	41	31	36	36	31	30	34	42	45	36	35	37	37	1.9359
51	46	00	20	41	32	43	38	37	35	31	31	36	39	46	31	36	46	40	1.9361
44	57	12	35	43	36	48	39	42	31	29	35	37	40	47	29	39	44	40	1.9366
45	36	21	34	45	36	44	35	42	36	34	40	39	41	44	26	35	38	37	1.9374
44	58	14	35	50	40	44	32	37	44	30	39	34	41	49	30	28	48	39	1.9385
54	54	17	29	52	41	49	38	43	41	33	37	39	41	44	36	34	42	39	1.9392
40	48	20	46	53	41	53	42	43	42	31	37	41	35	51	30	38	41	39	1.9398
53	54	21	44	46	44	43	39	42	47	31	35	40	41	47	23	38	44	39	1.9401
49	60	15	40	49	43	44	38	45	46	25	39	40	45	46	18	40	43	38	1.9406
45	53	20	40	41	40	49	42	43	46	30	37	40	41	40	32	42	45	40	1.9410

[a] The figures in the table are to be understood as subjoined to 1.900. Thus, for 68 read 1.968 calories, etc.
[b] Computed from smooth curves representing the three groups.

ber of successive repetitions of the mean form of the 8-month periodicity. Thereupon inspection seemed to indicate an 11-month periodicity. With this also removed, a 7-month periodicity showed itself. Proceeding in this way, periodicities of 7, 8, 11, 21, 25, and 45 months were successively removed.[9] The residual curve remaining after their removal showed very plainly as its major feature a periodicity of 68 months. It has the largest amplitude of any of the solar periodicities.

[9] In our latest analysis, extending from 1920 to 1934, additional solar periodicities of 9¾, 34, 39½, 92 months, and one of 23 years were added to the above list.

Unfortunately, accurate solar-constant determinations have not been available long enough to fix the lengths of these periods very accurately. In the discussion of weather periodicities below, evidence is presented indicating corrections of plus 1 day, minus 3 days, and plus 1 month, respectively, to the periodicities stated above as 8, 11, and 45 months.

6. Synthesis of Solar Variation

Having resolved the curve of observation of solar variation into 12 periodicities of approximately determined lengths and amplitudes, the next step was to synthesize these constituents and see how well their summation represents the original curve of observation. This operation is shown graphically in its details and completion in figure 7. The average of residuals between the original curve A and the synthetic curve B is only 0.0036 calories, or 0.19 percent. It appears that the whole solar variation displayed by the observed monthly means is comprised in these 12 periodicities. The small average deviation may reasonably be ascribed to experimental error.

7. Long-Range Predictions of Solar Variation

The curves in figure 7 represent the third analysis and synthesis of solar variation. A 3-year forecast of solar variation is given there. This analysis is based on so much longer a period of observation than the first and second analyses that several new long periodicities are disclosed which add decidedly to the accuracy of the representation. The first and second analyses were published each with a 2-year forecast attached. (See Smithsonian Misc. Coll., vol. 85, no. 1, 1931; vol. 89, no. 5, 1933.) These predictions and the events are shown in figure 8. The average of residuals for the first prediction is 0.0079 calorie, or 0.41 percent. The reader will observe that the first prediction indicated an expectation of values all above normal, although at the time the prediction was made the solar radiation had been almost continuously below normal for many months. The event generally confirmed this expectation.

Unfortunately, a volcanic eruption in Chile interrupted the continuity of the solar-constant observations at Montezuma, so that this series of 2-years' observations is at a disadvantage. It is probable that part of the discrepancy, May to November, 1932, is caused by the volcano. Only Montezuma values are used in preparing the figure. The second prediction was made from data closing in September 1932, and again a prediction of solar variation for 2 years in advance

was ventured. The average of residuals between predicted and ob-
served values is 0.0071 calorie, or 0.37 percent. Although maxima
and minima are well placed, there is a decided separation of the curves
near the end in figure 8. This is cured in figure 7, and in that figure
the average deviation for the curves thus far observed is reduced to
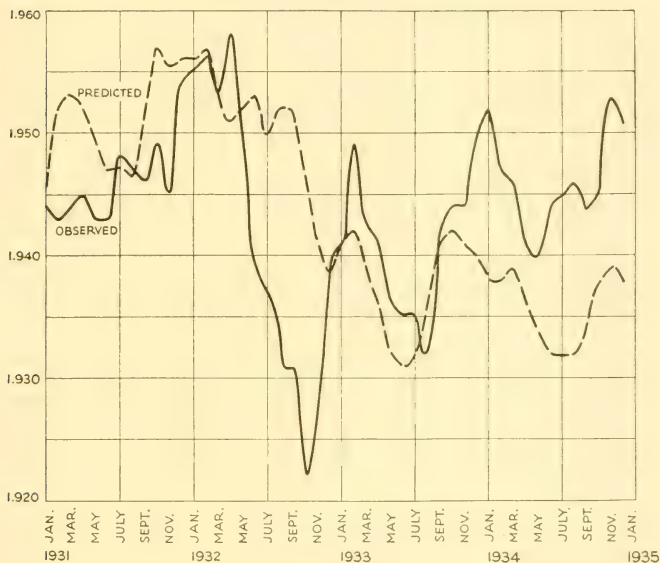
Fig. 8.—Predicted and observed solar variation. The maxima and minima
occur in the two curves at nearly identical phases. The observed curve may be
faulty in 1932 owing to the Chilean volcanic eruption. The separation of the
curves toward the end is due to a 23-year periodicity not taken account of.

0.0036 calories, or 0.19 percent. As explained in caption 26, on
page 86, there may possibly be a change of phase in solar variation
about 1934, tending to modify the 3-year forecast given in figure 7.

II. WEATHER RESPONSIVE TO PERIODIC SOLAR CHANGES

8. Sun-Spot Influence

Having strong indications of 12 long-continued periodic fluctua-
tions in solar radiation, statistical studies were made to seek for their
effects on temperature and precipitation. First taking the departures
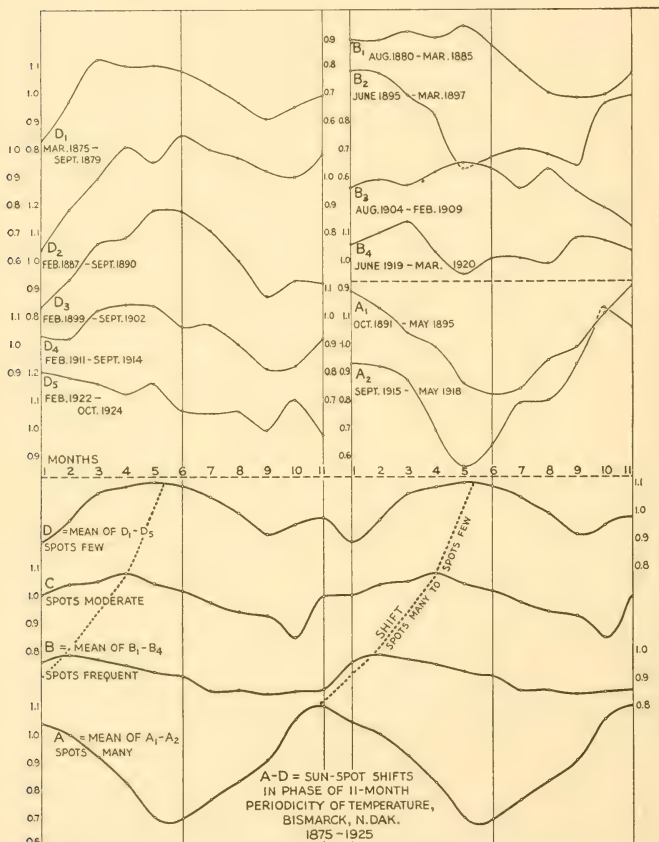
Fig. 9.—Sun-spot numbers and phase changes. The 11-month periodicity in temperature departures at Bismarck, N. Dak.

from normal temperature at Bismarck, N. Dak., from 1875 to 1925 as computed from " World Weather Records," computations similar to those illustrated in connection with table 3 were made. It was soon found that evidences of terrestrial counterparts of each of the seven solar periodicities then known were apparent for short intervals, but changes of phase occurred, showing that continuity is lacking. Further studies seemed to show that these puzzling changes of phase were absent if the computations were restricted to intervals when the sun-spot activity as measured by Wolf's numbers is nearly constant. Later, when longer series of weather records were studied, another phase relationship of much more importance was disclosed. But of this we shall write later.

Figure 9 shows the results of analyses of Bismarck temperatures aimed to disclose and evaluate the 11-month periodicity during the interval 1875-1925. The data are segregated into four groups in which low, medium low, medium high, and high sun-spot numbers prevailed. The dates included in this classification are indicated on the curves. It will be seen that a gradual shift of the maxima of the 11-month periodicity amounting in total to fully half a period is disclosed by the mean values.

Here, as in what follows, the reader is reminded that owing to the presence of other periodicities, and of accidental fluctuations besides, it is not fair to expect perfect correspondence between periodic curves of a given length of period, when these are determined from rather brief intervals containing but a few repetitions of the periodicity in question. Specifically, for instance, the curve D_5 of low sun-spot number statistics in figure 9 differs at months 1, 2, 3 in its trend from the other four. Also the four curves B_1 to B_4 corresponding to medium high sun-spot numbers, show considerable disagreement, although each of them has its maximum in the first half of the period. But when it is recalled that curves D_5, B_2, and B_4 in figure 9, which are the most unsatisfactory of those shown, represent, respectively, only two, two, and one recurrences of the 11-month periodicity, it does not seem surprising that they deviate as much as they do from the better determined mean forms with which they are associated. Naturally, the effects produced by the influences which determine all other periodic and accidental changes of temperature departures cannot be eliminated by taking the mean of only one or two recurrences of the 11-month periodicity.

9. PREPARATION OF WEATHER DATA

When a large program of computation of periodicities in weather departures was undertaken, it was soon found that the monthly fluc-

tuations from normal values of temperature and rainfall, as derived
from the tables of " World Weather Records " were so large that they
obscured the principal trends which might reveal periodicities cor-
responding to those found in solar radiation already mentioned. As
the computations proposed were very laborious and the available com-
puters inexperienced, it seemed necessary to restrict the smoothing
process to be employed to one of great simplicity. Hence the traveling
mean of 5 months was chosen. For instance, the values employed for
March and April of any year would be represented as follows:

$$\text{March} = \frac{\text{Jan.} + \text{Feb.} + \text{Mar.} + \text{Apr.} + \text{May}}{5}$$

$$\text{April} = \frac{\text{Feb.} + \text{Mar.} + \text{Apr.} + \text{May} + \text{June}}{5}$$

In computing the monthly departures themselves, the mean values
used throughout were those found in the first volume of " World
Weather Records," neglecting those found in the second volume. It
was desirable to use the same normals at all times because we wished
the departures used to be homogeneous throughout the entire interval
of years examined. Departures from these normal values were com-
puted for the monthly mean temperatures of a great many stations in
all parts of the world, and the 5-month traveling means were computed
from these departures as described above.

With regard to precipitation a modified course was pursued. It
is well known that the precipitation at most stations is seasonal, and
at many stations the seasons present extreme variations in normal
values. Hence a departure from the normal value, expressed in inches
or centimeters, which would be moderate if it occurred in the rainy
season, would be immense and perhaps unheard of if it occurred in
the dry season. But it was indispensable for our purpose that the
departures from normal should be comparable whether occurring in
the wet or the dry season. Hence the monthly mean precipitations
were first expressed in percentages of the normal values, and then
smoothed by taking 5-month traveling means. It would perhaps have
been preferable to smooth the percentage values by taking the fifth
root of the product of five values, but for simplicity the monthly mean
percentage values of the normal were smoothed in exactly the same
way as the departures from normal temperatures.

10. Amplitudes of Periodicities Diminished by Smoothing

It was appreciated that the 5-month traveling means of weather
data could not yield the full amplitudes of periodicities as short as

7 or 8 months. The fractional diminution produced thereby on the amplitude of the 7-month periodicity is estimated to exceed one-half. For the 8-month and $9\frac{3}{4}$-month periodicities the effect is still considerable, though smaller. For periodicities of 11 months or more it is believed to be inconsiderable. No corresponding effects of diminution occur in the analysis of the solar-constant variation itself because the solar data are not smoothed by 5-month traveling means as are the weather data.

11. Sun-spot Data

As indicated under caption 8, there was evidence to indicate that changes of phase in weather periodicities occur when the activity of the sun alters as measured by the Wolf sun-spot numbers. Therefore, before entering upon statistical computations from weather data extending over the past century, the first step was to assign the beginnings and ends of intervals throughout which sun-spot numbers were approximately equal. To this end the monthly mean sun-spot numbers given in "World Weather Records" were plotted as in figure 10. In preparing figure 10, a 23-year arrangement of the sun-spot data has been adopted. It will be noticed that, excepting the first of the 23-year cycles shown, there is a very fair constancy of positions of maxima and minima in the successive 23-year intervals. From this plot the following intervals were selected as of comparable sun-spot activity:

(*a*) *Sun-spot numbers generally below 40.*

Jan. 1811–Aug. 1815; Aug. 1818–Feb. 1826; Jan. 1832–Nov. 1834; May 1841–Oct. 1844; Aug. 1853–Aug. 1857; Apr. 1865–Sept. 1868; Aug. 1874–May 1880; Nov. 1889–June 1891; Dec. 1897–Sept. 1903; Mar. 1910–Oct. 1914; June 1922–Apr. 1925.

(*b*) *Sun-spot numbers generally above 40 but below 80.*

(b_1) Ascending values (or ascending and descending values contiguous). Sept. 1815–July 1818; Mar. 1826–Dec. 1831; Dec. 1834–July 1835; Nov. 1844–July 1846; Sept. 1857–Mar. 1865; Oct. 1868–Apr. 1869; June 1880–Oct. 1886; July 1891–Jan. 1892; Oct. 1903–Feb. 1910; Nov. 1914–Feb. 1917; May 1925–Dec. 1929.

(b_2) Descending values. Aug. 1839–Apr. 1841; July 1849–July 1853; Jan. 1873–July 1874; June 1894–Nov. 1897; July 1919–May 1922.

(*c*) *Sun-spot numbers generally above 80.*

Aug. 1835–Aug. 1839; Aug. 1846–June 1849; May 1869–May 1873; Feb. 1892–May 1894; Mar. 1917–June 1919.
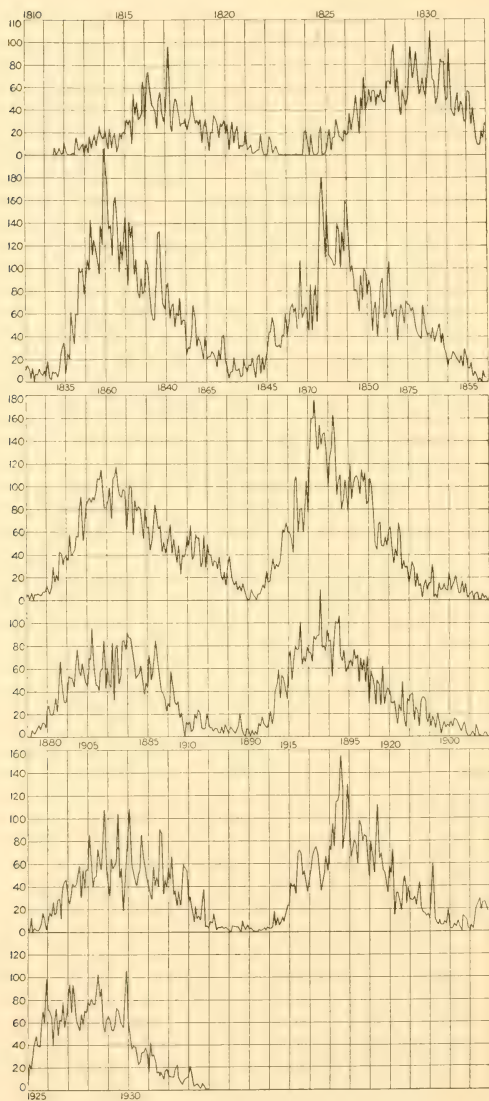
Fig. 10.—Wolf sun-spot numbers, 1810-1933.

It was recognized that this arrangement was very imperfect because of the irregular wide fluctuations of sun-spot numbers. Hence, if, as seemed indicated, the phases of weather periodicities actually alter with sun-spot activity, it could not be hoped that any such arrangement would eliminate altogether these phase changes. Therefore, some dissimilarity between the periodic curves computed for the different intervals of time given above must certainly be expected. All that could be hoped for would be that periodicities in weather of the lengths found in the solar variation would seem to persist without more than a few months of shifting backward or forward, as between the individual intervals stated above, while during the century there would be so persistent and obvious a tendency for maxima and minima to recur in a certain unchanged phase as to justify a belief in the veridical existence of the periodicity in question.

12. Corrections of Solar Periods

It was apparent that since the interval during which daily solar-constant work has been carried on continually is only a little over a decade of years, it is unlikely that the supposed solar periods are determined in length to within several percent of probable error. It was hoped that if these periodicities were really reflected in the weather, the records of such stations as Berlin, Helsingfors, Copenhagen, and others which are published for over a century, might enable the lengths of the solar periodicities to be determined to very high percentage accuracy. A change of periodic length shows itself if the successively determined forms of any assumed period, as for example 11 months, are plotted successively vertically over one another. The maxima and minima will be found to shift steadily to the left or the right according as the true period is less or greater than 11 months. The first station records worked upon were those of Berlin.

13. Full Lines Required in the Statistical Tabulations

It is well known that the temperatures and precipitations frequently tend to depart from normal values continually in a given sense during considerable intervals of time. This must be so if the assumption of a plurality of regular periodicities in weather is a true one, for the combination of several periodicities must lead to prevailingly high values at some times and prevailingly low values at other times. Hence, if a table for computing a periodicity is arranged as indicated above in caption 4, it is improper and leads to error if the first and last lines

of the table are left incompletely filled.[9a] Owing to influences aside from the periodicity in progress of being computed, the variable under investigation may be particularly high or particularly low throughout the intervals of the time represented by the first line or the last of the table. To use a part but not the whole of such a line in a short table must produce distortion of the averages. Yet the total intervals given under caption 11 are so short that one can ill spare any part of them. The best course seems to be to fill the first and last lines of the tables by extending the table a little past the limits set by equality of sun-spot activity as represented in the caption 11. Yet this may also lead to a distortion of the curve of averages owing to changes of phase produced by changes of solar activity. Perfection under these circumstances is unattainable, and some indulgence to irregularities is to be given on these accounts in criticizing the results.

14. Berlin, Germany. Departures from Normal Temperatures

It will be difficult, within the allowable limits of tabular and graphical illustration, to demonstrate the findings of this research so thoroughly as to lead the minds of readers to conclusions such as impressed themselves on those of us who followed all the computations from day to day.

A. SEGREGATED WITH REFERENCE TO SUN-SPOT NUMBERS

a. The 11-month Periodicity

Recalling that, owing to the smoothing by 5-month traveling means, the 7-month and 8-month results must necessarily be unrepresentative, let us take up first of all the 11-month analyses. In figure 11 are given all of the 11-month mean curves for Berlin temperature departures obtained by the process outlined above in captions 4, 5, 9, 10, and 11. In order that the reader may more vividly grasp the nature of this work the periodicity computation for low sun-spots for the interval January 1811 to July 1815 is given in table 4. To avoid printing numerous decimal points, the values as given are the 5-month smoothed departures from normal monthly temperatures expressed in tenths of degrees Centigrade.

Table 4.—*Sample Computation of 11-month Periodicity*

— 6	— 5	1	16	21	16	15	12	7	7	3
3	— 6	—17	—21	—18	—22	—20	—14	—10	—13	—23
—27	—18	—20	—14	1	3	— 5	— 8	—13	—16	—14
—10	—13	—25	—29	—24	—32	—30	—13	— 8	—17	—14
— 8	— 9	—16	— 8	— 2	— 2	— 3	6	— 3	— 9	—13

Mean — 9.6 —10.2 —15.4 —11.2 — 4.4 — 7.4 — 8.6 — 3.4 — 5.4 — 9.6 —12.2

[9a] In table 3, what is here called a line is there a column.

Fig. 11.—Eleven-month periodicity in Berlin temperatures. Low, medium, and high sun-spot numbers. A broken line connecting curves indicates a slight defect from full 11 months in the periodicity. Alternate full and dotted pairs of curves cover 23-year cycles measured from 1819.

In this sample the table contains five lines. Of 11 such tables illustrated in figure 11 by plots depicting the 11-month periodicity from low sun-spot temperature departures, there are four tables of four lines, four tables of five lines, one of six lines, and two of seven lines. It is clear enough that the mean values from columns as short as these are subject to a large fractional error. As remarked above, the presence in the data of other periodicities than that sought, and of accidental departures, cannot but distort mean curves depending on so few values per point.

If, now, the general mean value is taken at all times of low sunspot numbers through more than a century, it results as follows. The unit is still the tenth of 1 degree Centigrade. An arbitrary zero is chosen to give positive and negative values about equally.

0.4   1.2   0.8   1.1   1.3   —0.4   —0.6   —0.5   —0.3   —0.4   0.7

But if it is assumed that the true period is 11 months minus 3 days, then the corresponding general mean is as follows:

—1.5   —0.5   —0.1   0.7   1.7   2.0   0.9   —0.3   0.0   —0.6   —0.3

The latter periodicity has an amplitude of 0.°35 C., about twice the amplitude of the former. It results from 56 lines of smoothed values of temperature departures covering all periods of low sun-spot numbers from 1811 to 1925. The method of allowing for the 3-day decrease of period is partially indicated by the broken inclined line of figure 11. In detail the method is as follows: In the computation of the general mean, the 11 means which represent individual periods of few sun-spots were arranged in a table in such a manner that the values connected by the broken inclined line in figure 11 composed together one vertical column. The mean form, with phase chosen to agree with that expected of the top curve, a_1 of the figure, is given in curve l_1 at the bottom of figure 11.[9b] It is obvious that curve a_1, just singled out for numerical illustration is not in the expected phase, but is 3 months out of phase with the best periodicity. This selection for illustration was, indeed, made to draw attention to occasional irregularities of phase, to which we shall recur. Had I permitted myself to alter arbitrarily the phases of two or three of the mean curves by 2 months each, on the plea of accidental displacement by terrestrial influences, then the general mean would have had an amplitude of a full half degree Centigrade.

It seems difficult to avoid the conclusion that a periodicity lacking 3 days of 11 months in length, and with an average amplitude of 0.°35 C., persists in the temperature of Berlin during times of low sun-spot activity for the interval of 114 years covered.

[9b] The mean for 11 m. o d. is given by curve l_1^1.

But the amplitudes alter widely from time to time among the 11 curves shown. Not only do they thus vary, but the forms of the curves differ widely also. When these features are carefully scanned, there seems to be disclosed an interesting regularity. *Beginning with the year 1819,* the forms and amplitudes may be arranged *in pairs* with very good effect. The only deviation from noticeable similarity among these pairs occurs for the pair covering the interval March 1886 to July 1903. Of this pair of curves the first covers that period when the sky was still filled with dust from the tremendous volcanic eruption of Krakatoa. Dr. W. J. Humphreys has called attention to the disturbance of weather which volcanic dust produces.[10] We shall recur frequently to the similarity of such pairs when considering other data.

Curves a_2 to k_2, figure 11, similarly deduced, cover the intervals of time in caption 11 when the Wolf monthly mean sun-spot numbers lay generally between 40 and 80. In part of the data the sun-spot activity was increasing, and in the other part it was decreasing. But no appreciable difference in the data seems to arise thereby. It appears that neither 11 months 0 days nor 11 months minus 3 days gives the maximum amplitude of the periodicity in this case. The best period is 11 months minus $1\frac{1}{2}$ days. The following mean values show this:

Assumed period	Mean values										
11 m. 0 d.............	—0.9	0.0	—1.1	0.0	0.8	0.7	0.3	0.1	1.8	0.4	—0.5
11 m. minus 3 d......	0.2	1.4	1.0	1.4	0.9	0.3	—0.3	—1.2	—0.6	—0.4	0.4
11 m. minus $1\frac{1}{2}$ d.....	1.5	1.3	0.3	—0.9	—1.9	—2.2	—2.8	—1.2	—0.2	1.5	2.0

The relative amplitudes as just given are 2.9, 2.6, and 4.8, respectively, which show a decided preference for 11 months minus $1\frac{1}{2}$ days. In each case the phase given is the same as that expected for the interval 1815-1819. Here, as before, it is noted that the curves show decided similarity when grouped in pairs beginning with the second curve. The only exception is the last pair which presents dissimilarity. Curve l_2 gives the mean result, assuming a period of 11 months minus $1\frac{1}{2}$ days.[10a] It depends on 58 lines of temperature departures, and shows a range of 0.°48 C., and therefore, like the case already discussed, may fairly be regarded as demonstrative.

Turning now to the temperature data corresponding to Wolf sunspot numbers exceeding 80, these are graphically expressed in curves a_3 to e_3 of figure 11. These curves rest on few data, only 4, 3, 4, 3, and 2 lines, respectively. Excepting a_3, they are closely similar. The curve a_3 is in fact displaced 5 months in phase from all the others.

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[10] Journ. Franklin Inst., vol. 176, pp. 131-172, 1913.
[10a] The mean for 11 m. 0 d. is given by curve $l_2{}^1$.

No explanation for this displacement is offered. The mean curve, l_3 is computed by transposing the phase of a_3 by 5 months and taking a straight mean as of period 11 months 0 days. The result is as follows, still in units of one-tenth degree Centigrade:

0.7   —0.4   1.1   —3.6   —3.8   —0.9   —0.1   2.6   4.0   3.2   1.0

The range is nearly 0.°8 Centigrade.

The skew relationship of period between the best 11-month periodicities as determined for the low, medium, and high sun-spot activities is puzzling, but perhaps not impossible to account for. It will be recalled that the periods found were 11 months minus 3 days, 11 months minus $1\frac{1}{2}$ days, and 11 months 0 days, respectively. What this implies, as far as the 11-month periodicity goes, is the advance of the temperature influence associated with high sun spots over that associated with low sun spots by 14 months in 130 periods. As the 11-month periodicity is only one of many, and produces less than a tenth of the total influence which, as we shall see, is exerted by those periodicities which are nearly aliquot parts of 23 years, the effect is not conspicuous.

B. THE 8-MONTH PERIODICITY

Figure 12 shows, in curves a_1 to k_1, the mean 8-month periodicity results derived from the intervals of low sun-spot activity. As shown by the inclined lines there seems to be an advance of 5 months in 110 years, corresponding to a corrected period of 8 months plus 1 day. Taking account of this modification, but preserving the same phase expected as of 1811-1815, the mean results are as follows:

—0.6   0.4   1.6   2.2   2.3   0.1   —2.4   —2.5

The range is almost 0.°5 Centigrade, which owing to the modifying influence of the 5-month smoothing, already referred to, must be less than the real average range of this periodicity. The mean curve, l_1, figure 12, is based on 75 lines covering the intervals of low sun-spot numbers from 1811 to 1925. Scanning the curves a_1 to k_1 on figure 12, the pairing tendency, already referred to in discussing the 11-month analysis, is recognizable. The only marked inconsistency of the pairs, as arranged with a beginning in 1819, occurs for curves d_1 and e_1. It will be noted that for 8-month periodicities, as with the 11-month results, the pairs palpably begin with the *second* curve, about 1819.

Turning to the intervals when the Wolf sun-spot numbers lay between 40 and 80, we again find the greatest amplitude by assuming a period of 8 months plus 1 day. Choosing the phase to agree with
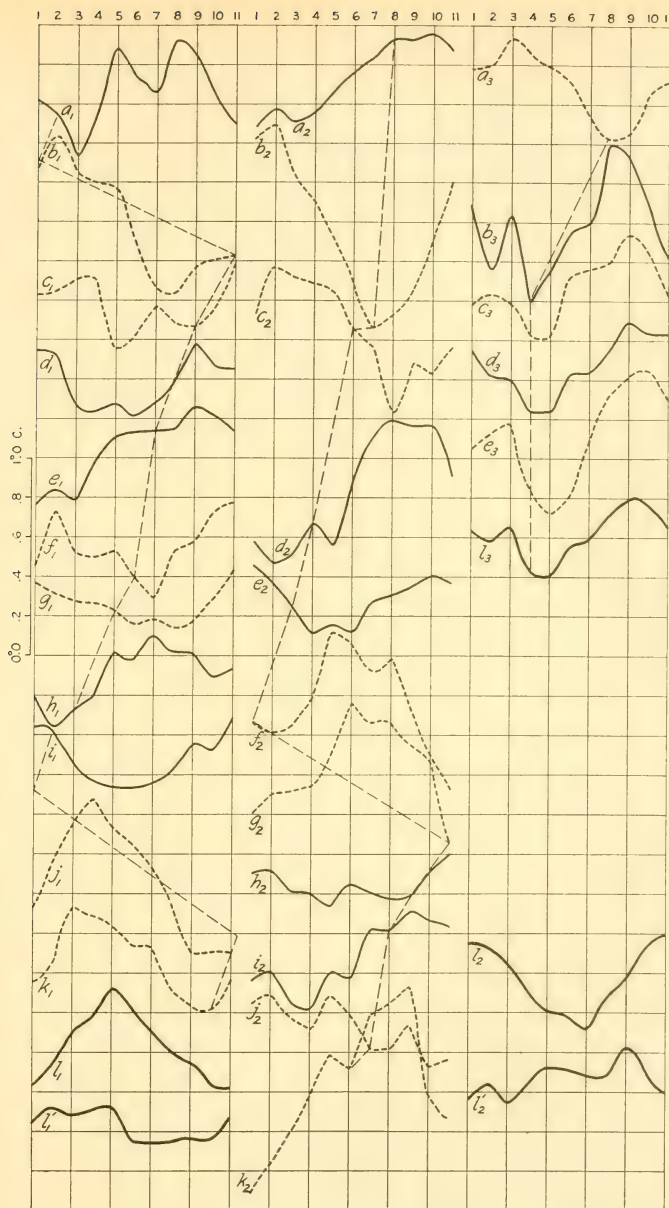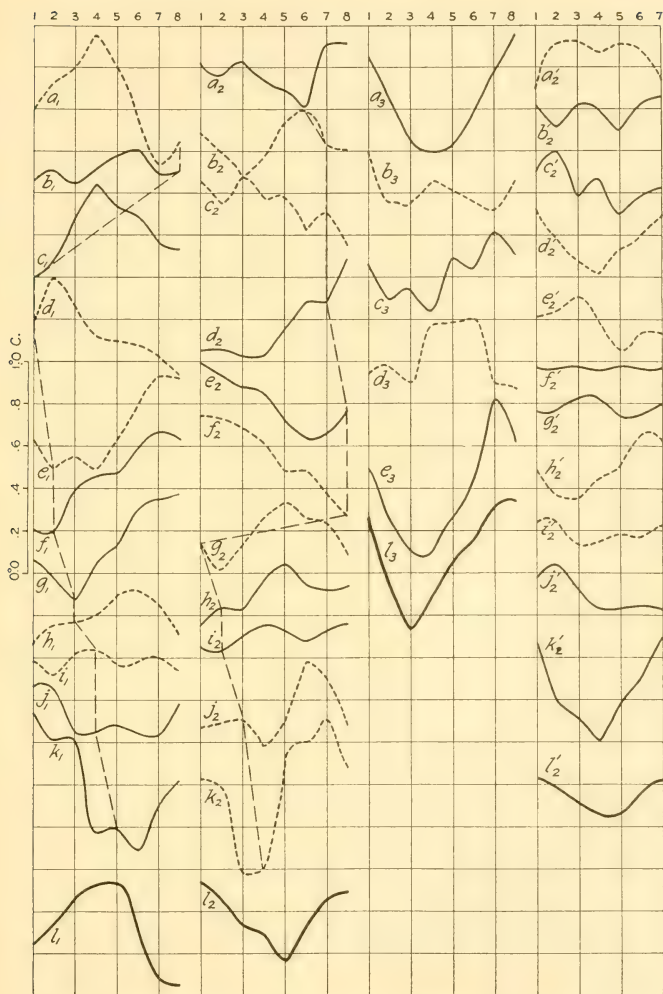
Fig. 12.—Eight-month periodicity in Berlin temperatures. Low, medium, and high sun-spot numbers. A broken line connecting curves indicates a slight excess over 8 months in the periodicity. Alternate full and dotted pairs of curves cover 23-year cycles measured from 1819.

3

that expected for the first interval, the mean values as thus reduced run as follows:

Assumed period	Mean form							Range
8 m. o d.	0.1	—0.6	—1.1	—1.0	0.3	0.4	0.6 —0.3	1.7
8 m. plus 1 d.	1.9	1.0	—0.1	—0.6	—1.9	—0.3	1.1 1.4	3.8

The average range of the 8 months minus 1 day periodicity is almost 0.°4 Centigrade (see fig. 12, l_2). This range is more than twice as great as for the periodicity 8 months 0 days.

Pairing is not so well marked in these curves as appears in figure 12, a_1 to k_1. It, indeed, shows strongly as between curves h_2, i_2, and j_2, k_2, but the curves a_2 to g_2 seem inclined to change form at *every* sun-spot period of 11+ years instead of every *second* period, as in former cases. We shall note this tendency frequently in other connections.

Curves a_3 to e_3 of figure 12 relate to intervals when the Wolf numbers generally exceeded 80. As in the corresponding case of the 11-month periodicity, they show no definite deviation from the originally assumed period, 8 months 0 days. There is on the whole a good agreement between the curves. Only the curve d_3 runs counter to all of the others, but it is at the same time one of the weakest, representing the mean of but four lines. The general mean is represented in the curve, l_3 and runs as follows:

$$2.2 \quad —1.0 \quad —2.6 \quad —1.7 \quad 0.0 \quad 1.1 \quad 2.6 \quad 2.9$$

Its range is over 0.°5 Centigrade.

c. The 7-month Periodicity

The 7-month periodicity, as already stated is much modified by the 5-month smoothing. However, in the curves representing intervals with sun-spot numbers between 40 and 80 there is such an excellent case of the pairing which starts with the year 1819 that these curves are given, a_2 to k_2 annexed to figure 12. There is no exception to the similarity of the pairs from curve b_2 to curve k_2. Two excellent pairs are found corresponding to low sun spots, but generally these forms change with each new sun-spot period.

There is no indication in any of the analyses of the 7-month periodicity of a departure in length from the period assumed. The following are the mean forms and ranges. The ranges may be assumed to be only about half as great as would be found without 5-month smoothing.

Sun-spot numbers	Seven m. o d. mean periodic forms							Range
Below 40	0.7	1.8	0.0	—0.1	0.4	—0.6	—1.4	0.°3 C.
40 to 80	0.8	0.3	—0.4	—0.9	—0.9	0.1	0.7	0.°2 C.
Above 80	1.2	0.8	—1.2	—1.9	—0.6	0.6	1.7	0.°4 C.

D. DEPENDENCE OF PHASE ON SUN-SPOT ACTIVITY

In caption 8, evidence was presented showing that the phases of the 11-month and other periodicities observed in temperature departures of Bismarck, N. Dak., altered as a function of the sun-spot activity. Referring now to figure 13, the data for Berlin are not wholly consistent with that conclusion. As not all of the 11-year sun-spot periods show high Wolf numbers, let us restrict our inquiry to the periods culminating about 1837, 1847, 1871, 1893, and 1918. Consider first the 11-month periodicity. In table 5 are given the months within the 11-month period when maxima prevail. The results cover times of low, medium, and high Wolf numbers. The shift of maxima for medium and high Wolf numbers is indicated in the fourth column. In the last column are given without details the corresponding shifts found for the 8-month periodicity data.

TABLE 5.—*Shift of Phase, Berlin Temperatures, Attending Sun-spot Activity*

Years covered	Wolf numbers	Months of maxima	11-month shifts	8-month shifts
1831-1834	Below 40	11 to 4	0.0	0.0
1834-35 and 1839-41	40 to 80	1 to 5	+1.0	—1.0
1835-1839	Above 80	2 to 4	+1.0	—4.0
1841-1844	Below 40	9 to 2	0.0	0.0
1844-46 and 1849-53	40 to 80	6 to 11	—2.5	—2.0
1846-1849	Above 80	8 to 9	—3.0	—1.5
1865-1868	Below 40	10 to 11	0.0	0.0
1868-69 and 1873-75	40 to 80	5 to 8	—4.0	+2.0
1869-1873	Above 80	8 to 10	—1.5	0.0
1886-1890	Below 40	11 to 2	0.0	0.0
1890-92 and 1895-97	40 to 80	10 to 2	—0.5	—0.1
1892-1895	Above 80	9 to 11	—2.0	—1.0
1910-1914	Below 40	3 to 5	0.0	0.0
1914-17 and 1919-21	40 to 80	1 to 5	—1.0	—3.0
1917-1919	Above 40	8 to 11	$\left\{ \begin{array}{c} -6.5 \\ \text{or} +5.5 \end{array} \right\}$	—2.0

There appears a prevailing tendency for the phase to be earlier with higher sun-spot activity, but it is not as conspicuous or regularly progressive a tendency as appeared in the Bismarck data. In fact the evidence seems to show that though there is a small change of phase toward earlier dates within the cycles, when Wolf numbers increase, yet this effect is small compared with changes of phase which, as we are about to point out, occur at integral multiples of $11\frac{1}{2}$ or of 23 years, counted from January 1819. Such changes of phase will next be demonstrated.

E. DEPENDENCE OF PHASE ON EPOCH COUNTED FROM 1819

It was desired to present this phenomenon apart from changes of phase accompanying variations of sun-spot activity. Hence the data
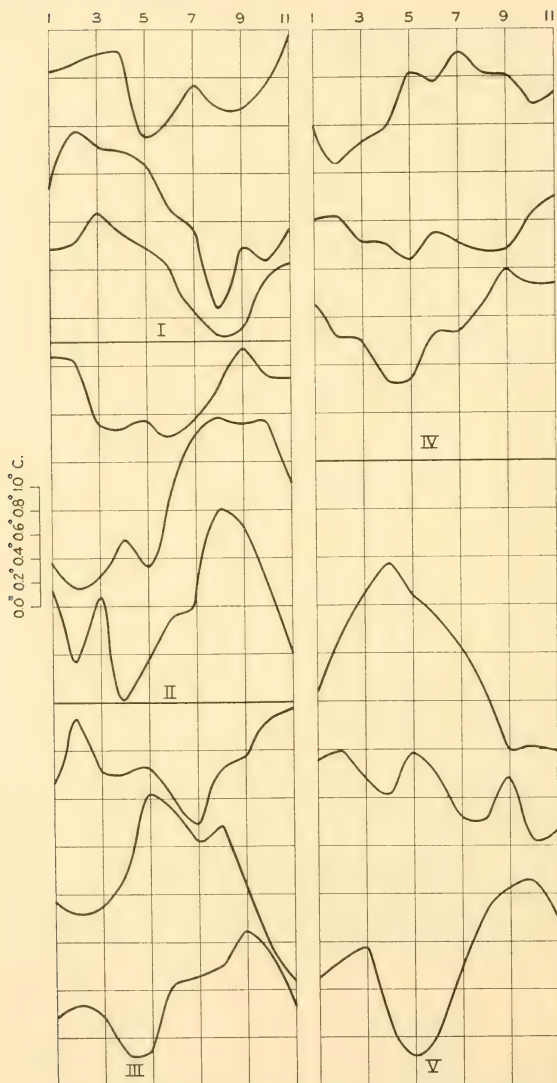
Fig. 13.—Sun-spot numbers and phase changes. Eleven-month temperature periodicity at Berlin for low, medium, and high sun-spot numbers.

were limited to times of low Wolf numbers. Smoothed departures from normal temperatures at Berlin were arranged in periodicity tables each of which fell entirely within a period of 23 years, and the beginnings and ends of such 23-year periods fell always at an integral multiple of 23 years counting from January 1819. Periodicities of 7, 8, 9¾, 11, 12, 13.6, 21, 25, 34, and 46 months were investigated in this manner. Owing to the moderating influence of the 5-month smoothing, already referred to, the 7-month periodicity was indecisive and is omitted here. Of the 12-month periodicity I shall treat separately. Figure 14 shows the results of all others. In the figure the 8-month curves are corrected in phase to the more exact period 8 months plus 1 day, and the 11-month curves are corrected in phase to the more exact period 11 months minus 3 days. The scales of abscissae and ordinates are altered in the 21-, 25-, 34-, and 46-month plots for greater convenience.

In table 6 the Roman numerals I to V refer to 23-year intervals ending respectively at one, two, three, four, and five times 23 years after January 1, 1819.

TABLE 6.—*Comparison of Phases and Amplitudes, Berlin Temperature Periodicities*

Periodicity	Phase	Amplitude
8-month	I, II, III, and V similar; IV opposed.	I and II moderate; III and V large; IV small.
9¾-month	I and V similar; II, III, and IV opposed.	I, III, and V moderate; IV large; II small.
11-month	I, II, and V similar; III and IV opposed.	II, III, and IV moderate; I and V large.
13.6-month	I, II, and III similar; IV and V opposed.	IV and V moderate; I and III large; II small.
21-month	I and V similar; II, III, and IV opposed.	Amplitudes nearly equal.
25-month	I, III, and V similar; II and IV opposed.	III, IV, and V moderate; I and II large.
34-month	I, IV, and V similar; II and III opposed.	II, III, and V large; I and IV very large.
46-month	I and V similar; II, III, and IV opposed.	All large, II, IV, and V very large.

Notes.—As all the tables were prepared from the same original smoothed departures, the influence of the unremoved shorter periodicities is very pronounced in causing irregularities in the curves representing longer periodicities. This must obviously occur because only a few repetitions (in the 46-month tables sometimes only two, sometimes three) were available for the longer periodicities. Sometimes the longer periodicities display periodic submultiples conspicuously. For instance in 46-I there is obviously a periodicity of 9.2 months superposed, while in 46-II there is obviously a periodicity of 11.5 months superposed. These two unusual periodicities correspond, respectively, to 1/30 and 1/24 of 23 years.

Referring to the table, let us now tentatively suppose that the smoothed temperature departures of Berlin were plotted in 23-year cycles for the 115 years, 1819 to 1923. Considering figure 14 and table 6, it would almost certainly be found that many features of similarity would appear in the successive plots. For so many periodic
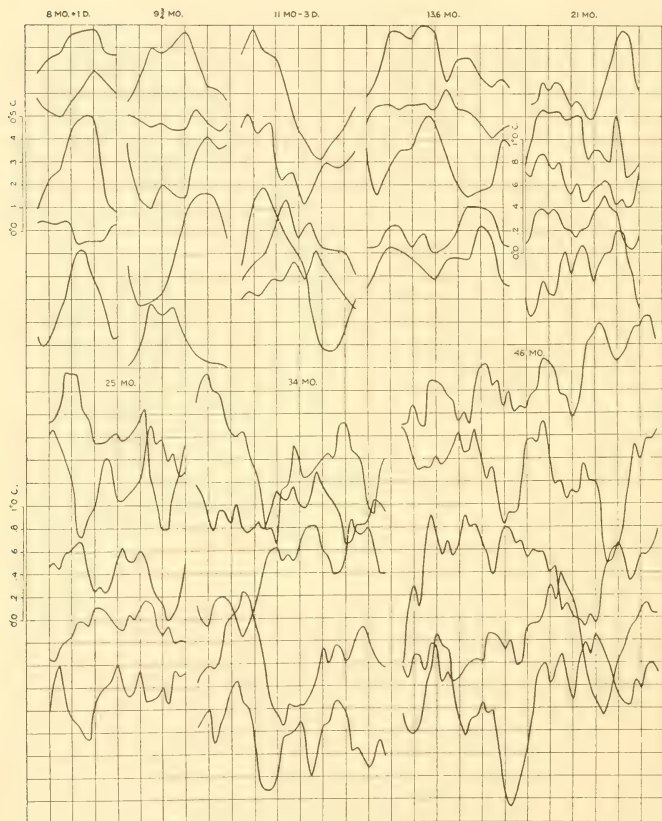
Fig. 14.—Dependence of phase in periodicities of Berlin temperatures on epoch measured from 1819. Each curve given is the mean form for 23 years. In each group the top curve starts from January 1819. Note prevailing similarity of curves I, III, V and again of curves II, IV. Exceptions noted in text.

features would recur in successive 23-year intervals in nearly the same phases that the successive complex curves formed by their summation must themselves show features of some similarity, though a little altered in phase and amplitude from one 23-year interval to another. It is clear that, of the various intervals, V would be most similar to I, because its phase is found similar to I for all periodicities given except 13.6. Interval III is next most similar to I, but IV, and next to that II, would be most dissimilar to I. On the other hand, II and IV would be found to present many features of similarity each to each. We shall recur to this when we consider the possible application of periodicities to long-range forecasting. Here I content myself with hinting that three most similar intervals, I, III, and V, and two opposed similar intervals, II and IV, have separations of 46 years.

The 12-month periodicity is particularly instructive. Meteorologists have long known that a very long interval of years does not suffice to yield monthly means of temperatures which will be closely followed in the mean during a succeeding equally long interval of years. Hence it was expected that a 12-month periodicity would be found in the departures from normal temperatures at Berlin. But it would be natural to suppose that its cause is purely terrestrial and that it would show no relation to solar periodicities. The contrary is certainly the case. Figure 15 shows clearly that the 23-year interval is of decisive influence in changing the phase and amplitude of the 12-month periodicity. This is true not only at Berlin but at all other stations which we have investigated, including Helsingfors, Copenhagen, Greenwich, Cape Town, Adelaide, and others.

In preparing figure 15, the 12-month data were not restricted to times of low sun spots as were the data for figure 14. For it was not to be presumed at first that this 12-month periodicity was due to changes originating in the sun, but rather on the earth. These more numerous data gave two tables of about a dozen lines each for each 23 years. In this way abundant evidence proves the critical importance of January 1819 and multiples of 23 years thereafter as determining points in the pairing of the curves, such as has already been referred to. Another interesting reference to these curves in figure 15 will be found below under caption 14-B.

From the studies rehearsed above under the various captions of 14-A, we conclude:

1. Certain periodicities found in solar variation are found persisting throughout more than a century in Berlin temperature departures.

2. Small corrections to the supposed lengths of two of these solar periods are indicated by these long ranges of data.
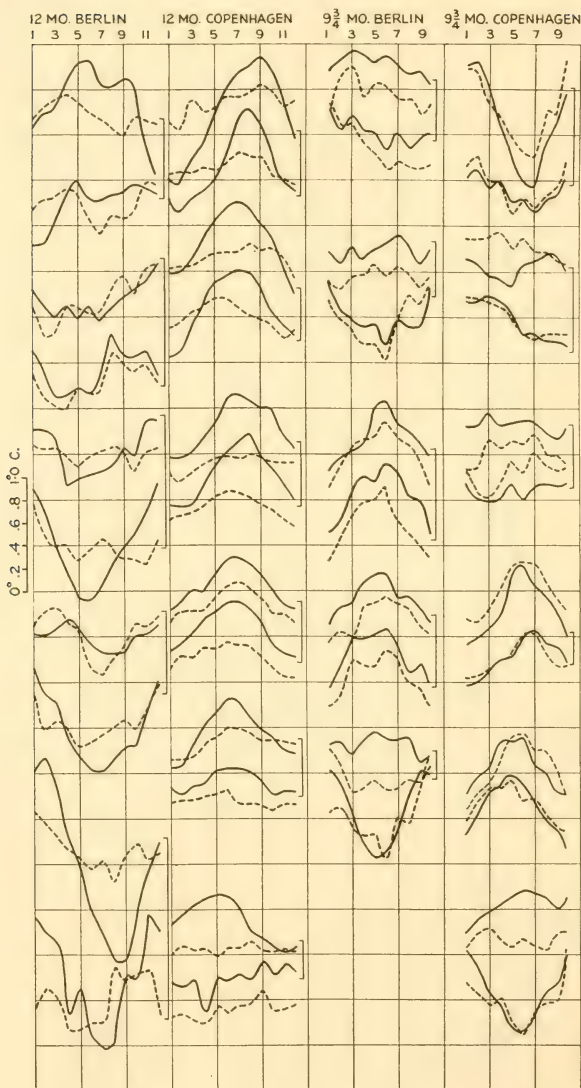
Fig. 15.—The 23-year influence on periodicities of 9¾ and 12 months. Each bracketed pair covers 23 years. Full curves are from original data, dotted curves from residuals after removing many periodicities.

3. The 23-year period, which is the approximate least common multiple of the observed solar periodicities, and is also the approximate length of Hale's solar magnetic cycle, is of dominating importance in the terrestrial weather-responses to solar influences.

4. While the intensity of sun-spot activity has some influence on the phases of the temperature periodicities, it is by no means as important as the arrival of integral multiples of the 23-year interval measured from January 1819. These define large modifications both of phases and amplitudes.

5. The 23-year period governs not only periodicities which seem to be of purely solar causation, but also the phases and amplitudes of the 12-month periodicity in departures from normal temperature. This periodicity might otherwise have been regarded as purely of accidental terrestrial origin.

6. It is not possible to arrive at definite conclusions as to the veridity of periodicities of long duration from data restricted to 23-year intervals, and further restricted to intervals of comparable sun-spot activity. Another attack on this part of the subject follows.

B. ANALYSES GROUPED IN PERIODS OF 11½ YEARS AND 23 YEARS, BASED
ON JANUARY 1819, AS DATE OF DEPARTURE, AND
INCLUDING ALL DATA

The preceding discussion of Berlin temperatures was restricted to intervals of comparable sun-spot activity. But though this is desirable it is not vital, and restrictions relating to 23-year intervals having been proved to be more essential, it becomes necessary to merge all data, whatever the prevailing sun-spot activity, in order to study fairly the longer periodicities. It has been proved advantageous to base our studies on the zero date January 1819.

A. THE 11-MONTH PERIODICITY

As before, we begin with the 11-month period. As there is here no intention of making a century-long comparison, no account need be made of the correction (minus 3 days), nor when we deal with the 8-month periodicity of its correction (plus 1 day). Table 7 gives, for illustration, a complete tabular determination of the mean 11-month periodicity curves from January 1819 to October 1864. The similarity of the two halves of each of the two 23-year periods covered, and the complete opposition of these two 23-year periods, each to each, are clearly shown in figure 16. It is instructive to note how abruptly the transition occurs from one type to the other just at the turn of 23 years after January 1819. The two types differ
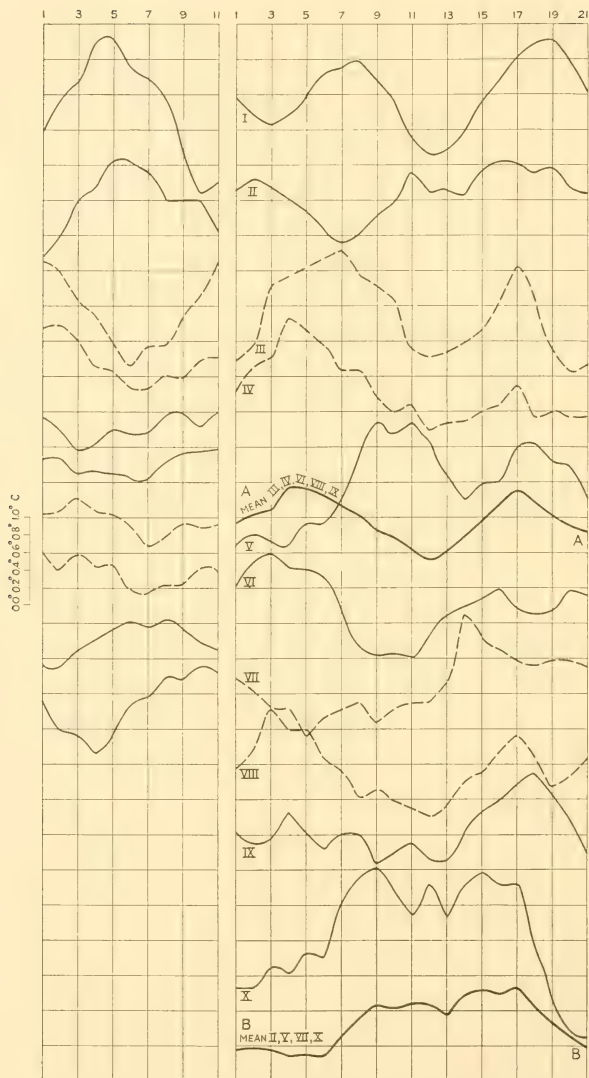
Fig. 16.—The 11- and 21-month periodicities in Berlin tempera-
tures. Phase dominated by the 23-year cycle from 1819. Full and
dotted pairs of curves each cover a cycle of 23 years.
Under A, wording should read " Mean I, III, IV, VI, VIII, IX."

in much the same way as the right and left hands. In what follows we may sometimes speak of them as the right and left types.

TABLE 7.—*Berlin Temperature Departures 11-month Periodicity*

Jan. 1819–Dec. 1829											
	8	.9	16	16	17	19	19	14	6	—7	—22
	—24	—24	—17	—5	—1	—6	0	—5	—8	—6	—7
	—10	—10	—12	2	8	0	—1	—1	—7	—4	10
	19	26	29	34	31	27	22	17	8	1	3
	5	—3	—23	—23	—26	—32	—27	—7	—7	—6	—4
	—2	3	10	14	20	18	14	8	0	—6	—9
	—5	—1	6	16	25	22	15	12	4	—6	—8
	—2	—4	—3	3	11	0	2	4	1	—6	9
	13	17	18	20	16	12	3	—12	—11	—5	—2
	3	19	16	12	10	1	3	1	—5	—7	2
	—1	3	9	6	2	1	0	0	—7	—16	—19
	—18	—20	—9	0	1	—2	—6	—13	—32	—42	—49
Mean	—22	+13	+33	+79	+82	+50	+37	+15	—48	—92	—80
Jan. 1830–Nov. 1841											
	—44	—34	—15	—2	7	3	—3	—3	2	—1	—9
	—7	—7	—6	—5	4	3	3	—7	—1	0	1
	1	5	3	6	0	0	—5	—8	—12	—7	—8
	—1	—5	4	1	—4	2	10	1	—5	—3	—12
	—15	—4	13	16	20	19	16	10	10	23	25
	20	17	10	8	11	12	9	5	2	—1	—3
	2	2	—6	—10	—10	—12	—1	5	3	4	1
	—12	—14	—5	—8	—3	4	5	—4	—5	—12	—15
	—17	—8	—7	—2	1	3	—18	—27	—28	—33	—33
	—16	—6	—11	—5	—6	—8	—6	1	—1	—4	—7
	—7	—7	—7	—4	5	5	7	3	5	2	—3
	—2	—2	—2	—2	0	—4	—5	0	—10	—9	—19
	—13	—16	0	—1	6	2	1	—1	4	13	9
Mean	—85	—61	—22	—6	+24	+22	+10	—19	—21	—22	—56
Dec. 1841–Nov. 1852											
	8	7	0	—4	0	—3	—4	—1	—5	—11	—4
	—1	—5	—4	3	—7	—14	—10	—6	—10	—5	2
	10	10	8	5	3	—4	—8	—10	—12	—15	—15
	—11	—15	—8	—19	—34	—35	—29	—30	—15	—3	—7
	—3	0	1	6	14	21	18	12	13	10	8
	8	15	12	1	—8	—13	—16	—21	—9	—6	—1
	3	4	—2	1	—6	—23	—14	—8	—7	—5	14
	7	0	—7	—4	—6	—2	0	9	7	5	5
	4	—6	—9	—9	—12	—11	—14	—21	—12	—14	—13
	—8	5	—4	—1	—5	—7	—6	—3	2	8	11
	11	2	—6	—10	—11	—15	—3	—4	2	11	14
	7	4	2	—6	—4	1	7	5	9	14	21
Mean	+29	+18	—14	—31	—63	—88	—66	—65	—31	—9	+29
Dec. 1852–Oct. 1864											
	16	6	—4	—16	—23	—17	—9	—4	0	—4	—12
	—8	—7	—6	—5	3	0	2	—1	—1	—1	—2
	—1	—1	—16	—21	—22	—29	—27	—12	—9	—7	2
	—1	—9	—6	—10	—4	—5	1	—1	—8	—6	—11
	—5	—10	—3	—2	0	—1	2	—1	1	2	7
	11	18	14	20	13	1	—8	—7	—17	—11	—3
	2	6	11	13	14	19	21	26	16	16	12
	12	9	11	11	10	1	3	1	—2	—4	2
	—4	—4	—4	—3	—6	—10	—13	—19	—12	—5	—6
	—6	8	4	—1	2	9	7	7	5	4	7
	7	10	10	8	3	1	1	1	5	13	18
	18	20	19	11	1	—1	—3	3	5	15	5
	5	2	—4	—18	—11	—13	—22	—19	—13	—15	—18
Mean	+35	+37	+20	—10	—15	—35	—35	—20	—23	—2	+1

The little double table (table 8) extracted from table 7 emphasizes this behavior. The 11-month periodicity as computed from January 1819 to December 1829, and from January 1830 to November 1841, shows high maxima at the fifth month. From December 1841 to November 1852 and from December 1852 to October 1864, on the contrary, deep minima are found at the sixth month. The transition from the first of these types to the second is abrupt. To show its abruptness the last 22 months ending with November 1841 may be contrasted with the first 22 months beginning with December 1841.

TABLE 8.—*Abrupt Phase-change. Berlin 11-month Temperature Periodicity*

—2	—2	—2	—2	0	—4	—5	0	—10	—9	—19
—13	—16	0	—1	6	2	1	—1	4	13	9: Nov. 1841
Mean	—7.5	—8.0	—1.0	—1.5	3.0	—1.0	—2.0	—0.5	—3.0	2.0	—5.0

Dec. 1841:	8	7	0	—4	0	—3	—4	—1	—5	—11	—4
	—1	—5	—4	3	—7	—14	—10	—6	—10	—5	2
Mean	3.5	1.0	—2.0	—0.5	—3.5	—8.5	—7.0	—3.5	—2.5	—8.0	—1.0

Obscured as they are by the influences of other periodicities and accidental effects, yet in the mean of the first two lines of table 8 the maximum occurs on the fifth month, and in the mean of the last two lines the minimum occurs on the sixth month, just as happens with the general means found in table 7. Even in details the two mean curves representing 22 months each are opposite, as shown by figure 17.

B. THE 21-MONTH PERIODICITY

Take as an example of another type the 21-month periodicity shown in figure 16. In this instance the transition from left to right in type usually occurs at each 11½ years, though not invariably. One type holds for instance through the two periods of 11½ years each from October 1841 to June 1864. But then, note the abrupt transition between the 42 months preceding and the 42 months following July 1864. The mean of the first pair of lines is almost precisely opposite to the mean of the last pair, as is shown in figure 17 and table 9.

Of the 10 curves illustrating the 21-month periodicity, numbers 1, 3, 4, 6, 8, and 9, beginning 1819, 1841, 1852, 1875, 1897, and 1910, respectively, are generally similar in phase, and not greatly different in amplitude. Opposed in phase are curves 2, 5, 7, and 10, but they are not quite so similar each to each. From this we see that during about 70 years out of 110, the 21-month periodicity, whether we regard it as true or spurious, would have produced nearly identical effects upon the temperature of Berlin. The general mean effect over 70 years, as
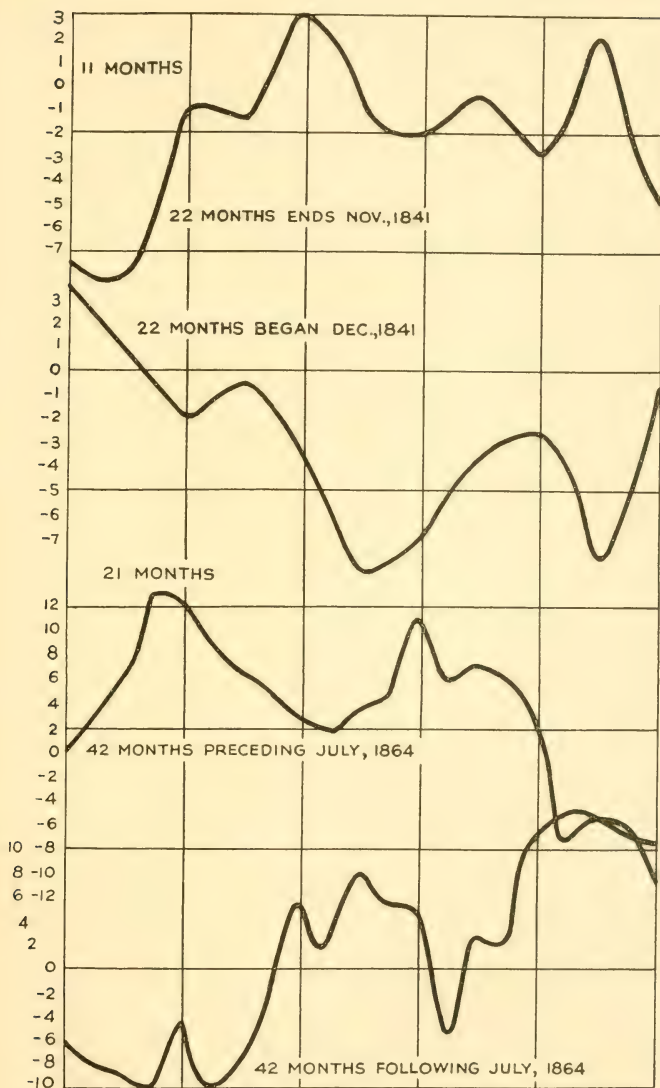
Fig. 17.—Details of the 11- and 21-month periodicities in Berlin temperatures. Showing abrupt reversal of phase.

TABLE 9.—*Abrupt Phase-change. Berlin 21-month Temperature Periodicity*

1	−22	−10.5	14	7	10.5
1	−13	−6.0	24	−1	11.5
1	−11	−5.0	26	−1	12.5
3	−18	−7.5	28	−2	13.0
8	−4	2.0	24	−2	11.0
10	2	6.0	12	−7	2.5
10	5	7.5	14	−9	2.5
7	5	6.0	3	−14	−5.5
7	15	11.0	11	−2	4.5
4	5	4.5	11	0	5.5
5	3	4.0	7	9	8.0
7	−3	2.0	−8	12	2.0
7	−1	3.0	−1	12	5.5
9	1	5.0	−16	9	−3.5
2	11	6.5	−21	5	−8.0
−1	19	9.0	−18	−2	−10.0
4	20	12.0	−10	1	−4.5
8	18	13.0	−18	−2	−10.0
−6	18	6.0	−15	−4	−9.5
−6	13	3.5	−13	−3	−8.0
−5	5	0.0	−19	8	−5.5

Mean

Mean

computed from curves 1, 3, 4, 6, 8 and 9, is as follows and is illustrated at A of figure 16. The mean values which follow are expressed as usual in units of 0.°1 Centigrade.[10b]

1.3		2.3		2.8		5.4		5.2		4.6		3.4		2.3		0.6		—0.3		—1.8	
	—2.8		—1.9		—0.2		1.5		3.4		5.1		3.8		2.1		1.2		0.4

The range of the general mean is 0.°8 Centigrade. This mean curve represents the tabulation of 39 lines in each of its 21 columns or 819 months in all. The contradictory results found in the remaining 24 lines, representing 504 months, themselves somewhat approach a common type. Its mean form, shown at B of figure 16 is as follows:

—4.4		—4.2		—4.4		—5.1		—5.0		—5.2		—2.8		—0.7		0.6		0.2		0.9	
	0.8		—0.5		1.6		2.3		1.9		2.6		0.5		—1.3		—2.9		—4.3

Being plainly associated with periodic changes in the sun, as the dates of the appearance and disappearance of contrasting phases in these curves 2, 5, 7, and 10 appear to be, the existence of these curves of a contradictory type does not, in my judgment, reasonably require us to doubt the evidence of the other 70 years or of their own 40 years that 21 months is a veridical period in terrestrial temperature, produced by a periodic solar variation.

c. PROGRESSIVE REMOVAL OF DETERMINED PERIODICITIES

Acting on the conclusion just expressed, I have felt it justifiable to remove, one after another, the mean evaluations of the various periodicities, *and to remove them in parcels of 11½ or 23 years at a time,* so as to eliminate them to the highest degree possible despite changes of both phase and amplitude. As I am aware that this course will be criticized and perhaps disowned by meteorologists and statisticians, I pause at this point to refer to the 12-month periodicity, as computed from the residuals of the 5-month smoothed Berlin temperatures, after removing in the way just indicated, and in the following order, the 7, 8, 11, 13.6, 21, 25, 34, 46, 68, and 9¾ month periodicities. Mean values for each 11½ years from 1819 to 1929 are given by the dotted lines in figure 15. These results may be compared with the closely juxtaposed curves for the 12-month periodicity, as previously computed directly from the original data, and already referred to under 14-A. The very great similarity in general between the two sets of curves indicates that the removal of all of those many periodicities in 11½-year or 23-year parcels has not ruined the residuals for the purpose of the 12-month analysis. Figure 15 also includes a similar pair of juxtaposed analyses of 12-month periodicities for Copenhagen, and

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[10b] The lines of these two tables (too long for page width) are to be read consecutively like two lines of text, not staggered as might be thought.

also the $9\frac{3}{4}$-month mean curves for Berlin and Copenhagen as computed from the original data and again from the residuals after removal of many other periodicities. I hope that this may be a step
toward promoting greater confidence in the procedure. But the curves
about to be referred to, representing other periodicities, will furnish
other grounds for confidence in these methods.

It has already been pointed out in the analysis of the original data
that the expiration of an integral multiple of 23 years from January
1819 is often the signal which warns us of a reversal of phase impending in the temperature periodicities. As this also occurs frequently in periodicities which are computed from the residuals which
remain after removal of many determined periodicities by $11\frac{1}{2}$-year
and 23-year steps, it would seem to indicate that the data were not
harmed by such removal. For it is to be recalled that the effect of such
removal, applying as it does the actual mean values over each $11\frac{1}{2}$-
or 23-year period to correct all monthly values within that very period,
must tend in the strongest way to smooth the residual curve which
remains after such removal. If then such a *smoothed* residual curve
shows plainly the newly sought periodicity, and not only shows it in
approximately the same phase at many intervals during a century,
but also shows the reversal of its phase at the critical dates, after the
manner often noted in earlier analyses—the combination of these
regularities of behavior seems to strongly support the hypothesis that
the computed periods are veridical, and cumulatively defends the
method used in their removal.

But still another type of confirmation of veridity is available. It
will be noted that in the list of 10 periodicities which were said to
have been removed before seeking the 12-month periodicity, one of
$9\frac{3}{4}$ months was mentioned last. This periodicity was not noticed in
the original data, nor was it suspected until after the 68-month curve
was determined. Then seven waves appeared so definitely in the mean
curves for 68 months, as shown in figure 18, that no question of the
reality of the $9\frac{3}{4}$-month periodicity could be entertained. Yet the 68-
month curves themselves were not computed until after the entire
previous list of eight periodicities had been removed in $11\frac{1}{2}$- or 23-
year parcels. That the $9\frac{3}{4}$-month curve should have survived so much
modification of the data seems to indicate that real and not spurious
periodicities had been found and removed. In order further to demonstrate this argument more conclusively, I show in figure 15 the $9\frac{3}{4}$-
month curves for Berlin and Copenhagen, both as computed from the
original data and as computed after nine periodicities had been removed therefrom.

D. Criterion for True and False Periodicities and Limit to the Number
of Periodicities

If it were the case that in long intervals of time only very small
changes in phase and amplitude took place in the forms of the peri-
odicity curves, it would be simple as well as obviously indicated to
pick out, evaluate, and remove periodicity after periodicity until no
more of them could be discerned in the residual temperature depar-
tures. In fact it would have been done by meteorologists long ago.
But as we have now shown, this simplicity does not obtain. Although,
for instance, the 11-month less 3 days periodicity may be traced at
Berlin during times of low sun-spot numbers for 110 years, with an
average amplitude of about 0.°4 Centigrade, there are wide fluctua-
tions of phase and amplitude during that long interval. So the ques-
tion arises, if we are to admit that obscure causes produce reversals
of phase and wide fluctuations in amplitude, how shall we know if a
supposed periodicity is real or arbitrary?

The quandary is much more serious for long periods than for short
ones. During $11\frac{1}{2}$ years there are, for instance, twelve 11-month
periods and still more of 7, 8, and $9\frac{3}{4}$ months. If so many repetitions
yield, as we have seen that they do, definite smooth mean curves of
considerable amplitude representing the periodicity throughout these
abundant repetitions, and there follows an abrupt change to another
type which continues equally well verified through a second interval
of $11\frac{1}{2}$ years, the mere change of type, associated as Hale has shown
it to be with a reversal of the magnetic status of the sun, is not a valid
argument for the rejection of this otherwise excellent periodicity.

When, however, the longer periods of 21 to 68 months are in ques-
tion, the number of repetitions of them in $11\frac{1}{2}$ or even in 23 years
is not enough to eliminate irregular fluctuations, or to inspire much
confidence. For the mean curves are left very ragged. If no sup-
porting evidences were available, they would sometimes seem probably
accidental.

But let us take as a specific example the 68-month curve at Berlin,
as shown in figure 18, I to V. The following observations may be
made:

1. Each curve shows seven waves, indicating a periodicity of $9\frac{3}{4}$
months.

2. Removing, in imagination, the waves due to the $9\frac{3}{4}$-month peri-
odicity, each subfigure shows a smooth curve of 68 months' period,
roughly similar in form to a sine curve.

4

3. Each of the subfigures is the result obtained from 23 years of observation, including four repetitions of the periodicity. Although not a century, 23 years is, after all, a long time.

4. The ranges of the smoothed 68-month curves are substantial. For curves I, II, III, IV, and V, the ranges are $0.°4$, $1.°1$, $1.°1$, $0.°5$, and $1.°0$ Centigrade, respectively. The extreme range of the original data before any periodicities at all were removed, but smoothed by 5-month traveling means, seldom exceeds $5.°0$ Centigrade. This includes, as we have seen, several short interval periodicities of a range of $0.°5$ Centigrade or more, which when combined in common phase may produce a range of at least $2.°0$ Centigrade. Hence much of the original range disappears with their removal. This makes it apparent that the 68-month curves contain a very considerable part of the residual range remaining available to disclose long periods.

5. Each 68-month curve is the mean of four mutually supporting constituents. As an example, comparing the constituents of curves II and III, each of the four individual constituents in group II shows positive departures at the two ends and negative departures at the middle. Each of the four individual constituents in group III, on the contrary, shows negative departures at the two ends and positive departures in the middle. This behavior of reversal in phase, exactly at 46 years after January 1819, is precisely similar to that which we have many times referred to, relating to the short periodicities, whose validity seems unquestionable because of the great numbers of repetitions on which they depend. Thus the behavior of the 68-month curves is exactly in line with reasonable expectation.

6. Corroboratively, the curves I, III, and V, covering (with two intermissions of 23 years each) 110 years, are so nearly similar in phase as to yield the mean form VI, figure 18. It has a range of $0.°6$ Centigrade.

But why, the reader may ask, have so many periodicities additional to those heretofore recognized in the variability of the sun been added in the list of terrestrial periodicities, and why are they chosen as integral submultiples of 23 years? The answer is that they are forced upon our attention by the progress of the computations. One illustration has been given. As stated above, the periodicity of $9\frac{3}{4}$ months was discovered because the curves for 68 months showed seven waves. Similarly the periodicity of 34 months was discovered because preliminary computations of the periodicity of 68 months (not here reproduced) showed the half-period curves of 34 months too plainly to
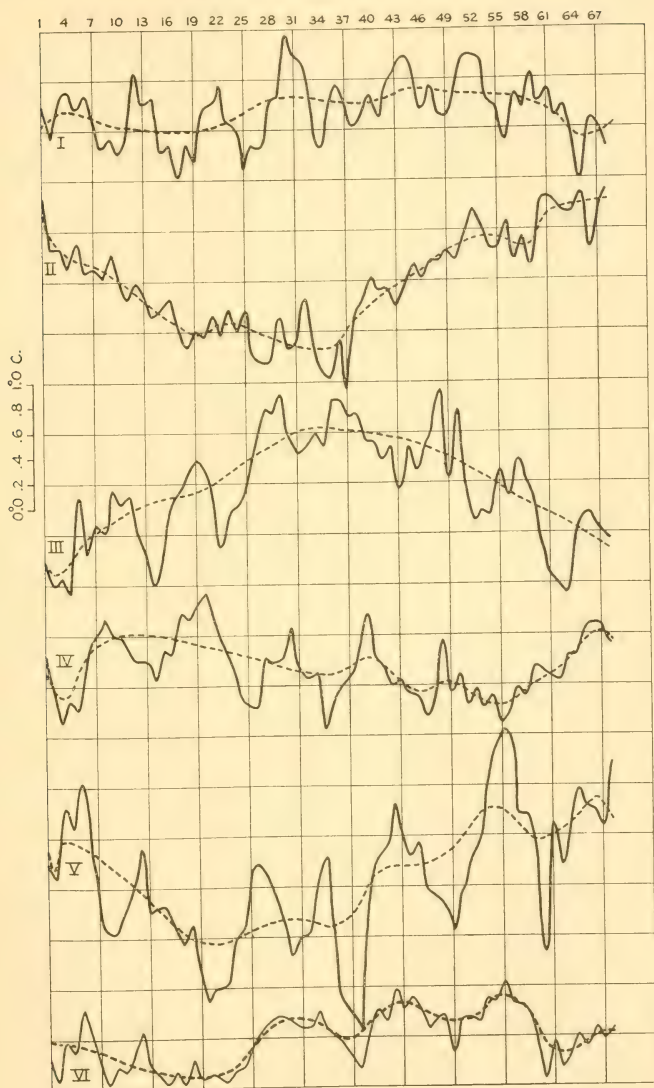
Fig. 18.—The 68-month periodicity in Berlin temperatures.

7-MO. PERIODICITY
ADELAIDE
PRECIPITATION
1842-1930

11-MO. PERIODICITY
COPENHAGEN TEMP.
1798-1930

12-MO. PERIODICITY
BERLIN TEMP.
1819-1930

ODD AND EVEN
25-MO. PERIODIC
COPENHAGEN TEMP.
1798-1930

8-MO. PERIODICITY
HELSINGFORS TEMP.
1830-1930

9⅔-MO. PERIODICITY
COPENHAGEN TEMP.
1793-1930

13·6-MO. PERIODICITY
HELSINGFORS PRECIPITATION
1853-1930
3ᴿᴰ, 5ᵀᴴ AND 7ᵀᴴ CURVES INVERTED

21-MO. PERIODI
GREENWICH TE
1842-1930
1ˢᵀ, 3ᴿᴰ AND 8ᵀᴴ C

FIG. 19.—Periodic cur
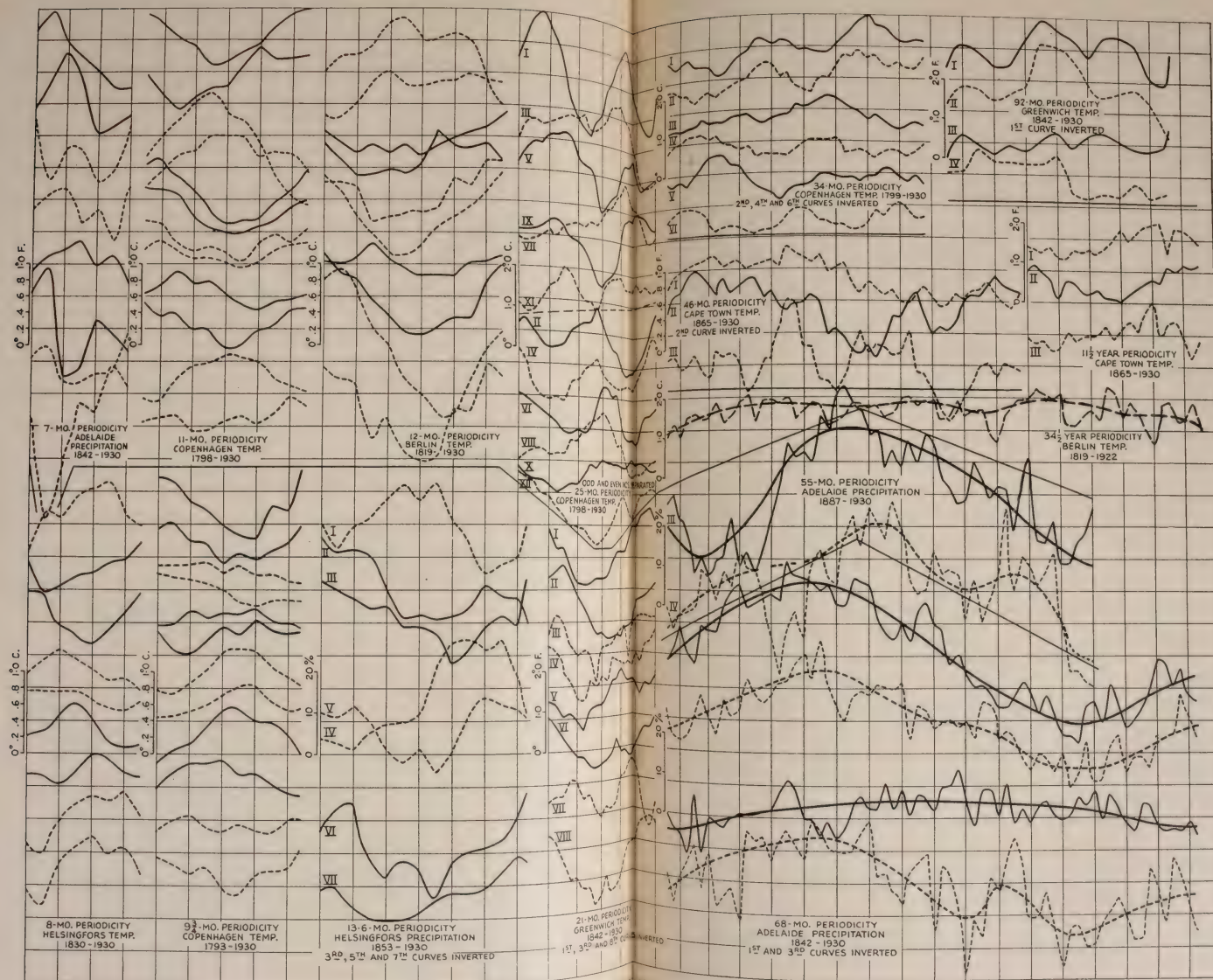
various stations.

FIG. 10.—Periodic curves at various stations.

be ignored." Similarly the periodicity of 13.6 months was disclosed by five waves in the preliminary curves computed for 68 months.

But it is freely admitted that if only one station had been investigated, some of the periodicities, especially those of 46 and 55 months might have been regarded as doubtful. Much support for the veridity of all of the longer periodicities is found by comparing results at several stations. In order to help the reader to appreciate the value of this support, I give in figure 19 some of the more convincing examples of each of the 14 different periodicities which are accepted as caused in terrestrial temperatures and precipitations by the solar influences integrally related to 23 years. To save space in depicting so many curves, certain special arrangements are made in figure 19, as follows: In the periodicities of 21, 34, 46, and 68 months, certain curves are inverted, as described in the legend. In the 25-month periodicity, odd-numbered curves are given separately from even-numbered curves. All of these arrangements emphasize the phase reversals already noted. As amplitudes are large in the longer periodicities, the scales of ordinates are diminished for them.

It is believed that if the reader bears in mind the abundant evidence already presented, which shows that periodicities of 8, $9\frac{3}{4}$, 11, 12, and 21 months change phases and forms radically at the expiration of integral multiples of $11\frac{1}{2}$ years after January 1819, he will be prepared to accept as veridical all of the periodicities shown in figure 19.

Accepting this evidence as proving in general the veridity of all of these periodicities because they are all so well marked at *some* stations, and almost without exception in solar radiation, as shown in figure 7, it seemed but a matter of course to compute them for each and *all* stations, and for departures of both temperature and precipitation from normal. All such computations gave more or less favorable curves. Some curves covering short time intervals, had they stood alone, might not have been regarded indeed as expressing a veridical periodicity. But reinforced by the better curves representing that same periodicity for the same station at other intervals within the century, and by such evidence as is given in figure 19, even these less satisfactory curves were acceptable.

If I am so fortunate as to have carried the conviction of the reader thus far, he will perhaps still ask, why I have stopped with 14 of the 23 periodicities which are integral submultiples of 23 years, and

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whether there are not other periodicities not integrally related to 23 years. The answers to these questions will be found in sections 14-C and 14-D.

C. RESIDUALS AFTER REMOVAL OF EVALUATED PERIODICITIES

Having evaluated and removed, in Berlin temperature departures, after the manner discussed in caption 14-B, periodicities of 7, 8, 9¾, 11, 12, 13.6, 21, 25, 34, 46, 55, and 68 months, mean values for each 6 months were computed from the residuals. From these 6-month mean values, periodicities of 92 and 138 months were sought. These computations were segregated into groups covering 23-year intervals. In both instances, groups I, III, and V showed considerable and nearly similar ranges of the periodicity, while groups II and IV showed slight ranges in opposite phase. These results are indicated in figure 20. The respective ranges are as follows:

<p align="center">Ranges of Mean Values, Berlin</p>

	92-month period	138-month period
In mean of I, III, and V	1°2 C.	0°7 C.
In mean of II and IV	0.4 C.	0.5 C.

After removing all of the periodicities, including the two last mentioned, the residuals remaining were compared with the original 5-month smoothed temperature departures of Berlin as shown in figure 21.

It is apparent that the range of the residuals shown in curve B of the figure is very much less than the range of the original data shown in curve A. The average amplitudes are in fact 0.°60 and 0.°90 C. *Careful scrutiny has not suggested to us any other periodicities existing in the residuals* except perhaps the Bruckner period of 34½ years. This seems to show an average amplitude of 0.°6 Centigrade in the residuals. For reasons explained at much length above, but by no means exhaustive of all the evidence in our hands, I believe that all of the many periodicities named above have real veridity, and that the processes described in their evaluation and removal are defensible. Further evidence, however, will follow.

Nevertheless, I am sure that statisticians, if they take a snap judgment, will make the obvious remark that complex curves may be represented with much accuracy by a Fourier analysis of 14 terms, though these terms have no physical significance whatever. For an example, Dr. D. C. Miller has represented almost perfectly the profile of a girl's face by Fourier analysis in 30 terms. But I think great diffi-
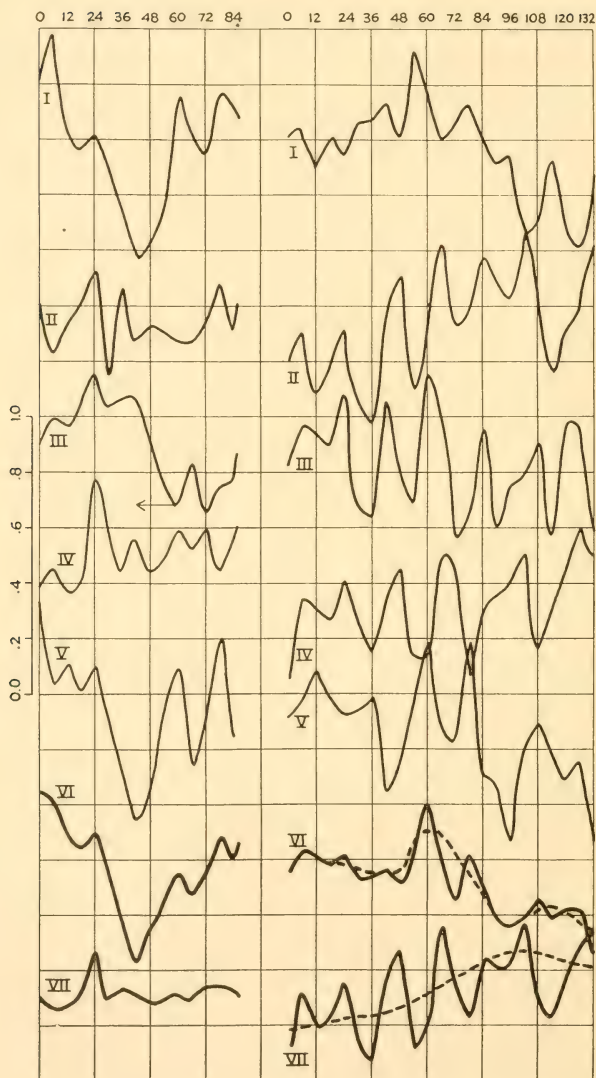
Fig. 20.—Periodicities of 92 and 138 months, Berlin temperatures.

culty would be found in making a satisfactory Fourier analysis in
14 terms of the temperature departures of Berlin from 1819 to 1929
or in discovering by that method the remarkable reversals of phase
which occur at intervals which are integral multiples of $11\frac{1}{2}$ years
after 1819. Furthermore, I hope statisticians will be fair enough to
weigh carefully the arguments I have presented, and having done so
will suspend adverse judgment until they have examined what is yet
to follow.

Fig. 21.—Residuals after removing periodicities, Berlin temperatures. Heavy
curves, original data, light curves, residuals.

D. ANALYSES BY INTERVALS NOT INTEGRALLY RELATED TO 23 YEARS

The periodicities employed in the preceding discussion were selected
partly because they had been found in solar variation, partly because
they seemed to appear in Berlin and other temperatures and precipita-
tions. But it will be objected by some who ignore the fact that we re-
peatedly scanned the curves, and sought all periodicities existing
therein, that there was no reason for selecting integral submultiples

of 23 years as the assumed periodicities whose validity was to be tested, or any particular time as better than another for departure, or any preferable time interval for delimiting the tables. Such hasty critics may suppose that any other periods or lengths of tables would probably have been equally successful.

To test this objection, computations were carried through to test for the existence of periodicities of $7\frac{3}{4}$, 10, 12, $12\frac{3}{4}$, $15\frac{3}{4}$, 19, and 29
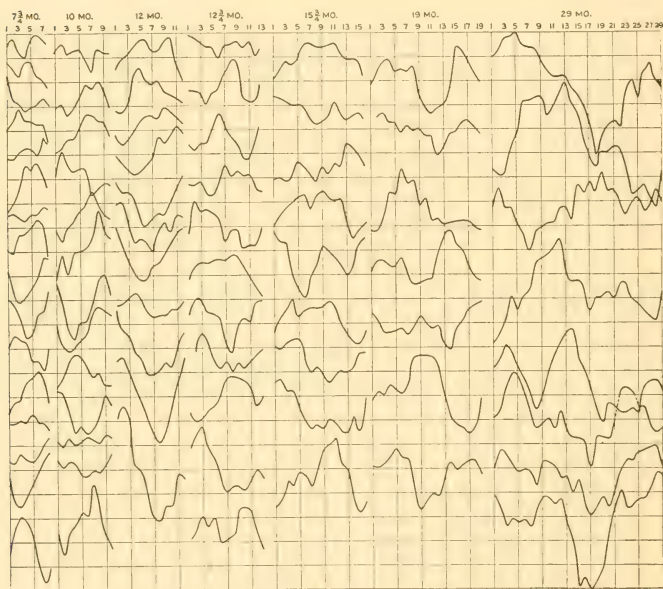
Fig. 22.—Trials of periodicities not related to 23 years. Compare with figures 19 and 23.

months in the temperature of Berlin. These tabulations, like the others, commenced with January 1819, but were arranged in tables of 10 lines. Thus they covered intervals of time having no particular relation to the 23 years which previous computations proved to be so important. The results are shown in figure 22.

With regard to the 12-month periodicity, this analysis differs but little from that shown in figure 15. The first and second 12-month curves in figure 22 cover about the same intervals of time as in figure 15. Also other pairs in figure 22, as the sixth and seventh, the eighth

FIG. 23.—Cape Town periodicities in temperature departures. Bracketed pairs of curves each cover 23 years. For periodicities of 34 months or over only one curve is computed for each 23 years.

and ninth, and the tenth with the eleventh correspond, respectively, closely to V-VI, VII-VIII, and IX-X of figure 15 in time intervals. Hence, results were to be expected in these cases nearly parallel to those previously obtained.

But as to the other six sets of curves in figure 22, there is hardly a vestige of indication supporting the periods chosen, excepting for the last three curves among the 29-month group. The similarity of these three curves is indeed curious. In the 10-month group there is the nearest semblance to continued periodicity. Here it may be that a case could be argued for a periodicity of 10 months plus 3 days. But this would be 1/27 of 273 months, and would but add one more to the group of nearly integral submultiples of 23 years, already discussed.

15. Other Analyses

Besides the temperature of Berlin, both temperature and generally precipitation also have been analyzed with equal thoroughness at Helsingfors, Copenhagen, Greenwich, Cape Town, and Adelaide. The results were very similar to those already discussed for Berlin. The dominating importance of the 23-year period displays itself quite as conspicuously in these other analyses as in the case of Berlin temperatures. That is to say, all the periodicities which seemed to be indicated were nearly integral submultiples of 23 years. Also if the date January 1, 1819, was selected as a point of departure, changes of phase and amplitude occurred abruptly at multiples of $11\frac{1}{2}$ or of 23 years thereafter.

As it is felt that the united evidence from these widely separated stations is of great importance, excerpts from the results from various stations are given in graphic form in figure 19. In addition, the complete analysis of the temperature of Cape Town is shown in figure 23.

16. Conclusions Derived from Analyses of Berlin and Other Temperatures and Precipitations

a. It is shown that 14 apparent periodicities may be found in the smoothed temperature departures of Berlin and other stations since 1819.

b. Summing these periodicities and subtracting their sum from the original smoothed departures, the residual departures at Berlin have an average range of two-thirds of the originals. Similar results occur in the other analyses.

c. Thirteen of the supposed periods are primarily attributed to solar changes, and are approximately aliquot parts of 23 years, being, re-

spectively, some interval between 272 and 276 months divided by the following numbers:

<div align="center">39, 34, 28, 25, 20, 13, 11, 8, 6, 5, 4, 3, and 2.</div>

d. The fourteenth period is the terrestrial period, 12 months, which would certainly exist because no single expression of the march of the monthly mean temperature or precipitation fits satisfactorily over an interval of a century or more.

e. The amplitudes of the 14 periodicities vary with respect to each other and also from time to time.

f. The phases of the 14 periodicities vary from time to time.

g. In a majority of cases the periodicities retain approximately the same phases, and to a less degree approximately the same amplitudes, through either 23 or 46 years, and then abruptly alter.

h. In a minority of cases abrupt changes in phase and amplitude occur after a lapse of $11\frac{1}{2}$ years.

i. The 12-month periodicity is no exception to the general rules laid down under g and h.

j. Almost without exception, when phases remain unchanged through 23 years, such a 23-year interval begins an integral number of times 23 years after January 1819.

k. The amplitudes of the periodicities disclosed in the temperature at Berlin range from 0.°2 to 1.°5 Centigrade. As stated in another form under b, these 14 periodicities combined account for about one-third of the whole range of 5-month smoothed departures from the normal in the temperature of Berlin. The amplitudes of temperature departure periodicities at other stations are of comparable magnitudes. In precipitation the amplitudes range from 20 to 300 percent. Here also the synthesis of the 14 periodicities found accounts for a substantial part of the entire departures from normal in the 5-month smoothed values. These are by no means as striking results as were found in respect to the periodic features in the solar variation reported in caption 6. But it must be remembered that the terrestrial effects are subject to various disturbing intermediate influences, besides the original solar causes.

l. Attempts to substitute some other set of periodicities, not related to the 23-year interval, are conspicuously less successful either to display continued periodic fluctuations or to bring to light any conspicuous regularities of behavior such as those stated under g and h above.

m. Other stations as widely separated from Berlin as Cape Town and Adelaide show similar results in temperature and rainfall with regard to numerous periodicities approximately integrally related to 23 years, and governed in phase and amplitude by the lapse of integral

multiples of $11\frac{1}{2}$ or 23 years from January 1819. It is therefore hard to attribute these similarities of behavior to causes not extra-terrestrial.

17. Summary of Preceding Studies and Their Guidance Toward Those Which Follow

It has been shown that the sun is variable. Its variations comprise numerous periodicities. These periodicities are so definite as to justify synthetic forecasts of solar variation. Apparently, all the periodicities in solar variation are integral subdivisions of 23 years.

With this background it seemed reasonable to attempt to trace the effects of solar periodicities in weather. Analyses have been presented of temperatures and precipitation at several stations widely separated. The 23-year period is thereby found to exercise a dominating influence in weather. Numerous periodicities which are integral submultiples of 23 years seem to exist in weather. Nevertheless, changes of phase and amplitude complicate these relations. But it has been shown that these changes of phase and amplitude are apt to occur abruptly at times which are integral multiples of $11\frac{1}{2}$ or of 23 years after January 1, 1819.

These studies lead us to expect that many of the features in weather which occur apparently unordered are really produced by the summation of periodic changes integrally related to 23 years. Hence they will be apt to be found, though doubtless with considerable modification, in successive 23-year cycles. There is ground to expect that the similarity of such features will be greater after 46 than after 23 years. As these periodic changes seem to be of solar origin they should be observable throughout the world.

We may also expect that phenomena which depend intimately on the sunshine or the weather, such as the growth of vegetation, the numbers of creatures that feed on vegetation, the flow of rivers, the level of lakes, the thickness of varves, whether produced by the flow of glacial rivers or by the summer dessication of lakes, all such phenomena may display the influence of the 23-year cycle. In the remainder of this paper it will be shown in how far it has been found that these expectations are realized.

18. A Test of the 23-Year Hypothesis in the Precipitation of Southern New England

In 1934, C. M. Saville [12] published a table of annual precipitation over southern New England given as percentages of base values from 1750 to 1932. The values depend on reports from 1 to 10 stations.

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[12] Quart. Journ. Roy. Meteor. Soc., vol. 60, p. 324, 1934.

In the same journal [13] I have used Saville's data to indicate evidence for a periodicity of $22\frac{2}{3}$ years. I now incline to prefer 23 years, and have some reason to trace a periodicity of 46 years as well as one of 23 years. Accordingly, I have rearranged the data, omitting decimals of percentages, as given in table 10.

These data are also shown graphically in figure 24. The first cycle of 23 years is discordant. It is, indeed, almost the exact inversion of cycle II. The latter is shown inverted by the dotted line on cycle I. A similar, though less complete inversion occurs with cycle VII. Fortunately, the cycles are in almost exact step with the important date, January 1819. This adds interest to these inversions, which, as we have seen, are apt to occur at integralmultiples of $11\frac{1}{2}$ years measured from 1819. Noting the considerable similarity of cycles III, V, VII as forming one group, and cycles II, IV, VI, VIII as forming another, I have plotted in curve IX the mean of groups III, V, VII, omitting I. In curve X, I have plotted the mean of groups II, IV, VI, VIII. Although both curves IX and X agree in many particulars, and both show a marked maximum at about the thirteenth year, they also tend to show opposition in some minor features, of the type which I have hitherto called, to give it a name, " right- and left-handedness." This tendency is apparent even in the individual 23-year cycles, for they show alternately the " left " and " right " tendency, corresponding to a 46-year period superposed on one of 23 years. The range from the first to the thirteenth year in the mean of group II, IV, VI, VIII is +18 percent, and in group III, V, VII, +9 percent. Having completed cycle VII in the year 1933, and assuming that the average march shown by group III, V, VII will now take place, we may expect nearly 10 percent more annual precipitation in Southern New England about 1945-1946 than in 1934. Should group II, IV, VI, VIII prove the more representative, then the precipitation about 1945-1946 would be nearly 20 percent above that of 1934.

19. A Lake Level Test of the 23-Year Hypothesis

By courtesy of the United States War Department, Corps of Engineers, a set of charts of the levels of the Great Lakes was obtained. These charts were cut and pasted by the present author so as to present 23-year intervals superposed. These charts all began with the year 1860. R. E. Horton, hydraulic engineer, was good enough to send me additional data covering nearly completely the 23-year period 1835 to 1859. This furnished valuable additional evidence.

Figures 25 and 26 show these data on lake levels. Figure 25 gives original data for Lake Ontario. Figure 26 gives the march of yearly

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[13] Quart. Journ. Roy. Meteor. Soc., vol. 61, pp. 90-92, 1935.

TABLE 10.—Cycles in the Precipitation of Southern New England, 1750-1934. Departures in Percentage from Normal

I	—1	25	—11	22	9	—10	—17	—3	26	15	—9	—23	—43	—5	14	—23	—12	0	—14	—25	—3	6	15
II	—24	—12	—3	0	—17	—13	1	4	—14	—4	17	41	47	—3	—14	—25	5	—7	4	—26	—17	—23	10
III	—29	—8	—4	—17	6	—7	—10	2	—4	—16	6	6	16	5	—8	12	4	25	16	7	4	2	—5
IV	—15	3	0	—16	26	2	—14	4	24	—5	7	11	14	5	—7	—12	—15	—6	—17	—9	8	0	4
V	—3	9	—13	—3	—21	7	—5	—12	24	2	2	20	10	6	1	13	—4	17	—4	2	9	22	—12
VI	4	4	14	16	18	6	12	7	7	1	5	8	4	23	0	—10	4	—2	—13	9	0	6	13
VII	12	19	20	9	—11	8	—11	—2	—4	17	25	—4	7	18	7	4	1	—10	1	2	—2	—9	—17
VIII	—7	—7	—6	—17	6	—9	—12	—16	2	12	—12	3	—5	—17	—7	—3	10	—5	—8	—23	—11	1	(5)
General mean	—7.9	—4.1	—0.4	0.7	20	—2.5	—7.0	—3.0	7.6	2.7	3.3	7.8	6.3	4.1	—1.7	—6.3	—2.4	1.5	—4.4	—7.9	—5.2	0.6	1.6
Mean of III, V, VII....	—7.3	7.3	1.0	—3.7	—8.7	2.7	—8.7	—4.0	5.3	1.0	6.0	7.3	11.0	9.7	0.0	9.9	—0.3	10.7	4.3	3.7	2.0	4.3	—11.3
Mean of II, IV, VI, VIII	—12.5	—3.0	1.2	—4.2	8.2	—4.5	—3.2	2.1	4.8	1.0	4.2	15.8	15.0	2.2	—7.0	—12.5	—1.5	—5.0	—8.5	—12.2	—8.0	—4.0	8.0
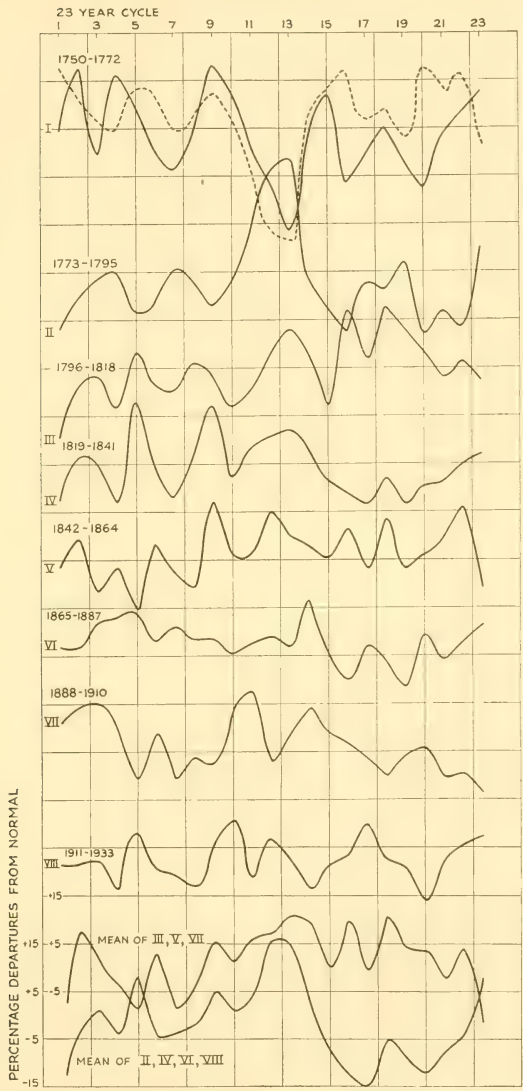
FIG. 24.—Cycles in the precipitation of southern New England.
Dotted curve is cycle II inverted.
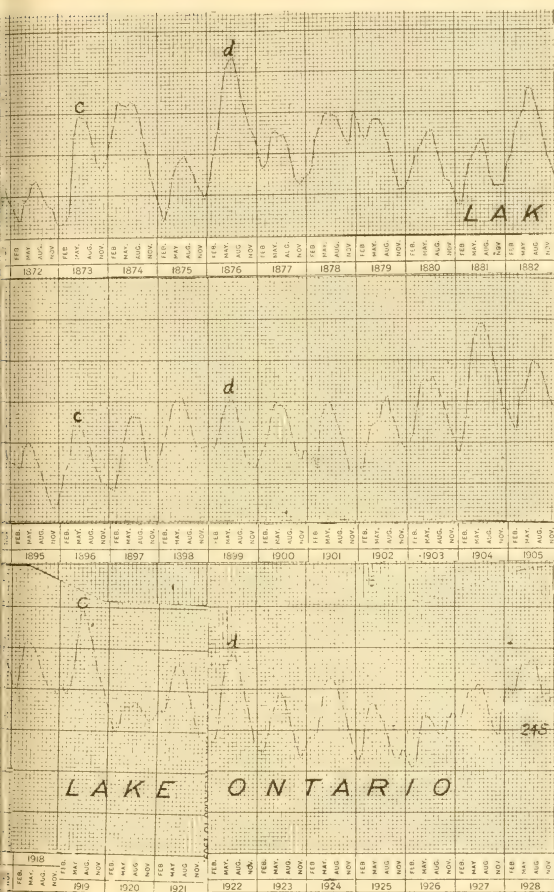
UNITED STATES LAKE SURVEY
MONTHLY MEAN WATER LEVELS OF THE GREAT LAKES
From Official Records, 1910 to date.

Fig. 25.—Levels of Lake Ontario, 23-year cycles. Note general s

c about the sixth year, also approximate repetition of features *a, b, c, d.*
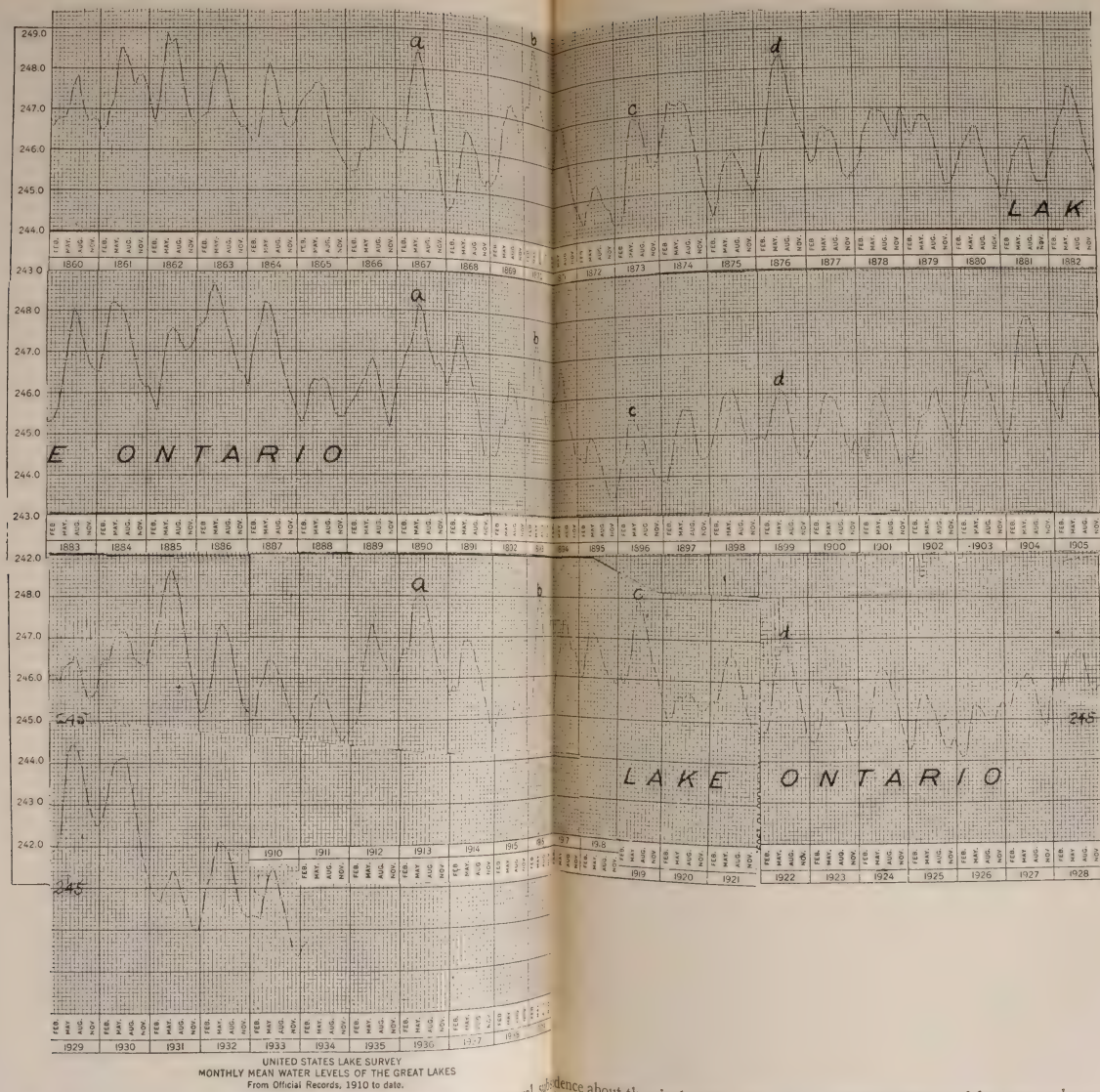
UNITED STATES LAKE SURVEY
MONTHLY MEAN WATER LEVELS OF THE GREAT LAKES
From Official Records, 1910 to date.

FIG. 25.—Levels of Lake Ontario, 23-year cycles. Note general subsidence about the sixth year, also approximate repetition of features *a, b, c, d.*

means computed from the original data for four lakes. It is unneces-
sary to include Lake Michigan, for its level practically duplicates that
of Lake Huron. Some features, as the low levels of the intervals from
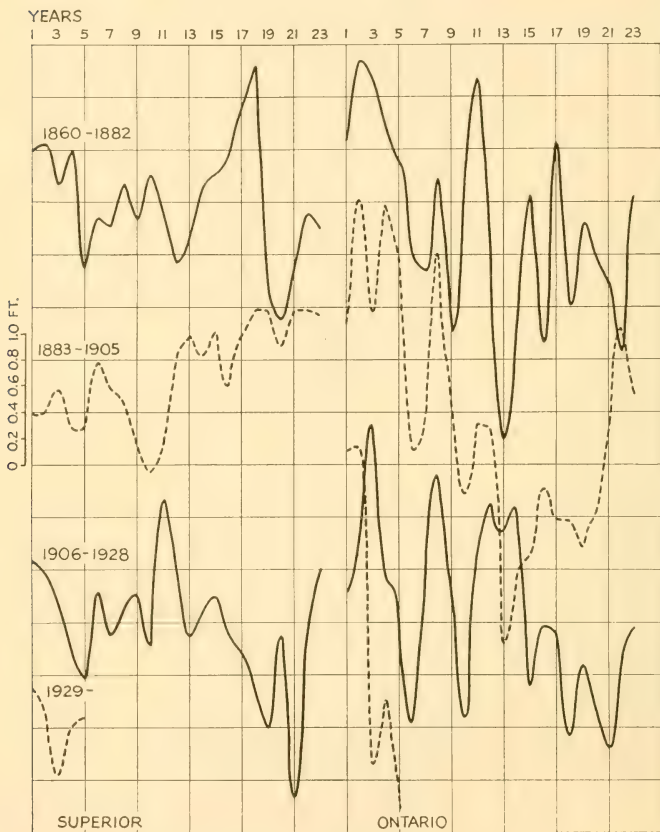
FIG. 26A.—Levels of Great Lakes, 23-year cycles.

about the fourth to the tenth year, are so conspicuous as to be striking.
This shows distinctly in all of the Lakes, but least so in Lake Superior.
It may be remembered in this connection that much of the drainage
into Lake Superior comes from far to the north and west in Canada,
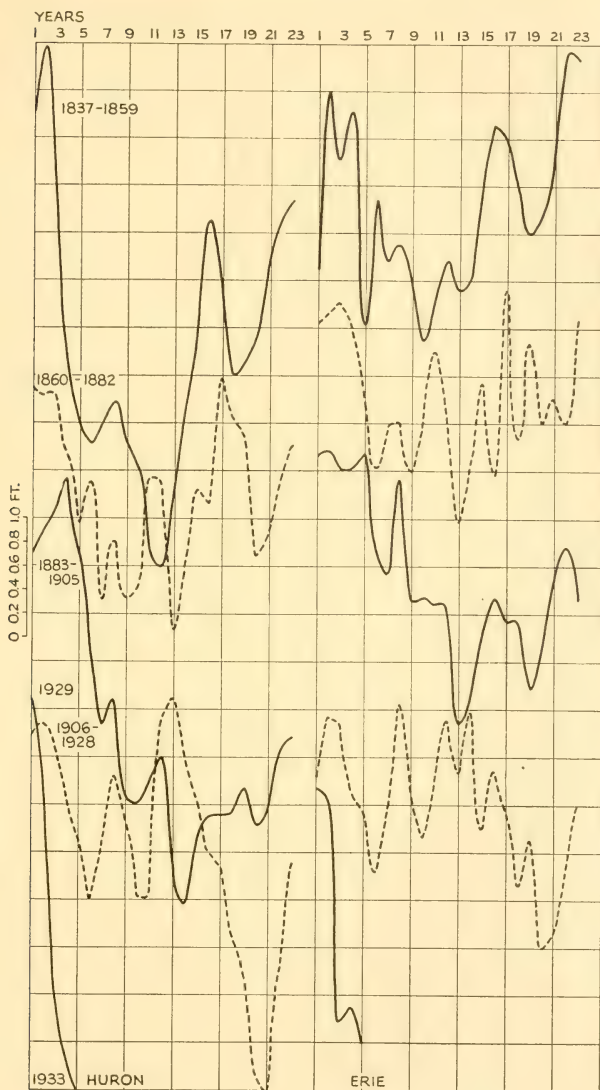
FIG. 26B.—Levels of Great Lakes, 23-year cycles. Note the marked
subsidence culminating after 11 years in the full curves.

where, at least in the last few years, the severe drought which affected our Northwestern Central States was less severe, or even absent. In the levels of Lake Ontario several minor features by which the yearly ranges have been decidedly modified seem to be repeated each 23 years. These features have been marked in figure 25 with letters.

It is especially interesting, in view of caption 14-g, that the additional cycle for Lakes Huron and Erie furnished by Mr. Horton seems, when studied in connection with those commencing in 1883 and in 1929, to indicate a 46-year cycle. The first and third, and so much as has elapsed hitherto of the fifth 23-year cycle in the levels of these two lakes since 1837 indicate a much more conspicuous and long-continued low after about the fourth year than do the second and fourth cycles.

It is not necessary to dwell upon the association which these figures seem to bear to the drought in Northwest Central United States in recent years. The inference, if the 46-year hypothesis is sound, is obvious, and disquieting for the immediate future.

20. A Fishery Test of the 23-Year Hypothesis

Dr. Paul Bartsch, of the United States National Museum, suggested to me that since ocean fishes live upon plankton, largely a vegetable product, then if the weather is governed by 23-year cycles, the fish food would probably be subject to related changes in its abundance. Hence the fish population, as reflected by the annual catch, might vary by 23-year cycles. On my application through the Bureau of Fisheries, Dr. O. E. Sette was good enough to supply Fishery Circular 14, issued in 1933, and Bureau of Fisheries Document No. 1034, issued in 1928, which give, respectively, the catches of mackerel and cod taken since 1804. The catch of mackerel I read off from figure 1 of the first cited document. The catch of cod is taken from table 2 of the other.

Very great changes of scale in the mackerel catch occurred after 1816 and after 1885. In order to make the data fairly comparable, I omitted values of the mackerel catch 1804 to 1816, inclusive, and I multiplied the values recorded from 1886 to 1931, inclusive, by the factor 3. Five 23-year cycles remained for examination. No distortion of the 23-year cycles is produced by the alteration of scale at the date just noted, because it occurs at the beginning of a cycle.

As for the cod, the catch reported was considerably smaller during the first half of the nineteenth century than since. In order to make my data more comparable, I omitted the years 1804 to 1811, inclusive, and multiplied the values from 1812 to 1857, inclusive, by the factor 5/3 (again making the change of scale at the beginning of a cycle).

Fig. 27.—Catch of mackerel and cod in the North Atlantic, 23-year cycles from 1812 to 1931. Curve for cod shifted in phase 2 years. Dotted curves and dashed curves are means of cycles I, III, V and II, IV respectively. Full curves are general means of all five cycles.

Five 23-year cycles remained for examination, but they were based on the year 1812 for the cod instead of 1817, which latter was the basal year for the mackerel data.

The results are given in tables 11 and 12 and in figure 27. As a 46-year cycle had frequently been encountered in weather data, I took a mean of the first, third, and fifth 23-year cycles separately from the mean of the second and fourth for both mackerel and cod fisheries. As there is little definite support for a 46-year cycle in these curves, I also took the general mean in each case. Thus three curves for each fishery are given in figure 27.

The general mean range during the 23-year cycle for the mackerel fishery is astonishingly large, from 16 to 40 millions of pounds. For the cod fishery it is from 460 to 570 millions of pounds. The constituent cycles, as indicated by the curves of partial means, support the general mean very well. Also when a difference of phase of 2 years and a difference of percentage amplitude of variation are both allowed for, as shown in figure 27, the two general mean curves are surprisingly similar. As noted above, it will be observed that neither the mackerel nor the cod curves show sufficient dissimilarity as between the partial mean curves to prove definitely that a 46-year period is superposed upon the 23-year period. Yet there are some indications of it, as seen in the tendency to opposition at certain years of the cycle, contrasted with the general fair agreement between the partial means.

TABLE 11.—*23-Year Cycles in North Atlantic Mackerel Fisheries, 1817-1931.*

Values Given in Millions of Pounds

		Cycle			Mean of cycles 1, 3, 5	Mean of cycles 2, 4	General mean all cycles
1	2	3	4[a]	5[a]			
6	7	41	33	18	22	20	21
7	8	37	36	6	17	22	19
14	10	42	18	9	22	14	19
16	9	38	12	9	21	11	17
15	11	33	9	12	20	10	16
24	28	29	21	24	24	24	24
20	25	36	24	24	27	25	26
26	34	51	27	30	36	30	34
35	41	39	24	39	38	32	36
22	29	28	12	18	23	21	22
26	32	29	36	15	23	34	28
32	45	42	9	18	31	27	29
31	25	20	9	9	20	17	19
43	18	35	12	12	30	15	24
53	18	18	48	33	35	33	34
30	29	27	33	27	28	31	29
30	29	30	21	48	36	25	32
35	24	47	24	72	51	24	40
26	19	53	21	60	46	20	36
22	14	52	24	48	41	19	32
18	32	31	12	72	40	22	33
14	26	65	27	66	48	26	40
10	33	38	24	69	39	28	35

[a] These two columns are three times their originals, as stated in the text.

TABLE 12.—*23-Year Cycles in North Atlantic Cod Fisheries, 1812-1927. Values Given in Millions of Pounds*

Cycle					Mean of cycles 1, 3, 5	Mean of cycles 2, 4	General mean all cycles
1 [a]	2 [a]	3	4	5			
414	434	385	568	469	423	501	454
516	514	448	520	565	510	517	513
548	479	488	568	546	527	523	526
626	444	455	544	576	552	494	529
604	524	466	486	652	574	505	546
593	554	376	507	575	515	530	521
584	608	382	419	468	478	514	492
554	608	365	452	538	486	530	503
526	569	340	419	546	471	494	480
524	523	381	408	492	466	466	466
516	608	342	477	441	433	542	477
508	541	415	412	552	492	476	486
513	519	438	416	602	518	467	498
569	566	438	432	687	565	499	538
564	710	421	502	641	542	606	568
529	665	489	444	677	565	554	561
531	625	583	448	536	550	536	545
544	601	432	475	613	530	538	533
559	573	408	504	578	515	538	524
453	491	397	479	508	516	485	506
376	680	398	498	472	415	589	485
414	768	517	546	496	476	657	548
484	842	516	524	564	521	683	586

[a] These two columns are 1⅔ times their originals, as stated in the text.

21. A TEST OF THE 23-YEAR HYPOTHESIS IN THE FLOW OF THE RIVER NILE

C. F. Talman, librarian of the United States Weather Bureau, was good enough to draw to my attention to, and lend me, Prince Omar Toussoun's " Memoire sur l'histoire du Nil," Cairo, 1925. Volume 2 of this publication gives an extended table of annual high- and low-water stages of the Nile beginning with A. D. 622. A short comparison indicated to me that the low-water stage was preferable for my purpose. It showed much smaller apparently accidental fluctuations than the high-water stage. The earliest low-water records seemed probably less accurate, for they too showed wide irregular fluctuations. After about 1430 until 1839, the low-water stage records were unfortunately fragmentary, so that these four centuries had to be omitted. After 1884 the work of British engineers so greatly modified the natural flow of the river that the records cease to be useful for my purpose. Because of these several considerations, I limited my research to a study of low stages of the Nile for 690 years from 735 to 1424, and 46 years from 1839 to 1884.

Figure 28 gives a number of individual 23-year cycles in the level of the Nile at low water. It will be seen that the early cycles of the eighth century differ from the two cycles of the nineteenth century in phase, indicating either that there is a slight deviation from exactly

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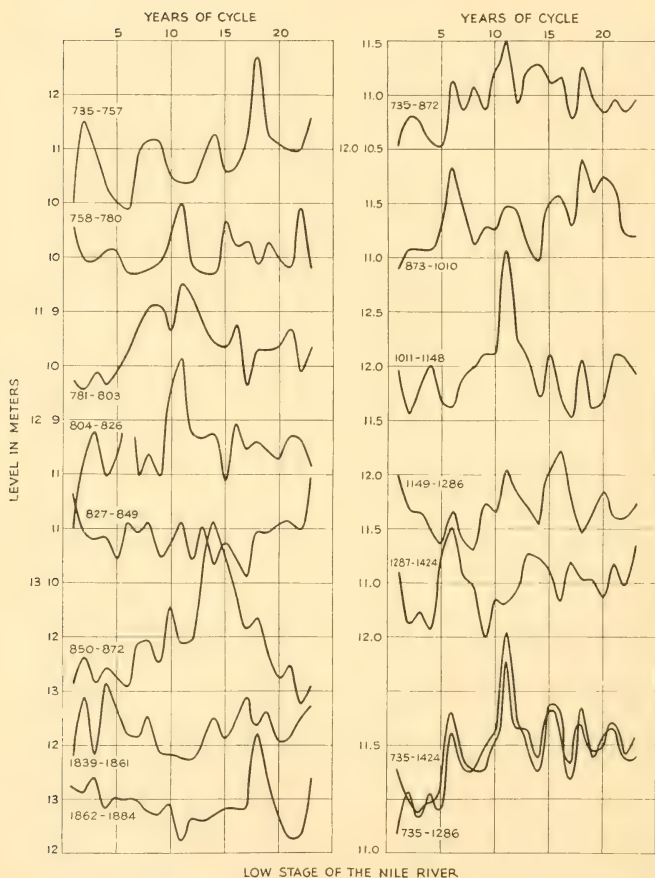
Fig. 28.—Low-level stages of the Nile River. Showing 23-year periodicity, A. D. 725-1424, and A. D. 1839-1885. See description in text.

23 years, or a mutation of phase due to unknown causes. But the individual 23-year cycles in both the eighth century and the nineteenth century show much similarity. Fortunately, they differ but little from being in step with the important date 1819. This adds interest to the apparent inversion of phase shown by cycles 1, 2 ; 4, 5 ; and 5, 6 of the early period. Figure 28 also includes five mean curves, each one the mean of 138 years or six successive 23-year cycles. Finally curves are given to represent the general mean forms of the 23-year cycle for 542 years and 690 years of observation, respectively. These latter means are taken separately, because the 138-year period ending in 1424 seems to show a change of phase tending to approach the form of cycles which prevailed from 1839 to 1884.

The general result seems to be that the Nile, before its regulation by British engineering works, showed plainly the influence of the 23-year cycle. During the 690 years preceding 1424, the average range of the low level during the 23-year cycle was about 1 meter. The extreme range of the original values during any of those centuries seldom exceeded 2½ meters, so that a very large part of it was due to the 23-year cycle. Maxima and minima repeated themselves so nearly in phase throughout the interval of 552 years from 735 to 1286 that the cycle can hardly differ by as much as 1 month from 23 years.

22. A Test of the 23-Year Cycle in the Widths of Tree Rings

In the appendices to his " Climatic Cycles and Tree Growth," Volumes 1 and 2, A. E. Douglass gives many tables of measurements of the widths of tree rings from many localities. In volume 1, pp. 117-123, we find two records of Sequoia trees, the first of 1 to 4 trees extending from 1306 B. C. to 251 B. C., the second of 11 trees extending from 274 B. C. to A. D. 1910.

I have arranged most of these data in tables of 23 columns and 5 lines, each table covering 115 consecutive years. Each group of trees just referred to gave the same general type of result, namely: At the first part of each Douglass table, where the rings are wide, there is a well-marked indication of a periodicity of 23 years, as determined from my tables of 115 years' duration. But the amplitudes of the curves diminish as time goes on. After two or three centuries, when the rings become much narrower, the 23-year periodicity practically disappears. The same thing is also observed with the long Flagstaff table, 1390-1911, found in volume 1 on page 113.

Figure 29, which contains but a few examples of my results, illustrates the preceding statements. It seems but a reasonable considera-
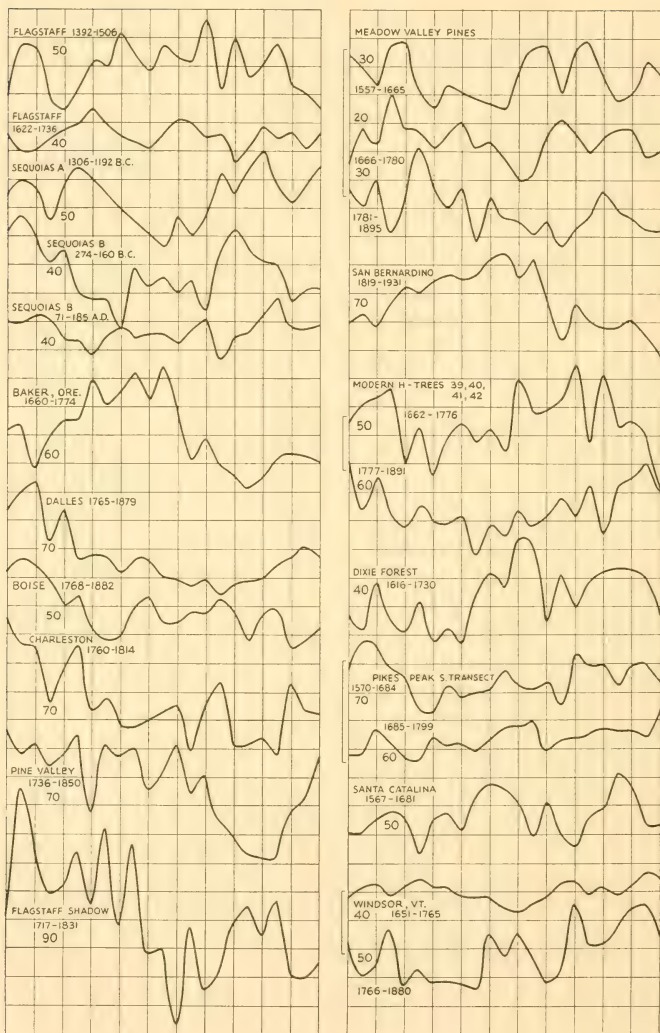
Fig. 29.—Cycles of 23 years in tree-ring widths. Average results of 115-year intervals. Numbers indicate percentage ranges of mean values representing 115 years. Note successive curves at Meadow Valley, Modern H, Pikes Peak, and Windsor.

tion that while a tree is young, with its roots shallow and but little extended, the water supply on which growth so largely depends would respond more directly to periodic changes in precipitation than when the tree becomes very old, with a widely extended root system, possibly tapping never failing sources of water supply at a considerable distance from its trunk.

With this view in mind, I have for the most part restricted this investigation of 23-year periodicity, and the illustrative curves to which I shall refer, so as merely to present periodic changes in the widths of tree rings from about 20 selected localities from which wide rings at the top of a Douglass table led down in a century or two to much narrower rings. In these cases it seemed most probable that his measurements had to do with young trees.

Figures 29 and 30 give the results of these investigations. It appears that in all of these cases, tabulations extending over 115 years indicated changes of tree-ring width during 23-year cycles ranging between 40 and 120 percent, and with such definiteness of gradation, from low to high and return, as seems in harmony with the idea of periodicities of 23 years in the water supply on which the tree growth depended.

In another investigation of this subject I have kept each 23-year cycle by itself, but have combined the results from five localities in southern California and Nevada. In that way I have determined individually the march of four successive 23-year cycles from 1829 to 1920 as represented by the average thickness of the rings of about 40 trees from five separate localities. Figure 30 shows these results. Not only is a 23-year cycle apparent, but many details are reproduced with such moderate alterations of phase and amplitude as to give reasonable certainty of the veridity of these minor features in all four cycles. As remarked above, the amplitudes of these features which compose the cycles tend to diminish as the trees grow older.

23. A Test of the 23-Year Cycle in Pleistocene Varves

In a paper by C. A. Reeds,[14] he gives many pages of illustrations representing the march of the thickness of glacial varves near the Connecticut and Hackensack Rivers. Independent measurements by Antevs and Reeds are shown. Continuous series represent the present thicknesses of these varves resulting, it is believed, from annual weather-reactions extending in unbroken sequence for nearly 1,000 years.

[14] Ann. Rep. Smithsonian Inst. 1930, pp. 295-326, 1931.
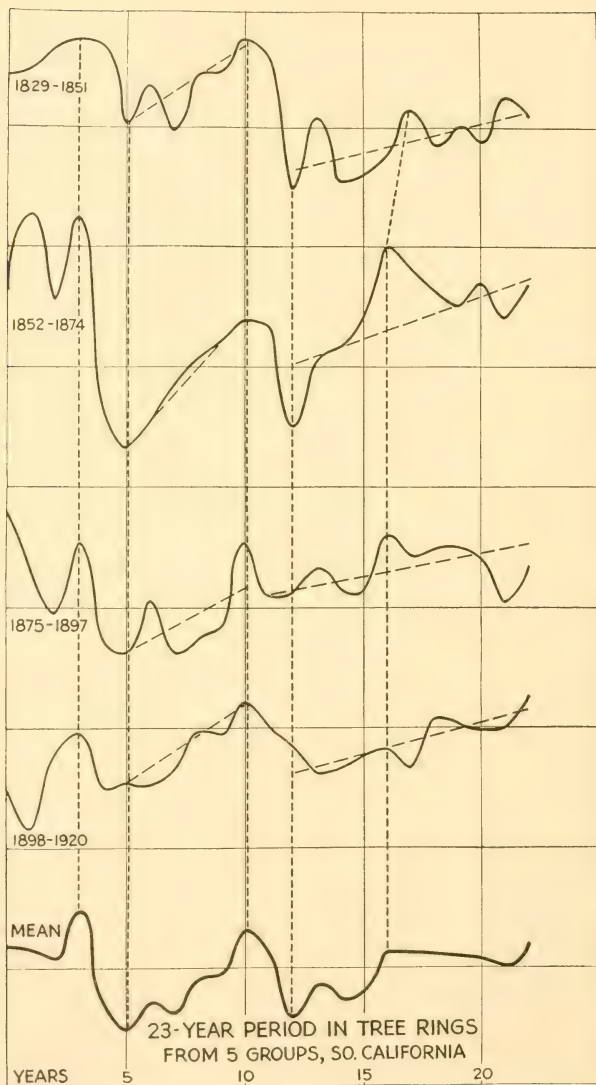
Fig. 30.—Cycles of 23 years in tree-ring widths. Individual cycles of 23 years show features which are found preserved in the mean of four cycles, or 92 years.

The varves are supposed to have been formed as follows: During Pleistocene glaciation considerable melting of the surface of the ice, as well as copious rainfall, took place during the summer of each year. This produced glacial torrents which scoured the sides of the glacial valleys and carried down sediment. Settling occurred in the quiet lakes which at the foot of the glacier intercepted the torrential flow. In such settling the coarser particles reached bottom first, and the finer particles were superposed thereon. The settling took place mainly in the colder months after the melting had greatly diminished and snow rather than rain fell, so that the turbulent streams nearly ceased. In this way each year a layer of sediment was deposited, coarser at bottom, finer above, and layer after layer formed as the years succeeded each other.

Many thousand years have since passed. Many variations of pressure, of hardness, of exposure, and of still other factors must be supposed to have affected the thickness of varves, besides the warmth and the rainfall, of which we are now to invoke them as the witnesses. Hence we can not hope to find the 23-year cycle very sharply defined in varve thicknesses. But it may be that by taking the mean values over intervals of 115 years, covering five cycles each, as was done with the tree-ring measurements, interesting results will appear.

With this anticipation I read off from Reeds' plots the thickness of varves for a continuous interval of 575 years, and arranged the values in five tables of 23 columns and 5 lines each. In figure 31, I give the results of that investigation. It seems to show that in Pleistocene time, as now, a 23-year cycle in temperature and rainfall resulted from the summations of the effects of periodic variations of the sun. Eight crests which appear in the general mean seem to be present almost without exception in very nearly the same phase in the five constituent curves. The range of values plotted in the general mean curve, F, is from 1.44 to 2.00, a range of 40 percent. The range in curve A is from 1.02 to 2.22, a range of 120 percent.

24. A Test of the 23-Year Cycle in Eocene Varves and Tree Rings

Dr. Wilmot H. Bradley, United States Geological Survey, was so good as to furnish me with several sets of measures of varves and tree rings relating to Eocene times. These data included a continuous series of varves from the Green River formation, Parachute Creek, Colo. They appear to have been formed by the annual expansion and drying up of a lake bed. These varves each presented
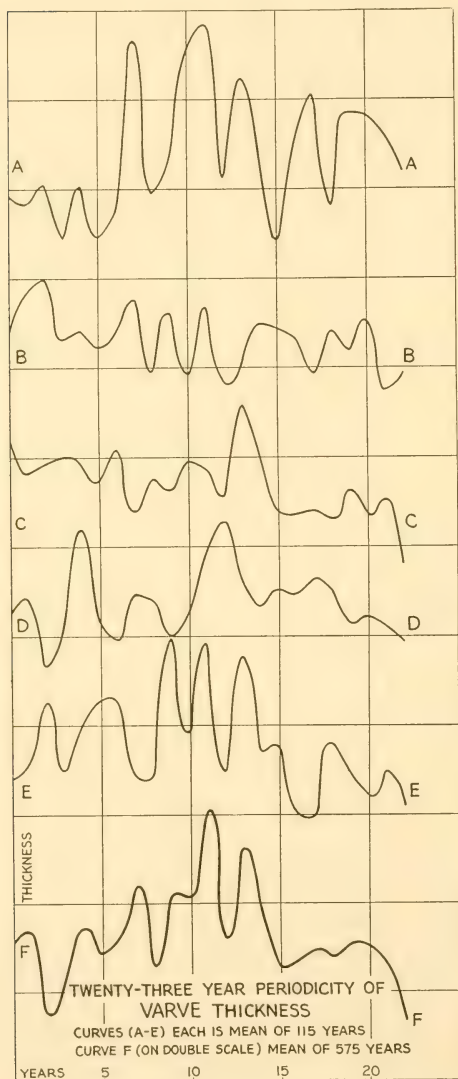
Fig. 31.—Cycles of 23 years in Pleistocene varves.
Average results of 115-year intervals.

two fairly well differentiated layers, one rich in organic material, the other in mineral substance. The measurements give the thickness of each part, and I have also added them to give the total thickness.

Dr. Bradley remarks that " the organic-rich portion of each varve represents the material derived from the plankton produced in the lake each summer, and as the volume of the plankton varies directly with the amount of sunlight and the temperature (assuming an adequate food supply) it seems reasonable to expect a correlation with variations in solar energy. . . . . The mineral-rich layers consist largely of carbonate, and therefore may also be expected to vary in thickness with the temperature of the lake water."

Figure 32 gives a 23-year analysis of these data. Five successive cycles of the march of the total thickness of the varves are given, and the general mean of them all, covering 115 years. In addition, I give the general mean for the 115 years of the thicknesses of the organic and inorganic parts separately. All three mean curves show a similar march, including certain details. All appear to show not only the 23-year cycle, but the approximately $11\frac{1}{2}$ year cycle as well, though with alternately slightly longer and shorter intervals. The ranges of the mean curves are about 100 percent.

Dr. Bradley also furnished measurements of the widths of the annual rings extending from the center to the bark in a fossil coniferous tree of late Green River Eocene age. There were 107 successive rings measured. On arranging the data in 23-year cycles, they proved inharmonious to this arrangement. On rearranging them in five cycles of $21\frac{1}{2}$ years, the result shown in figure 32 was found. In this arrangement the first two cycles are discordant, but the last three, covering over 60 years show a beautiful accord. May it not be that during some part of the Eocene, lasting millions of years, the unknown forces which govern the periodicities in solar variation acted more vigorously than in other parts of the Eocene, the Pleistocene, or the Recent?

25. A Weather Test of the 23-Year Hypothesis

As stated under caption 9 departures from normal monthly temperature and rainfall and 5-month traveling means therefrom have been computed from " World Weather Records." These relate to more than 100 stations in many parts of the world. The departures were smoothed by 5-month traveling means in order to eliminate such rapid and abrupt fluctuations as would obscure principal trends. Lack of funds prevents the publication of these valuable data.

It follows that should the working hypothesis outlined in caption 17 be a true one, then such a series of departures from normal tempera-

Fig. 32.—Cycles disclosed in varves and tree rings of Eocene age.

ture or from normal rainfall as just described must show numerous features during any 23-year cycle which would tend more or less strongly to be reproduced in each succeeding 23-year cycle. To test this probability, the data on departures from normals of temperature and precipitation for all available stations were plotted on sheets of specially prepared plotting paper. These sheets were ruled in abscissae to represent 276 months or 23 complete years, and in ordinates to present 300 millimeters, or 30 centimeters.

As an illustration, figures 33 and 34 present the percentage precipitation of Peoria, Ill., and the temperature departures of New York City. Features thought to be common in successive 23-year periods are indicated on the curves by letters. Principal trends are also to be observed. A dotted continuation of the last line of the plot covers the years 1934, 1935, and 1936. This continuation represents the mean expectation as based on former cycles. As the features in former cycles show considerable differences, such a mean can only roughly indicate their future forms. The method of drawing the mean which is the most probable expectancy may be clearly understood by observing the faint construction lines above and below the dotted continuation. Similar continuations for 1934, 1935, and 1936 were drawn before the events occurred, and may be regarded as forecasts for both precipitation and temperature for over 30 stations in the United States.

A year having elapsed, the actual departures of temperature and precipitation for all of these stations just mentioned were computed and smoothed by 5-month traveling means. These observed results for 1934 were plotted alongside of the predicted values for 1934. By inspection the agreement was then classified as " Excellent," " Fair," " Half and half," or " Bad." Under this classification the cities were grouped as follows :

A. *Temperature.*

Excellent, 7 :   Eastport, Key West, Detroit, Salt Lake, Helena, Portland, San Diego.

Fair, 17 :   Albany, New York, Washington, Hatteras, Mobile, Nashville, Cincinnati, Chicago, St. Paul, St. Louis, Omaha, Bismarck, Cheyenne, Denver, Santa Fe, Red Bluff, Spokane.

Half and half, 3 :   New Haven, Galveston, North Platte.

Bad, 4 :   Charleston, Little Rock, Abilene, San Francisco.

B. *Precipitation.*

Excellent, 11 :   Eastport, Burlington, New York, Detroit, Chicago, Duluth, St. Paul, St. Louis, Little Rock, North Platte, Bismarck.
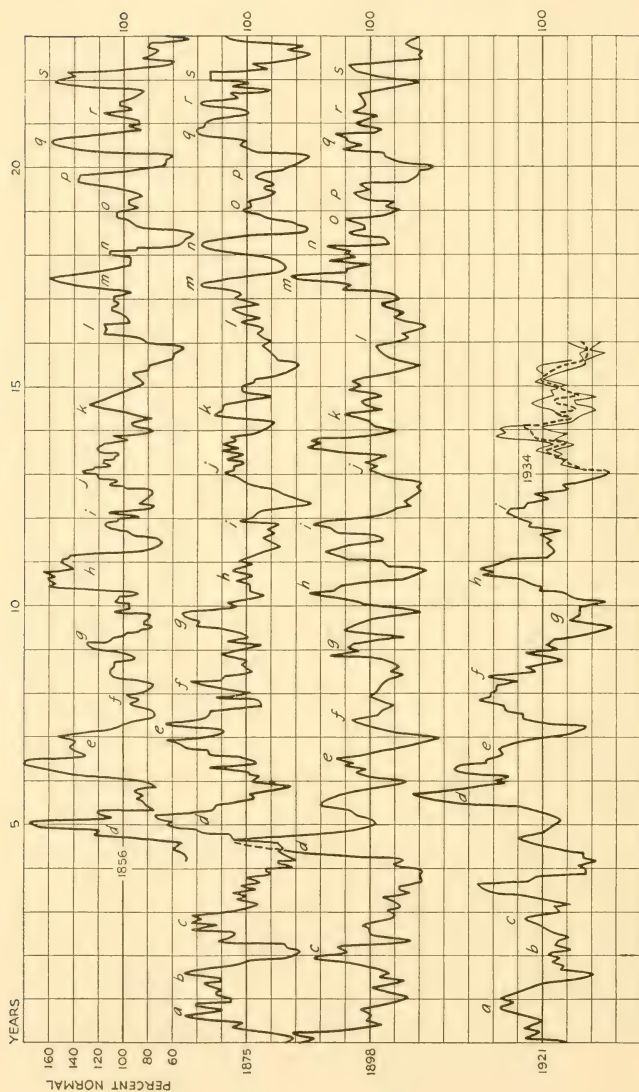
FIG. 33.—The 23-year cycle in the precipitation of Peoria, Ill. Years 1934, 1935, 1936 predicted from previous data, and expressed by the dotted curve. Corresponding features in the several curves are marked by corresponding letters.
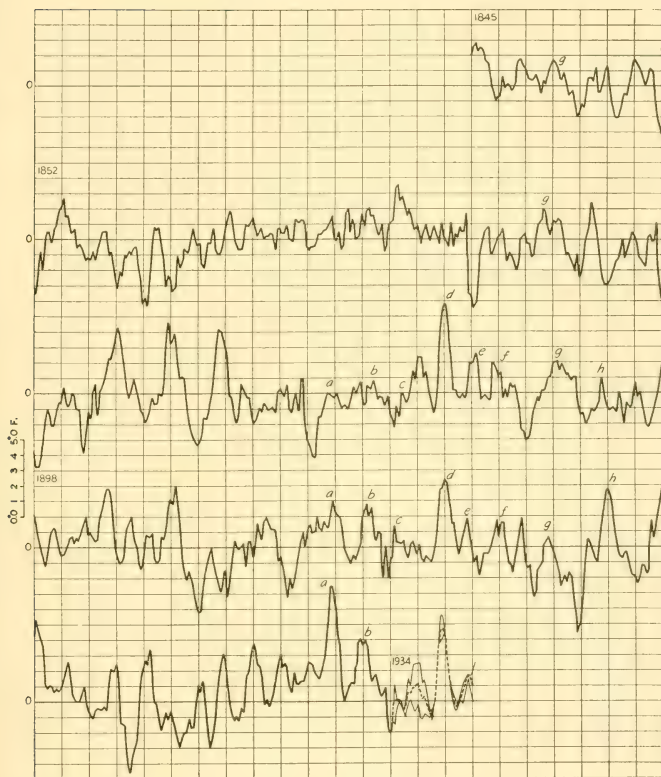
Fig. 34.—The 23-year cycle in the temperature departures of New York City. Years 1934, 1935, 1936 predicted from previous data and expressed by the dotted curve. Corresponding features in the several curves are marked by corresponding letters.

Fair, 11 : New Haven, Albany, Philadelphia, Washington, Charles-
                ton, Peoria, Galveston, Santa Fe, Denver, San Fran-
                cisco, Spokane.
Half and Half, 8 : Key West, Cincinnati, Omaha, Helena, Salt Lake,
                San Diego, Red Bluff, Portland.
Bad, 5 : Hatteras, Mobile, Nashville, Abilene, Cheyenne.

In order to give the reader a fair idea of this system of ranking
these forecasts, I present in figure 35 a sample prediction and verifica-
tion during 1934 from each group named above.

As a further comment on the basis on which these predictions rest,
I refer again to figures 33 and 34 which show precipitation and tem-
perature departures arranged in 23-year cycles. It is observed, as
illustrated in figure 34 and as might be expected in view of caption
14-g, above, that frequently the resemblance is closer between cycles
separated by 46 years, than by those separated by 23 years.[15] Changes
of phase and of amplitude certainly exist between repetitions of the
characteristic features which comprise a 23-year cycle. These must
indeed have been expected in view of the discussion given above of
the periodicities in the departures at Berlin and other stations. Never-
theless, in the preparation of nearly 70 three-year predictions, above
mentioned, the conviction was steadily deepened that many features
may nearly always be recognized in successive 23-year cycles.

Owing to the great financial importance which these predictions
would assume if they could be regarded as trustworthy, it has seemed
improper to publish them until the lapse of another year, or even 2
years, shall have proved to what extent they may be relied upon.

Employing only weather data previous to and including 1921, fore-
casts have been made, first for Bismarck, N. Dak., in one continuous
interval from 1922 to 1932, and then by successive steps for Vienna,
Austria, and North Platte, Nebr., in 11 intervals of 1 year each from
1922 to 1932. These forecasts and their verifications are shown in
figures 36 and 37.

26. Causes

Evidence has been presented which seems to show that the radiation
of the sun varies in a complex mode comprised of the summation of
12 or more periodicities, all of which are integral submultiples of
23 years. Corresponding periodicities have been traced in weather, and
several other weather periodicities have been found which are also
integral submultiples of 23 years. Inversions, or at least major changes
in form, phase, or amplitude, have been disclosed in the periodicities

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[15] Compare the general swing of curves 2 and 4 in figure 34.
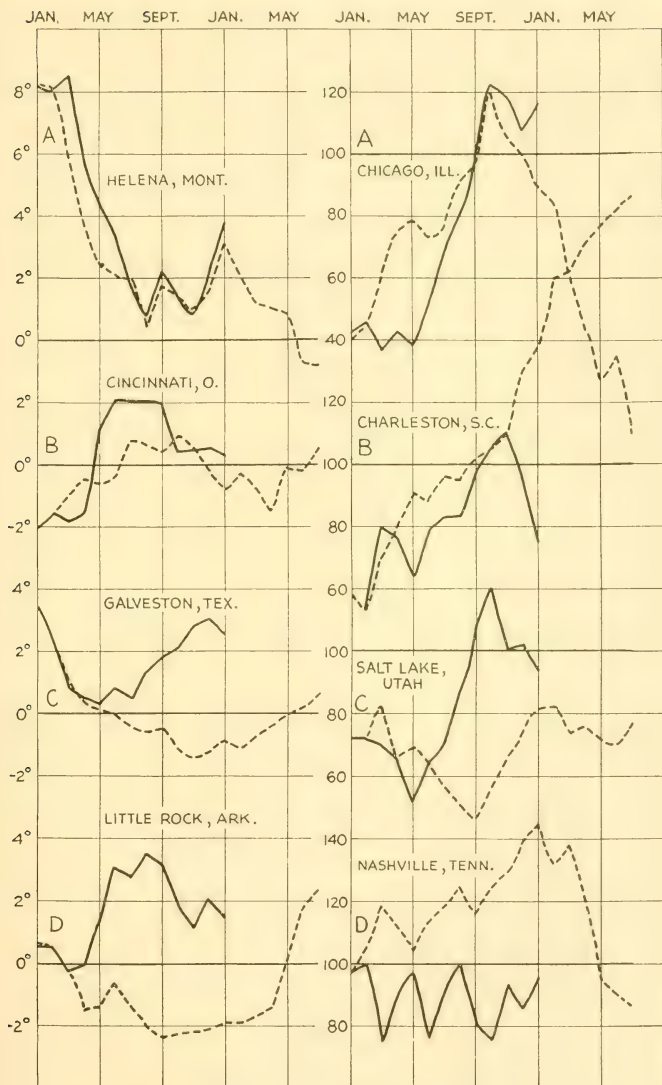
FIG. 35.—Sample forecasts and verifications. Dotted curves are forecasts. Grades of results: A, excellent; B, fair; C, half and half; D, bad. Left, temperature; right, precipitation.
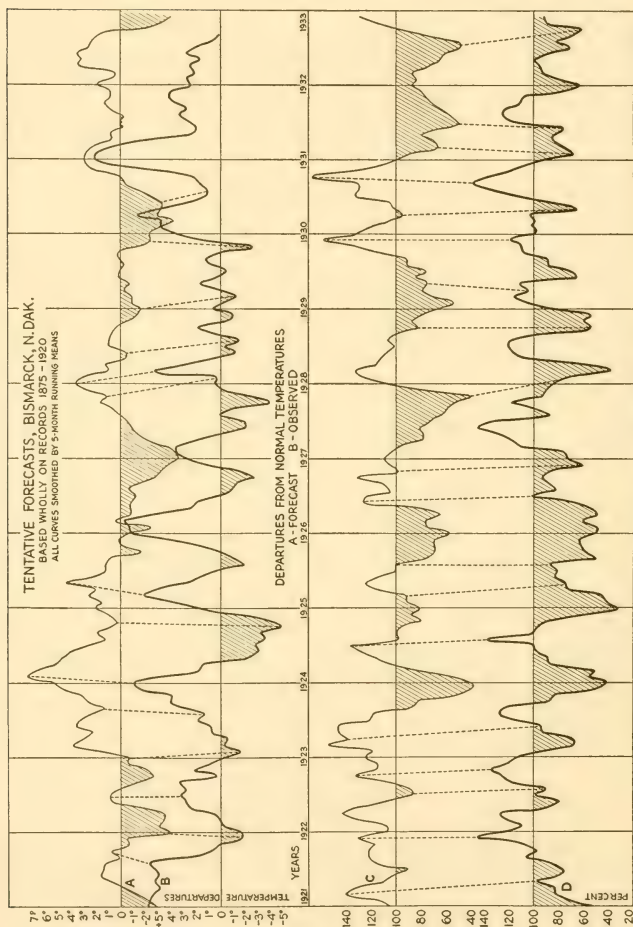
Fig. 36.—Eleven-year forecast for Bismarck, N. Dak., with verification.
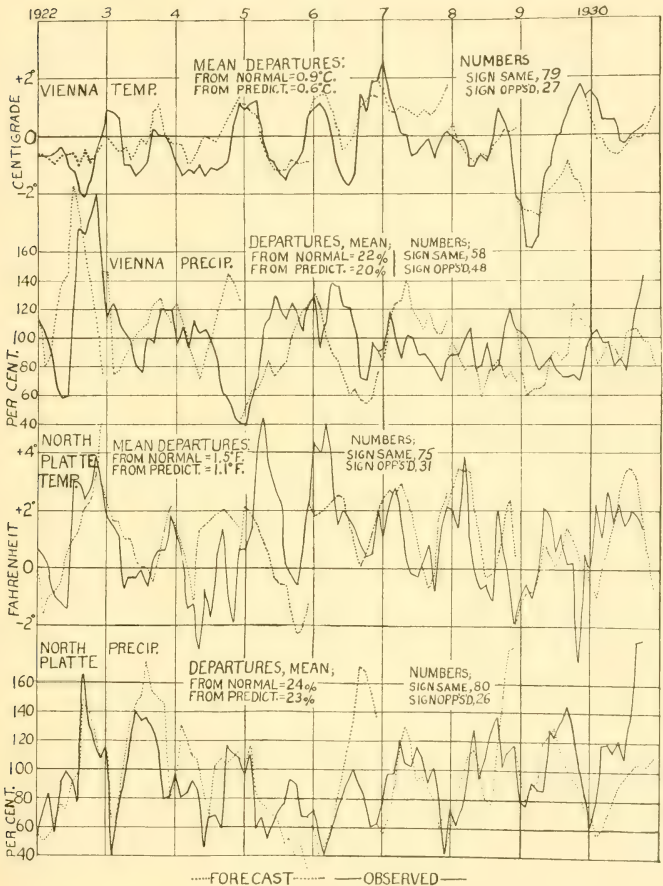
FIG. 37.—Eleven-year forecasts for Vienna, Austria, and North Platte, Nebr., with verifications. Forecasts made step by step.

of weather. These are found to occur at integral multiples of 11½ years measured from January 1819.

These phenomena, if accepted as facts of Nature, propounded to us several problems:

A. Why should the sun, a gaseous body, emit complex pulsations of radiation which are of the nature of a fundamental and 11 or more overtones? A violin string may do this, but why should a gaseous sphere?

B. Why should the terrestrial responses to these pulsations show changes of phase, form, and amplitude at intervals intimately related to the fundamental period of 23 years?

C. Are the terrestrial responses of an order of magnitude reasonably corresponding to the solar impulses?

For question A, I confess that I have no suggestion to offer. I must leave its solution to those theorists who may be convinced by section I of this paper that there is a real body of facts which prove the existence of complex solar variation.

As for question B, the most natural hypothesis is to assume that the phases and amplitudes of the solar periodicities themselves change from time to time at intervals related to 11½ years. Solar-constant observations are not yet of long enough standing to verify this. I have therefore sought to find some helping clue in a regularity of behavior regarding changes of phase among the different stations. In this inquiry I have compared the changes shown by the 8-, 11-, 21-, 25-, and 68-month periodicities in temperature as presented by the various stations Berlin, Copenhagen, Helsingfors, Greenwich, Cape Town, and Adelaide. It seemed superfluous to examine the precipitation which, as meteorologists are aware, is loosely dependent on temperature.

I have devised a sort of shorthand adapted to exhibit the results of this comparison. It is shown in figure 38. At the left of each subfigure will be found the approximate dates of beginning and end of each 11½-year interval for which tabular computations of periodicities were made. Under the names of the stations appear symbols which are designed to represent the types of curves found during the various intervals of 11½ years. These symbols are five in number, but may be combined to indicate that the first half of a curve is of one type, and the second half of another. The symbols are as follows: Numbers 1 and 2 are vertical and horizontal lines. They represent inverted phases of curves of approximately the same form. Numbers 3 and 4 are lines inclined at 45° respectively to the left and the right. They also represent inverted phases of curves of approximately the same form, but of a form essentially differing from that represented
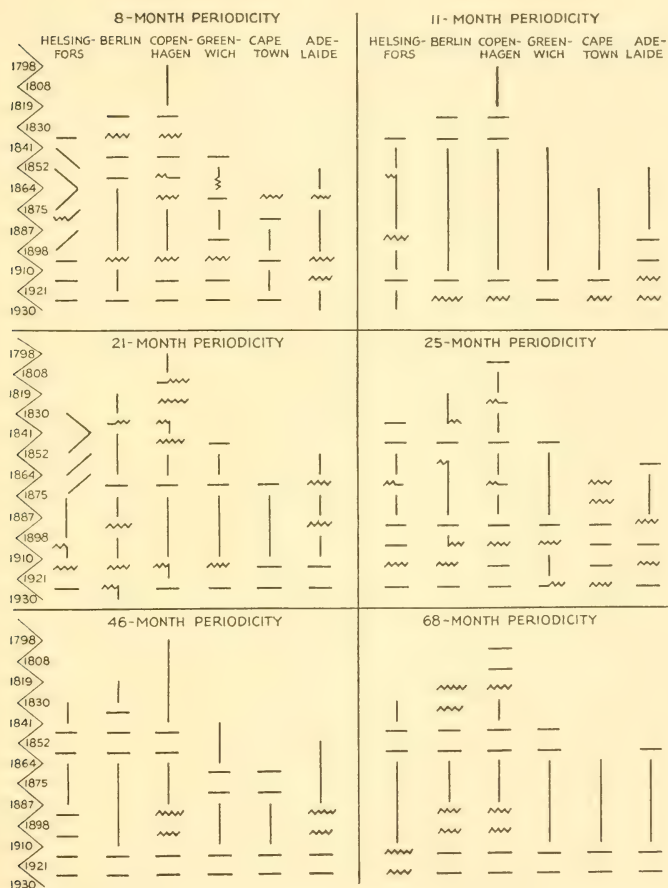
FIG. 38.—Comparison of stations with respect to phase-change of periodicities.

by symbols 1 and 2. Number 5 is a zigzag line. It represents an inde-
terminate form of curve not similar to those represented by 1, 2, 3,
and 4. It is not intended to imply that curves 1 and 2 or 3 and 4 are
always similar in form as between representations of periodicities of
different stations or periodicities of different lengths. It is only im-
plied that all curves 1 and 2 within a single vertical column of the
same subfigure are approximately similar though inverted, and all
those represented as 3 and 4 within a single vertical column of the
same subfigure are approximately similar though inverted.

Owing to local influences, it was not to be expected that complete
harmony would prevail throughout all the subfigures. But if the
changes of phase and form in terrestrial periodicities to which ex-
tended references have been made, are due to radical changes in the
solar radiation, it would naturally be expected that similar mutations
of phase and form would tend to occur in all terrestrial periodicities
and all stations at about the same time.

Figure 38 seems to show that on the whole this expectation is fairly
supported by the facts. Though exceptions occur, there is a prevailing
tendency for inversions to occur in all periodicities and all stations
simultaneously. Thus, for illustration, at the years 1841, 1864, and
1910, reversals or at least major modifications of form occurred in
nearly all cases, and this also frequently happened at the year 1887.
It is believed that the exceptions are neither more numerous nor more
radical than might fairly be attributed to local terrestrial influences
affecting conditions differently at these widely separated stations.

If this conclusion is sound, modifications may well be expected from
the prediction I have ventured of solar variation for the years 1935,
1936, and 1937 as given in figure 7. For on that basis it is very
probable that a radical change in the phases or amplitudes of solar
variation, or in both, will have occurred about 1934, being 115 years
after 1819, and will greatly modify solar variation in subsequent years.
But yet this result might not occur, for at several epochs the terrestrial
periodicities appear to have continued stability for 23 years or even
longer, which might call for a similarly long-lived stability in the solar
variation, and no mutation of it in 1934.

As for the third query, C, let us restrict our investigation to the in-
terval 1920-1930, for it is only then that we have actual observations
of the amplitudes of the periodicities, both of the solar radiation and
the terrestrial temperature. In table 13 I give the amplitudes of the
periodicities expressed in percentages of the solar constant (1.94
calories per square centimeter per minute) and in percentages of
the absolute temperature of the earth, which I take as 290° Centigrade.

TABLE 13.—*Comparison of Solar and Terrestrial Periodicities*

Period in months	Solar		Berlin		Greenwich		Cape Town		Adelaide			Berlin	Greenwich	Cape Town	Adelaide
	Calories	%	Cent.	%	Fahr.	%	Fahr.	%	Fahr.	%					
8	0.004	0.21	0°5	0.17	0°6	0.12	0°6	0.12	0°3⁵	0.07		81	57	57	33
11	9	.47	1.0	.35	0.6⁵	.12	0.2	.04	0.3⁵	.07		75	26	9	15
21	10	.52	1.2	.41	1.8	.31	0.7⁵	.14	1.9	.36		79	60	27	60
25	7	.36	1.6	.55	1.4	.27	1.2	.23	1.4	.27		153	74	64	75
34	7	.36	1.2	.41	0.7	.13	0.5	.10	1.3	.25		114	36	28	70
46	10	.52	1.6	.55	1.2⁵	.24	1.0	.21	1.4	.27		166	46	39	52
68	10	.52	1.2	.41	0.4	.68	0.5	.10	0.8	.15		79	15	19	28
92	10	.52	1.2	.41	1.0	.21	0.6⁵	.12	1.4	.27		79	40	23	52
Mean percentages												96	44	33	50

Ranges in percentage as ratios of solar ratios expressed in percentage

The result of this investigation indicates that the percentage change of terrestrial temperatures is from 33 to 96 percent of the percentage change of solar radiation involved in corresponding periodicities.

It might have been supposed that since the earth radiates approximately as a " black body," the relationship would be governed by Stefan's law, $R = \sigma T^4$. In that case $\dfrac{dR}{R} = \dfrac{4dT}{T}$, and we should expect the percentage temperature ranges to be only 25 percent of the percentage solar ranges. The actual figures deviate from this in the sense of showing larger temperature ranges than would be expected. Yet the discrepancy is not so great that one cannot entertain as an explanation the contributing influence of indirect causes, such as cloudiness, which might produce changes quite as great as the primary direct cause, variation in solar radiation.

SUMMARY

In the foregoing paper I have tried to present within moderate compass a general view of an investigation started by Dr. Langley more than half a century ago, carried on in recent years with the indispensable financial, intellectual, and moral assistance of Mr. John A. Roebling, the National Geographic Society, and others, and now apparently reaching definite conclusions as to the dependence of weather on the variation of the sun.

I am painfully aware that the limitations of space and funds, the extensive mass of evidence on which I base conclusions, my own ineptness in its presentation, and the preoccupation of readers with other concerns must all combine to prevent even the most interested of readers from deriving that vivid conviction of the truth and importance of these conclusions which is shared with me by those of my colleagues and friends who are most conversant with the evidence. Nevertheless, I hope I shall not have failed to convince the reader of the following propositions:

1. The output of radiation of the sun varies, as proved by simultaneous observations at three stations remote from each other.

2. The solar variation, seemingly irregular, really comprises 12 or more regular periodicities, which support successful predictions of solar changes for years in advance.

3. The periodicities in solar variation are integral submultiples of 23 years.

4. These same and other periodicities which are all integral submultiples of 23 years occur in departures from normal temperatures

and precipitations at numerous terrestrial localities. The inference is that solar changes influence weather.

5. Changes of phases and amplitudes occur in these terrestrial periodicities.

6. The changes of phases and amplitudes in these terrestrial periodicities occur at integral multiples of $11\frac{1}{2}$ years measured from January 1819.

7. On account of the integral relationships of the terrestrial periodicities to 23 years, the weather at all stations contains features which tend to repeat themselves at intervals of 23 years.

8. On account of reversals of phase of some of the periodicities at 23-year intervals rather than at $11\frac{1}{2}$-year intervals, some of these features are more accurately reproduced at intervals of 46 years than at those of 23 years.

9. Various phenomena depending on weather show the influence of the 23-year cycle. Among those examined are the level of the Nile River, the levels of the Great Lakes, the rainfall of Southern New England, the widths of tree rings, the abundance of cod and mackerel, the thickness of varves of Pleistocene and Eocene ages.

10. From tabular and graphic representations of departures from the normal in both temperature and precipitation for more than 100 stations, the weather itself has disclosed many features which repeat themselves in cycles of 23 years, and which though obscured by modifications of phase and amplitude may support predictions of future weather conditions.

11. Forecasts based on these relations having been made to cover the years 1934, 1935, and 1936 for more than 30 stations in the United States, these forecasts are fairly well verified both as to temperature and precipitation in 1934.

MELANESIANS AND AUSTRALIANS
AND THE PEOPLING OF AMERICA

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

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CONTENTS

INTRODUCTION

Speculation as to the origin of the American Indians dates from almost the moment of their discovery. It dates more particularly from the voyages of Vespucci, Balboa, and Magellan, which showed that America was a new world with new people. These people, as is well known, were taken by Columbus for the inhabitants of " the Indies ", whence their collective name of " Indians ". When this notion was shown to have been erroneous, there was a general effort to find their derivation; and as there were neither traditions nor any other data on the subject, a mass of opinions gradually accumulated.

The derivation of the American natives came to be attributed by different writers, in the course of time, to one or another of practically all the peoples of the Old World who knew navigation. Gradually, however, most of the initial theories came to be dropped, leaving a small but tenacious residue. Three main hypotheses remained. The first was that the Indians were the descendants of the Ten Lost Tribes of Israel. Lord Kingsborough, as late as the earlier half of the last century, bankrupted himself trying to prove this contention; and there are some who incline to believe thus to this moment. The second opinion, fathered by many, was that America had been reached and populated by various Old World peoples, of different racial origins, such as the Carthaginians, the Norsemen, other Europeans, and the Asiatics. This view gradually changed, on supposed cultural, morphological, and especially linguistic grounds, to a form which will be discussed later. The third hypothesis, upheld as early as 1635 by Brerewood, was that the Indians as a whole were of Asiatic ancestry and related to the Tartars and Mongolians.

It is the second theory, or that of multiple origins, in its present aspects which is to be discussed more especially in this paper. It postulates that more than one race contributed to the original peopling of the American continent, and while conceding the main element to have been northern Asiatic, would bring here contingents of aboriginal man from as far as Polynesia, Melanesia, and Australia. The principal exponent of this thesis at the present time is Rivet, the well-known and able French Americanist.

A brief historical review of the field will be useful.

EARLIER SPECULATIONS

A remarkably sensible opinion on the subject of the origin of the American Indians is met with as early as 1590 in the book of Padre

Acosta, one of the best informed of the earlier authorities on America.
He says:

> It seems to me very probable that there came in times past to the West Indies,
> overcome by strong winds, men who had no thoughts of such a voyage. . . . .
> We may thus assume that the New World commenced to be inhabited by men
> who had been driven there by contrary winds, as in the end happened with the
> discoveries in our own times.[1]

But the presence of various animals on the continent that are also
known in the Old World indicated, Acosta believed, that the land
somewhere in the as yet unexplored far north joined or closely ap-
proached that of the Old World. If this were so, then it would be
easy to resolve the problem of the coming of man. He came not only
over the sea but also traveling by land. This journey, too, was made
without planning, little by little; and thus in the course of time were
filled the lands of the West Indies by so many nations, peoples, and
languages.

His conclusion is that man of the Old World gradually extended
his domain until he reached the New, aided in this by the continuity
or vicinity of land; and that, while there may have been different
ways of peopling the very extensive American territories, the princi-
pal and truest cause of the peopling of the New World was this con-
tinuity or nearness of its land with that of some part of the Old
World.[2]

---

[1] "Assi'que me parece cosa muy verisimil, que ayan en tiempos passados venido
a Indias hombres vencidos de la furia de el viento, sin tener ellos tal pensa-
miento. . . . . Assi qu podriamos pensar, que se commenço a habitar el nuevo
orbe de hombres, a quien la contrariedad del tiempo, y la fuerça del Nortes,
echò alla, como al fino vino descubrirse en nuestros tiempos. . . . . Concluye
pues con dezir, que es bien probable de pensar, que los primeros aportaron a
Indias por naufragio y tempestad de mar." (Pp. 67-68.)

[2] Los primeros pobladores de las Indias "passaron no tanto nauegando por
mar, como cammado por tierra. Y esse camino lo hizieron muy sin pensar,
mudando sitios y tierras su poco a poco. Y unos poblando las ya halladas, otros
buscando otras de nuevo, vinieron por discurso de tiempo a henchir las tierras de
Indias, de tantas naciones, y gentes, y lenguas. . . . . El lineage de los hombres
se vino passando poco a poco, hasta llegar al nuevo orbe, ayudándo a esto
la continuidad o vezindad de las tierras y a tiempos alguna nauegacion; y que
este fue el orden de venir, y no hazer armada de proposito, ni suceder algun
grande naufragio. Aunque tambien pudo auer en parte algo desto: porque siendo
aquestas regiones larguisimas, y auiendo en ellas inumerables naciones, bien
podemos creer, que unos de una suerte, y otros de otra, se vinieron en fin a
poblar. Mas al fin en lo que me resumo es, que el continurase la tierra de
Indias con essotras de el mundo, alomenos estar muy cercanas, ha sido la mas
principal, y mas verdadera razon de poblarse las Indias." (P. 81.)

By 1607, the time of Padre Garcia, another of the older authorities
on the Indians, the opinions as to the origin of the latter are already
legion. He summarizes them under 10 headings as follows (p. 12) :

1. Over the seas (Ophir, Tarsis, and others).
2. Over the seas, accidental (storms, winds).
3. Over the land, or where the New World closely approached the Old,
   in the far north.
4. Carthaginians.
5. The Ten Lost Tribes of Israel.
6. Other Semites.
7. Atlantis.
8. Europe: Old Spanish, Romans, Greeks, Phoenicians, Canaanites.
9. Chinese (especially in Peru), Japanese, Coreans, Tartars.
10. Autochthone; Egyptians, Moors, and other north Africans; Canary Is-
    landers; Ethiopians (Yucatan) ; old French, Celts; English and Irish;
    Courlanders; Troyans; Norwegians, Danes, Germans, Frisians; etc.

Garcia's own opinion is a sort of compound of all the above. He
says:

The Indians proceed neither from one nation or people, nor have they come
from one part alone of the Old World, or by the same road, or at the same
time, in the same way, or for the same reasons; some have probably descended
from the Carthaginians, others from the Ten Lost Tribes and other Israelites,
others from the lost Atlantis, from the Greeks, the Phoenicians, and still others
from the Chinese, Tartars, and other groups.[3, 4]

Others of the more noteworthy earlier authors who have ranged
themselves more or less on the side of multiple origins of the Ameri-

---

[3] " los Indios que oi ai en las Indias Occidentales, i Nuevo Mundo, ni proceden
de una nacion, i Gente, ni à aquellas Partes fueron de sola una de las del
Mundo Viejo, ni tampoco caminaron, ò navegaron para allà los primeros Pob-
ladores por el mismo camino, i viage, ni en un mismo tiempo, ni de una misma
manera, sino que realmente proceden de diversas Naciones, de las quales unos
fueron por Mar, forçados, i hechados de Tormenta, otros sin ella, i con Nave-
gacion, i Arte particular, buscando aquellas Tierras, de que tenian alguna
noticia. Unos caminaron por tierra, buscando aquella, de la qual hallaron hecha
mencion en Autores graves: otros aportando à ella, acaso, ò compelidos de
hambre, ò de Enemigos circumvencinos, o idendo caçando para comer, como
Gente falvagina: . . . . Lo que siento acerca de esto, es, que unos Indios pro-
ceden de Cartaginenses, que . . . . poblaron la Española, Cuba, &c. Otros
proceden de quellos diez Tribus, que se perdieron, ... Otros proceden de la
Gente, que poblò, ò mandò poblar, Ophir en la Nueva-España, i Perú. . . . .
Otros proceden de Gente que viva en la Isla Atlantica de Platon. Otros de
algunos que partieron de las partes proximas i mas cercanas à la sobredicha Isla,
pasaron por ella à las de Barlovento, que estàn bien cerca de donde ella estaba,
i de aquellas à la Tierra firme. . . . . Otros proceden de Griegos. Otros de
Fenicianos. Otros de Chinos, i Tartaros, i otras Naciones. . . . ." (P. 315.)
[4] Shows Latin-like words in Peru (p. 174 et seq.), Greek (pp. 191-192),
Phoenician (p. 253 et seq.).

cans include Milius (1607), Grotius (1642), De Laet (1643), Horn
(1652), Holm (1702), Charlevoix (1744), and Clavigero (1807).
They collectively add little if anything original. But the two last
mentioned, unquestionably the best instructed, though adhering to
American polygeny, each expressed independently a view on the
problem which deserves to be quoted.

Charlevoix (1744) regards the majority of the theories hitherto
advanced as " purely chimerical " and is of the opinion that

nearly all the writers on the subject have based their conjectures on such
ruinous foundations, or had recourse to such frivolous deductions from names,
customs, religion, and languages, that it appears quite as useless to try to refute
the same as to conciliate them with each other. (Vol. 5, p. 2.)

And a similar sentiment is voiced by Clavigero, who says (vol. 2,
p. 205) :

There are authors who, in order to do wrong to no people, believe the
Americans the descendants of all the nations of the world. So great a variety
and extravagance of opinion is owing to a persuasion that, to make one nation
be believed to have sprung from another, no more is necessary than to find
some affinity in the words of their languages, and some similarity in their
rites, customs, and manners.

LATER THEORIES

Scientific work proper on the American Indian commences with
Linné, Buffon, and Blumenbach abroad, and with Jefferson and
Barton in this country. All these write on the subject toward the
end of the eighteenth or beginning of the nineteenth century; and
since then there is a long list of students of man who occupy them-
selves with the problem of American origins. A majority of all these,
particularly those of this continent and who had the broadest experi-
ence with the Indian, although well aware of the multiplicity of types
and tribal variation, incline strongly toward the idea of his general
north- and east-Asiatic affinities. Yet there were and are also other
notions, particularly among European anthropologists, who have had
less extensive direct contact with the Indian.

During the nineteenth and the present centuries polyracial theories
of the origin of the American Indians are advanced not only by
writers such as Coates and Baldwin, but also by a number of pro-
fessional scientific men, among them Quatrefages, Rudolph Virchow,
Rivet, and Corrêa. But the theories change and crystallize in new
directions. The hypotheses of European, north-African and western
Asiatic origins have practically been given up, but new ideas arise and
are strongly supported. Basing their beliefs on apparent linguistic,

cultural, and even some physical resemblances, the later advocates of multiple American origins urge the acceptance of the theory that the Polynesians and Melanesians, and even the Australians, participated in the peopling of North and especially South America.

DOCUMENTARY AND MATERIAL EVIDENCE

The theories that will receive attention in this paper are only those that relate to the presence on the American continent, aside from the introductions through the white man's agencies, of African or Melanesian blacks, and of the Australians.

THE " NEGROES " OF DARIEN AND PERU

The beginnings of the theory of Melanesian migrations into America date far back. According to Pereira (1648), the first opinions to that effect were to be found in Martinez, Ortelio, and other early writers. He says (p. 21) :

The extension, on the south or toward the Antarctic pole and beyond the Straits of Magellan of the land of Patagones, is unknown; but it is held as certain that, cold as these regions must be, they will be found peopled and continuous below the frigid zone. And, we are told by Martinez, Ortelio, and others, they join New Guinea, the Solomon Islands, the outskirts of Peru and the kingdom of Chile. Facilitating thus a transit, the population of and propagation in America were not difficult.

With these old opinions regarding the Melanesians, there are also some early references to " Negroes " on the American continent.

The first to refer to this subject is Peter Martyr, who, writing within 3 years after the discovery of the Pacific by Balboa and using information from letters received from the Isthmus, includes the following unaccredited passage in his *Thyrde Decade:*

There is a region not past two dayes iourney distant from *Quarequa,* in which they founde only blacke Moores [in the original Latin text " Nigritos "] ; and those excedynge fierce and cruell. They suppose that in tyme paste certeyne blacke mores sayled thether owt of *Aethiopia* to robbe : and that by shippewracke or sume other chaunce, they were dryuen to those mountaynes. The inhabitantes of *Quarequa* lyue in continuall warre and debate with these blacke men. (Dec. 3, lib. 1, p. 139.)[5]

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[5] According to Lehmann the Latin text reads : " Mancipia ibi negra repererunt, ex regione distante i Quarèqua dierum spatio tantum duorum, quae solos gignit Nigritos, et eos feroces atque admodum truces. Ex Aethiopia putant traiecisse quondam latrocinii causa Nigritos, inque illis montibus naufregatos fixisse pedem." (P. 330.)

The same " blacks " are later (1552) referred to by Gomara, who says :

In Cuareca Balboa found neither bread nor gold. . . . . Instead he found some Negro slaves of the lord. He asked whence they had them but they could not tell him or understand more than that there were men of that color nearby with whom they carried on regular war. These were the first Negroes seen in the Indies and I believe there were seen no more.[6]

Apparently the same " blacks " are also referred to by Gutiérrez, who, however, gives this version:

In the pueblo Quareta were found two fine Negroes, slaves of señor Thoreca, who were said to have come here in balsas from the west from the south sea that at present is known as New Guinea.[7]

Oviedo, the first official historian of the newly discovered parts of America, who wrote earlier (1535-) than Gomara and who reached Darien personally within less than a year of Balboa's journey across the isthmus, spent a large part of his life in those regions and had direct contacts there with the Indians. He used what Balboa himself had written, consulted with him, and was intimately acquainted with the experiences of the other Spaniards who during his sojourn at Darien overran and exploited the territory. He gives much more numerous details about the natives than does Gomara, but in his account of the events at Darien (Lib. 29) has nothing whatever to say about any Negroes. There is no allusion to such people in the published accounts of any of the other Spanish officials and priests who were then or later in that region.

There is no doubt, of course, that the Darien Indians had slaves or serfs. Oviedo gives interesting and possibly significant information on this point. Speaking of the chiefs of some of the Darien tribes he tells us that:

And the same caciques gave the Spaniards some Indians whom they hold among themselves as slaves, who serve them, and whom they have captured in war that is never wanting among the Indians. They call these slaves *paco*, and each cacique has his slaves branded by a different sign on the arm or face,

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[6] In Cuareca (Isthmus of Panama) Balboa " no halló pan ni oro, que lo habían alzado antes de pelear. Empero halló algunos negros esclavos del señor. Preguntó de dónde los habían, y no le supieron decir o entender mas de que había hombres de aquel color cerca de allí, con quien tenían guerra muy ordinaria. Estos fueron los primeros negros que se vieron en Indias, y aun pienso que no se han visto más." (Vol. 1, chap. 62, p. 143.)

[7] " En el pueblo de Quareta se hallaron dos negros finos, esclauos del señor Thoreca, que señalaron auer venido allí en balsas de hazia el poniente por esta mar del Sur que oy dia se llama la Nueua Guinea." (Vol. 4, chap. 66, p. 573, quoted by Lehmann, p. 331.)

while some mark them by extracting one of their front teeth. Also, the caciques and their subjects paint themselves, and their devices and inventions in this respect are much different from those that they use for their slaves.[8]

The reports of " blacks " in the Panama territory fail also of any corroboration by later writers. In 1901 Vergara y Velasco states that, according to a report of a subchief, there existed in the Cuna district of Darien, until 10 years before, " remnants of an aboriginal population of reduced height, black skin, not exceeding 100 or 200 individuals and entirely savage " ;[9] but as this applies to something existing (if such was the case) nearly four centuries after the introduction of the Negro into the Spanish American possessions, it can at best have but little bearing on the subject under discussion.

Nevertheless, the reports on the Darien " blacks " are evidently taken for facts by De Quatrefages, one of the foremost European anthropologists of his time. As early as 1861, in his " Unité de l'espèce humaine ", Quatrefages says (p. 405) :

> Study of the physical characters leads, hence, to the admission that America has been peopled by emigrants from the Old World and belonging more or less to the three principal races of the same, namely, the white, the yellow, and the black.

On page 413 he refers to the " Negroes " spoken of by Martyr and Gomara. The above thought involves only the African Negro, but in time Quatrefages' view extends. One of the main though not immediate causes of this is the discovery of the Lagoa Santa type of skulls in South America.

Lehmann adds to the above one or two references (p. 331) from hazy legends of pre-Columbian Peru on black-skinned prisoners or slaves; he mentions further the paintings on two pieces of pottery found in the vicinity of Trujillo and pictured by Wiener, which show " dark-colored people who are driven by light-colored ones " building

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[8] " Y los mismos caçiques daban á los españoles algunos indios que entre ellos tienen por esclavos, y se sirven dellos, que los han avido en la guerra, la qual nunca falta entre los indios unos con otros y al ques esclava llámanle *paco*, y cada caçique tiene sus esclavos herrados con su señal diferençiada en el braço ó en la cara, y algunos tienen por señal sacarle al esclavo un diente de los delanteros de la boca. Tambien los caçiques se pintan á sí y á sus indios y gente, y tienen sus divisas é invençiones de pinturas para esto de otra manera, muy diferençiadas de las que usan poner á los esclavos." (Vol. 3, lib. 29, cap. 2, p. 8.)

[9] " Según informes de uno de sus prinzipales jefes, en esas montañas existian hace diez años restos de una población aborigen, de reducida talla, negra la piel, muy escasa en numero (100 à 200) y enteramente salvaje; refería que los Cuna-cunas quitaron à ese pueblo el terreno que hoy ocupan despues de una gran matanza y temen encontrar à alguno dellos que quedaron por creerlos hechiceros y hasta demonios." (Vol. 1, p. 878; quoted by W. Lehmann, p. 331.)

in one case a wall of stones, in the other a wall of bricks. All this, as well as what will follow on the subject of "blacks" in North America, will receive consideration in the critical part of this paper.

THE LAGOA SANTA SKULLS

In 1835-44, in certain caves of the state of Minas Geraes, Brazil, and in association with the bones of extinct as well as still living animals, P. W. Lund, a noted Danish naturalist, found a series of remains of human skeletons.[10]

These remains included 17 or 18 more or less imperfect skulls, one of which came to be preserved in the Historical and Geographical Institute of Brazil, Rio de Janeiro, one—of a child—in the British Museum, and the rest in Copenhagen. They are commented upon, as far as their racial features are concerned, thus by Lund himself (1844) :[11]

If we consider these remains of man from the standpoint of the ethnographic traits which they present, we shall see that all the skulls bear the distinctive features of the American race. . . . . The race which occupied this part of the world in remote antiquity was in its general type the same as that which inhabited the country at the time of the discovery by the Europeans.

In 1876 the skull preserved in Rio de Janeiro is described by Lacerda and Peixoto. Their main conclusion is (pp. 72-73), that the fossil cranium of Lagoa Santa "closely approaches in its characteristics the crania of the Botocudos."

In 1879, on the occasion of the Anthropological Congress in Moscow, Quatrefages presents a communication dealing with the Lagoa Santa discoveries and the Lacerda and Peixoto report on one of the skulls from the cave of Sumidouro. In discussing the characteristics of this skull [12] he calls especial attention to its height. His statements in this connection could not be more explicit, yet in course of time they have been so abused that they deserve to be quoted in full. They are as follows :

By the union of dolichocephaly and hypsistenocephaly the skull of Lagoa Santa approaches in a very unexpected way the skulls of divers other races, and particularly those of the Papuans. The two characteristics are even more accentuated in it than in the average of the Melanesians so well studied by M. Hamy. . . . . In calling attention to these resemblances I intend in no

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[10] For a detailed account of these remains see Hrdlička (1912).

[11] In his important communication to C. C. Rafn, Secretary of the Société Royal des Antiquaires du Nord. See Lund in *Literature Cited*.

[12] The principal measurements of the specimen, which belonged to a male of about 30 years of age, are given thus: Capacity, 1388 cc; diam. ant.-poster., 18.5 cm; transverse max., 12.9 cm; "vertical", 14.5 cm; C. I., 69.7.

way to draw a conclusion as to identity, nor even to a closeness of the races. Their dimensions in the skulls which I compare do not approach each other except in result of the reached compensations. Thus in the Papuans a plane passing from the anterior alveolar border and external occipital protuberance leaves beneath it only a very small portion of the occipital bone. This is different in the skull of Lagoa Santa, in which the inferior occipital region bulges considerably. It is the exceptional development of this portion which compensates for the lowering of the vault and gives to the skull its great height.[13]

To which Quatrefages adds :

In taking here 'the Papuan head for comparison, I do not intend to establish any ethnological relation between the man of Sumidouro and the inhabitants of New Guinea. Hypsistenocephaly is found also in the African Negroes and among the Malaysian populations, but at the moment when I wrote the present memoir, the Papuans were the only ones whose craniological study had been finished. This is why I believed it interesting to point out the characteristics possessed in common by these two human groups so distant in space and in time.[14]

Notwithstanding Quatrefages' clear and most sensible statements, a " Melanesian " suggestion has been made and will insistently be used by later authors in support of their theories.

The next to discuss the Lagoa Santa crania is the anatomist and anthropologist Kollmann (1884). After a study of 11 of the specimens at Copenhagen, his conclusions, so far as the characteristics of the skulls are concerned, are that—

howsoever valuable all these individual features established by means of craniology are, much more significant still is the fact, which must impress itself

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[13] " Par la réunion de la dolichocéphalie et de l'hypsisténocéphalie, la tête de Lagoa-Santa se rapproche d'une manière assez inattendue des têtes de divers autres races et en particulier des têtes papouas. Les deux caractères sont même plus accusés chez elle, que chez la moyenne des Mélanésiens si bien étudiés par M-r Hamy. . . . . En signalant ces ressemblances, je n'entends nullement conclure à une identité, ni même à un voisinage des races. Les chiffres précédents ne se rapprochent que par suite des compensations établies dans les têtes que je compare. Ainsi chez les Papouas un plan passant par le bord alvéolaire antérieur et la protuberence occipitale externe, ne laisse au dessous de lui qu' une très faible portion de l'occipital. Il en est autrement dans le crâne de Lagoa-Santa, où la région occipitale inférieure se renfle considerablement. C'est le dévelopement exceptionnel de cette partie qui compense le surbaissement de la voute et donne au crâne sa grande hauteur." (Pp. 329-330.)

[14] " En prenant ici la tête papouas pour terme de comparaison, je n'entends établir d'ailleurs aucun rapport ethnologique entre l'homme du Sumidouro et les habitants de la Nouvelle Guinée. L'hypsisténocéphalie se retrouve chez les nègres africains, chez les populations malaisiennes, mais au moment, où je redigeais le mémoire actuel, les papouas étaient les seuls dont l'étude craniologique fut terminée. Voila pourquoi j'ai cru interessant de signaler la communauté de caractères existant entre ces groupes humains si distant dans l'espace et dans le temps." (Footnote 2, p. 329.)

upon everyone, that the skulls from Lagoa Santa have the character of American crania, the racial features of the still-living Indians. (Pp. 198-199.)

In 1885 a succinct report on his study of the whole collection of the Lagoa Santa crania preserved at Copenhagen is published by Ten Kate. After showing that these skulls are not as uniform as has been represented by Kollmann, who did not study quite all the specimens, the author says:

I accept willingly the view that the skulls of Lagoa Santa offer close analogies with other American series, notably with the Botocudos and natives of Lower California. (P. 243.)

The year 1888 sees the publication by the Lund Museum of a volume of the Danish studies on the Lagoa Santa remains, and this includes communications on the human bones by Lütken and Hansen.

Lütken, in an excellent exposition of the subject, is justly skeptical as to the great antiquity of the remains and avoids all speculation as to their racial affinities. In the same volume, however, Hansen publishes an exhaustive study of the Lagoa Santa human skeletal remains that are preserved in Copenhagen, and though he has no Melanesian materials for comparison, he accentuates Quatrefages' suggestion as to the resemblance of the Lagoa Santa skulls and bones to those of the Papuans. He says: The type of the skulls "corresponds perfectly to the Papuan type, a fact already announced by M. de Quatrefages in connection with the skull of Rio, but still more pronounced when one considers the whole series"; and, "The bones of the limbs indicate a small or medium stature but robust [body], a new resemblance with the Papuans." [25]

Meanwhile, some especially interesting discoveries, which eventually give the theory of Oceanic blacks in America a certain standing, are reported from Lower California.

THE SKELETAL REMAINS OF LOWER CALIFORNIA

The finds in Lower California were initiated in 1883 by the visit to that region of one of the foremost students of the American natives of the latter part of the past century, Dr. Ten Kate. Part of the results of this trip was the collection, from caves on the island of Espiritu Santo and the neighboring coast, of seven skulls and a small series of other parts of the skeleton. In the caves the bones lay

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[25] " Ce type correspond parfaitement au type Papou, fait déjà signalé par M. de Quatrefages pour le crâne de Río, mais encore plus prononcé si l'on regarde toute la série au lieu de la seule pièce qu'il connût. . . . . Les os des membres indiquent une stature petite ou moyenne mais très forte, ressemblance nouvelle avec les Papous." (P. 36.)

either free and mixed on the floor or were inhumed at but a slight
depth from the surface. These remains were reported upon in 1884.

The main feature of the skulls is the exceptionally narrow and high
vault. In various respects they resemble the skulls of the Melanesians,
though they are even more dolichocephalic, but in others they resemble
those of some American Indians. Ten Kate says further: " I have
nothing in my collection of Lower California that would remind me
of more or less Melanesian types *in the living*. All the individuals I
saw had the characteristics of the various mixbloods and Indians that
are found in Mexico in general." [16], [17] To which he adds: The old
authors, speaking of the Indians of the Peninsula, say that " these
much resembled other ' Mexicans ', and that there were large differ-
ences in stature and skin color. . . . . I have seen but two individuals
reputedly legitimate Indians, an old lady who was of a noted Indian
type such as may be found in almost any part of Mexico ", and a man,
of uncertain derivation. And if these two were Indians, " then surely
there are still to the south of La Paz many Indians, such as those
I met on the road and who call themselves ' gente de razon ' and con-
sequently Catholics, who presented Indian types much more marked
than those of the above two individuals."

The main conclusions of Ten Kate in this article (1884) have been
so misrepresented that they must here be quoted in the original.
They are:

1. Il existait, dans la partie australe de la presqu'île californienne et les îles
de la côte avoisinante, une race indigène dont le cractère le plus frappant est
la réunion de la dolichocéphalie et l'hypsisténocéphalie;

2. Cette race se rapproche d'une côté des Mélanésiens; d'un autre côté,
des races américaines se rapprochant le plus de la race dolichocéphale dont
le type de Lagoa Santa est le représentant le plus ancien;

3. La race de la presqu'île de la dite morphologie céphalique était d'une
taille un peu au-dessus de la moyenne (1^m, 65 environ). (Pp. 568-569).

In 1887 Ten Kate published in Mexico a second and similar paper
on the anthropology of Lower California. After giving the measure-
ments of the seven skulls dealt with in his earlier report, and of some

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[16] " Je n'ai rien dans mes souvenirs de la basse Californie qui me rappelle des
types plus ou moins mélanésiens observés *sur le vivant*. Tous les indivdus
que j'ai vus avaient les traits de métis et d'Indiens si variés que l'on trouve
au Mexique en général."

[17] " Plusieurs de ces caractères se trouvent plus ou moins prononcés sur des
crânes mélanésiens et à en juger d'après l'impression générale de notre série,
on croirait avoir affaire à des Mélanésiens. . . . . Les auteurs anciens ne nous
décrivent pas le type des Péricués en particulier, mais bien celui des Indiens
de la péninsule en général. Ils disent qu'ils ressemblent beaucoup aux autres
' Mexicains ' et qu'il y avait de grandes différences de taille et de couleur de
la peau. Baegert a observé évidemment l'oeil bridé chez les Guaycuri."

bones, he says once more: " Many of these characters of the skulls are encountered, more or less marked, in Melanesian skulls, and to judge from the general impression of our series it might be believed that we were dealing with Melanesians." However, (p. 14) " if on one hand our Californian skulls offer similarities with the Melanesians, on the other they possess similar characters with those of certain American series ", especially such as those of the Botocudo, the Patagonians, and the ancient Lagoa Santa group.

In 1888 Ten Kate publishes in Science an excellent critique of the paper in which Dr. Brinton attempted to deny the Mongoloid affinity of the American Indians. In this critique, based on extensive personal observations among both the North and the South American tribes, he unequivocally asserts his conviction of such an affinity, and has no word to say about the possibility of any other racial constituents on the continent.

In 1887 and 1889 the field is entered, once more, by Quatrefages. In these years he publishes two volumes on the " Histoire générale des races humaines ". In the first volume (1887) he makes no reference to any Melanesian element in the region of Lagoa Santa or anywhere else in South America, but believes (pp. 145-146) that the Melanesian Negroes " have reached on one side Easter Island and on the other even California ". His map of human migrations in the Pacific (opp. p. 144) fails also to show any oceanic human stream advancing beyond Easter Island toward South America. In the second volume, however, published in 1889, there are a number of references to Melanesian elements in the New World. So far as South America is concerned, but little is said in this connection, and that little is very vague or even negative; but there are some positive statements as to California.

On page 308 of this volume we read: The characteristics of the Lagoa Santa skulls " might make us think that the fossil race of Brazil belonged to the Negro type. But in the special memoir which I have devoted to the subject I have already stated that such an approach should be discarded." [18] He adds in the next paragraph:

In reality, among the present populations there are those that have preserved in a remarkable manner the craniological type of Lagoa Santa and are evidently

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[18] " Des recherches encore inédits, que M. Hansen a bien voulu me communiquer, il résulte que la race américaine de Lagoa-Santa est bien décidément à la fois dolichocéphale et hypsisténocephale. En outre, la phototype que nous devons à MM. Lacerda et Peixoto nous la montre comme présentant un prognathisme très accusé. Au premier abord, la réunion de ces trois caractères pourrait faire penser que la race fossile du brésil se rattachait au type nègre. Mais dans le mémoire spécial que je lui ai consacré, j'ai déjà signalé ce rapprochement comme devant être écarté."

representatives, at times but very little admixed, of this race. But none of these resemble the Negro in the general aspect, in color, in the hair, etc., while a large quantity of evidence shows them by all the external characteristics to be very close to certain of the yellow races.[19]

Struck by the resemblance of the dolicho-hypsistenocephalic skull type to that of the Eskimo, Quatrefages suggests that " the race of Lagoa Santa, as far as can be judged from the data we possess, might be considered as a simple group of the Eskimoid family." [20]

Other references to the Oceanic blacks in this volume are as follows:

The blacks played but a small rôle in the constitution of the American races.[21]

The arrival of the Papuans in New Zealand and especially in California was incidental and

due, very probably, to some accident on the seas, to the carrying away of some canoes by the currents of New-Holland or the Kouro Sivo.[22]

In Malaysia, the black element, so easy of recognition when pure, shows its intervention even after much crossing. In America, this element has disappeared everywhere, except in a very few and circumscribed localities.[23]

The three fundamental types of humanity [white, yellow, black] are encountered therefore in America, as in Malaysia.[24]

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[19] " En effet, parmi les populations actuelles, il en est qui ont conservé d'une manière remarquable le type craniologique de Lagoa-Santa et sont évidemment les représentants parfois assez peu métissés de cette race. Or, aucune d'elles ne ressemble au Nègre par le facies général, par le teint, par la chevelure, etc.; tandis qu'une foule de documents nous les montre comme étant très voisines de certaines races jaunes par tour leurs caractères extérieurs. C'est donc parmi les représentants de ce type qu'il faut chercher des affinités ethniques reliant les tribus fossiles à leurs descendants." (Pp. 308-309.)

[20] " La race de Lagoa Santa, à en juger par les documents dont nous disposons, pourrait être considérée comme un simple groupe de la famille esqui-male." (P. 310.)

[21] " Les Noirs n'ont été que pour très peu de chose dans la constitution des races américaines." (P. 335.)

[22] " On ne saurait, je pense, attribuer en entier l'expansion des Papouas à l'initiative et à l'activité volontaire de ces insulaires. Leur arrivée à la Nouvelle-Zélande et surtout en Californie est due, bien probablement, à quelque accident de mer, à l'entraîntement de quelques canots par le courant de la Nouvelle-Hollande et par le Kouro-Sivo." (P. 360.)

[23] " En Malaisie, l'élément noir, si facile à reconnaître lorsqu'il est pur, accuse son intervention même après de nombreux croisements. En Amérique, cet élément disparaît de partout, sauf sur un très petit nombre de points extrêmement circonscrits." (P. 550.)

[24] " Les trois types fondamentaux de l'humanité se sont donc rencontrés en Amérique comme en Malaisie." (P. 551.)

On pages 550-552 Quatrefages, now seriously influenced by the
Ten Kate finds in Lower California, thus summarizes his views on
the subject:

On the whole, America appears to have been peopled, for the larger part,
by immigrants connected more or less with the yellow stem. Relations of all
kinds existing between American aborigines and different Asiatic groups
have been noted many times by a multitude of travelers who have seen and
compared the two races. The European anthropologists have been able on
different occasions to recognize the exactness of these relations.

Notwithstanding this he believes that there also came to the
American coasts, through accidents of the sea, some blacks from the
South Seas. And these blacks

have not all remained on the coasts. Some of their tribes have penetrated
considerably into the interior of the continent. The ethnological map of M.
Powers shows that the tribe of the Achomawis, among others, reached the
Sierra Nevada and confines of the Shoshones. Judging from the following
statement, which I take from Schoolcraft, they reached much beyond this and
farther to the south. In 1775 the Padre Francisco Garcés visited Zuñi, one of
the southernmost pueblos, and found there two races of men and two languages.
One part of the inhabitants showed a clear red color and handsome features;
the others were black and ugly. An instructed native, interrogated on the
subject, replied that the red people had come from one of the pueblos that
became ruined, while the blacks were the ancient inhabitants of the country.
Thus at least at this point the Papuas, represented doubtless by mixbloods, have
preceded the Pueblos, as they have preceded the Maoris in New Zealand. . . . .

I have mentioned before the little that one can attribute to the African
Negroes, and I do not return to that part. As to the Melanesian blacks,
their rôle, although circumscribed, has been much more considerable. Already,
the details given by La Pérouse on the natives in the environs of Monterey
authorize plainly the admission that a black element had at least modified at
that point the color of the local races. The information which we owe to
Stephen Powers on several other Californian tribes should not leave place
for the slightest doubt. It results from his descriptions that the color is, as
was said by La Pérouse, perfectly or nearly perfectly black among the Yuroks,
Karoks, Chillalas, Gallinomeros, Achomawis, etc. This author speaks, among
other things, of the shiny and supple skin of some of these tribes, and compares
them in this regard to the Ethiopian Negroes; and this character is in com-
plete discord with what one observes in the yellow races. Unfortunately,
Mr. Powers says nothing about the hair, nor about the form of the skull. But
this last deficiency is filled by the discovery of M. Ten Kate. . . . .

The California family is far from being homogeneous and should later on
be divided. The three fundamental types of humanity, the black, the yellow, and
the white, here encounter each other. We know that the representatives of
the first have arrived by the sea from the Melanesian islands. As to the two
others, at least on the whole, they came from the north. Possibly linguistics,
interrogated on the point of the mixture of the black race with the yellow and
white, will also give indications on the subject.

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In addition to the above, Quatrefages came to believe in the presence and rather wide dispersion in pre-Columbian America of the early Norsemen, the Canary Islanders, and perhaps other contingents of the white race; in smaller accidental accretions of the African Negroes; in the presence of small elements of the Polynesians and Indonesians, and of larger numbers of the Chinese and Japanese.

In 1890, before the VIII International Congress of Americanists at Paris, Ten Kate (1892) returns once more to the question of the racial affinity of the American natives. In speaking on the " Question of Plurality and Parentage of the American Races ", he expresses himself thus:

I maintain that the Americans, by the assemblage of their characters, belong to the yellow races and that they are, as the Malay and the Polynesians, congeners of the so-called Mongolic peoples of Asia. Moreover, I believe this to be the opinion of the majority of anthropologists, French as well as others. . . . . I have not arrived at this conclusion until after I have seen and examined a great number. (P. 293.)

In 1917 Ten Kate still holds that " the somatic characteristics of the American Indians, taken as a whole, are those of the yellow races in general " ; also that " one finds Americanoid types almost everywhere : in Siberia, in the Himalayas and the neighboring regions, in China, Japan, Indonesia, and Polynesia." He believes he can distinguish in America at least six principal or " primordial " and perhaps as many secondary " races " ; some of which races, both principal and secondary, inhabit also certain parts of eastern Asia and Oceania. He makes no point of the occurrence of the seemingly Melanesian-like skulls about La Paz in Lower California, and there is no reference in the paper to Melanesian or other blacks.

In 1894 approximately 100 additional skeletal parts, including one skull, are brought from the east coast of Lower California by Léon Diguet and are shortly after that briefly reported upon by Deniker (1895). The skull resembles in the essentials those reported by Ten Kate ; the bones indicate a stature, in the men, of about 162 cm.

These remains, together with nine other skulls and some bones from the same region brought by Diguet as a result of his second trip to Lower California in 1898, became the property of the Muséum d'Histoire Naturelle, Paris, and came to be studied, together with the Ten Kate material which is in the collections of the Société d'Anthropologie in the same city, by Paul Rivet. Utilizing also data on the small collection of Lower California remains preserved in the United States National Museum at Washington, furnished by Hrdlička, Rivet in 1909 published a handsome report on the materials.

He has obtained from the long bones the stature, for the males, of
164.4 cm; and the characteristics of the 18 available skulls, together
with those of the other parts of the skeleton, lead him to the follow-
ing deductions:

The Pericues [Lower Californians] differ from the American races in
general and especially from the neighboring Indian populations in the pro-
portions of their body and in a certain number of the characteristics of their
skeleton, which appear to approximate them to Negritic peoples, without
however showing a perfect identity with the latter.[25]

The main features that present similarities with the blacks, in
Rivet's opinion, are the lack of platycnemy in the tibia and the high
pilasteric index of the femur, together with the relative shortness of
the neck and the torsion of this bone. As to the skulls, there is no
line of demarcation between those of the Pericues and those of the
Indians farther north, the characteristics of the one group passing
gradually into those of the others;[26] but he regards this as evidence
of an infiltration of the southern type into the more northern.[27]

Following Quatrefages, Rivet calls attention to the resemblance of
the South California cranial type to that of the northern Eskimo on
one hand, and to the Lagoa Santa skulls on the other, and then con-
cludes that,

[25] " Ils différaient des races américaines en général et surtout des populations
avoisinantes par les proportions du corps et par un certain nombre de caractères
squelettiques, qui semblent les rapprocher des populations nigritiques, sans qu'il
y ait toutefois identité parfaite avec celles-ci." (P. 212.)
[26] " On constate également de la façon la plus évidente que plus on s'éloigne
de la Basse-Californie en allant vers le nord, plus l'indice cephalique tend à
augmenter, et ce phénomène apparaît avec une netteté vraiment frappante. Ce
fait, qui a été déjà signalé par Boas puis par Matiegka, ne laisse pas d'être assez
embarrassant. En effet, étant donnée la continuité des termes de passage qui
existent entre la forme hypsisténocéphale typique de Basse-Californie et les formes
plus ou moins platymésati- ou platybrachycéphales de l'archipel septentrional,
il est extrêmement difficile de faire des coupures dans un groupement en ap-
parence aussi homogène, ou, en d'autres termes, d'indiquer une limite entre les
variations extrêmes de deux ou plusieurs types humains réunis les uns aux
autres, comme dans le cas précédent, par des formes de transition aussi nom-
breuses que possible. En réalité, le problème est insoluble si l'on s'en tient aux
rapports métriques, c'est-à-dire aux indices, et pour le résoudre, il faut faire
appel à la morphologie." (Pp. 239-240.)
[27] " Une infiltration du type hypsidolichocéphale s'est donc certainement pro-
duite vers le continent, plus accentuée, semble-t-il, que vers les iles, mais elle a
été arrêtée et submergée par les flots d'une autre race à caractères tout à fait
différents, et paraît de ce fait avoir été assez limitée." (P. 242.)

the Pericues of Lower California and the race of Lagoa Santa, with their multiple representations, belong to one and the same ethnic type, which is none other than the dolicho-acrocephalic Oceanic type of Biasutti and Mochi.[23]

In the following pages (244-248) Rivet inclines gradually more and more to the conclusion that the Lower Californian and related types of man in the two Americas are of Melanesian origin, owing to ancient immigration from the Pacific; and that the differences they present from the parent stock and among themselves are due to local differentiations. He summarizes his views thus:

[The Lower Californians] connect closely with the South American race of Lagoa Santa. They present no less evident affinities with the hypsi-stenocephalic race spread over Melanesia and Australia. The differences which exist between the three varieties of the same race, both as to skull and as to skeleton, are explainable by the different conditions of life and different environment to which they have been subjected. The double hypothesis advanced by Ten Kate in 1884 finds therefore in all points a confirmation. (P. 248.)

This adds a strange and unexpected chapter to the whole subject. From this it would seem to be but a short step toward the conclusion that the Australians have actually reached pre-Columbian America, and this step, it will be seen, is not long in being taken.

Meanwhile, in 1877 and again in 1888, Rudolf Virchow, seeing the variety of American-Indian crania, reaches the belief that this indicates a heterogeneity of origin; but we find here, as so often before as well as later, an evident confusion of the concepts of " race " and " type ". He says, in his earlier communication (p. 155) :

The general craniological classification does not accordingly exclude the possibility that, at very different times, dolichocephalic as well as brachycephalic immigration into America took place. . . . . The most dangerous of all is the acceptance of a uniform old American stock. . . . . The " red race " is probably just as little uniform as autochthonous.

In 1888 he amplifies this statement thus:

Today I restrict myself to declaring that the physiognomic characters of the American heads [skulls] show a divergence so manifest that it is necessary to renounce definitely the conception of a universal and common type of the American aborigines. They, too, are a mixture of several original races, and the program of future researches will find its final expression in the separation of the different ethnic elements that have entered into the composition of the various living and extinct tribes. (P. 260.)

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[23] " En définitive, les minimes différences qui existent au point de vue cranien entre les deux races hypsicéphales de l'Amérique du Nord et de l'Amérique du Sud me semblent explicables par l'évoultion divergente d'un même type originel et les différences beaucoup plus marquées du squelette facial par des conditions de vie et surtout d'alimentation diverses, et je crois avec Ten Kate que les Péricues de Basse-Californie et la race de Lagoa-Santa, avec ses multiples représentants, appartiennent à un seul et même type ethnique, qui n'est autre que le type dolicho-acrocéphale océanique de Biasuttie et Mochi." (P. 244.)

THE PUNIN AND TUNEBO SKULLS

In 1923 Mr. Tate, field assistant of the department of mammalogy, American Museum of Natural History, found in a ravine near the village of Punin, central Ecuador, a human cranium without the lower jaw (Sullivan and Hellman, 1925). The skull lay " in a low bank, directly over the water-course of the Quebrada Chalan, down which a trickle of water flows normally but which is subjected to torrential violence when rains are heavy." The bank at this point was about 6 or 7 feet high, and the skull appeared " under conditions which suggested but offered no definite proof of considerable antiquity ". (P. 314.) The specimen, which upon being taken out broke under its own weight, was brought to the American Museum and repaired and examined by Sullivan, while the dental arch and teeth were studied by Hellman.

The cranium is defective, especially in the facial parts, and lacks the lower jaw. It appears to have certain resemblances to an Australian skull. The conclusion of the authors is as follows:

> While the skull is undoubtedly American in the sense that the Lagoa-Santa, Pericue, and Paltacalo material is American, it is not a common American calvarium; . . . . In so far as the calvarium under discussion is concerned, we can only say that there is absolutely no basis for excluding it from a series of Australian or Tasmanian crania and every reason for including it. It is quite possible that if we had the mandible and other parts of the skeleton our decision might be different. We wish to emphasize particularly the point that in claiming that this calvarium is Australoid we have in mind a basic racial relationship and do not believe that it necessarily represents migration from Australia or Melanesia. We feel that unless this is indeed a very remarkable case of parallelism this type in America and the similar type in Australia and Melanesia are derivations of the same basal racial stock. (Pp. 321-323.)

The statements in the last two sentences are not readily understandable, and no effort is made to explain them.

The author who, next to Rivet, takes the most pronounced stand on the subject of the presence of Melanesians in America, is the esteemed veteran of French anthropologists and Rivet's close friend, R. Verneau (1924). In 1922 he receives from a missionary two Indian skulls from Colombia. One of these is deformed, but the other, that of a recent " Tunebo Indian " who died of a snake bite and whose body was abandoned by his friends, is normal. The skull is large (capacity 1705 cc [29]) and the principal measurements of the vault are: length max., 19.1 ; breadth max., 13.3 ; and basilo-bregmatic height, 13.9 cm.

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[29] This must be an error; the outside dimensions of the skull indicate a capacity in the neighborhood of 1550 cc.

Except for the capacity, Verneau finds these dimensions to be very close to those of the Papuans and especially the Malicollo Islanders of New Hebrides; there are also Melanesian resemblances, together with some differences, of visual character. The facial parts and particularly the facial breadth are somewhat less like those of the South Seas blacks.

Though conscious of the danger of drawing deductions from a single skull, Verneau nevertheless feels justified in concluding that the Tunebo cranium reproduces the Papuan type. Compared with those of different Melanesians, and more particularly with a selected skull of a Papuan, the specimen in question shows various differences, but these may individually be encountered in other Melanesian crania and hence do not affect the conclusions. " Our Tunebo ", he says, " offers such a sum of characters identical with those of the Papuans that the few differences it presents—which can only correspond to individual variations—do not in any way authorize its separation." [30]

A further support is given also to the Papuan resemblances of some of the crania from Lower California. "All in all," Verneau decides, " it now appears no longer permissible to doubt the great extension of the Papuan type in the New World. Its traces it was found possible to follow, in space, from Lower California to the southern extremity of the continent and from the Atlantic to the Pacific; in time, from the epoch of the race of Lagoa Santa to our day." Verneau admits, it is true, that there are still " many gaps in our knowledge " on the subject, and that " nothing is known as to the mode of the Papuan migration "; but those are his only concessions.[31]

OTHER FINDS

In 1924, also, Lebzelter reports, before the Göteborg assembly of the Congress of Americanists, on a normal male adult Ona skull collected by Father Gusinde. The specimen is contrasted with the casts of one Tasmanian skull, one Lagoa Santa skull, and the Chapelle-aux-

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[30] " Notre Tunebo offre une telle somme de caractères indentiques à ceux des Papouas que les quelques particularités qu'il présente—et qui peuvent ne correspondre qu'à des variations individuelles—n'autorisent nullement à l'en séparer." (P. 378.)

[31] " En résumé, il ne semble plus permis de douter, à l'heure actuelle, et la grande extension du type papoua dans le Nouveau Monde. Ses traces ont pu être suivies, dans l'espace, depuis la Basse-Californie jusqu'à l'extrémité australe de l'Amérique, et de l'Atlantique au Pacifique; dans le temps, depuis l'époque où la race vivait à Lagoa-Santa jusqu'à nos jours. Certes, il existe encore beaucoup de lacunes dans nos connaissances, mais que de progrès ont été accomplis depuis le jour òu A. de Quatrefages a attiré l'attention sur la question." (P. 382.)

Saint Neanderthal cranium. The results indicate, in Lebzelter's opin-
ion (1925), that the Ona specimen in many respects shows a primitive,
" so-to-speak, Australoid " type, though " of course the specimen
did not belong to a representative of that race; it is on the whole
of a highly developed type, but one which presents a large number of
primitive characters." [32] On the purely morphological grounds of the
available material it does not seem to Lebzelter very probable that
unmixed Australoids had ever been present in South America,

for we know up to the present not a single skull that could be attributed to the
Austro-Melanesian race; we know only American crania with more or less
primitive "Australoid" features. . . . . Should an Australoid element in South
America be ever surely determined, we should then have to accept the fact
that in the three southernmost parts of the inhabited world there exist the
remains of one and the same racial group which, following anthropological
usage, we call the "Australoid" group.[32]

[32] " *Wir finden also an dem untersuchten Schädel eine solche Menge primitiver
Merkmale, dass die Annahme, dass innerhalb der Onabevölkerung auch Erban-
lagen einer sehr primitiven, sagen wir ' australoiden' Rasse vorhanden sind,
wohl nicht umgangen werden kann.* Freilich gehörte der untersuchte Schädel
nicht zu einem Vertreter dieser primitiven Rasse, sondern wir haben einem
im ganzen hochentwickelten Schädeltypus vor uns, an dem bloss eine grosse
Anzahl primitiver Merkmale vorhanden sind." (P. 429.)

[33] " *Das Vorhandensein dieser ' primitiven' Züge* lässt sich nicht leugnen. Die
Frage ihrer Herkunft kann verschieden beantwortet werden. Einmal kann das
Auftreten solcher primitiver Merkmale in die natürliche Variationsbreite sowohl
der Eskimos wie der Dolichoiden Süd-Amerikas fallen. Diese beiden Rassen
hätten sohin als Ganzes eine Reihe primitiver Erbanlagen. Die zweite Möglich-
keit besteht darin, dass diesen beiden Rassen oder zumindest doch den südamer-
ikanischen Dolichoiden ein primitives, sagen wir ' australoides' Rassenelement
beigemengt ist. Dabei bleibt zu erwägen, ob diese Beimischung bereits vor der
Besiedlung Amerikas erfolgte, oder ob die Einwanderer auf eine australoide
Schichte gestossen sind, die schon früher vorhanden war. Nach der rein mor-
phologischen Betrachtung des vorliegenden Materiales erscheint es nicht sehr
wahrscheinlich, dass es in Süd-Amerika jemals unvermischte Australoide ge-
geben hat, denn wir kennen bisher keinen einzigen Schädel, der etwa der
austromelanesischen Rasse zugezählt werden könnte; wir kennen nur amerikan-
ische Schädel mit einer grösseren oder geringeren Zahl primitiver ' australoider'
Merkmale. Dies würde darauf hindeuten, dass die Beimischung australoider
Elemente sehr weit zurückliegt und quantitativ nicht bedeutend war. Die An-
thropologie allein wird nicht in der Lage sein, diese Frage zu lösen, hier
müssen geographische und historische Erwägungen eingreifen. 'Australoide'
Rassen waren in vergangener Zeit viel weiter verbreitet. Wir wissen, dass sich
die Neanderthal-Rasse von Mitteleuropa bis zum Kaukasus und bis nach Süd-
Afrika ausgedehnt hat. In Süd-Afrika hat neuerdings R. Broom australoide
Einflüsse nachgewiesen.

" Sollte sich wirklich auch in Südamerika ein ' australoides' Element mit
Sicherheit nachweisen lassen, dann hätten wir an den drei südlichsten Enden der
bewohnten Welt die Reste ein und derselben Rassengruppe anzunehmen, die wir
nach wissenschaftlichen Brauch die ' australoide' Gruppe nennen." (P. 434.)

LATEST THEORIES

About this same time there is another communication on Polynesian and Melano-Australian elements in America by Rivet, and the evidence begins now to be extended also to the philological and cultural realms. The paper is published in 1924 and reprinted in 1925. In the former we read as follows:

A North American [Hoka] and a South American [Tson] linguistic group can be attached, respectively, to the Melano-Polynesian and the Australian families.

In 1909, taking up again an idea advanced once by Ten Kate and de Quatrefages, I have demonstrated that, by their osteological characters, the ancient inhabitants of the southern part of Lower California and the South American race called Lagoa Santa, presented very clear affinities with the hypsistenocephalic race of Melanesia, and this thesis has recently been entirely confirmed by R. Verneau. . . . . Gräebner, E. Nordenskiöld, and Father Schmidt pointed out the remarkable similarities which exist between the American and the Melano-Polynesian civilizations.

The date when the Australians and Melanesians arrived in America cannot, naturally, be fixed with precision; but it is at all events possible to affirm that it was very ancient. . . . . When the Europeans arrived in America the " uniformization " in the aspect of the American tribes had already been realized under the double influence of the environment and of mixture (the latter having been surely the most efficacious) ; and it must have required many centuries for this result to be attained.[34]

An especially definitive article on the problem under consideration, by Rivet, appeared in 1925 in L'Anthropologie. The paper is a terse

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[34] " Un groupe linguistique nord-américain et un groupe sud-américain peuvent être rattachés respectivement à la famille mélano-polynésienne et à la famille autralienne." (P. 336.)

" En 1909, reprenant une idée autrefois émise par ten Kate et par de Quatrefages, j'ai démontré que, par leurs caractères ostéologiques, les anciens habitants de la partie méridionale de la péninsule californienne et la race sud-américaine, dite race de Lagoa Santa, présentaient des affinités très nettes avec la race hypsisténocéphale de Mélanesie, et cette thèse a été entièrement confirmée récemment par R. Verneau . . . . Graebner, E. Nordenskiöld et le Père Schmidt on signalé les similitudes remarquables qui existent entre les civilisations américaines et mélano-polynésiennes." (P. 339.)

" La date à laquelle les Australiens et les Mélanésiens sont arrivés en Amérique ne peut être naturellement fixée avec précision. On peut affirmer toutefois qu' elle est très ancienne. . . . . Lorsque les Européens sont arrivés en Amérique, cette uniformisation d'aspect des tribus américaines était déjà réalisée sous la double influence du milieu et du métissage (cette dernière ayant été certainement la plus efficace) ; or, il a fallu, sans aucun doute, de nombreux siècles pour que ce résultat soit atteint." (Pp. 340-341.)

discussion of the whole subject. It presents no new facts. The author
marshalls succinctly all the hitherto given physical, as well as certain
cultural and linguistic items of evidence that apparently favor the
theory of ancient Melanesian-Australian influx to the American con-
tinent, as well as some of the objections, and concludes:

> There are now certain proofs that four elements have entered into the
> formation of the American people:
>
> An Australian element;
>
> An element attached linguistically to the Malayo-Polynesian and by its physical
> characteristics to the Melanesian group;
>
> An Asiatic element, doubtless the most important, which gave the people of the
> New World in general a certain uniformity of external aspect; and
>
> An Uralian element, represented by the Eskimo.
>
> The order of the coming of these different elements seems to have been that
> in which they are here enumerated.[35]

In 1926 the problem of Australoid immigration into South America
is dealt with by Corrêa (1926 a). The Wegener hypothesis of move-
ments of the continents leads Corrêa to the belief that South America
at one time had a land connection with Australia through the inter-
mediary of the since displaced and severed Antarctica, and that man
from Australia and Tasmania reached America over the land and over
the small straits, canals, and islands that marked the former con-
tinuity of the continental masses.[36]

In 1926, too, Corrêa presents his views more amply and explicitly
at the XXII International Congress of Americanists in Rome. He
offers no original observations, but combats the view of the basic
unity of the American race and formulates thus his conclusions:

> Anthropological, ethnographical, and linguistic analysis permits us to believe
> that the genesis of the pre-Columbian populations of America involves the
> intervention of divers ethnic strata. It is possible to distinguish, dispersed among

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[35] " En résumé, on a maintenant des preuves certaines que quatre éléments
sont intervenus dans la formation du peuple américain:

" Un élément australien;

" Un élément de parler malayo-polynésien se rattachant par ses caractères
physiques au groupe mélanésien;

" Un élément asiatique, sans doute de beaucoup le plus important, qui a imposé
à l'ensemble des habitants du Nouveau-Monde une certaine uniformité d' aspect
extérieur;

" Un élément ouralien, représenté par les Eskimo.

" Il semble que l'ordre d'arrivée de ces divers éléments soit celui dans lequel
je viens de les énumérer." (P. 311.)

[36] . . . . ficava " a possibilidade da passagem do Homen, que transporia mais
fácilmente pequenos estreitos e canais e aproveitaria istmos, penínsulas e ilhas
que marcavam, como ainda hoje algumas o fazem, a anterior continuidade dessas
massas continentais." (P. 229.)

the American Indians in variable degrees, Asiatic (Mongoloid and non-Mongo-
loid), Melanesian, Polynesian, Caucasoid, and Australian affinities. I believe
the first to be the clearest, the last most attenuated. There have also been men-
tioned [in connection with America] Pygmies, or Negritos. This problem awaits
solution.[37]

Regarding the Australia-Antarctic-South America route for human
immigration—" the topographic, biogeographic, paleontological, and
anthropological considerations render the utilization of this route very
probable "; though he is aware of the conjectural nature of his hy-
pothesis and of the fact that its adoption demands objective proofs.[38]

In the same year Rivet (1926 c) discusses the problem of the way
of the supposed Australian migrations toward the American continent.
He states that during the last few years it has been possible to " es-
tablish ", by anthropological, ethnographic, archeological, and lin-
guistic means, immigrations of Malayo-Polynesian, Melanesian, and
Australian contingents into the New World, but that the mode of
coming of the Australians offers still considerable difficulties. They,
as well as the Tson (the Patagonians, the Onas), their South Ameri-
can " relatives," knew but primitive means of navigation which
were insufficient for any long sea voyage, and there is no indication
that they possessed anything superior in this respect in the past.
The coming of the Australians by way of the Bering Strait must be
excluded—there are no traces of them on the way. There remains the
southern route suggested by Corrêa, over the islands and waters of
the Antarctic, which may have presented a different configuration in
the past, due possibly to a greater ice extension. The material evi-
dences of such migration remain to be determined.

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[37] " L'analyse anthropologique, l'ethnographie, la linguistique, nous permettent
de croire à la genèse des populations précolombiennes de l'Amérique en ad-
mettant l'intervention de diverses stratifications ethniques. On peut démêler
parsemées, en degrés variables, chez les Indiens de l'Amérique des affinités
asiatiques (mongoloïdes et non-mongoloïdes), mélanésiennes, polynésiennes, cau-
casoïdes, australiennes. Je crois que les premières sont les plus nettes, les
dernières les plus atténuées. On a parlé aussi de Pygmées, voire de Négritos.
C'est un problème à résoudre." (P. 107.)

[38] " Mais les considérations topographiques, biogéographiques, paléontologiques
et anthropologiques rendent très vraisemblable l'utilisation de cette voie d'accès.
. . . . Certes l'adoption définitive de mon hypothèse exige préalablement des docu-
ments objectifs de l'utilisation de cette voie par l'homme. Il faut cependant
espérer qu'on obtiendra dans l'avenir ces documents, dont un grand nombre sont
peut-être ensevelis sous les glaces mystérieuses des terres antarctiques." (P. 116.)
" Je ne conteste pas le caractère conjectural de plusieurs de mes considérations.
On n'oserait pas donner comme déjà établie la voie de transit dont j'ai présenté
l'hypothèse. Mais je n'hésite pas à considérer celle-ci comme légitime et très
vraisemblable." (P. 118.)

In 1926 in *Scientia*, Rivet, although not bringing any new evidence, states his beliefs with especial emphasis. All the hypotheses that endeavor to explain the coming of man to America over since-vanished continents may now be eliminated, for such disappearances, in the unanimous view of the geologists, were all anterior to the Quaternary period. The American Indians are not autochthonous. They did not have a unique [single] origin, but have suffered the dominant influence of a race which, in a certain measure, has produced uniformity of their external aspect; and they did not reach America before the end of the paleolithic period. There were three main ethnic elements that entered into the formation of the pre-Columbian American population, namely: the Australian; a group speaking a Malayo-Polynesian language but physically connected with the Melanesians; and, by far the most important, an Asiatic element, in which may be distinguished two related groups, one Uralian (Eskimo) and the other Sino-Tibetan (NaDene). The order of arrival of these elements on the American continent appears to have been that in which they are enumerated.

In 1927 Rivet, basing his conclusions on the Lagoa Santa skulls, on a collection of crania from limited localities in Ecuador and in Lower California, and on certain ethnographic and linguistic data, comes to a " renewed conception " of the peopling of America:

> Surely, the Asiatic element here plays the principal rôle, but henceforth a part must also be assigned to a Melanesian and an Australian element. . . . . The American aborigine appears therefore as a product of very diverse ethnic elements, among which the Asiatic was manifestly the dominant one.[39]

Rivet reaches further interesting conclusions as to the times of the immigration into America. Nothing to date, he believes, authorizes us to suppose that the first occupants reached America before the

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[39] " De cet ensemble de fait découverts en quelques mois, se dégage une conception renouvelée du peuplement de l'Amérique.

" Certes, l'apport asiatique y joue toujours le rôle principal, mais une part doit être faite désormais à un apport mélanésien et à un apport australien. En outre, la notion assez vague d'une migration asiatique s'est précisée, au moins en partie, puisque, dans la masse de ces émigrants, on peut maintenant discerner des Sino-Thibétains et des Finno-Ougriens.

" L'homme américain apparaît donc comme le produit d'éléments ethniques très divers, parmi lesquel l'élément asiatique a manifestement été dominant. C'est cet élément qui a donné à l'Indien cette uniformité d'aspect tout extérieure, sous laquelle une observation attentive découvre un extrême polymorphisme, manifeste non seulement dans le type physique, mais dans la civilisation et dans le langage." (Pp. 22, 23.)

end of the glacial epoch.[40] The routes from Asia were across Bering
Strait and the Aleutians. They were certainly followed at all subse-
quent times and have served for many human waves.[41] The Mela-
nesian migration must have been over the seas and was certainly very
ancient.[42] The Australians came, about 6,000 years ago, along the
shores of the Antarctic.[43]

The theory, it is seen, has developed.

FUEGIANS

A study of 47 Fuegian skulls in Gusinde's and certain European
collections, together with some Australian materials, led Gusinde and
Lebzelter in 1927 to the following somewhat ambiguous conclusions:

The general impression conveyed by the somatological status of each of the
three Fuegian tribes is unequivocally that of what is characteristic of the Ameri-

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[40] " Aucun fait ne nous autorisant à supposer à l'heure actuelle que le Nouveau
Monde ait reçu ses premiers occupants avant la fin de l'époque quaternaire, il
est certain que les voies d'accès que l'homme a pu emprunter étaient sensiblement
les mêmes qu'aujourd'hui et nous devons renoncer à supposer qu'il ait utilisé
des terres ou des continents disparus à des epoques géologiques antérieures."
(P. 23.)

[41] " Pour la migration asiatique, la route naturelle a été celle du détroit de
Behring et du chapelet des îles Aléoutiennes. Elle a été certainement suivie à
toutes les époques et a livré passage à de multiples vagues humaines." (P. 23.)

[42] " La migration mélanésienne a dû, par contre, être essentiellement une migra-
tion maritime, transpacifique. Pour un peuple qui avait occupé successivement
toutes les îles de la Polynésie, jusques et y compris l'île de Paques, atteindre la
côte américaine n'était presque qu'un jeu. J'ai, d'ailleurs, montré que les suc-
cesseurs des Mélanésiens, les Polynésiens, n'avaient pas perdu le secret de cette
route vers les terres de l'est et entretenaient avec l'Amérique du Sud des rela-
tions commerciales, à la faveur desquelles des échanges culturels et des emprunts
de plantes utiles (notamment le cocotier et le calebassier) se sont réalisés.

La date de la migration mélanésienne ne peut naturellement être fixée d'une
façon absolue. Elle est certainement très ancienne, tout d'abord parce qu'il a sans
doute fallu beaucoup de temps pour que cet élément ethnique soit absorbé par
les immigrants asiatiques, absorption déjà réalisée au moment de la découverte
de l'Amérique, et aussi parce que des éléments culturels mélanésiens typiques
apparaissent sur la côte péruvienne dès les horizons archéologiques les plus
anciens. C'est tout ce que, pour l'instant, on peut se hasarder à dire." (P. 23.)

[43] " L'arrivée d'un élément australien en Amérique s'explique beaucoup plus
difficilement, car les Australiens sont et ont toujours été de mauvais navigateurs
et n'ont jamais possédé d'embarcatins permettant de longues traversées.

" Après avoir envisagé plusieurs hypothèses, je me suis finalement rallié à
l'idée suggérée par Mendes Corrêa. Selon lui, les Australiens auraient gagné
l'Amérique en suivant les rives de l'Antarctique et en utilisant les chapelets d'iles
qui relient ce continent à l'Australie d'une part, à l'Amérique d'autre part. Il
est possible, en effet, qu'au moment de l'optimum postglaciaire, les conditions

can race; the tall Selk'nam, especially, show far-reaching analogies with the Tehuelche of Patagonia, while the smaller, more pygmoid Yamana and Hala-kwulup resemble some of the shorter-statured Indian tribes of northern South America, especially in the interior of Amazonas. However, notwithstanding this more general outer equality, there appeared on closer study various unmis-takable peculiarities which have the status of racial features.[44] (Pp. 259-260.)

On the basis of a relatively considerable amount of Australian and Fuegian material it has become possible to draw the broad conclusion that in the struc-ture of the individual bones, as in the total build of the cranial vault, there are extensive similarities, similarities that for the most part extend also to the Neandertal races. On the other hand, however, there is found, as apparent from the dimensional determinations, a smaller series of characteristics which the Fuegians share with the Neandertalers but not with the Australo-Melanesians. These facts indicate in what light the relations of these groups must be appraised: they point undoubtedly to an original connection; they all denote a certain original style of the structural plan, which manifests itself to small details. This assumption receives further strengthening and support from the study of the facial parts of the skull. (P. 266.)

THE " MELANESIANS " OF BOLIVIA

While the above reports were accumulating, a new " Melanesian " focus developed in eastern Bolivia. Called to the country by the University of La Paz about 1925, Dr. Richard N. Wegner visited Bolivia, observed some of the native tribes of the country, and believed that he saw or learned of physical types among them that resembled the Melanesians.

In 1927 he published a brief account of these types, with six photo-graphs of individuals. He has not seen the people in question, the photographs having been taken by Engineer R. Gerstmann, who had met with a small group and who furnished Wegner both the pictures and the information concerning them. They belong to certain nomads, small parties of which, surrounded by Indian tribes, roam through the forests of eastern Bolivia between the Piray and Grande Rivers. They are described as in some instances rather tall (one man 1.78 meters), with markedly wavy hair and a strong growth of beard. They also show thick lips, low root of the nose, flat nose with trans-verse apertures, dark, Negroid skin color; but they are asserted to have " not the least to do " with the now widely spread Negroes in the area. To find such a " strongly differing race " among the Indian tribes of the region is, in the opinion of Wegner, of " sensational "

climatiques de ces régions, aujourd'hui si inhospitalières, aient pu permettre le passage d'une migration humaine. Dans cette hypothèse, l'exode australien vers l'Amérique remonterait à 6.000 ans environ." (P. 24.)

[44] " die als Rassenmerkmale sich ausgaben ".

interest to science. In many points he sees their striking resemblance
to types of the southern seas, particularly those of New Guinea, both
the Negritos and the Papuans.

In 1930 Wegner states further his belief that he had also seen in
the Quruñgá traces of an older and lower race, which reminded him
of the Papuans or South Sea islanders.

The above reports have drawn attention anew to the tribes men-
tioned, especially to the Siriono. These groups, however, were not
unknown before. They are dealt with rather thoroughly, in fact,
by Father Cardús, one of the Franciscan missionaries among the tribes
of eastern Bolivia. Writing of the years 1883-4, Father Cardús says:

> The Sirionos are of the Guarani race, and their language is very much like
> that of the Guarayos. They are very savage and ferocious, and live dispersed over
> the forests and pampas along the streams and about the lakes of the region
> between the lands of the Bibosi, Guarayos, Carmen y Loreto de Mojos, and the
> Piray River. . . . .[45]

> The Sirionos are dark in color like the Guarayos, or possibly somewhat paler,
> for the reason that they are nearly always in the shade of trees. Some few
> were encountered who could be taken for Whites and with blue eyes, but this
> is due to the fact that such individuals were taken as children from some
> ranch or settlement of the Whites. There has also been seen among them a
> Negro, a son, we suppose, of some Negro deserter of the army in the time
> of the " independencia ". There are also among them some families of differ-
> ent origin, whose language the Guarayos cannot understand. They are proba-
> bly of the Mojo race and live in every way as the others.[46]

> What we are most sure of is that formerly the Sirionos did not do such
> harm as at the present and that at various places they came to beg something
> from travelers, without molesting the latter. It appears that the Whites were
> the first to hurt them, especially the traders, who through fear and cowardice
> started to shoot at them with their guns to drive them away from the forests
> and the roads; which certainly could not have been very agreeable to these
> savages who, like all the rest, are so suspicious and revengeful. The fact is
> that at present the Sirionos are very inimical to all the Whites as well as to

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[45] " Los sirionos son de raza guarani, y su lengua es muy parecida á la de los
guarayos. Componen una tribu muy salvaje y feroz, y viven diseminados por
los bosques, pampas, rios, arroyos y lagunas comprendidos entre las cercanías
de Bibosi, Guarayos, Carmen y Loreto de Mojos, y el rio Piray." (Pp. 279,
280.)

[46] " Los sirionos son de color moreno como les guarayos, y tal vez un poco
más pálidos, por razon de estar casi siempre bajo la sombra de los árboles. Se
han encontrado unos pocos que podrian decirse blancos y con ojos azules, pero
esto se debe á que siendo chicos han sido llevados de alguna estancia ó pueblos de
blancos. Tambien se ha visto algun negro entre ellos, que suponemos ser hijo
de algun negro desertor de la tropa en tiempo de la independencia. Hay tambien
entre ellos algunas familias de diferente origen, cuya lengua los guarayos no
pueden entender. Probablemente son de raza mojena, y viven en todo como los
demás." (P. 280.)

all the other Indians, and that they do not want to talk with anyone nor to
see anybody except, if they can, to discharge an arrow at them.[47]

Koch-Grünberg (1906), referring to the many little-known hordes
roaming the primeval forests of eastern Bolivia and neighboring
regions, though not mentioning the Siriono, believes that they all
belong to the great poorly defined group known by the opprobrious
name of " Makis " and representing the remains of the old original
population of the territory.[48] A portrait of a Makú (p. 180) shows a
typical Indian; but two other pictures—one that of a woman from
the same river (Tiquié) as the Makú (p. 179), the other of a youth
from the Rio Ica—show a decided Negro (African) admixture.

In 1911 the Siriono and their material culture were briefly dealt
with by Nordenskiöld. They have a rather wide distribution, are
treated roughly by the Whites, and are feared and hated by the sur-
rounding Indians. It is not certain whether all that are called
" Siriono " in Bolivia belong to one tribe. They have been mentioned
in literature since 1839 (D'Orbigny). Their language is said to be
corrupted Guarani, but they seem also to have another language.
Nordenskiöld saw two Siriono youths, one of whom he pictures. His
skin was of the same brown as that of the Guarayu Indians. The
hair of the second youth was somewhat brownish, and his skin was
unusually light, like that of " a strongly anaemic White who has lived
long in the Tropics ".

The Siriono seem to Nordenskiöld to belong to the Makú tribes;
they are probably " primitive Indians who as a result of their con-
tacts with Guarani-speaking fugitives were largely ' Guaranized '."

[47] " Lo que sabemos mejor es, que antes los sirionos no hacían tanto daño
como ahora, y que en varios lugares salían á pedir algo á los viajeros, sin
molestarlos. Parece que los blancos han sido los primeros en molestarlos á
ellos, principalmente los comerciantes, quienes por temor y por cobardía empez-
aron á dispararles algunos tiros con armas de fuego, para alejarlos de las pascanas
y caminos; lo cual no podía ciertamente agradar mucho á unos salvajes que,
como todos los demás, son tan desconfiados y vengativos. El hecho es que
actualmente los sirionos están muy enemistados con todos los blancos y con
todos los demás indios, y que no quieren hablar con nadie, ni ver á nadie sin
que, si pueden, no les disparen un flechazo." (P. 282.)

[48] " In der Tat versteht man unter diesem Sammelnamen eine ganze Anzahl
von Horden mit sehr voneinander abweichenden und sehr primitiven Sprachen,
die eine ganz neue Gruppe darstellen. Ich möchte alle diese niedrigstehenden
Horden, die sich somatisch sehr von den übrigen Stämmen dieser Gegenden
unterscheiden, auch kulturell einen durchaus altertümlichen Charakter tragen
und sich über ein riesiges Gebiet, sozusagen von Manáos bis zu den Ande aus-
dehnen, für die Reste einer sehr ursprünglichen Bevölkerungsschicht halten."
(P. 180.)

The hair of the second youth as pictured by Nordenskiöld (plate 6) is curly, and his aspect, in the opinion of the present writer, is that of an Indian-Negro mixblood.

Finally—as a result of a trip to Chile and Bolivia and the examination of considerable skeletal material from those countries, Dr. O. Aichel reported that he had found " interglacial man " and " Neanderthaloid types ", but failed to obtain evidence of either Australian or Oceanic immigration. (Aichel, 1932.)

CRITIQUES

The subjects dealt with in this paper have never as yet received a thorough discussion. A sensible, broad and well-documented exposition of the whole subject of the peopling of America appeared in 1922 from the pen of the respected veteran French anthropologist, Henry Vignaud ; and the most relevant section of the treatise leaves no doubt as to the conclusions of the author. It reads as follows :

A number of these scientists believe that Malayo-Polynesian [term used often by Rivet] immigrations have sensibly modified the primitive yellow type of the American Indians, who would thus form today but a mixed race. We believe that the most recent researches do not justify this opinion. We know nothing of the migrations to which is attributed such a great importance, and the proof that they had any influence on the formation of the American physical type is completely wanting. In our opinion, this type has remained what it was originally—the type of a branch of the great original yellow race, and one that has suffered the least through environment and through contacts with foreign elements.[49]

Noteworthy as the above statement was, it received scant or no attention, and new contributions to the Malayo-Polynesian and Melano-Australian theories followed.

A mildly critical discussion, based on historical, cultural, and linguistic evidence, of the problem of Australian, Melanesian, and Malayo-Polynesian presence in pre-Columbian South America, was published in 1930 by the well-known Americanist, Walter Lehmann. In this

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[49] " Plusieurs de ces savants croient que des émigrations malayo-polynésiennes ont sensiblement modifié le type jaune primitif des Indiens américains, qui ne formeraient plus aujourd'hui qu'une race métisse. Nous pensons que les plus récentes recherches ne justifient pas cette opinion. Nous ne savons rien de ces migrations auxquelles on attribue une si grande importance et la preuve qu'elles ont exercé une influence quelconque sur la formation du type physique américain manque complètement. Selon nous, ce type est resté ce qu'il était originairement, et c'est celui de la branche de la grande race jaune primitive qui a subi le moins l'influence des milieux et des contacts avec l'étranger." (P. 25.)

discussion due notice is taken of the assumed evidence on the sub-
ject, including the vague early references to " blacks " in the Darien
region and elsewhere, as well as of all the seeming proofs advanced
by Rivet, but they are found wanting, and the author, while not
closing the door to any possible new and more satisfactory evi-
dence, remains in general unconvinced or skeptical. Speaking of the
supposed relations of the Chon (Patagonian and Ona) with the Aus-
tralian languages, he says:

> It remains uncertain whether the word comparisons of Rivet do justice to the
> realities of the languages used. . . . . The dictum of Wilhelm von Humboldt
> that such comparisons should not be trusted readily is true even today. . . . .
> For the present it cannot yet be said that the similarities he [Rivet] brings
> forth can be regarded as assured facts.[50]

As to the ethnographical resemblances enumerated by Rivet, Leh-
mann is of the opinion " that it is still too early to draw, from his
comparisons, any valid conclusions." [51]

The question of the Darien or other " Negroids " is undecided;
the subject calls for further investigation.

An able treatment of the subject of migrations to America from the
Pacific was presented in 1933 by Roland B. Dixon,[52] one of the
foremost American ethnologists. His principal conclusions on the
problem were as follows:

> It has been seen that the claims for similarity between American and Oceanic
> traits are in the majority of cases only superficially true. The resemblances,
> so far as they exist, are analogies and not homologies, and as soon as one studies
> details, the differences are found to be both significant and fundamental. (P. 344.)

> A further point of significance is that if we are to explain the presence of
> these Polynesian or Melanesian traits in America as due to diffusion, why do
> we not also find here other traits equally or even more characteristic of the
> supposedly immigrant peoples? (P. 345.)

> I believe, therefore, that quite apart from the lack of validity of many of
> the analogies claimed between American and Oceanic cultural traits, the
> practical difficulties in the way of diffusion as an explanation are well-nigh
> insurmountable. (P. 351.)

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[50] " Es bleibe dahingestellt, ob die von Rivet versuchten Wortvergleichungen
dem wirklichen Wesen der herangezogenen Sprachen gerecht werden. . . . .
Noch heute gilt der Ausspruch Wilhelm von Humboldts zu Recht, dass man
sich derartigen Vergleichen night leichtgläubig anvertrauen darf. . . . . Es kann
heute noch nicht gesagt werden, dass die von ihm aufgestellten Gleichungen
als geisicherte Tatsachen angesehen werden dürfen." (P. 326.)

[51] " dass es noch verfrüht ist, aus den von ihm vorgenommenen Vergleichen
irgendwelche endgültigen Schlüsse zu ziehen."

[52] The question of possible Polynesian voyages to America is discussed more
especially by this author in his paper published in 1934.

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When all the many instances are sifted and critically weighed, there remains a very small residue of, perhaps, two or three which render the acceptance of trans-Pacific contact not only just, but apparently inescapable, although the *modus operandi* is still very difficult to understand. Such contacts as did occur were, however, limited I believe to Polynesia; I know as yet of no valid evidence for any with Melanesia or beyond. But although Polynesians did thus very rarely, and probably at long intervals, make such contacts with the people of South America, the net result was negligible so far as America as a whole or South America in particular was concerned; and the claims of the diffusionists for the far-reaching influences of trans-Pacific cultural diffusion must, I believe, be disallowed. (P. 253.)

The latest (1934) discussion of the subject dealt with in this treatise is contained in Von Eikstedt's " Rassenkunde ". Regarding the Melanesians, this author is skeptical so far as the Lagoa Santa and other South American groups are concerned; the cranial resemblances mean merely a partial convergence; but, basing his belief on some mentions of " blacks " in the early writers,[53] he accepts readily the presence of true " Melanesoids " in Darien and Lower California.[54]

On page 750 of the same publication Von Eikstedt is even more explicit. Speaking of the cranial resemblances of the Australians and Melanesians with some of the South American Indians, he says:

It is understood that there can be no question of direct race relation. This is excluded not only by the spatial conditions, but also by the physical characteristics of the living. We have here not related races but similar phylogenetic phases. The so-called Australimorphous hominid stage is found in old Europe as the Aurignacian race, in South Africa as the Cape-flats race, in Australia as the Australians, and finally also in the coast type of Brazil.[55]

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[53] Martyr, Petrus, 1533; De Gamboa, Sarmiento (?); Vizcaino, 1602.

[54] " Der bewiesene melanesid-lagide Parallelismus stellt ausschliesslich einen kraniologischen Parallelismus dar. Die heutigen Ges und Tunebo sind alles andere als dunkelhäutig und kraushaarig. Wir haben in diesen Fällen also eine partielle Konvergenz vor uns, die wohl ein abstammungsgeschichtliches Interesse haben kann, aber keine taxonomische Bedeutung besitzt. Altperuanische Berichte sind zu vage, um überhaupt gewertet zu werden. Was aber die offenbar in Darien und Kalifornien vertretenen richtigen Melanesoiden angeht, so ist ihr Auftreten nicht überraschend." (P. 871.)

[55] " Selbstverständlich kann es sich nicht um direkte Rassenverwandtschaft handeln. Das schliessen nicht nur die räumlichen Verhältnisse, sondern schliesst auch die Somatologie der Lebenden aus. Es liegen mithin nich verwandte Rassen, sondern ähnliche phylogenetische Schichten vor. Die sog. australimorphe Schicht der Hominiden findet sich als Aurignac-Rasse im alten Europa, als Cape-flats-Rasse in Südafrika, als Australier in Australien, und schliesslich bietet der alte Küstentypus Brasiliens die gleiche Schicht auch im letzten Raum der zirkumasiatischen Landmassen, in Amerika." (P. 750.)

DISCUSSION

Thus the theories have grown, and the simple realities have become more and more obscured. An untraceable mention, an overstatement by an imaginative correspondent or writer, a dark skin, a broad nose, wavy hair, a brief visit to a few tribes, a few measurements and peculiarities of a skull, or just an inspiration without direct knowledge of America or the Indian, have seemed to scientific theorists justification enough for bringing to the New World the most unlikely human groups, with their women, over thousands of miles of unknown oceans, in spite of the obstacles of thirst, hunger, winds, and currents.

If these hypotheses are true, they ought to withstand critical examination. Being brought forward by men whose words deserve attention, they cannot be wafted aside by any mere negation, even though this were based on sufficient knowledge. Let us then, with open minds, test the evidence brought in support of these theories. This should be done from the point of view of that branch of science which must be the chief arbiter in such matters, namely, physical anthropology; though other relevant considerations may be unavoidable.

TIME

When are the different contingents of " blacks " supposed to have reached pre-Columbian America?

So far as the " Africans " of Darien are concerned, the matter is fairly simple. They are said (in Peter Martyr) to have reached the American shores but recently. But the source of the reports of this group is not known. They are not authenticated by either the authorities of the territory nor by Oviedo, the official historian and early settler of the newly discovered land. Moreover, a group of either pirates or slaves from a ship of the time would of necessity have been small and without women. For such a group to penetrate a territory of virile tribes, maintain itself as such for any length of time, and even conduct war with the natives, borders on the impossible. There is no further notice or trace of the group, Velasco's 1901 second-hand report applying to conditions nearly four centuries after the multiple introduction of the Negro into America by the Spaniards. Can any scientific weight, under such conditions, continue to be given to this item? It does not seem possible. Moreover, such an occurrence, even if by some rare chance real, would have had no effect on the American native population.

There remain, therefore, only the Melanesians and the Australians.

The spread of the Melanesians in the South Seas preceded, it is known, that of the Polynesians, but was antedated by that of the Negritos. According to various indications, the " Melanesian " sailings belonged essentially to the last millennium before the Christian era. But by that time America was already peopled; furthermore, judging from the reception given the first contingents of Whites, what chance of survival would there have been for a small stray group of any other people, and especially one not stronger than the native Americans? Where the first Whites were not massacred or sacrificed, they were soon provided with native wives, and their blood was thus started on a progressive dilution until within a few generations it practically disappeared; and the same would have been the lot of any isolated small parties of other strangers.

To leave any traces of their type, and especially any plain traces, the Oceanic blacks would either have had to reach America in respectable numbers of both sexes—which, considering the distances they would have had to cover and their means of transportation, appears impossible—or they would have had to reach the continent before the Indians did, which borders on the fabulous. At this point it is legitimate to ask whether there were as yet any " Melanesians " before the time of the peopling of the Americas from the far north. They are a mixed people. They show to this day types that approach now the Indonesian, now the Negrito, and not seldom even that of the true Negro, all of which indicates as yet imperfectly assimilated mixtures. These conditions differ, moreover, from group to group. And to this day there is known no real antiquity of any of the groups. Who then can venture to say just who were the forefathers of the Melanesians far back of the historic period. There are serious difficulties, it is evident, whichever way one turns.

With the Australians matters are still worse. These people, too, are badly mixed, and the strains differ from province to province. (Hrdlička, 1928.) Rivet suggests that they came to America some 6,000 years ago, and Mendez Corrèa's Antarctic theory would tend to place the coming in a still more remote past; but what and where were the "Australians" of that time, and which of the strains of today represents the ancestral strain that would have reached America? One might even ask whether 6,000 years ago Australia itself was as yet peopled, for even with the Talgai skull there is no conclusive evidence on that point. Added to this are the same difficulties concerning the American preservation of the type as there were with the Melanesians.

The above are no mere academic objections, but real material obstacles that would have to be scientifically disposed of before the claims they relate to could be accepted as established.

EXTENSION

The Oceanic " blacks " are represented as having reached Tierra del Fuego, a part of Brazil, Ecuador, and Colombia, and lower as well as upper California, spreading as far eastward, at least, as New Mexico. This is a very wide distribution, but the voids in it are even more remarkable. They comprise vast regions in Argentina, Brazil, the Andean and Pacific South America, and all central America. There is no comfort in the suggestion that many of these parts are still but little known and that the gaps may be closed through future discoveries. A population of such assumed extent would of necessity have represented such numbers and so long a presence that its material remains would have to be at least fairly abundant, and some remains could not have failed to be discovered by this time. Great difficulties here, alone, confront those who would foster the Melano-Australian notions in relation to America.

CULTURAL REMAINS

So far as known, the supposed Australian and Melanesian blacks have left no sites that could be attributed to them, no recognizable accumulations, no archeological remains whatsoever in any part of America. They must have forgotten the boats they came in and even the sea itself, becoming largely land dwellers. There is no trustworthy tradition about them. They left, it is claimed, a series of words in some of the Indian languages; but the words of comparison are taken from different observers, and from the recent Indians as well as the recent Australians and Melanesians, the assumption being that these select words remained the same in both parts of the world from the far past to this day.

These matters should not be discussed by one not a specialist in these lines; but there is to be remarked the very striking fact that not one of the numerous American workers of note in the lines of archeology, cultural anthropology, or linguistics, men who have devoted their lives to these subjects and had the closest contact with the American aborigines, has either advanced or identified himself with the Melano-Australian hypotheses.

" MELANESIANS " IN NORTH AMERICA

While very lucid and critical about the Lagoa Santa and other South American remains, so far as then known, Quatrefages in his last major work (1889) has accepted, as significant, references that lacked scientific support or were even grossly erroneous.

Three separate accounts were used by this author (1889), the first found in the Journal of La Pérouse, the second in Stephen Powers, and the third in the account of Padre Francisco Garcés.[56] The first two relate to Indians of California, the last to the Zuñi.

As to La Pérouse (1791), all that this explorer says is as follows: In old and new California there are

about 50,000 wandering Indians. . . . . These Indians are in general small and weak, and discover none of that love of liberty and independence which characterizes the northern nations, of whose arts and industry they are also destitute; their colour very nearly approaches that of the negroes whose hair is not woolly; the hair of these people is strong, and of great length; they cut it four or five inches from the roots. Several among them have a beard, others, according to the missionary fathers, have never had any, and this is a question which is even undecided in the country. . . . . We perceived only half the adults to have a beard, this, with some of them, was very ample, and would have made a figure of some importance in Turkey, or the vicinity of Moscow. (Vol. 2, pp. 196-198.)

To this is added the following: At Mission San Carlos, near Monterey—" The colour of these Indians, which is that of Negroes. . . . ." (Vol. 2, p. 212.)

The exact reference to the work of Powers is not given, but it can only be his " Tribes of California " (Contributions to North American Ethnology, vol. 3, Washington, 1877). This is one of the classics in its field. It was not written by an expert, the author having been a journalist, but it gives by far the most comprehensive and generally reliable information on the Indians of California published to that date. In all its 635 pages there is not the slightest suggestion of any race but the Indian. The text must have been badly misunderstood. What Powers says about the physical characters of the several tribes mentioned is as follows:

[*The Karok.*]—On the Klamath there live three distinct tribes, called the Yú-rok, Ká-rok, and Mó-dock, which names are said to mean, respectively, "down the river", "up the river", and "head of the river". (P. 19.)
The Karok are probably the finest tribe in California. Their stature is only a trifle under the American; they have well-sized bodies, erect and strongly knit together, of an almost feminine roundness and smoothness. . . . .

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[56] Said to be recorded by Schoolcraft, but I was not able to locate it in the Schoolcraft archives.

(P. 19.) The Klamath face is a little less broad than that on the Sacra-
mento; in early manhood nearly as oval as the American; cheek bones
large and round-capped, but not too prominent; head brachycephalic; eyes
bright, moderately well sized, and freely opened straight across the face;
nose thick-walled and broad, straight as the Grecian, nares ovoid, root not so de-
pressed as in the Sacramento Valley; forehead low and wide, nearly on a perpen-
dicular line with the chin; color ranging from hazel or buff-hazel to old bronze,
and almost to black. . . . . (Pp. 19 and 20.) With their smooth, hazel skins,
nearly oval faces, full and brilliant eyes, some of the young women—barring
the tattooed chins—have a piquant and splendid beauty.

[*The Yurok.*]—Living nearer the coast, they are several shades darker than
the Karok, frequently almost black; and they are not so fine a race, having
lower foreheads and more projecting chins. On the coast they incline to be
pudgy in stature, though on the Klamath there are many specimens of splendid
savagery. Like all California women their mohelas (a Spanish word of general
use) are rather handsome in their free and untoiling youth . . . . (p. 44).

Portraits of Yurok women (figs. 2 and 3), and all other portraits
of the Californians in the book, show purely Indian features.

[*The Chillula.*]—Like most of the coast tribes they are very dark-colored,
squat in stature, rather fuller-faced than the interior Indians. (P. 87.)

[*The Gallinomero.*]—May be considered a branch of the great family of the
Pomo. . . . . They are nearly black, Ventura being the blackest of all; and on
a warm, sunny day in February when he is chopping wood briskly his cuticle
shines like that of a Louisiana field-hand. The nose is moderately high, straight
and emphatic, with thick walls, and ovoid or nearly round nares; lips rather
thick and sensual; forehead low, but nearly perpendicular with the chin; face
rounder and flatter than in the Atlantic Indian; eyes well-sized and freely
opened straight across the face, with a sluggish but foxy expression; color
varying from old bronze or brown almost to black. (P. 174 et seq.)

[*The Achomawi* (Pit River Indians)].—The faces are broad and black and
calm, and shining with an Ethiopian unctuousness; the foreheads are like a
wall; in those solid, round-capped cheek-bones, standing over against one another
so far apart, and in those massive lower jaws, there is unmistakable strength,
bred in the bone through tranquil generations. . . . . Here is a hearty and a
lusty savagery which it is pleasant to see. (P. 267 et seq.)

[*In general.*]—Physically considered the California Indians are superior to
the Chinese, at least to those brought over to America. (P. 401.)

There is no word in Power's work likening the people to Negroes,
African or Melanesian; nor is there any trace in the text or the illus-
trations of wavy or curly hair, or of anything else that would suggest
aught but Indian.

As to the Zuñi, Quatrefages quotes from Schoolcraft (citation not given) thus:

In 1775 the Padre Francisco Garcés visited Zuñi, one of the southernmost pueblos, and found there two races of men and two languages. One part of the inhabitants showed a clear red color and handsome features; the others were black and ugly. An instructed native, interrogated on the subject, replied that the red people had come from one of the pueblos that became ruined, while the blacks were the ancient inhabitants of the country.

All these references to " blacks " in California Quatrefages regards as applying to Oceanic Negroes and in connection with the Garcés account says:

Thus at least at this point the Papuas, represented doubtless by mixbloods, have preceded the Pueblos, as they have preceded the Maoris in New Zealand.

As to Father Garcés, the fact is he never visited the Zuñi. The farthest he reached were the Hopi in Arizona. And it is of the Oraibi village of the Hopi that he has the following to say:

There are in this pueblo two languages, and I noted that even the modes of singing are diverse, as are the two classes of persons, who are distinguished from each other in the stature and color of both males and females (Indios y Indias). There are some of a very light (claro) and somewhat ruddy (rubio) complexion, as well-formed as the Yabipais; there are others small, dark, and ill-favored. (1900 edition, vol. 2, p. 384.)

It does not need any argument to see that in all three of the references to " blacks " in California and the southwest the eminent author was unfortunate and that they cannot be used in support of the presence in those regions of any other racial element than the Indian.

Another reference that may be brought forth in this connection is that of Vizcaino, of which Quatrefages did not know. It relates to the southern end of Lower California and hence to the region from which proceed the Ten Kate and Diguet collections. It dates from 1602 and is given by Torquemada (1615) as follows:

Father Antonio asked a Negro to carry in a basket some biscuits and distribute them among the Indians; the Negro went, and they showed much pleasure at seeing the Negro and gave him to understand that they were friendly and had had dealings with some Negroes; and that somewhere nearby there ought to be some settlement of Negroes.[57]

The only comment that seems possible on the above note is that it is very vague and uncertain. The Spanish did not know the language

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[57] " El Padre Frai Antonio. . . . . llamò à un Negro, que traìa en una Espuerta, ò Tanate, un poco de Vizcocho, para repartirlo entre ellos; y el Negro se llegò, y ellos se hollgaron mucho con vèr el Negro; y le dieron a entender, tenian ellos amistad, y trato, con algunos Negros; y que por alli cerca debia de aver alguna Poblacion de Negros." (P. 698.)

of the tribe they met with and had no interpreter; and the encounter took place in 1602, 97 years after the importation of Negroes into the West Indies [58] and scores of years after their introduction into Mexico. A little out-of-the-way settlement of escaped slaves would then have been quite possible; but there is no corroboration of any such people in this region by either the early missionaries or other writers. A fact which might possibly be drawn upon in this connection is the presence in the collection from this territory in the U.S. National Museum of two evidently Negro skeletons; but this collection was made 200 years later, after the Negro had effected a wide penetration.

SKIN, HAIR, NOSE, AND OTHER FEATURES

The basic pillar of anthropology is variation, and there is no anthropologist who is not deeply cognizant of this principle. The entire organic evolution, including that of man, is based upon and made possible only by individual and groupal variability. This means that however pure, i. e., free of mixture, human or other beings may be, there will be no two individuals, nor even any two features, exactly alike; and the same applies even more strongly to any two families, clans, tribes, or other groups. The demonstration of these facts is all about us. Further, it is well known that the normal genetic variations are influenced by the environment including habits, food, and even pathology.

But the lessons of all this are often forgotten, even by scientific workers. Thus the skin color of the Indian ranges normally and outside of all admixtures from yellowish-tan to the dark brown of solid chocolate. It is especially dark in hot and dry regions, such as Arizona and the Californias, and that particularly in the old men, who used to go almost or wholly naked. But the color is never black. It could only be compared with that of the not infrequent fullblood Negro who is dark brown rather than black. Between the color of such a Negro and that of a dark fullblood Indian there is but little difference, and it means no more that the Indian has any Negro blood than that the Negro has any Indian admixture. They are both within the possibility of normal plus environmental and conditional range of variation of their two races. These are simple facts, with many analogies in other parts of the world.

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[58] " As early as 1505 Negroes were sent to the Antilles to work in mines." The Catholic Encyclopedia, vol. 3, pp. 397-398. See also page 41.

As to the hair and features, the normal ranges of individual variation here, too, account for racial approaches. But there enters here another important factor on the originally Latin parts of the American continent, and that is the extensive admixture with post-Columbian African blacks. During more than four centuries the Negro has been brought to America. The total number of African blacks thus introduced into this continent reached millions. A considerable number from among these blacks have mixed with the Indians, and the resulting mixbloods have, as captives or visitors, spread the new blood widely, even to tribes that may never have had any direct contact with the Negro. Thus more or less truly Negroid features, as those of Whites, may today appear almost anywhere in the American tribes, but they mean as a rule a post-Columbian African, or again European, admixture. All this is well known to all anthropologists, but is often lost sight of.

THE SKULL AND THE SKELETON

What has just been said about the body applies also to the skull and the skeleton. Apparently Negroid characteristics of and about the nasal aperture, especially, are not rare in America, particularly in the hot regions. In the Southwest it is the Pueblos that show this more than the Californians, but the resemblance is limited to the nasal aperture, not extending to the nasal bones or other structures. Moreover, there is generally no reflection of it in the living.

As to the relative dimensions of the vault of the skull—in other words, its type—these are as much simply architectonic as of racial significance. Individual skulls from widely different races may and do closely resemble each other in both their absolute and relative proportions without there having been the slightest contact between the groups. It is well established that all recent human groups belong to the same species, that their differentiation is not very ancient, that their skeletal development follows the same laws, and that barring their distinguishing external marks, they present many similarities. It is only the totality of detailed cranial and facial characters of an ample series of skulls that is of much value in racial differentiation. To what disastrous results an implicit dependence on some of the cranial measurements or characters might lead, especially in single or but a few specimens, has been shown repeatedly even in cases of noted authors. With the bones of the skeleton matters are even more difficult, the general pan-human resemblances being still closer. It would be a rash anthropologist who from the skeleton alone, less the skull, would attempt a positive racial identification, except perhaps

in specially characteristic examples of the African Negro. This is
not to deny the value of craniometry or osteometry, but only to
emphasize the fact that these, like all other scientific methods, have
their limitations.

ADDITIONAL NOTES : LOWER CALIFORNIA

Let us look more closely and critically at the cornerstone of all
the contentions here dealt with, the case of Lower California. We
find the following :

Lower California was reached by Ortun Jimenez as early as 1534 ;
its coasts were explored in part by Cortés in 1536, fully by Ulloa in
1537-38, and were touched upon by Cavendish in 1587.

The bay of San Barnabè, discovered by Cavendish, was reached
and briefly occupied in 1596 by the expedition of Sebastian Vizcaino.
Other trips to the southeastern coast of the peninsula were made from
Mexico at different times during the century. Pearl fisheries had been
conducted by the Mexicans in the gulf along the eastern coasts of the
peninsula since 1615 and, some rich pearls having been brought out,
" from that time on many of the settlers from the provinces of
Culiacan and Chiametla commence to frequent the gulf in small boats
to fish for pearls and to obtain these from the natives " (Venegas),
as a result of which the Indians suffered many vexations. In 1632
a new effort at a " conquest " of the peninsula and at colonization
was made by Orteya. Still other efforts followed, all abortive, until
the arrival in 1697 of Padres Salvatierra and Piccolo, who established
the first missions, guarded by soldiers. The Philippine galleons began
in 1734 to touch at Cape San Lucas for taking on water, debarking
the sick, and repairing. In 1735-36 Yaqui and other soldiers from
Sonora and Sinaloa made war against the Lower Californians. More-
over, throughout the latter part, at least, of the history of the country
there is evidence of a continuing admixture of the Indians through the
agency of soldiers and others, besides which there was an introduction
of some Yaqui women and even whole families.[59]

In addition to all this, there was early and repeated introduction
of the African Negro among the Indians of southeastern and southern
California. The introduction of the Negro into America began with
the second voyage of Columbus in 1494. By 1501 " no Jews, Moors,
or new converts were to go to the Indies, or be permitted to remain
there " ; but Negro slaves " born in the power of Christians, were
to be allowed to pass to the Indies, and the officers of the royal revenue

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[59] See especially Lassépas (1859, pp. 8-10).

were to receive the money to be paid for their permits." (Helps, vol. 1, p. 180.) Not long after Ovando had come to the government of Hispaniola, it appears that he " solicited that no Negro slaves should be sent to Hispaniola, for they fled amongst the Indians and taught them bad customs, and never could be captured." (Helps, vol. 1, pp. 219-220.) Las Casas, to relieve the burden of the Indians, advised " that each Spanish resident in the island should have licence to import a dozen Negro slaves." (Helps, vol. 2, p. 18.) " The number of Negroes imported into America from the year 1517, when the trade was first permitted by Charles the Fifth, to 1807, the year in which the British Parliament passed the act abolishing the slave trade, cannot be estimated at less than five or six millions." (Helps, vol. 4, p. 371.) " Many instances might be adduced showing that, in the decade from 1535 to 1545, Negroes had come to form part of the households of the wealthier colonists. At the same time, in the West India Islands, which had borne the first shock of the conquest and where the Indians had been more swiftly destroyed, the Negroes were beginning to form the bulk of the population; and the licences for importation were steadily increasing in number." (Helps, vol. 4, p. 401.)

Cortés, in 1535 or 1536 (De Humboldt, 1825) in his journey to Lower California, carried with him 300 Negro slaves. Both Ulloa (1539) and Alarchon (1540), his lieutenants, were accompanied by Negroes.[60] Venegas says (pp. 94, 201): " It is known that some ships have left Mulattoes and Mestizos at Cape San Lucas." " Yeneca ", Clavigero tells us in his History of Lower California (1852, p. 83), " was a place inhabited by a tribe of Indians whose chief was a mulatto named *Chicori* "; while " the governor of Santiago [mission between La Paz and Cape Lucas] was a convert named Boton, son of a mulatto and an Indian woman". From the records about the missions it is seen that mulattoes or Negroes who lived with the Indians were instrumental in the insurrections of the Lower Californians against the Missions; and that the first permanent settlers were released soldiers, sailors, and those who knew how to work the ground (see Lassépas, op. cit.). Among these men, who generally married native women, were not a few colored.

These data show that from at least as early as 1545 the African Negro came into contact with the natives of Lower California and eventually mixed with them. There is a bare possibility that a few Oceanic blacks may have been left in the vicinity of Cape San Lucas

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[60] See also Helps, A. (1855); Winsor, J. (1885); Rippy, J. F. (1921).

by the Philippine galleons; but in general the blacks who reached the territory were African. They admixed the natives especially about the more frequented ports, such as La Paz, and they or their descendants could not but have left some of their skeletal remains with those of the Indians. That this actually happened has already been noted, and that it influenced the theories of the peopling of the peninsula will be shown later.

PHYSICAL CHARACTERS OF THE LOWER CALIFORNIA ABORIGINES

None of the explorers, missionaries, or others who ever came in contact with the natives of Lower California calls them anything but Indians, and none makes any allusion to anything other than Indian concerning their looks or behavior. This has some weight, for among the explorers and especially the missionaries were men of education, who, moreover, were well acquainted with the Indian elsewhere. What statements there are concerning the physical characteristics of the natives in question show them to be only Indians. The relevant notes are as follows:

1539. Ulloa (1810, vol. 3, pp. 478-486):

The next day wee rode at anker here [southern parts of east coast Lower California] for lacke of good weather to sayle withall: whereupon the Captaine determined to goe on shore with nine or ten in his company, to see whether there were any people there, or any signe of people that had bene there, and they found on the maine land seuen or eight Indians like to Chichimecas, which were gone a fishing, and had a raft of canes; . . . . these Indians were of great stature and saluage, fat also and well set, and of browne colour. . . . . Iuan Castilio the Chiefe Pilot went that day in the bote on shore with seuen in his company, and they landed neere the Sea, and on a certaine low ground they found foure or fiue Indians Chichemecas of great stature, and went toward them, who fled away like Deere that had been chased. After this the Pilot went a little way along the Seashore, and then returned to his boate, and by that time he was entered thereinto, he saw about fifteen Indians of great stature also, with their bowes and arrowes.

1759. Venegas (p. 58):

Of all the nations hitherto discovered, the [Lower] Californians are at least equal to any in the make of their bodies. Their faces also are far from being disagreeable, though their daubing them with ointments, painting them, and boring holes through their nostrils and ears are very great disadvantages. Their complexion indeed is more tanned and swarthy than that of the other Indians of New Spain. But they are in general robust, vigorous, and of healthy countenance.

1773. Baegert (pp. 357-358):

In physical appearance the [Lower] Californians resemble perfectly the Mexicans and other aboriginal inhabitants of America. Their skin is of a dark

chestnut or clove color, passing, however, sometimes into different shades, some individuals being of a more swarthy complexion, while others are tan or copper colored. But in new-born children the color is much paler, so that they hardly can be distinguished from white children when presented for baptism; yet it appears soon after birth, and assumes its dark tinge in a short time. The hair is black as pitch and straight, and seldom turns gray, except sometimes in cases of extreme old age. They are all beardless, and their eye-brows are but scantily provided with hair. The heads of children at their birth, instead of being covered with scales, exhibit hair, sometimes half a finger long. The teeth, though never cleaned are of the whiteness of ivory. The angles of the eyes towards the nose are not pointed, but arched like a bow [epicanthus]. They are well-formed and well-proportioned people, very supple, and can lift up from the ground stones, bones, and similar things with the big and second toes. All walk, with a few exceptions, even to the most advanced age, perfectly straight. Their children stand and walk, before they are a year old, briskly on their feet. Some are tall and of a commanding appearance, others small of stature, as elsewhere, but no corpulent individuals are seen among them, which may be accounted for by their manner of living, for, being compelled to run much around, they have no chance of growing stout.

1789. Clavigero:

In features, in hair, in beard, and in color, they [the Lower Californians] are similar to the natives of Mexico.[61]

NATIVE TRADITIONS

All the native traditions of their origin, among the Indians of Lower California, pointed to the north. No known tradition of any of the neighboring tribes, to the north or to the east, has anything in it that would refer to any non-Indian population in, or influx to, those parts of the world.

MODERN EXPLORATION

None of the Mexicans who within the last or the present centuries have studied their native tribes suggest even by a single word anything but Indian in aboriginal Lower California or on the west coasts of Mexico.

During the period from the latter part of the last century to the present time, the tribes in the vicinity of Lower California have been visited and studied by many American, as well as some European, anthropologists, including Ten Kate, Hrdlička, McGee, Kroeber, and all those who have given their attention to the tribes north of the peninsula, particularly Boas and C. Hart Merriam. There is not

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[61] " Nelle fatezze, nei capelli, nella barba, et nel colore sono similli ai popoli ne Missico." (1789, vol. i, p. 113.)

one word in the reports of any of these that would suggest the presence in these regions of any people but Indians. Diguet's portraits (1899) of the few survivors of the Lower Californians, except where the individual is plainly a mixblood, show characteristic Indian physiognomies, without trace of anything extraneous.

SKELETAL REMAINS (LOWER CALIFORNIA)

The American studies of the skulls and bones of the Californian, southwestern, and Mexican Indians have shown nothing that does not fall within the range of variation of the Indian.[62]

The United States National Museum has seven adult skulls from the east coast of Lower California, several of which show red paint. One, U.S.N.M. no 61398, from the vicinity of La Paz, collected by L. Belding—one of the original Ten Kate specimens—is painted red but is distinctly Negroid (African). It shows, moreover, a marked scaphocephaly due to premature union of the sagittal suture, a frequent and highly characteristic feature of the African Negro. The skeletal parts, also stained red, show a marked case of rickets, a disease absent in the Indians and so far as known also in the Melanesians, but common in the American colored people. The bones show marks of no great age and may well be late post-Columbian. The skeleton seems to be unquestionably that of an African Negro, who, judging from the rickets, was probably born in America.

Of the remaining six skulls, five are plainly enough Indian, though not of the common Indian types. One alone, U.S.N.M. no. 148213, from Espiritu Santo Island, is in its vault rather strongly reminiscent of some Melanesian types, but it differs from these in the teeth, the glabella, the nasion-orbital region, the malars, the alveolar protrusion, and other particulars. One can readily see how, without sufficient American material for comparison, the opinion that such a specimen was Melanesian might be formed by reputable men of science. Such opinion, however, would fail to take into consideration the fact that the vaults of skulls of the same cranial indices, particularly in the very long, narrow, and high, as in the short, broad, and low skulls, resemble each other considerably all over the earth, regardless of race; and it would fail to realize the possibilities in American as well as other skulls, under related conditions, of related developments.

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[62] Hrdlička (1906, 1927, 1931).. See also report on crania measured by Kroeber, Loud, Gifford, and Hooton *in* Gifford, E. W. (1926).

Pronounced grades of dolicho-steno-hypsicephaly occur in native skulls in other parts of America, and they even occur in instances among English and American whites, with no pathological significance. The essential character in such skulls or heads is the narrowness of the vault, the length and height being in the main of compensatory nature. The causes of the excessive normal narrowness are as yet not clearly understood. The sutures in such cases show no premature occlusion, the temporal muscles no excessive development. Such individual skulls do not fall outside the curve of normal variation: they are merely at its extreme; there is no reason, therefore, to regard them either as mutants or as extraneous. This type of skull tends, however, to " run " in families, and an incidental segregation of such families could quite possibly produce a regional strain or group marked predominantly by conspicuous narrowness of the skull.

Such a segregation has apparently taken place in southern Lower California, as may have happened before in the Lagoa Santa region and elsewhere in America. Recent evidence shows a similar group in southwestern Texas. Some very narrow skulls, proceeding from north-central Texas, were recently brought to our attention by Hooton (1933). Of four of the five crania, Hooton says: " They are excessively dolichocephalic ", but otherwise " in no particular unusual "; they may represent one of the earlier strata of the American population, but " there is a definite possibility that the extreme dolichocephaly of these skulls is merely a local or familial variation." Western Texas seems particularly fertile in this type of specimens. The whole subject is now being studied by Dr. Stewart (1935) of the United States National Museum. Decidedly narrow and long, and often high, crania may be seen not uncommonly among the eastern Algonkins, especially those of Long, Manhattan, and Staten Islands (Hrdlička, 1927, 1916). Cranial vaults (not considering facial parts) exceedingly like those of Lower California and Texas, are now known from Labrador, Greenland, the old igloos near Point Barrow, and Seward Peninsula (Hrdlička, 1930).

It seems that henceforth it will be necessary to recognize in both the Americas a widespread though irregular occurrence, among the dolichocephalic types, of skulls with excessively narrow, long, and frequently relatively high vaults, with here and there a local segregation and consequent prevalence of these characters. Such grouping, as indicated, is especially common among the Arctic Eskimo, but has manifested itself also here and there among the Indians. The " type " thus produced means, according to all the evidence, nothing extra-American, nor does it mean as Quatrefages inclined to believe, an

extension of the Eskimo, but is essentially of cranio-technological character, multiplied in various localities through heredity. Its realization is to be viewed as an interesting and peculiar natural phenomenon and not necessarily a foreign introduction. One of the greatest faults and impediments of anthropology has always been and is largely to this day, in spite of ever-growing evidence to the contrary, the notion of the permanence of skull types, and of their changeability only through racial mixtures or replacements. It is time that this attitude be replaced by more modern and rational views on the subject, based on the steadily increasing knowledge of biological laws and processes, together with such powerful factors as segregation and isolation.

RÉSUMÉ

A critical examination of the few mentions of " blacks " in America shows that, impartially considered, none bears the character of scientific evidence, particularly as to pre-Columbian occurrence.

From the standpoint of physical anthropology, the question of the presence in pre-Columbian America of a substratum of Melanesians and even Australians begins with Quatrefages', and somewhat later Ten Kate's suggestions of morphological similarities with express disavowals of racial connections. As times goes on these suggestions are gradually clothed with unwarranted significance; the presence of a Melanesian, and eventually even Australian, element in the American aboriginal population takes on more and more of reality; the doctrine is supported by resemblances in certain cranial forms and dimensions and eventually also by a series of cultural and linguistic similarities; until finally the belief assumes the semblance of a demonstrated fact. The Melanesians come to account for the American dolicho-hypsistenocephals wherever these are met with, and the Australians, though less in importance, occur from Ecuador to Tierra del Fuego. The presence of the Australians is determined on the basis of a few defective crania and resemblances in a small series of words, and these suffice not merely for the formulation of the conclusion as to the presence of the Australians in America, but also for the invocation of geographical conditions in the Antarctic that would permit the immigration of these poor navigators from Australia. Publications are multiplied, and the same communications are published repeatedly, to convince. The evidence appears at first sight so sufficient and so well backed that some serious students, though perhaps they have never had the chance to study the American natives first hand or to any material extent, feel justified in accepting and even fostering the hypotheses.

To the writer, who has spent the major part of his life in somato-logical and medical studies among the American natives, who has personally visited more than 100 tribes from Point Barrow in the north to Patagonia in the south, who now has at his disposal in his division in the U.S. National Museum over 10,000 American crania and skeletons, all of which have passed through his hands, and who was fortunate enough to examine a larger number of Australian skulls than any other man (1928), the acceptance of the theory of the pres-ence on the American continent of old contingents of either Mela-nesians or Australians has not been possible. To him the whole his-tory of the case appears to have transcended the realm of critical science and passed into that of psychology. He has asked for proofs (1926), but these were not furnished. He has scanned the assumed evidence with open mind, and found it wanting.

The objections are briefly as follows:

The assumed basic foundations of the contentions are built on sand. They are the statements of Quatrefages and Ten Kate. Both these observers made legitimate suggestions regarding some of the morpho-logical features of certain American skulls. If both went somewhat beyond this, the dearth of material in their time, the prevalent exag-gerated values then attributed to various cranial features, deceptive statements in publications of non-scientific writers, and the lures of theory, were perhaps sufficient explanation. Yet neither has seen anything really Melanesian or especially Australian in South America, which is a point of especial weight with Ten Kate, who spent a con-siderable length of time in Argentina and studied Indian material in that country. Nothing could be clearer than the statement of Quatre-fages concerning his reference to Papuan skulls in connection with the skull from Lagoa Santa.

There remain the skulls of Lower California. These skulls, like those of southwestern Texas, do bear certain resemblances to some of those of Melanesia. But this type is found also in not a few other and widely separated regions of America, both among the Indians and the Eskimo. It is contemporaneous with other types of these Ameri-can people and connects with them. In the regions in which it is found there were never reported any aberrant strains or any strains other than the Indians or the Eskimo.

The only conclusion that appears possible in view of all the facts is that the hypotheses of either Melanesian or Australian, and even that of recognizable Polynesian, presence on the American continent is not demonstrable, nor even probable; that the dolicho-steno-hypsi-cephalic cranium is not extraneous but represents one of the several

cranial types of both the Indian and the Eskimo; and that whatever
cultural or other resemblances may appear to exist between the pre-
Columbian Americas and the South Seas must have other explana-
tions than any material accession of the peoples of the latter parts of
the world to the American populations.

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PIGASETTA, 1519, Brazil; in Burney, J., A chronological history of the discoveries
    in the South Sea or Pacific Ocean: Voyage of Fernando de Magalhanes,
    1517, vol. 1, p. 21 et seq., London, 1803.

    The Brazilians of the region of Rio de Janeiro are thus described by
Pigasetta: "They are without religion. Natural instinct is their only law.
It is not uncommon to see men 125 years of age, and some of 140. They live
in long houses or cabins they call *boc,* one of which sometimes contains a
hundred families. They are cannibals, but eat only their enemies. They
are olive coloured, well made, their hair short and woolly. They paint
themselves both in body and in the face, but principally the latter. Most of
the men had the lower lip perforated in three places, in which they wore
ornaments, generally made of stone, of a cylindrical form, about 2 inches
in length. Their chief had the title of Cacique. . . . .
    "In colour they were blacker than was thought to correspond with so
cold a climate. . . . ."
    According to Burney: "Pigasetta was a man of observation, but with
very moderate literary acquirements; he was fond of the marvellous, and
much addicted to the superstitions of his time. . . . . His narrative was
written in a mixed or provincial dialect of the Italian language." His
description of a Patagon (p. 33): " 'This man', says Pigasetta, 'was so
tall that our heads scarcely came up to his waist, and his voice was like
that of a bull.' The guanaco is described by Pigasetta to 'have head and
ears like those of a mule, a body like a camel, legs like a stag, and a tail
like that of a horse, which it resembles likewise in its neighing.' Pigasetta
gives also some 'strange descriptions of birds seen by them; some which
never make nests, and have no feet, but the female lays and hatches her
eggs on the back of the male in the middle of the sea.' "

CAVENDISH, 1587, southern end of Lower California; in Kerr, Robert, A general
    history and collection of voyages and travels, vol. 10, Edinburgh, 1814.

    Cape St. Lucas, Lower California:
    "Within this cape, there is a large bay, called by the Spaniards *Aguada
Segura,* into which falls a fine fresh-water river, the banks of which are
usually inhabited by many Indians in the summer. . . . . Having dismissed
the Spanish captain with a noble present, and sufficient provision for his
defence against the Indians. . . . ." (Pp. 80-81.) The above is all that
is said about the natives.

VIZCAINO, 1596, 1602, lower end of Southern California; in Torquemada, J. de,
    Monarchia Indiana, vol. 1, book 5, chaps. 41-45.

    There are the following more relevant references to the natives; they
contain no trace of any suggestion as to Negroid characters.
    Near Puerto San Sebastian the Spanish "hallaron grande numero de
Indios Infieles, Gente desnuda, y con Arcos, y Flechas, que son sus Armas
ordinarias, y algunos Dardos de Varas tostadas, que suelen arrojarlos, y
hacen mucho daño con ellos. Fueron mui bien recibidos de todos aquellos
Indios, sin ninguna resistencia, aunque por ambas partes huvo grande
vigilancia, porque los Indios recelaban alguna traicion, y los nuestros algun
daño." (P. 682.)

At Puerto San Sebastian: " disparáron algunas Pieças de Artilleria, en presencia de much multitud de Indios, que alli estaban, que avian salido à vèr los Forasteros." (P. 683.)

Report of two soldiers on their trip to an inland village of above Indians:

" Lo que dieron por nueva fue, que vieron gran suma de Gente, y muchas Mugeres, y Niños, que los salieron à vèr, que tenian las Casas debaxo de Tierra, algunas cabadas en Peñas, y otras paxiças. Esta Gente, Rancheada por aquellos Lugares, venia cada Dia donde los nuestros estaban, dando siempre mues tras de Paz, los unos, y los otros; mas en quince Dias que alli estuvieron." (P. 683.)

Puerto La Paz: " mucha Gente, que rècibieron bien, y con muchas señales de Paz, y amistad ña nuestros Españoles, haciendo grandes demonstraciones de contento, con su venida."

" acudia todos los Dias grande numero de ellos, y con mucha familiarida los trataban, y comunicaba, y les traìan algunas Frutas, y Pescado. Los Religiosos, por su parte, incitaban à los Indios, que les diesen à sus Hijos, y à todos los Muchachos, que tenian, para enseñarlos."

Puerto San Bernabè: " en la Plaia avia un grande numero de Indios desnudos, todos con Arcos y Flechas, y algunos de ellos, con Dardos en las manos; los quales con gran grita, y voceria, y hechando Arena con las manos en alto, parecia llamban à los de los Navios."

" Los Indios andan desnudos, y usan Copetes, y en ellos ponen quantas cosas hallan, que les parezcan vistosas. Algunos de ellos tenian los cabellos rubios, usan emijarse de blanco, y negro, y son afables, alegres, agradecidos, y Gente de buenas entrañas, y un natural docil."

DIXON, ROLAND B., The independence of the culture of the American Indian. Science, vol. 35, pp. 46-55, 1912.

" The Papuan tribes are not, so far as we know, a markedly seafaring people, and so far no evidence of their actual presence east of the 180° meridian has come to light." (P. 54.)

"Although certain curious coincidences undoubtedly exist with parts of Oceania and southeastern Asia, no historical relationship between the cultures of the two widely separated regions can as yet be said to have been established."

DIXON, ROLAND B., Contacts with America across the Southern Pacific. *In* American Aborigines, Fifth Pacific Sci. Congr., pp. 315-353, published in Toronto, 1933.

" What, then is the answer to this problem of trans-Pacific cultural diffusion? Does the demonstration that a Polynesian contact took place once entitle the diffusionist to assert that all his other claims must be admitted too? I do not think so. For the speciousness of most of his trait analogies still holds, and in all such cases the claim for exotic introduction has no real basis. When all the many instances are sifted and critically weighed, there remains a very small residue of, perhaps, two or three which render the acceptance of trans-Pacific contact not only just, but apparently inescapable, although the *modus operandi* is still very difficult to understand. Such contacts as did occur were, however, limited I believe to Polynesia; I know as yet of no valid evidence for any with Melanesia or beyond. But although Polynesians did thus very rarely, and probably at long intervals, make such contacts with the people of South America, the net result was negligible so far as America as a whole or South America in particular was concerned; and the claims of the diffusionists for the far-reaching influences of trans-Pacific cultural diffusion must, I believe, be disallowed."

FRIEDERICI, GEORG, Malaio-Polynesische Wanderungen. Verhandlungen des neunzehnten deutschen Geographentages zu Strassburg, im Elsace, pp. 210-211, Berlin, 1915.

FRIEDERICI, GEORG, Die vorkolumbischen Verbindungen der Südseevölker mit Amerika. Mitteil. deutsch. Schutzgebieten, vol. 36, p. 45, 1928.

FRIEDERICI, GEORG, Zu den vorkolumbischen Verbindungen der Südsee-Völker mit Amerika. Anthropos, vol. 24, pp. 441-487, 1929; with extensive bibliography.

　　Critical discussion of the seeming cultural and linguistic evidence. Author remains skeptical.

NORDENSKIÖLD, E., Origin of the Indian civilizations in South America. *In* American Aborigines, Fifth Pacific Sci. Congr., pp. 249-311 (with 5 pp. of bibliography), published in Toronto, 1933.

　　" I wish to make it clear that by this time I have become very skeptical of Indian culture having been appreciably influenced from Oceania, although I shall endeavour to stand entirely apart from that, and discuss the problem as objectively as possible." (P. 261.)

　　"As is well known, we find in South America quite a number of culture elements of which parallels are found in Oceania. *These we may call Oceanic, although it certainly does not imply any proof that they have been imported into America from Oceania.*" (P. 264.)

　　" In conclusion I ought to remark that South American Indian civilization includes certain elements that have been adopted in post-Columbian times from Negroes and Europeans, and have so completely merged into this culture that it is only through the most careful investigation that proofs of their origin are establishable." (P. 306.)

NICOLLE, C., Un argument d'ordre médical en faveur de l'opinion de Paul Rivet sur l'origine océanienne de certaines tribus indiennes du nouveau monde. Journ. Soc. Américanistes Paris, vol. 24, pp. 225-229, 1932.

　　Advances the theory that the typhus of the rat had been brought to America on the boats of the Pacific migrants.

DIGUET, L., Anciennes sépultures indigènes de la Basse-Californie méridionale. Journ. Soc. Américanistes Paris, n. s., vol. 2, pp. 329-333, 1905.

　　Among the few cultural objects found by Diguet in the Southern California caves with the human bones, was a string apron such as described by the early missionaries as the unique garment of the women among the Pericue Indians.

WIENER, CHAS., Pérou et Bolivie, Paris, 1880.

　　Fig. p. 481: " Peinture d'un vase, trouvé à Santiago de Cao, près de Trujillo, représentant des macons construisant un mur en briques." Two figures with white faces, four black; the white figures look like Whites, have peaked soft caps (like night caps); the black figures—without any definite racial characteristics—are evidently slaves. Bricks small, like ordinary white man's bricks.

　　" Peinture d'un vase trouvé à Puno représentant des Indiens construisant une maison." (P. 471.) No description; three figures with white faces, two with dark; clothing of white-faced figures like that of Whites (especially last figure on right); that of dark-faced is Indian; features of large dark figure an Indian, those of small dark figure indistinguishable.

Oetteking, Bruno, Anthropomorphologische Beziehungen zwischen der Oster-
insel und America. Eugen Fischer Festband, Zeitschr. Morphol. und An-
throp., vol. 34, pp. 303-313, 1934.

    The author points to the resemblances between a skull from Easter
Island and some of those of California and Texas, but draws from this
no unwarrantable conclusions. He accepts the opinion that some contacts
between the Pacific Islanders and the American continent had been realized,
but as to their time, magnitude, and nature, states that all is still problem-
atical. He comments on the improbability of any very ancient or extensive
comings; America must have been well peopled before any Pacific accretions
could have reached it. A justified objection concerns Oetteking's assumption
that similarity of cranial and especially vault type means the same deriva-
tion; it may not, in fact, mean even a close racial relation.

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[63] This author's name is sometimes spelled " Clavijero ", and the initials are
variously given as " F. S.", " F. X.", or " F. J."

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MOUNT ST. KATHERINE, AN EXCELLENT SOLAR-RADIATION STATION

(WITH TWO PLATES)

BY
C. G. ABBOT
Secretary, Smithsonian Institution

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AN EXCELLENT SOLAR-RADIATION STATION

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(With Two Plates)

For many years the Smithsonian Astrophysical Observatory has been engaged in measuring solar radiation on mountain peaks in desert lands, and computing therefrom the solar constant of radiation. By that we mean the intensity of the sun's radiation as it would be found by an observer with a perfect instrument, constantly stationed in free space, outside the earth's atmosphere, at the earth's mean distance from the sun. Our object in this work is to determine to what degree the sun's output of radiation is variable, and what effects its variations produce on weather.

In his " Report of the Mount Whitney Expedition ", Langley speaks strongly of the difficulty of measuring solar radiation *anywhere* as " *formidable* ", and that of correcting such measurements for *atmospheric losses* as " *perhaps insuperable* ". But over 50 years have passed since Langley made this statement, and new apparatus and new methods have been devised.

About one million dollars has been spent in making solar measurements at the most favorable stations to be found on the earth. The most earnest efforts have been made to conquer the difficulties so forcibly stated by Langley. Many discussions of the sources of error and the degree of their elimination have been published. Tests and tested inferences which indicate very high present accuracy have been disclosed. We have not, indeed, claimed to determine the exact intensity of that ultraviolet part of the solar radiation which never reaches the earth because it is cut off completely in the upper atmosphere by ozone. This is, however, but a very small fraction of the solar constant. This region of the solar spectrum is probably the most variable. Because its rays are lost at high altitudes, its variations do not perceptibly affect the variation of the sun as an agency to be taken account of in weather.

Meteorologists have, I feel, somewhat neglected our proofs of the accuracy of our work, and have been, I think, somewhat misled by certain criticisms which have appeared in the literature.

Hence it is with unusual satisfaction that I am able to report the close agreement between the results obtained at Mount St. Katherine, our new station in Egypt, and those obtained on the same days at Montezuma in Chile. For since these totally independent stations are in opposite hemispheres, winter at the one coincides with summer at the other. If the contrasting atmospheric and geometric conditions of winter and summer do not bring about appreciable discordance, we may, it would seem, now admit that Langley's two obstacles are sensibly overcome, and the work which has gone on at Montezuma for some years may be accepted with still greater confidence than heretofore.

In the year 1931 I published, under the title " Weather Dominated by Solar Changes ", evidence that the short-interval changes in the intensity of the sun's radiation are of considerable influence in governing the ordinary fluctuations of weather. The solar-radiation values used in that paper were exclusively from the Smithsonian station at Montezuma, Chile. The results seemed to indicate that solar fluctuations of less than 0.5 percent are associated with notable weather changes. But it was impossible from the observations at one station, subject to accidental errors of the instruments and observers and to the difficulty of evaluating the losses in our atmosphere, to be sure of distinguishing solar changes of less than 0.5 percent from errors of observation, except when numerous apparently favorable cases were averaged.

Our station at Table Mountain, Calif., did not then and does not now yield results as accurate as those of Montezuma. The difficulty at Table Mountain lies not in the inadequacy of the apparatus or the observers, but in some obscure invisible changes of atmospheric conditions, whose effects we have hitherto been unable to eliminate completely. New efforts to improve Table Mountain results are now on foot.

With the generous support of the National Geographic Society, an attempt was made about 10 years ago to find and equip a supporting station in the Eastern Hemisphere equal to Montezuma. After a journey to Algeria, Egypt, Baluchistan, and South Africa, I fixed on Mount Brukkaros in South-West Africa as most suitable. Five years of observing there demonstrated that owing to high winds, which carry dust over the mountain, this station was inferior both to Montezuma and to Table Mountain.

Thereupon, with generous support from Mr. John A. Roebling, Mr. and Mrs. A. F. Moore made a second journey of exploration occupying about 20 months. They were equipped with portable in-
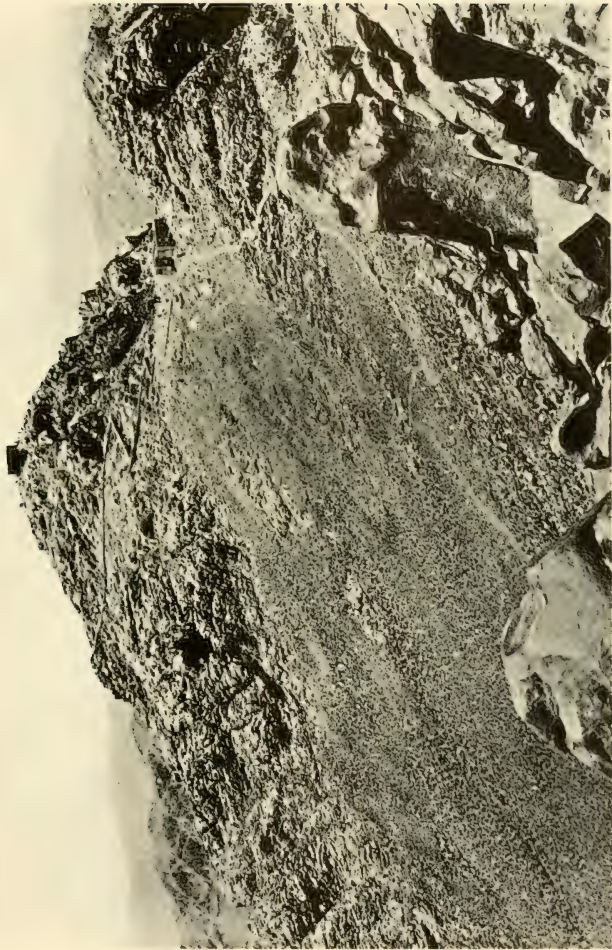
SOLAR OBSERVING STATION ON MOUNT ST. KATHERINE, SINAI PENINSULA
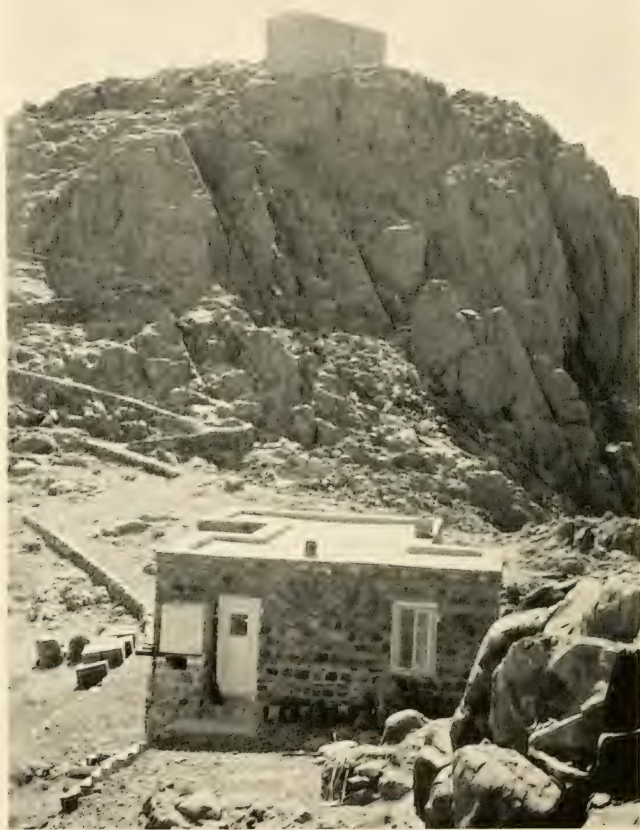
VIEW SHOWING THE WEST AND NORTH SIDES OF THE OBSERVATORY
AND THE DWELLING. MOUNT ST. KATHERINE

struments, almost, indeed, adequate to observe the solar constant of radiation, and they spent weeks and even months in observing at some of the more promising stations. In this way they visited the Cape Verde Islands, many peaks in South-West Africa, and finally Mount St. Katherine, about 10 miles from Mount Sinai in Egypt, having an altitude of about 8,500 feet. No station visited proved as promising as the last mentioned. Mr. and Mrs. Moore observed there on about 100 days during the months of March, April, May, June, and July, 1932. As a result I was convinced that Mount St. Katherine had a fair chance of proving to be nearly as satisfactory as Montezuma in Chile for solar-constant observations.

With further support from Mr. Roebling, and with the generous gift from the National Geographic Society of the apparatus which had formerly been installed at Mount Brukkaros, Mount St. Katherine was occupied in the summer of 1933, and regular observations of the solar constant of radiation were begun there in December 1933.

It is a pleasure to acknowledge the great aid received and the cordial relations which have prevailed at all times with His Eminence Porphyrios III, Archbishop of Mount Sinai, and with the monks of St. Katherine's Monastery, under his direction, on Mount Sinai. During Mr. and Mrs. Moore's reconnaissance, the monks placed an existing structure on Mount St. Katherine at the disposal of these observers and brought them supplies. When a permanent occupation was undertaken, the authorities of the Monastery built the observatory and living quarters of stone on Gebel Zebir, a spur of Mount St. Katherine, built trails, and developed water. They still continue to transport supplies to the station from the Red Sea, and are helpful in uncounted ways.

The station was built, equipped, and occupied under the supervision of Harlan H. Zodtner, our field director, assisted by Frederick A. Greeley. Mrs. Zodtner and their two children accompany Mr. Zodtner, and she makes a home for the expedition.

Plates 1 and 2 show the inhospitable mountain site, and the buildings erected by the authorities of the Monastery for the instruments and observers.

Records of the observations made from December 1933 to April 1935 have now been reduced under the direction of my colleague, L. B. Aldrich. A short method similar to those in use at our stations Montezuma and Table Mountain was developed by him for St. Katherine. Also some improvement based on additional observations has recently been made by him in the reduction tables for Montezuma, and more correct new values, differing by a few thousandths of a

calorie from those first computed, have been substituted for the broad-casted Montezuma observations of the solar constant of radiation for the past few years.

Our first care was to reduce the St. Katherine results to the same average scale as Montezuma. The scale depends on the adopted constants of the pyrheliometers, and no favorable weather for determining these was available in Washington before the departure of the Egyptian expedition. The scale correction was obtained by computing the average difference for 180 individual days of good quality at both stations. The resulting mean difference, 0.034 calorie, was subtracted from all St. Katherine daily values.

Next the average mean difference of the daily results of good quality common to the two stations was computed for each month without regard for sign, as shown in table 1, together with the num-

TABLE 1.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine*

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean Value	..	..	..	..	..	..	..	..	..	..	..	7
	Number days	..	..	..	..	..	..	..	..	..	..	..	4
1934	Mean Value	4	8	7	14	12	9	5	7	7	11	7	8
	Number days	4	7	10	13	5	11	19	19	26	14	11	8
1935	Mean Value	13	12	8	12	..	..	..	..	..	..	..	..
	Number days	9	4	7	11	..	..	..	..	..	..	..	..

General mean, 182 days, 0.0086 calorie.

ber of days represented in each mean. The values given are in thousandths of a calorie.

Thus the general mean of all the daily differences, numbering 182 in all and covering a period of 17 months, is approximately 0.45 percent of the solar constant, taken as 1.940 calories. Omitting 6 aberrant values, it is 0.0079 calorie, or approximately 0.40 percent. Dividing by $\sqrt{2}$, we find the average daily accidental error of a single station is 0.30 percent.

It was particularly important to determine whether the daily differences, Montezuma minus St. Katherine, show a yearly period. Accordingly mean values of them were computed monthly having regard to sign. The results are given in table 2. They are expressed in thousandths of a calorie.

TABLE 2.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine Taken with Regard to Sign*

Year	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean	..	..	..	..	..	..	..	..	..	..	..	+1
1934	Mean	+ 3	−4	0	+14	+12	−4	+1	+2	−3	−9	+4	+2
1935	Mean	+13	−1	−6	− 6	..	..	..	..	..	..	..	..

calorie from those first computed, have been substituted for the broad-casted Montezuma observations of the solar constant of radiation for the past few years.

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1933	Mean Value	..	..	..	..	..	..	..	..	..	..	..	7
	Number days	..	..	..	..	..	..	..	..	..	..	..	4
1934	Mean Value	4	8	7	14	12	9	5	7	7	11	7	8
	Number days	4	7	10	13	5	11	19	19	26	14	11	8
1935	Mean Value	13	12	8	12	..	..	..	..	..	..	..	..
	Number days	9	4	7	11	..	..	..	..	..	..	..	..

General mean, 182 days, 0.0086 calorie.

ber of days represented in each mean. The values given are in thousandths of a calorie.

Thus the general mean of all the daily differences, numbering 182 in all and covering a period of 17 months, is approximately 0.45 percent of the solar constant, taken as 1.940 calories. Omitting 6 aberrant values, it is 0.0079 calorie, or approximately 0.40 percent. Dividing by $\sqrt{2}$, we find the average daily accidental error of a single station is 0.30 percent.

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TABLE 2.—*Monthly Averages of Daily Differences, Montezuma Minus St. Katherine Taken with Regard to Sign*

Year	Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1933	Mean	..	..	..	..	..	..	..	..	..	..	..	+1
1934	Mean	+ 3	−4	0	+14	+12	−4	+1	+2	−3	−9	+4	+2
1935	Mean	+13	−1	−6	− 6	..	..	..	..	..	..	..	..

Fig. 1.—Comparison of solar-constant values from two stations 7,000 miles apart on opposite sides of the Equator. One percent equals four vertical divisions.

Except for the large positive values found sporadically in January 1935, and April and May 1934, there seems to be no evidence of appreciable yearly periodicity. For the differences are no larger than would be expected as the result of unbalanced experimental errors. During the months just excepted somewhat unsatisfactory conditions prevailed at one or both stations. This general conclusion is highly satisfactory. It means that on good days the differences of exposure of instruments caused by unequal altitudes of the sun and the differences of procedure and magnitudes in allowing for atmospheric losses at two independent stations in opposite hemispheres, separated by nearly a third the circumference of the earth, produce no differential periodicity in excess of two or three tenths of 1 percent of the solar constant of radiation. Accordingly the yearly range of systematic error for one station, being half as great as the combined ranges of two stations, is surely negligible. Summer with its increased heat, haziness, and humidity, opposed by winter with its greater cold, clearness, and dryness, and besides these the observation of the sun at different angles above the horizon at the constrasted stations, have altogether failed to produce differences in the results which indicate that systematic errors are certainly appreciable.

Finally, the individual daily values at the two stations during the five best months, June to October, 1934, have been tabulated in table 3, and plotted in figure 1. In computing the mean values and deviations in the table, I have included a few fairly good values marked " unsatisfactory " which were excluded in tables 1 and 2.

A heavy line in the figure gives the best value of the march of the solar constant of radiation.[1] The independent results of the two stations are indicated by a lighter line for Montezuma and a dotted line for St. Katherine. The close accord shown by these two remote and contrasting stations cannot but encourage the belief that the observations of the variability of the sun hitherto reported from Montezuma are very close to the truth.

Every day but six within this interval of 152 days from June to October 1934 is covered by good observations at one station or both. The two stations obviously support each other in displaying in common many variations of the intensity of solar radiation. The most conspicuous variation of long period shown has a periodicity of a little more than 40 days, perhaps even 45 days, and has an amplitude of about $\frac{3}{4}$ of 1 percent. This effect is doubtless to be associated with that solar periodicity of about 45 days to which I once drew attention

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[1] The table and diagram were prepared independently and may differ slightly.

TABLE 3.—*Comparative Solar-Constant Results at Montezuma and St. Katherine*

The values given are thousandths of a calorie, and in columns 2, 4, 6 are to be understood as added to 1.900 calories

1934	Montezuma		St. Katherine		S. C. Mean	Stations used [a]	Montezuma minus St. Katherine
	S. C.	Gr.	S. C.	Gr.			
June 1	..	..	..	..	..	..	..
2	..	..	..	..	..	..	..
3	45	S—	..	..	45	M	..
4	51	S—	106	U	51	M	..
5	52	U	..	..	52	M	..
6	38	S—	102	U?	38	M	..
7	40	S	42	S—	41	B	— 2
8	..	..	34	S—	34	K	..
9	..	..	43	S—	43	K	..
10	51	S—	43	S—	47	B	+ 8
11	..	..	47	S—	47	K	..
12	..	..	35	S—	35	K	..
13	40	S—	58	S—	49	B	—18
14	45	S—	52	S—	48	B	— 7
15	45	S	..	..	45	M	..
16	49	S—	39	S	44	B	+10
17	46	S	39	S—	42	B	+ 7
18	37	S—	50	U	43	B	—13
19	..	..	66	U	..	..	..
20	..	..	91	U	..	..	..
21	39	S—	47	S	43	B	— 8
22	..	..	44	S—	44	K	..
23	45	S—	44	S	44	B	+ 1
24	..	..	44	S—	44	K	..
25	..	..	46	S—	46	K	..
26	38	S—	45	S—	42	B	— 7
27	35	S	49	S	42	B	—14
28	41	S—	55	S—	48	B	—14
29	..	..	..	..	..	..	..
30	..	..	..	..	..	..	..
July 1	43	S—	42	S—	42	B	+ 1
2	39	S—	47	S—	43	B	— 8
3	50	S—	43	S—	46	B	+ 7
4	..	..	51	S—	51	K	..
5	49	S	52	S—	50	B	— 3
6	46	S—	51	S—	48	B	— 5
7	50	S	..	..	50	M	..
8	48	S—	..	..	48	M	..
9	..	..	57	S—	57	K	..
10	..	..	59	S	59	K	..
11	..	..	50	S	50	K	..
12	..	..	49	S—	49	K	..
13	39	S	35	S—	37	B	+ 4
14	49	S	40	S—	44	B	+ 9
15	43	S	57	S—	50	B	—14
16	36	S—	31	U	34	B	+ 5
17	45	S	51	S—	48	B	— 6
18	45	S	45	S—	45	B	0
19	42	S	38	S	40	B	+ 4
20	38	S—	41	S	40	B	— 3
21	44	S	46	S	45	B	— 2
22	46	S—	43	S	44	B	+ 3
23	40	S	37	S—	38	B	+ 3
24	41	S—	39	S	40	B	+ 2
25	45	S	45	S	45	B	0
26	49	S	32	S—	40	B	+17
27	..	..	45	S—	45	K	..
28	..	..	44	S—	44	K	..
29	..	..	48	S—	48	K	..
30	36	U	47	S—	42	B	—11
31	44	S	39	S—	42	B	+ 5

[a] M = Montezuma.   K = St. Katherine.   B = Both.

TABLE 3.—Continued

1934	Montezuma		St. Katherine		S. C. Mean	Stations used [a]	Montezuma minus St. Katherine
	S. C.	Gr.	S. C.	Gr.			
Aug. 1	..	..	46	S—	46	K	..
2	..	..	45	S—	45	K	..
3	..	..	41	S—	41	K	..
4	52	S—	28	S--	40	B	+24
5	46	S	41	S—	44	B	+ 5
6	..	..	41	S—	41	K	..
7	45	U	42	S—	43	B	+ 3
8	46	S	44	S—	45	B	+ 2
9	46	S—	47	S—	46	B	— 1
10	46	S—	40	S—	43	B	+ 6
11	43	S—	53	U	48	B	—10
12	41	U	47	U	44	B	— 6
13	..	..	49	S—	49	K	..
14	45	S—	44	S—	44	B	+ 1
15	51	S—	43	S—	47	B	+ 8
16	50	S—	48	S—	49	B	+ 2
17	30	S—	48	S	39	B	—18
18	59	U	50	S	54	B	+ 9
19	51	S	50	S	50	B	+ 1
20	49	S—	57	S—	53	B	— 8
21	52	S	38	S	45	B	+14
22	54	S	45	S	50	B	+ 9
23	49	S	40	S	44	B	+ 9
24	49	S	52	S	50	B	— 3
25	47	S—	47	S	47	B	0
26	..	..	45	S	45	K	..
27	53	S—	45	S—	49	B	+ 8
28	..	..	46	S—	46	K	..
29	..	..	40	S	40	K	..
30	..	..	47	S	47	K	..
31	34	S—	37	S	36	B	— 3
Sept. 1	36	S	26	S	31	B	+10
2	37	S—	47	S ·	42	B	—10
3	46	S—	42	S—	44	B	+ 4
4	43	S—	46	S	44	B	— 3
5	..	..	39	S—	39	K	..
6	47	S—	48	S—	48	B	— 1
7	43	S	49	S -	46	B	— 6
8	47	U	48	S—	48	B	— 1
9	41	S	47	S—	44	B	— 6
10	44	S—	50	S	47	B	— 6
11	39	S—	46	S	42	B	— 7
12	44	S—	53	S	48	B	— 9
13	50	S—	41	S—	46	B	+ 9
14	51	S	33	S—	42	B	+18
15	51	S	52	S—	52	B	— 1
16	44	S	43	S—	44	B	+ 1
17	47	S—	50	S	48	B	— 3
18	46	S	46	S	46	B	0
19	38	S	42	S	40	B	— 4
20	44	S—	47	S—	46	B	— 3
21	44	S—	54	S—	49	B	—10
22	38	S—	53	S—	46	B	—15
23	53	S—	54	S—	54	B	— 1
24	44	S—	52	S—	48	B	— 8
25	38	S	56	S—	47	B	—18
26	56	S	55	S—	56	B	+ 1
27	42	S	48	S	45	B	— 6
28	31	S—	52	S	42	B	—21
29	45	U	53	S—	49	B	— 8
30	42	U	46	S—	44	B	— 4

[a] M = Montezuma. K = St. Katherine. B = Both.

Table 3.—Continued

1934	Montezuma S. C.	Montezuma Gr.	St. Katherine S. C.	St. Katherine Gr.	S. C. Mean	Stations used [a]	Montezuma minus St. Katherine
Oct. 1	41	S—	54	S—	48	B	—13
2	46	S—	56	S	51	B	—10
3	44	S	58	S	51	B	—14
4	44	S—	52	S	48	B	— 8
5	49	S—	56	S	52	B	— 7
6	42	S—	65	S—	54	B	—23
7	45	S—	52	S—	48	B	— 7
8	50	U	49	S	49	B	+ 1
9	52	S—	46	S—	49	B	+ 6
10	34	S—	51	S—	42	B	—17
11	39	S	47	S—	43	B	— 8
12	50	S—	45	S—	48	B	+ 5
13	37	S—	47	S—	42	B	—10
14	47	S	19	U	47	M	..
15	50	S	34	U	42	B	+16
16	..	..	43	S—	43	K	..
17	45	S—	65	S—	50	B[b]	—20
18	45	S—	54	S—	50	B	— 9
19	37	S—	67	U	37	M	..
20	54	S—	82	U?	54	M	..
21	55	S	92	U?	55	M	..
22	54	S	..	..	54	M	..
23	51	S	..	..	51	M	..
24	56	S	..	..	56	M	..
25	46	S	103	U?	46	M	..
26	41	S	..	..	41	M	..
27	53	S	..	..	53	M	..
28	49	S—	52	U	50	B	— 3
29	..	..	..	..	..	..	..
30	53	U	52	S—	52	B	+ 1
31	52	U	51	S—	51	B	+ 1
Nov. 1	53	S—	53	S	53	B	0
2	51	S—	55	S—	53	B	— 4
3	58	S—	56	S—	57	B	+ 2
4	..	..	67	U?	..	..	..
5	58	S	..	..	58	M	..
6	57	S—	47	S—	52	B	+10
7	42	S—	94	U	42	M	..
8	50	S	..	..	50	M	..
9	..	..	51	S—	51	K	..
10	63	S—	45	S—	54	B	+18
11	45	U	52	S—	49	B	— 7
12	..	..	58	U	..	..	..
13	..	..	..	..	..	..	..
14	50	S	..	..	50	M	..
15	59	S—	46	S	52	B	+13
16	..	..	50	S	50	K	..
17	..	..	58	S—	58	K	..
18	..	..	58	S—	58	K	..
19	53	S	52	S—	52	B	+ 1
20	53	S—	44	S—	48	B	+ 9
21	44	S	..	..	44	M	..
22	44	S—	..	..	44	M	..
23	55	S—	..	..	55	M	..
24	..	..	48	S—	48	K	..
25	52	S—	..	..	52	M	..
26	50	S	43	S—	46	B	+ 7
27	53	S—	54	S—	54	B	— 1
28	47	S	57	S	52	B	—10
29	43	U	66	S—	55	B	—23
30	..	..	54	S—	54	K	..

[a] M = Montezuma.   K = St. Katherine.   B = Both.
[b] Montezuma given greater weight in the mean.

as having occurred in the year 1924.[2] Many short interval fluctuations are also supported by both stations.

There is little to choose between the two stations as to the smoothness (*i. e.*, freedom from wild values) of their curves during this interval of 5 months. St. Katherine yields a few more days than Montezuma. As the average daily discrepancy between the stations during these 5 months is only 0.007 calorie, we infer that the average accidental error of a single station then was but 0.005 calorie, or $\frac{1}{4}$ of 1 percent.

A careful record of conditions at St. Katherine has been kept under Mr. Zodtner's direction. It is set forth in table 4.

On the whole it appears that Mount St. Katherine, except for a greater average wind velocity during the usual hours of observing, and greater haziness during the spring months, is equally as favorable a station for solar-constant observations as Montezuma. Moreover, the two drawbacks just mentioned do not seem to have lowered the quality of the daily St. Katherine observations below those of Montezuma. Thus far her numbers of days of good observing quality per year have slightly exceeded those of Montezuma, so that St. Katherine may be ranked quite as high on the whole as Montezuma.

In my paper " Weather Dominated by Solar Changes ", cited above, I indicated the dependence of weather on solar fluctuations of short interval. The results seemed to point to a possibility that at least at some stations and during some months of the year forecasts of weather for 10 days in advance might profitably be based on solar-radiation observations if these could be of sufficient accuracy and continuity. At that time it seemed doubtful if stations could be found whose combined results would yield on nearly every day in the year solar-constant values accurate to $\frac{1}{4}$ of 1 percent as regards accidental error, which seemed to be the minimum requirement for the purpose suggested. But not only do our two best stations now nearly reach that desired accuracy, but the impending substitution of Ångström type pyrheliometers at both stations as secondary instruments will probably increase this accuracy.

For nearly 20 years H. H. Clayton has worked assiduously on the problem of the correlation of solar variation with weather. In a recent paper [3] crammed with statistical results, he states: " In short, these extensive data, covering all parts of the world, prove that solar

[2] See Smithsonian Misc. Coll., vol. 85, no. 1, fig. 3, 1931.

[3] Clayton, H. H., World weather and solar activity. Smithsonian Misc. Coll., vol. 89, no. 15, p. 24, 1934.

TABLE 4.—*Observing Conditions at St. Katherine*

Month and year	Number of days			Observations possible:		Sky quality						Wind in m. p. h.		
	Clear	Part Cloudy	Cloudy	Long method	Short method	Haze near sun: None	Light	to	moderate	to	thick	Max. 24 h.	Min. 24 h.	Average for month
1933														
Oct.	17	14	0	23	31	4	6	6	12	3	0	30.7	3.6	13.3
Nov.	9	14	7	14	23	0	8	5	9	1	0	27.9	3.0	8.0
Dec.	7	5	19	8	12	8	2	0	1	1	0	46.4	5.1	16.2
1934														
Jan.	7	11	13	8	17	7	5	3	1	2	0	29.0	3.5	13.7
Feb.	15	6	7	16	21	6	7	2	2	2	2	41.4	1.9	14.3
Mar.	13	11	7	13	23	9	2	2	3	4	3	30.0	0.5	8.0
Apr.	15	11	4	20	26	4	5	3	7	4	4	32.2	1.8	9.8
May	5	12	14	9	17	0	4	4	3	0	6	25.0	0.8	8.1
June	13	12	5	19	25	2	6	2	4	1	0	13.5	0.7	5.3
July	16	13	2	27	29	8	5	5	8	2	0	11.0	0.2	3.6
Aug.	21	10	0	26	31	10	7	4	7	2	1	10.4	0.9	4.1
Sept.	23	7	0	30	30	8	10	3	6	0	2	18.6	1.2	5.5
Oct.	9	17	5	14	25	3	10	0	2	1	5	28.8	2.3	9.2
Nov.	3	19	8	10	22	11	8	1	0	0	0	18.4	0.9	8.2
Dec.	8	16	7	14	24	21	3	0	0	0	0	35.1	2.8	12.0
1935														
Jan.	5	16	10	11	18	13	2	2	0	1	0	…	…	19.0+++
Feb.	10	12	6	12	20	14	1	0	0	2	3	…	…	16.5++
Mar.	10	16	5	12	25	8	1	2	1	3	10	…	…	12.5+
Apr.	14	12	4	21	26	9	4	1	3	0	9	…	…	11.6
May	8	15	8	18	23	1	4	4	5	3	9	…	…	8.5
June	14	16	0	23	30	4	6	2	7	1	10	…	…	6.8
July	19	11	1	22	30	2	15	6	4	0	3	…	…	8.2

+   ++   +++ One, two, and three days, respectively, lost owing to very high winds.

variation is an important weather factor, even the dominating one, as also appears from figures 13 and 14 and 23-26."

Our experience in selecting and operating solar-radiation stations has now placed us in a position where we might with relatively moderate additional financial support set up several additional solar-radiation stations competent to produce first-rate results. We could then furnish almost every day in the year solar-constant values with accidental errors not exceeding $\frac{1}{4}$ of 1 percent. The conclusions of Clayton and ourselves relative to the dependence of weather on solar variation seem to have reached such a stage of probability as to warrant this additional expense in the interest of producing a new tool of possible value for meteorology.

MORPHOLOGY OF THE COLEOPTEROUS FAMILY STAPHYLINIDAE

BY
RICHARD E. BLACKWELDER
Stanford University, California

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CONTENTS

INTRODUCTION

One of the chief justifications for the study of the morphology of any group of organisms is the importance of this branch of the science in the classification of those organisms. Morphology is one of the important foundations of classification because it supplies the easiest and most usable key to the relationships between individuals. The discovery and evaluation of these relationships is an important part of our attempts at classification.

The purpose of such a morphological study as this may be stated as follows: In the first place, it is an attempt to increase the knowledge of the external morphology of the Staphylinidae as a basis for a better understanding of their classification. It is furthermore an attempt to add something to the knowledge of the morphology of beetles in general. This very large and important field has been so poorly explored up to the present time that any attempts to make additions are not only justified but very much to be desired.

In any very large group of animals the number of species whose morphology can be investigated in detail is necessarily limited by considerations of time and expense of publication. Any conclusions drawn from the comparatively few representatives examined must necessarily be only tentative and suggestive, and they must await the less detailed examination of the numerous other species for confirmation.

The large order Coleoptera is one of the best known of all the groups of insects. One of the largest included families is the Staphylinidae, containing approximately one-tenth of all the known species of beetles. The study of this family, however, has been relatively neglected and the list of known species probably does not include one-fifth of those actually in existence, and even from North America it is doubtful if over one-half the species have been recorded. This condition is due to the difficulties which attend the study of this family when it is carried on by the methods formerly employed by many entomologists—methods which fail to provide an adequate knowledge of the comparative morphology of the group. These difficulties vanish in large part when the study is approached in the right manner.

To a student of the Coleoptera desiring to undertake a comparative morphological study of some group as a basis for its classification, the family Staphylinidae has much to commend it. It is sufficiently large to show a wide range of structure; the total number of species is large enough to provide ample material for the full development of one's ideas of the principles of classification; a great number of its members are common enough to be very easily obtained; the ma-

jority of specimens are small enough to be suited to examination with the compound microscope; and, not the least, very little has been known of its fundamental structure and relationships.

The present study deals with a family which contains nearly 20,000 known species. The fact that it would be impossible to study all of these in detail is a very potent additional reason for studying a few representatives as well as possible with the goal of establishing a foundation and working outline of the external morphology which can later be used to support a classification or which may be tested and enlarged by further investigations on additional material.

It gives me pleasure gratefully to acknowledge the help and encouragement of Prof. G. F. Ferris, under whom this study has been carried out. I am also much indebted to R. E. Snodgrass, who has read the manuscript and given many very helpful suggestions.

The Literature on the Staphylinidae

In a brief review of the literature relating to the family Staphylinidae it is not necessary to go back beyond the works of Erichson in 1839 and 1840. Previous to his time most of the work done was a bare description of new genera and species. In the " Käfer der Mark Brandenburg " in 1839 Erichson began the studies that resulted the following year in his masterly volume " Genera et Species Staphylinorum ". This work contains a fairly complete classification of the family, with keys to genera, and descriptions of all species known at that time. It is undoubtedly one of the masterpieces of early systematic entomology.

From the time of Erichson there has been a continual stream of descriptions of new genera and species, published in many languages and in hundreds of different periodicals. Many of the most important studies of the staphylinids have been made in connection with large faunal monographs. But by far the largest part of the information published concerning this family has never been assembled in any way, with the one exception of the bibliographic catalogue in the publication of Junk and Schenkling, the " Coleopterorum Catalogus ". The student finds it necessary continually to go to the original publications, and he finds many of the keys for identification unsatisfactory or incomplete.

Any knowledge of the morphology of this family is exceedingly difficult to obtain from the literature. Most of the discussions are restricted to a certain species or to a certain group of structures on that species. Practically no real comparative study has been made of even

one set of characters, the only possible exception to this being the work of Eichelbaum and of Sharp and Muir on the genitalia.

MATERIAL

The material available for this study includes chiefly specimens from North America supplemented by additional ones from Central America and Europe. Wherever possible one of the common species was selected.

Eichelbaum (1909) listed 15 subfamilies of the Staphylinidae. In these he recognized 43 tribal groups. The present study includes representatives of 10 subfamilies and 25 tribes. The subfamilies of which representatives were not available are: Megalopinae, Lepto-typhlinae, Euaesthetinae, Trichophyinae, and Cephaloplectinae. Besides these, the tribes not represented include: Neophonini, Apateticini, Platyprosopini, Pygostenini, Trichopseniini, Deinopsini, Gymnusini, Myllaenini, Pronomaeini, Diglottini, Hygronomini, and Digrammini.

The species selected in each tribe are not considered as actual representatives or types but merely as members of that group and examples of it. In several cases more than one species has been used within a tribe because of the great variation in certain characters, but lack of time and space has prevented the further extension of the list.

It is very much to be regretted that members of the subfamily Aleocharinae are so difficult of identification while so abundant everywhere. Only the larger tribes are represented in this material, and this means that the aberrant and unusual forms have not been studied or included in the comparisons.

All the American species were identified by the writer. Most of the European species were obtained from Emmerich Reitter of Vienna.

PREPARATION OF MATERIAL

The preparation of material so that it can be adequately studied is one of the most important steps in the solution of any systematic problem. In the treatment of the specimens first consideration should be given to the making available of all characters which might be of value in the study. How far this ideal is from the condition actually attained in much systematic work has been discussed at length by Ferris (1928), and a similar inadequacy is often shown in morphological studies.

Three general means of mounting and preservation have been employed by entomologists. These are: On pins, in fluid such as alcohol, and on microscope slides. According to Chamberlin (1931):

It may be said that the important thing in the preparation of material for study is not the following of any particular set method, but rather the treatment of material in such a way that the structures which it is necessary to employ in systematic work (that is, those structures, regardless of size or obscurity, which the study of comparative morphology shows to be significant for such purposes) shall be rendered clearly visible.

In no group of insects will either of the first two methods alone suffice to this end, and in all of the groups of minute insects the slide preparations, supplemented in certain cases by the other methods, have unquestionably proved to give not merely better results but the only reasonably complete and satisfactory ones.

The Staphylinidae may properly be regarded as a group of minute insects, as only a comparatively small percentage of them exceed 8 mm in length, and the average length is probably below 5 mm. The actual size ranges from slightly over 5 cm down to less than 1 mm.

The usual methods of mounting small beetles on pins and paper points permit an examination of only the larger and more obvious characters, and is utterly useless in any detailed study of the morphology. It is essential in this type of work that the separate elements of the body wall be carefully dissected and perhaps examined with transmitted light, and this requires a considerable preparation of the material.

The method of preparation worked out for the present study is outlined below. It is a modification of the practice generally employed in the study of minute insects such as scale insects and lice.

Because of the methods used in the past in the examination and description of species and the establishment of classifications, it is impossible to correlate with the literature identifications in the Staphylinidae made from slide preparations. For this reason specimens should first be mounted on fine paper points on pins in the usual manner and identified as accurately as possible using all available aids.

The special technique is as follows: The specimen is dropped into a 10 percent solution of KOH and heated to near the boiling point for about half a minute. This is to soften the body sufficiently to prevent breakage when the elytra and wings are dissected off, which is done by removing the specimen to water in a watch glass and working under the binocular microscope with fine dissecting needles. The abdomen is now dissected away behind the metasternum, the head separated from the prothorax, and the prothorax from the remainder

of the thorax. These four parts of the body are replaced in the KOH and allowed to boil gently for about one minute. The elytra and wings are transferred from the water to 95 percent alcohol for several minutes and then mounted as described below. After boiling the body, it is removed again to water, where the disintegrated viscera may be pressed out and the antennae, mouthparts, legs, and genitalia dissected off. If any of these parts (notably the head and thorax) are too heavily pigmented to permit easy study with transmitted light they should now be placed in a 3 percent solution of hydrogen peroxide to which has been added a small amount of ammonia (about one drop per cm³ of peroxide). It is essential that fresh ammonia be used and that the mixture be not allowed to stand before using. It quickly loses its efficacy after being mixed. Two to six hours in this solution will suffice to bleach the darkest sclerites, and this treatment has the great advantage of leaving the edges and sutures darker than the rest. These parts are now placed again in the boiling KOH for a few seconds to remove the peroxide and are then returned to the water to remove the KOH. Now all parts are transferred to alcohol for several minutes and then mounted. The most satisfactory mounting medium known to me is euparal. (This can be obtained at a considerably reduced price under the name of Diaphane.) Specimens are arranged in a drop of the medium on the slide and a cover glass gently pressed down until all surplus medium is squeezed out. If necessary the cover glass may be supported by means of paper rings, which prevent the flattening and consequent distortion of the objects. The slides are then labeled and dried for two or three days.

Material prepared in this way has a few disadvantages. The parts can be studied only in the position in which they are mounted. The color and general shape or habitus of the insect is lost in large measure. But these are much more than offset by the ease of examination under the compound microscope and the fact that one can approach the ideal of being able to see and use all of the characters that are actually present on the body of the beetle.

ILLUSTRATIONS

The illustrations, which form an important part of this study, are intended to serve primarily two purposes. First, they illustrate the detailed anatomy of a typical staphylinid, together with that of other special structures found only on other species; and second, they illustrate briefly the variations within the family of each of the structures treated. They have been prepared with these two aims in mind,

and the figures showing variation have for the most part not been burdened with interpretations of structure. It is believed that this latter will be obvious upon comparison with the morphological figures. As far as possible, all unusual or extreme structures are described in the text.

The figures have all been drawn directly from slide mounts by means of a camera lucida. No attempt has been made to indicate or calculate the magnification attained, as this is believed to be purely incidental and of no importance to a knowledge of the morphology. Figures have been drawn to uniform sizes to show comparable details in the different species regardless of the original size.

The abbreviations used are the same on all the figures and are listed and explained at the end of the paper. They are for the most part the same as those adopted by Snodgrass in his recent papers.

It should be borne in mind that each figure is more or less of a composite, having been checked with as many specimens as possible and frequently drawn from parts of several.

MORPHOLOGY OF THE STAPHYLINIDAE

General Considerations

Because of the fact that there does not exist any single work which deals in any considerable degree of completeness with the comparative morphology of the Coleoptera as a whole, it has not been possible to adopt any one system of study or any single terminology. In the case of those structures that have been separately studied in a comprehensive way, an attempt has been made to follow that work in general. A very large part of the structure of beetles, however, has never been monographed comparatively, with the result that the present study has necessarily been built upon the basic works of Snodgrass and others, in which the Coleoptera are treated only as a whole along with the other orders of insects.

In the case of the structure of the head capsule, the interpretation adopted here is that worked out by Snodgrass and Böving. Its applications to the order Coleoptera have not previously been presented.

The orientation of the legs is a matter of common inconvenience. The fundamental position of the leg is assumed to be as follows: The leg is extended at right angles to the body, with each part extended distally and the empodium of the pretarsus facing downward, the coxa suspended from the body by the condyles at its proximal end. Following this orientation, it is possible to see four chief aspects of the leg, the anterior and the posterior, and the dorsal and the

ventral. The bicondylar joints all have one condyle anterior and one posterior with the exception of the trochantero-femoral joint which has one dorsal and one ventral. The claws are thus placed one anterior and one posterior.

An isolated leg can usually be readily oriented. The shape of the coxa will immediately determine the thoracic segment from which it came. Whether the leg came from the right or left side of the animal can frequently be told by the vestiture. On the coxae the vestiture is generally lacking on the posterior aspect except as the tip. The orientation of the posterior coxae can often be recognized at a glance by the expansion over the base of the trochanter, which occurs only on the anterior aspect.

The wing venation has been interpreted according to the scheme proposed by Forbes (1922). There was some hesitation, however, in accepting this course, as it is believed by some writers that the darker bands in the distal part of the wing do not represent veins that are in any way homologous with any veins in other insect wings. Certain parts can, however, be definitely correlated with other beetle wings, so that the classification of the veins of this family is probably as correct as that for the order as a whole. The spiracles of the thorax are four in number. One pair is situated in the conjunctivum between the prothorax and mesothorax on the ventral aspect, and the other pair is in the membrane just anterior to the base of the hind wing on the dorsal aspect. They are totally different in structure externally, the former resembling the abdominal spiracles very closely in appearance. They belong to the mesothorax and metathorax respectively.

The abdomen is 10-segmented in all staphylinids, and probably in all beetles in a morphological sense. The last two or three segments form the genitalia, whereas the first two are frequently much reduced or united to the metathorax. In all staphylinids the first segment is present only on the dorsum and is more closely united to the metathorax than to the second abdominal segment. It is practically always dissected off with the thorax.

As far as the family Staphylinidae is concerned only the genitalia have been treated in anything approaching a complete comparative study, and even in that case there has been no comprehensive summary except that given for the males by Sharp and Muir (1912). Their terminology has been followed chiefly, though it is rather artificial and obscures the true relationships. In the case of the genitalia of the female, it has been found necessary to modify somewhat the

interpretation of Tanner (1927). He has considered only one staphylinid, *Creophilus villosus*.

The spiracles are the chief landmarks of the abdomen. They occur on each segment from one to eight. They are in all insects morphologically a part of the tergum and in these forms are generally actually in the tergites. A curious error is made regarding these by Leconte and Horn (1883), as follows: "The breathing pores, or *spiracles*, are situated in the connecting membranes, or in the upper inflexed portions of the ventral segments." In the present family, at least, they are always very definitely placed in the tergal elements.

STRUCTURE OF A REPRESENTATIVE SPECIES

The species *Creophilus villosus* (Grav.) has been selected to be the subject of detailed investigation for the following reasons: It is one of the commonest, most widespread, and most readily attainable of American staphylinids; it very closely resembles related species that are common throughout most of the world; it is a typical staphylinid, being very similar to the type genus of the family; and it has been used, more than any other staphylinid species, as the basis for previous studies of the morphology of this family.

THE HEAD

The walls of the head are continuously heavily sclerotized on the dorsal, lateral, and ventral aspects. These walls thus form a solid capsule (fig. 1 F) with an opening at the posterior end, the foramen magnum. The walls of this capsule are formed of certain sclerites which have become united, with a corresponding obliteration of the sutures between them.

The dorsal aspect of the head (fig. 1 A) is occupied by a single large sclerite extending anteriorly from the rim of the foramen magnum (*for*) to the membranous anteclypeus (*aclp*) and occupying the entire width of the head. This area is the epicranium (*epi*) and is formed by the obliteration of sutures which would divide it into frons, vertex, genae, postgenae, and occiput. The occiput (*oc*) is represented by a narrow band around the dorsal and lateral rims of the foramen magnum, but it is undifferentiated from the vertex (*vx*). This is due to the obliteration of the occipital suture. The ventral continuations of the occiput on the sides of the head are the postgenae (fig. 1 A, E, *pge*). Since the occipital sutures, if present, would extend to the base of the labium and maxillae, it follows that the areas included by them, the postgenae, occupy in this species the two regions

on the sides of the gula (*gu*) and extending from the maxillary articulation to the foramen magnum and the lateral extensions of the occiput, from which they are not separated. The vertex itself occupies nearly the entire dorsal aspect of the head and most of the
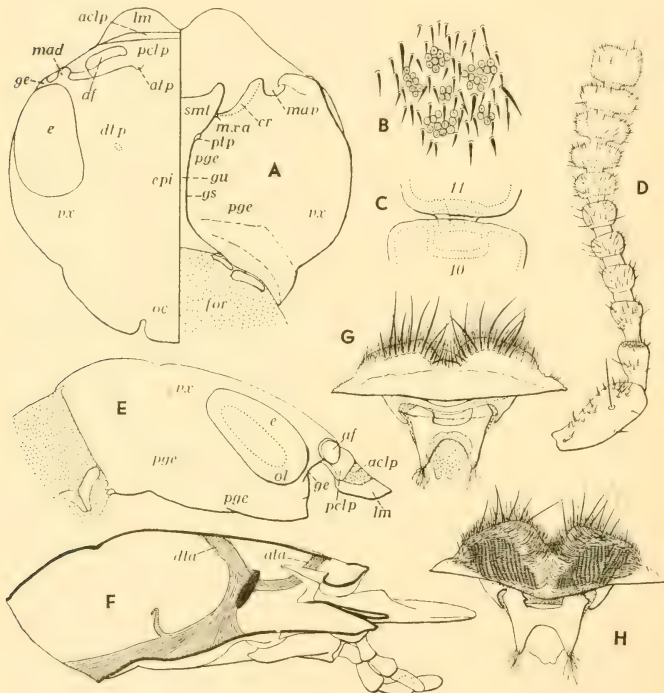
FIG. 1.—Morphology of the head of *Creophilus villosus* (Grav.).

A, dorsal and ventral aspects of head with appendages removed. B, minute setae and pores from terminal segment of antenna. C, detail of joint between the tenth and eleventh segments of antenna. D, antenna. E, lateral aspect of head with appendages removed. F, sagittal section of head to show tentorium. G, dorsal aspect of labrum. H, ventral aspect of labrum.

lateral aspects as well. The area between the eyes, from the anterior tentorial pits to the occiput and the areas immediately behind and beneath the eyes as far as the postgenae are all a part of this sclerite (fundamentally a pair of sclerites, one on each side of the midline

or epicranial suture). The term gena is used to designate the area
(fig. 1 E, *ge*) on the lateral aspect of the head between the eye and
the dorsal articulation of the mandible. It is not set off as a separate
sclerite. The frons is present as an area in all insects to be defined
by the frontal sutures and the epistomal suture, if present, but bear-
ing the origin of the labral retractor muscles. In the present species
neither the frontal nor the epistomal sutures are present, and the
frons is therefore represented only in a triangular area behind the
line of the anterior tentorial pits.

The clypeus is divided into two distinct sclerites, the postclypeus
(fig. 1 A, E, *pclp*) and the anteclypeus (*aclp*). The postclypeus is
fused with the frons at the line of the anterior tentorial pits and
extends around the antennal fossae. The anteclypeus is a membranous
strip between the anterior margin of the postclypeus and the labrum
(*lm*).

The labrum (fig. 1 G, H) is a broad bilobed sclerite attached to the
cephalic end of the clypeus. It is continuous with the rest of the dorsal
surface of the head. Its anterior dorsal margin is clothed with both
stout and fine setae, whereas the remainder of its dorsal surface is
smooth and less heavily sclerotized. The ventral surface is covered
with very fine recumbent hairs, with two large areas of cross-hatched
ridges. The ventroposterior projections of the labrum are the tormae
(*tor*) and carry the insertion of the retractor muscles of the labrum.

Lying between and posterior to the tormae and caudad of the ven-
tral surface of the labrum is an **H**-shaped sclerite (fig. 1 G, H) which
appears to articulate with the inner faces of the tormae. Its posterior
arms taper regularly to a stubby point, from which arise a cluster of
very fine fibers or hairs. This sclerite is apparently united by mem-
brane to the tormae.

The epipharynx is apparently not present as even a definite area
unless possibly it is represented by the two ribbed areas on the ventral
surface of the labrum (fig. 1 H).

The ventral aspect of the head (fig. 1 A) is occupied by three
sclerites or regions. These are a median and two lateral areas. The
first is the gula (*gu*), a narrow longitudinal sclerite with an expansion
at the posterior end. The lateral areas are the ventral prolongations
of the caudolateral parts of the epicranium. These represent the post-
genae and the subocular parts of the vertex as described above.

The gula (fig. 1 A, *gu*) is believed to be a sclerotization of the neck
membrane posterior to the submentum and the tentorial pits and be-
tween the ventral extensions of the postocciput. The cephalic migra-
tion of the tentorial pits from the foramen magnum has extended the

postoccipital sutures anteriorly along the ventral aspect as the gular sutures (*gs*). The result is a gular sclerite which is narrow between the postgenae, expands posteriorly along the ventral edge of the foramen magnum, and is continuous with the submentum anteriorly at the line of the tentorial pits. Posteriorly the gula closes the base of the foramen magnum and is in close contact with the cervical sclerites.

The anterior portion of the ventral aspect of the cranium bears on its inner surface a thickening or ridge known as the crassa (fig. 1 A, *cr*) (MacGillivray, 1923). This ridge extends from the region of the maxillary articulation to the mesal side of the ventral articulation of the mandible, and it is presumed to function as a support of this latter structure. Stickney (1923) interprets this as the occipital suture, and if this interpretation is correct, the ridge would be properly called the hypostomal ridge.

A number of other sclerites are present on the head of many beetles, but they are small and relatively unimportant. The oculata (fig. 1 E, *ol*) is a wide ringlike shelf on the inside periphery of the eye. There is apparently in this species no sclerite that can be identified with the antennal sclerite, which is normally situated within the antennal fossa.

Certain parts of the head capsule are modified to form rather definite condyles for the movable parts. These are of considerable importance because they are usually very definite and permanent in position and are thus very useful landmarks for identifying the other parts. The antenna generally articulates with the head by means of an obscure sclerite, the antennal sclerite, mentioned above. This has not been observed, but the condyle is probably present in some form as an articulating surface. The mandible articulates with the head by means of two condyles, forming the dorsal (fig. 2 J, *mad*) and the ventral (fig. 2 F, *mav*) articulations. The dorsal articulation is formed by a rounded protuberance, situated in front of the eye at the anterolateral corner of the head, which fits into an hemispherical acetabulum on the mandible. The ventral condyle is situated on the mandible and articulates with an acetabulum at the anterior end of the crassa (*cr*). The articulation of the maxilla is a small condyle on the mesal end of the cardo, which articulates in a small concavity on the inner face of the postgena at the mesal end of the crassa (*cr*). In the present species this condyle is undeveloped and is not actually in contact with the postgena.

The median anterior part of the lateral aspect of the head is occupied by the compound eye (fig. 1 E, *c*). This organ is ovate in

outline, somewhat convex, and the facets are moderate in relative size. The oculata is large, occupying nearly three-quarters of the area of the eye, as already described. No ocular suture or independent ocular sclerite has been observed, but there is a narrow unpigmented band separating the faceted part from the vertex. Ocelli are not present.

The vestiture of the head consists of a moderately dense clothing of setae along the posterior margin dorsally, with a few very large and long setae placed as follows: A pair at the anterior edge of the vertex at the corners of the postclypeus; one above the base of each antenna; one near the middle of the inner edge of the eye; and one to three in the area between the eye and the posterior constriction. The posterior areas are continued around onto the lateral and somewhat onto the ventral surface.

THE APPENDAGES OF THE HEAD

The appendages of the head consist of a pair of antennae, a pair of mandibles, a pair of maxillae, a hypopharynx, and a labium. With the exception of the antennae, which are sensory in function, these are all concerned with ingestion of food and are known collectively as the mouthparts or trophi.

The antennae (fig. 1 D) are situated at the anterior edge of the epicranium. They are inserted into an opening or antennal fossa (fig. 1 A, af). They are 11-segmented and feebly clavate, with the first segment elongated, as long as the second and third together. The segments diminish in length from the first to the fifth, and increase in width from the sixth to the tenth. The seventh to eleventh segments are covered completely with minute setae, and the eleventh alone has these setae interspersed with groups of minute pores (fig. 1 B). The outer joints (fig. 1 C) allow only a limited amount of movement, whereas the basal ones permit a much wider latitude. All the segments have a sparse vestiture of longer setae which are situated rather at random.

The mandibles (fig. 2 F, J) are prominent, falciform jaws, heavily sclerotized, and each articulated with the anterior margin of one side of the head. The expanded proximal part is produced into a slender, curved distal part which tapers to a blunt point. The lateral margin of the latter is regularly continuous with the curved outer margin of the basal part. The anteromesal corner of the basal part is produced to form two small, bluntly acute teeth (mat). The notch separating the two teeth of the left mandible (fig. 2 J) is nearly three times as deep as the corresponding notch on the right mandible (fig. 2 F).

The more distal tooth of the right mandible is actually double, there being another smaller tooth immediately beneath it, arising from the ventral surface of the mandible rather than from the inner edge as do the others (fig. 2 F). There is no definite molar surface on the inner face of the mandible, but the edge is divided longitudinally so that a groove is formed, extending from the dorsal condyle (*mad*) to the base of the tooth (*mat*). In the floor of this groove and about midway on the inner face is an oblong foramen (*prf*) from which extends a membranous lobe or prostheca (*prth*). This lobe is nearly one-third as long as the entire mandible and half as wide, and its inner edge is regularly divided into a series of equal lobes, about 15 to 20 in number. The entire structure is densely clothed with minute hairs.

Near the lateral edge of the dorsal aspect of the mandible is a shallow fold (fig. 2 J, *maf*) extending from the condylar region at the base to the end of the expanded proximal part of the mandible. Under this fold are the openings of a series of pores (*spc*) which apparently communicate with the interior cavity of the mandible. They lie nearly parallel to the dorsal surface of the mandible and project mesad from the fold. They may be branched (fig. 2 E) or unbranched, but the tip of each branch forms a capsule, the walls of which are traversed by numerous small canaliculi (*can*), which are little larger than the canaliculi normally found in most sclerotized integuments.

Just distad of the anterior end of the fold (fig. 2 J, *maf*) and at the lateral edge of the mandible there appears to be another pore (*mp*). This is not connected with the serial pores of the fold, but under high magnification is seen to be merely a thinning of the sclerotic wall in the form of a narrow sac or tube on the inside and a slight indentation of the outer surface (fig. 2 I). The reason for the existence of this structure as well as of the serial pore organ is entirely unknown to me.

The mandible is articulated with the head by means of one dorsal and one ventral condyle. The dorsal one is situated on the gena (fig. 2 J, *mad*) and the ventral one on the mandible (fig. 2 F, *mav*). The dorsal articulation is an hemispherical acetabulum on the mandible which fits over a spherical projection of the head capsule immediately in front of the eye. The posterior articulation is a spherical projection on the base of the ventral or outer face of the mandible. It fits into a crescent-shaped acetabulum at the anterior extremity of the crassa.

The maxillae (fig. 2 G) are situated immediately ventrad of the mandibles at each side of the labium. Each is composed of four parts,
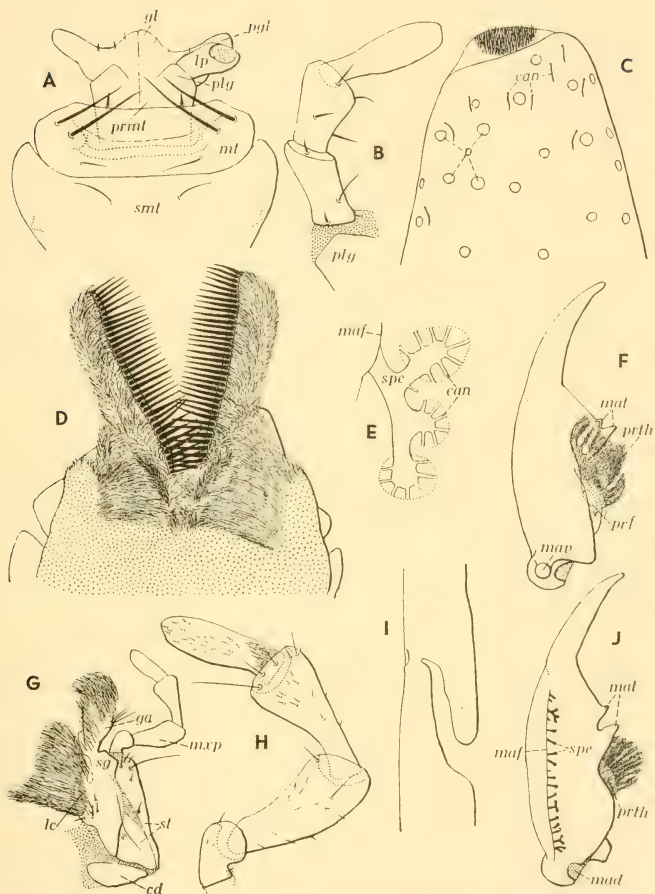
Fig. 2.—Morphology of the trophi of *Creophilus villosus* (Grav.).

A, ventral aspect of labium, without palpi. B, labial palpus. C, detail of tip of terminal segment of labial palpus. D, dorsal aspect of hypopharynx. E, detail of one of the serial pores from dorsal side of mandible. F, ventral aspect of right mandible, showing prostheca. G, ventral aspect of left maxilla. H, maxillary palpus. I, detail of median pore organ from outer edge of mandible. J, dorsal aspect of left mandible.

2

the body of the maxilla, separated into several sclerites, two distal lobes, the galea (*ga*) and the lacinia (*lc*), and the maxillary palpus (*mxp*). The body of the maxilla is composed fundamentally of three parts, the cardo, the stipes, and the palpifer. The cardo (*cd*) is the basal sclerite, which articulates at its mesal edge with the subgenae. The stipes (*st*) is secondarily divided into two sclerites, apparently the proximal or mesal one bearing the large lacinia (*lc*) and the galea (*ga*), while the distal or lateral one bears the palpus on its extremity. The lacinia is a large, densely hairy lobe, which is movable on the stipes but is apparently united to a considerable extent to the base of the galea (*sg*). The galea is covered with hairs similarly to the lacinia, but is placed distad of that organ and curved around the tip of it. The lateral corner of the galea bears a few long setae. The stipes bears the maxillary palpus on its extremity without the differentiation of a definite palpifer, the first segment of the palpus being joined to it by a membrane. The palpus (fig. 2 H) is four-segmented and nearly filiform. The basal segment is very small and is strongly geniculate. This arrangement allows the second segment to extend laterally at right angles to the axis of the maxilla. The second segment is rather swollen and larger than any of the others, and it is somewhat arcuate. The third segment is narrow at the base but expands at the apex to approximately the same size as the second. It extends cephalad from the tip of the second and is also slightly arcuate. The last segment is nearly straight, cylindrical, and both shorter and narrower than the two preceding. It is, however, slightly wider than the third at the base, and is obtusely rounded at the apex. All the segments are very sparsely beset with small setae, and the first three bear longer setae near their apices. The terminal segment also bears at the base of its dorsal surface an area of small close-set setae. The distal end of this segment bears a small area of what appear to be sensory papillae, extremely minute and gathered in a slight emargination in the tip. The distal two-thirds of the segment have a few scattered pores similar to those found on the labial palpi (fig. 2 C, *p*) but somewhat larger. There are also a few fine canaliculi as described from that organ (*can*).

The labium (fig. 2 A) is composed of three parts, the submentum, mentum, and prementum, the last bearing a pair of segmented palpi and three membranous lobes. The basal piece is the submentum, which attaches the labium to the head. It is separated from the postgenae by the submental sutures and is continuous with the gula between the tentorial pits.

The submentum is expanded anteriorly to clasp the base of the mentum. The mentum is a transverse sclerite, heavily sclerotized, and

bearing a pair of large setae on each side. The prementum arises from the inner or dorsal surface of the mentum. It is much narrower than the latter and roughly square in outline. Its distal end is expanded into two pairs of lobes, an inner pair of glossae and an outer pair of paraglossae. The glossae (*gl*) lie on either side of the median line, fused throughout their length except at the tip, which is slightly notched. They are ordinarily visible between the labial palpi (*lp*) on the ventral aspect. The paraglossae (*pgl*) are expansions of the anterolateral corners of the prementum. They are more distinctly produced than the glossae, but are almost always hidden behind the first segment of the labial palpi (*lp*). Both the glossae and the paraglossae are membranous, unpigmented, and translucent. They have no vestiture with the exception of a few scattered hairs on the anterior margin between the glossae and the paraglossae. The prementum bears on each side at its median lateral margin a large imperfectly differentiated lobe, the palpiger (*plg*) which bears the labial palpus (*lp* and fig. 2 B) on its distal end. There is a single stout seta at approximately the base of each palpiger. The labial palpus is three-segmented with the first two segments nearly equal in size and the terminal one somewhat elongated. This palpus differs from the maxillary palpus in being devoid of setae, except for a very few long hairs. The extreme tip of the third segment is slightly emarginated and bears a small median area of what appear to be sensory papillae (fig. 2 C, *senp*). The surface of the tip is also set with relatively very large pores (*p*), with a few of what appear to be minute canaliculi (*can*) ending at the surface in a small, dark dot.

On the inner or dorsal surface of the labium is a large appendage, the hypopharynx (fig. 2 D). This arises from the region between the mentum and submentum and the mouth opening, and bears two slender lobes distally. These lobes extend in a narrow **V**-shape behind the paraglossae of the labium and are armed along the inner edge with a comb of long stout setae. This entire organ is very membranous and translucent, and the distal portion is covered with a very dense vestiture of short fine hairs. It is so exactly beneath the labium (that is, dorsal to it) that the tips of the comb-bearing lobes appear to be the paraglossae of the labium, even in dissections. It is firmly attached to the ental surface of the labium.

THE TENTORIUM

Each half of the tentorium or internal skeleton of the head is composed of a posterior arm (fig. 1 F, *pta*), an anterior arm (*ata*), and

a dorsal arm (*dta*). The posterior arm extends along the ventral wall
of the head to the foramen magnum, with the edge of which it is com-
pletely united. It is marked on the exterior of the head by a small
pit or invagination at the cephalic end of the gular sutures. This is
the posterior tentorial pit (*ptp*). The anterior arm of the tentorium
extends to the anterior dorsal region of the head near the base of the
antennae. The point at which it reaches the head wall is marked on
the exterior by a shallow anterior tentorial pit (*atp*). This is situated
just mesad of the antennal fossa (*af*). The dorsal arm of the tentorium
extends dorsad and somewhat caudad to the dorsal wall of the head.
This point is marked on the exterior by a slight unevenness of the
surface, and the body wall itself is much thinner, or at least less
heavily pigmented, at that place. This point (*dtp*) represents the
dorsal tentorial pit. The two halves of the tentorium meet and fuse
at the midline of the head just caudad of the line of the base of the
mandibles. This union is the cephalic bridge or body of the tentorium
(*cp*). There has apparently been no study of the muscles which are
attached to the tentoria of Coleoptera, but the normal insect type is
given by Snodgrass (1928), who shows that many of the muscles of
the mouthparts and antennae are attached to specific parts of the
tentorium.

THE CERVIX

The neck region or cervix is largely membranous but contains cer-
tain sclerites which have been interpreted by some writers as parts
of a primitive cervical segment. Three pairs of sclerites are present
in this species. Two of these pairs lie in the membrane at the lateral
posterior corners of the gula. The third pair is more closely united
to the prothorax, and in dissections is most frequently retained on the
lateral cephalic edges of the prosternum.

In the dorsal parts of the membrane near its union with the thorax
are two areas bearing a few short setae. They are not sharply defined
and are apparently unsclerotized.

THE THORAX

The thorax is very obviously divided into two regions, owing to the
distinct separation of the prothorax from the rest (fig. 3 A) and the
close union of the mesothorax and metathorax to the abdomen.

The pronotum (fig. 3 A, *pron*) occupies the entire dorsal aspect
of the prothorax. Its posterior and lateral margins are inflexed upon
the ventral surface and are separated from the sternum by the sterno-

notal sutures (*sns*). The lateral and caudal margins are occupied by a fine ridge or thickening (*mrn*), which, near the anterior lateral angles, passes onto the ventral aspect and disappears. The area set off by the marginal ridge is known as the hypomera (*hypo*) or the inflexed part of the pronotum. The dorsal surface of the pronotum is moderately convex, nearly quadrate with the angles broadly rounded, and very slightly wider than long. The broad median area is smooth and even on the surface, but it is traversed by numerous fine canaliculi, which appear to be larger and more definite in arrangement than the usual irregular canals in sclerotized integuments. Each canal ends at the surface in a minute puncture which appears to bear an extremely fine and short point or setula. The sides of the dorsal surface are beset with moderate setae which are set in large punctures. This area is continued at the anterior corners onto the lateral and ventral aspects by the continuation of the marginal ridge.

The hypomera is itself slightly deflexed along the margin of the coxal cavity, and this deflexed part is set off by a rather definite line which extends posteriorly for some distance. Just caudad of the coxal cavity and nearly over the mesothoracic spiracle, this deflexed part is expanded medially into a membranous lobe (fig. 3 A, *prnl*, C) which partially closes the cavities behind. Its anterior edge is densely covered with very fine membranous processes (figs. 3 C, D) of two types. Single slender and finely pointed processes occupy the greater part of the area, and shorter fimbriate groups of five to seven points occur in a band around the margin. These groups and the single points are connected in series by fine folds of the surface and appear to be merely expansions of these folds. The posterior parts of the hypomera bear no setae but have many of the fine canaliculi on the lateral portions.

The ventral aspect of the prothorax is occupied by the sternum, the hypomera, the coxal cavities, and the anterior and posterior foramina, which receive parts of the head and mesothorax respectively. A considerable caudal area is membranous, and one sclerite (fig. 3 A, *peri*) lying in this area belongs to the mesothorax. This is the sclerite that bears the so-called prothoracic spiracle (*sp*), which is undoubtedly morphologically a part of the mesothorax.

The prosternum is composed of two sclerites, the basisternum (fig. 3 A, *bs*) and the furcasternum (*fs*), separated by a suture (*stcs*), the sternacostal suture. The basisternum is a transverse sclerite along the ventral or posterior border of the anterior foramen (*afor*), extending laterally to the notosternal suture (*sns*) and forming the

anterior border of the coxal cavities. It is heavily sclerotized and pigmented, and bears a few setae on its mesal part and a group of five or six minute punctures near the middle of each lateral side.

Fig. 3.—Morphology of the thorax of *Creophilus villosus* (Grav.).

A, dorsal and ventral aspects of thorax, showing general relationship of parts. B, prothoracic trochantin. C, notal lobe of prothorax. D, detail of processes of pronotal lobe. E, mesothoracic peritreme and spiracle. F, group of setae from membrane between prothorax and mesothorax.

The furcasternum is much shorter than the basisternum, less heavily sclerotized, and without vestiture or sculpture, except for the minute pores or pits found on most of the prothoracic integuments.

The remainder of the venter is occupied by the membranes lining the coxal cavities (fig. 3 A, *c.rc*) and that connecting the prothorax and the mesothorax (*mb*). In the lateral parts of this latter membrane and just caudad of the coxal cavities lies the pair of sclerites, the peritremes, bearing the spiracles of the mesothorax.

The pleural elements appear to have been so far reduced by the approximation of the notum and sternum as to have disappeared entirely as separate sclerites. This area normally forms the major articulation of the coxa (the anterior or dorsal articulation). In the present species the trochantin, whose apical end forms the posterior or ventral articulation, is prolonged around the base and provides also the dorsal articulation. This may be interpreted as an indication that the pleural elements have united with the trochantin and are represented only in that sclerite.

The trochantin of the prothorax (fig. 3 A, *tn*, B) is a long narrow sclerite with a lobate projection on the lateral side. This lobe bears the dorsal articulation of the coxa as described above. The cephalic part projects under the anterior margin of the coxal cavity. The caudal part, projecting into the coxal cavity, is more heavily sclerotized and thicker than the rest. It is elevated into a longitudinal ridge which bears a few setae and a series of the minute punctures with setulae. The surface, especially that bordering the ridge, is strigulose. The posteromedian end articulates with the inner edge of the coxa.

The mesothorax is much shorter than the prothorax or the metathorax and is closely united to the latter (fig. 3 A). It is united to the prothorax by a membrane (*mb*) which is of considerable extent on the ventral aspect, extending to the coxal cavities of the prothorax.

In this membrane lies the peritreme (fig. 3 A, *peri*, E) bearing the mesothoracic spiracle (*sp*). The peritreme is an oblong sclerite, placed transversely, and nearly two and one-half times as wide as long. It is thought to be a secondary sclerotization of the intersegmental membrane. The spiracle is located in the lateral three-fourths of the sclerite and is similar in appearance to the first abdominal spiracle (fig. 9 D). There are a very few scattered setae on the membranous declivity surrounding the sieve processes. At the sides just ventrad and caudad of the spiracles is an area bearing a few minute setae in relatively very large punctures (fig. 3 A, *x*, F). This area is not differentiated from the remainder of the membrane and is unsclerotized.

The dorsal aspect of the mesothorax is nearly covered by the projecting caudal edge of the pronotum (fig. 3 A). Its most conspicuous sclerite is the central shield-shaped area (fig. 4 C, A) which is gen-

erally known as the scutellum. It is formed by the union of the three normal sclerites of the mesonotum, the prescutum, scutum, and scutellum.

The posterior triangular portion is the scutellum (figs. 4 C, 3 A, 4 A, *scl*), which overlaps the metatergum posteriorly and is separated in front from the prescutum by an obvious transverse suture. Its surface is rather densely setigerous, with a narrow impunctate anterior margin. A rectangular area (*sclp*) on the ental surface of the posterior part of the scutellum is the part that is in close contact with the anterior edge of the metanotum. The anterior margins of the area are continued forward as the axillary cords of the wings (*axc*) which appear to proceed from the sides of the prescutum.

The part of the shield anterior to the scutellum is the prescutum (figs. 4 C, 3 A, 4 A, *psc*). It overlaps the scutellum somewhat posteriorly, especially at the sides. The prescutum is short and transverse, bearing the anterior notal wing process (*anp*), the lateral emargination (*em*), and a second process posterior to this. An irregular transverse line extends between the anterior wing processes dividing the prescutum into two areas. The posterior of these bears numerous setae, somewhat smaller than those of the scutellum, on its caudal half, and also a very few exceedingly fine setae at the anterior angles near the wing processes. The anterior area bears a small group of six to eight setae on each side of the center on the caudal margin, and also a median pair of very large setae (fig. 4 C).

The scutum (fig. 4 A, *sct*) of the mesothorax is completely separated by the union of the scutellum and the prescutum along the line of the suture *pss* into two parts. It projects laterad from beneath the shield and forms the posterior notal wing processes. Its exact outline is obscure as it is more or less united to the other sclerites entad. The axillary cord (*axc*) appears to arise from the scutum but probably merely traverses it from the margin of the scutellum of which it is the continuation. The ectal surface on each side is apparently transversely traversed by a fine suture (*scts*) which marks an ental apodeme.

The sternum of the mesothorax is represented chiefly by a single large sclerite (*s. II*) on the median part of the ventral aspect. It is separated from the anterior margin by a narrow strip, the prepectus (*prp*), which extends from the anterior portion of one episternum along the margin in front of the sternum and onto the other episternum. The prepectus may not be a distinct sclerite, but it is separated from both the sternum and the episternum by a distinct line or ridge and is somewhat inflexed. It appears to be divided into three

parts by the end of the sternopleural suture, and fuses with the episterna at its extreme anterior ends. It has no vestiture or sculpture.

The mesosternum is prolonged laterally in a narrow piece which forms part of the anterior margin of the coxal cavity and posteriorly in a broad median lobe, the mesosternal process (fig. 3 A, *mesp*). There are a few scattered very slender setae on the central part, particularly on its caudal margin, and almost the entire surface is densely covered with very fine punctures which appear to bear very minute setulae. On the lateral extensions these punctures are rather sparse, but the setulae are larger and more definite.

Posteriorly the mesosternum is separated from the metasternum by a narrow sclerite, the spinisternum (fig. 3 A, *ss*). This is a secondary sclerite formed from the intersegmental membrane and united to the mesothorax. It is very narrow medially, expanding somewhat on the floor of the coxal cavities. It is separated from the mesosternum by the spinisternal suture (*sss*) and from the metasternum by the suture *ists*. It bears no sculpture or vestiture.

The pleuron of the mesothorax is larger than either the mesonotum or the mesosternum. It occupies the lateral part of both the dorsal and ventral aspects and forms the processes that project into the prothorax for articulation. It is composed of the episternum, the epimeron, and the articulations of the coxa, and bears on its anterodorsal part the base of the elytra.

The episternum (fig. 3 A, *cps. II*) is the largest sclerite of the mesothorax. It is separated from the sternum by the sternopleural suture (*sps*). Its posterior corner extends to the rim of the coxal cavity and forms an articulation for the trochantin. Its ental projection fuses with part of the epimeron to form the pleural coxal process (*cxp*). On the ventral surface the episternum is completely separated from the epimeron by the pleural suture (*pls*), but this suture extends only to the lateral edge and is not continued on the dorsal aspect. Thus the episternum and epimeron are united on the dorsal surface, and this sclerite, the pleuron (*pl*), forms the anterior projections of the mesothorax.

The episternum is rather sparsely set with setae, which are short at the prepectal margin and become larger and longer toward the pleural suture. The lateral and dorsal parts, particularly anteriorly, are finely strigulose, the lines being considerably more apparent than the normal very fine markings of sclerotic surfaces. The ventral part is also sparsely set with the minute lageniform punctures similarly to the pronotum.

The epimeron (fig. 3 A, *cpm. II*) appears as a distinct sclerite on the ventral surface of the mesothorax but is united to the episternum on the dorsal aspect to form an undifferentiated pleuron. Posteriorly it overlaps the end of the metathoracic sternum and episternum, and forms the lateral wall of the mesothoracic coxal cavity. Its surface bears a few long sparse setae, similar to the adjacent area of the episternum, and has also the minute punctures. The dorsal aspect of the pleuron bears no setae but is strigulose as described above.

From the dorsal side of the anterior projections of the mesothorax arise the elytra. Discussion of the articulation of these will be left for the section dealing with the wings.

The trochantin of the mesothorax (figs. 3 A, *th,* 4 B) is smaller than that of the prothorax but is similar in arrangement and structure. It is an arcuate sclerite, nearly three times as long as wide, and tapering distally to form a blunt condyle for the coxa (*trla*). Its proximal portion forms a condyle that articulates with the projecting corner of the episternum (*mtla*). Its ventral or ectal surface is thickened into a broad ridge, and the proximal ental part is submembranous. A single long seta is set in a large puncture at the middle of the longitudinal elevation, and the surface is longitudinally strigulose.

The metathorax is the caudal one of the three thoracic segments and is larger than either of the others. It is very closely united to the mesothorax in front and to the abdomen behind. The tergum is in rather close contact with the tergite of the first abdominal segment, whereas the sternum is rather loosely joined by membrane to the sternite of the third abdominal segment.

The tergum of the metathorax (figs. 3 A, 4 F) is divided into five parts: The prescutum (*psc*), the two separated scutal areas (*sct* and *sctt*), the scutellum (*scl* and *sclt*), and the postnotum (*pn*). The prescutum, scutum, and scutellum are fundamental parts of the tergum, but the postnotum or postscutellum is a secondary sclerite formed from the intersegmental membrane caudad of the metatergum and subsequently joined to it (see Snodgrass, 1909).

The central triangular part of the metatergum is the scutellum. It is separated from the two scutal areas by two internal ridges, the V-ridges (figs. 5 A, 4 F, *vr*), and two curved sutures. It is separated anteriorly from the prescutum by a membranous area, and posteriorly from the postnotum by a suture (*acs*) extending between the bases of the wings. Since the posterior margin of the scutellum is morphologically continuous with the hind margins of the wings, this area is considered as extending laterad along the suture to the wings, and it is therefore fused with the posterior part of the scutum on each

side. The anterior half of the scutellum is very densely invested with short fine setae, and the posterior half has two large lateral, finely strigulose areas bearing numerous circular and occasionally anastomosing pores of unknown function.

The scutum of the metathorax is divided into two parts by the approximation of the prescutum and the scutellum. Medially these are separated from the scutellum by the suture of the V-ridge, but posteriorly they are continuous with the lateral extensions of the scutellum to the wing bases. From the prescutum and the axillary and subalar sclerites it is separated by the prescutoscutal suture (figs. 3 A, 4 F, *pss*). At the sides the combined scutum and scutellum form the posterior notal wing process (*pnp*), and just anterior to this process are two small invaginations and a process that articulates with the base of the first axillary sclerite (*ax. 1*). The entire surface of the scutum is densely, finely muricate, the posterior median part being likewise strigulose with the minute but rigid points born on the summits of the strigulae. Two small groups of fine setae are present on each area of the scutum. One is on the median lobe (*mls*) that overlaps the suture of the V-ridge; the other is on the lateral margin just mesad of the articulation of the first axillary sclerite (*axp*).

The prescutum is normally almost entirely covered by the mesonotum, but is readily recognizable in dissections as an irregular band along the anterior border of the scutal areas (fig. 4 F). It is rather irregularly and less heavily sclerotized and is broken up into a number of areas or sclerites. The transverse median part bears on its ectal surface a broad lobe (*pscl*) reflected so as to overlie somewhat the central membranous area between the prescutum and the scutellum. This lobe is exceedingly smooth and flat, without sculpture or vesti-ture of any kind. Near the anterior angles of the scutum, the pre-scutum is broken up into two small sclerites on each side. The inner one is very small and triangular and overlaps the median portion ectad. The outer one is also subtriangular, but it is larger and forms the very blunt anterior notal wing process (*anp*) which lies under the distal end of the first axillary sclerite (*ax. 1*). These two sclerites, as well as most of the median part, are very minutely muricate, and the membranous central area has a group of minute setae which is continuous with that of the scutellum as described above.

The postnotum (figs. 3 A, 4 F, *pn*) is the short transverse sclerite extending across the dorsum from one pleuron to the other and separated from the scutum and the scutellum by the postnotal suture (*pns*). It is connected by a very short membrane to the first abdominal tergite, and at the sides is reflected around the first abdominal
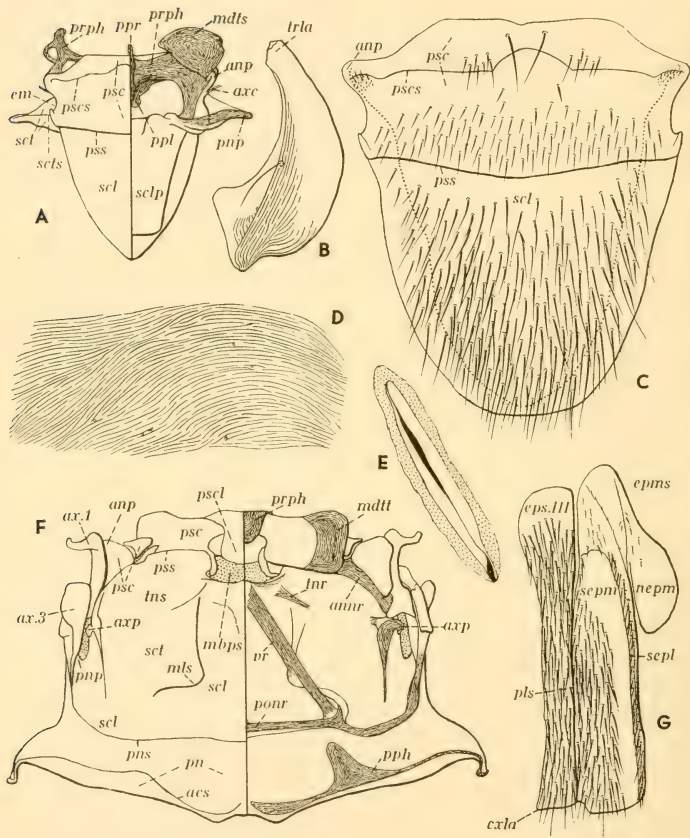
FIG. 4.—Morphology of the thorax of *Creophilus villosus* (Grav.).

A, ectal and ental aspects of tergum of mesothorax. B, trochantin of meso-
thorax. C, "scutellum" of mesothorax. D, detail of surface of notepimeron of
metathorax. E, metathoracic spiracle. F, ectal and ental aspects of tergum of
metathorax. G, pleurites of metathorax.

spiracle (*sp. 1*) to form an articulation with the epimeron (*pna*). The lateral anterior angles are extended along the antecostal suture to the axillary region. Along the posterior part of the sclerite extends a suture from the postnotal articulation to the midline, marking the location of an interior ridge. This is the antecostal suture (*acs*). There is no vestiture on the postnotum, but the narrow area caudad of the antecostal suture is finely muricate. The central area is densely covered with extremely minute rounded papilliform processes or excrescences.

The axillary sclerites will be described in the section dealing with the wings.

The ventral aspect of the metathorax is occupied by a single very large sclerite, the metasternum (fig. 3 A, *s. III*). It extends from the coxal cavities of the mesothorax to those of the metathorax, and bears no sutures with the exception of a line from the anterolateral angles around the coxal declivity. This line disappears medially and is more of the nature of a fold, as it bears no internal expansions or processes. The metasternum is separated from the mesosternum (*s. II*) by a suture (*ists*) which disappears for a short distance on the floor of the coxal cavity. Posteriorly the metasternum bears a small triangular median emargination bounded by two rounded lobes, the sternal articulations of the coxae (*stca*). Laterad of each articulation is a broad shallow coxal emargination, and a slight expansion of the sternum overlaps the coxal articulation with the pleuron. The entire surface behind the line of the postcoxal folds is densely clothed with long hairlike setae. The floor of the coxal cavity is finely strigulose and nearly reticulate, and the area between the coxal depressions and the poststernum is finely muricate. A narrow border of small setae lines the posterior edge of the coxal depression on the anterior or inner side of the coxal fold.

The pleuron of the metathorax is divided longitudinally into the usual two sclerites, the episternum, and the epimeron. The episternum (figs. 3 A, 4 G, *eps. III*) or the dorsal sclerite is very slender and rather rectangular, and its posterior dorsal angle forms an articulation for the lateral extremity of the metathoracic coxa. This articulation is the pleural coxal articulation (*cxla*). With the exception of a narrow band along the cephalic edge, the surface of the episternum is densely clothed with long setae. Also the entire surface is strigulose, the strigulae forming tiny folds over the base of each of the setae.

The epimeron of the metathorax is larger than the episternum and is secondarily marked with several longitudinal lines or sutures (fig. 4 G). One of these sutures (*epms*), marked by an internal ridge,

separates the epimeron into two parts, the notepimeron (*nepm*) and the sternepimeron (*sepm*). The sternepimeron lies along the epi-sternum, separated from it by the pleural suture (*pls*), and is slightly longer and considerably wider than it. Its posterior part overlaps the lateral end of the first abdominal tergite and the spiracle of that seg-ment, as well as the tip of the postnotum of the metathorax and, anteriorly, the caudal end of the epimeron of the mesothorax. Its cephalic end is the pleural wing process (*pwp*) but apparently is not specially modified. Its surface is rather convex and marked with a distinct impressed line (*scpl*) which sets off the anterior quarter and a narrow band along the dorsal edge. The surface is clothed with setae similarly to the episternum except for a space dorsad and caudad of the sternepimeral line. The anterior part bears only a few small scattered setae. The notepimeron (*nepm*) is united to the sternepim-eron at its cephalic end, at which point the former is a narrow band. It expands posteriorly into a flat oval plate, bearing a few small setae anteriorly and a few minute sensory pores on the sides of the disk, and its surface is rather strongly strigulose (fig. 4 D).

The metathoracic spiracle (figs. 3 A, *sp. III*, 4 E) lies in the mem-brane anterior to the epimeron and along the dorsal side of the meso-thoracic pleuron. It is very pale and membranous, without sculpture or vestiture, and is not surrounded by a definite sclerite. It is entirely unlike the spiracles of the mesothorax and abdomen as it has no sieve apparatus, being composed of two sclerotic lips which fold together to close the opening. It is longer and much more slender than the other spiracles and is difficult to differentiate from the surrounding membrane.

THE ENDOTHORAX

The endoskeleton of the thorax is known collectively as the endo-thorax. It is composed of invaginations of the tergal, pleural, and sternal regions of each segment, and these apodemes are termed the endotergites, the endopleurites, and the endosternites respectively. The sclerotized tendons and some small invaginations are part of the endo-skeleton but are not considered here.

The endotergites (fig. 5 A) are found typically only in the meso-thorax and metathorax. In the prothorax the endotergites are repre-sented only by a rather indefinite group of processes on the hypomera in the region of the coxal cavity and the trochantin. These bear a large muscle disk (fig. 5 A). In the mesothorax the anterior margin of the prescutum is deflexed to form a transverse ridge—the ante-costal ridge or prephragma (*prph*), which bears a pair of large muscle

disks (*mdts*) at its ends. There is apparently just behind this small ridge and corresponding with a line or suture on the ectal surface, the prescutal suture (fig. 4 A, *pscs*), a large transverse phragma ex-
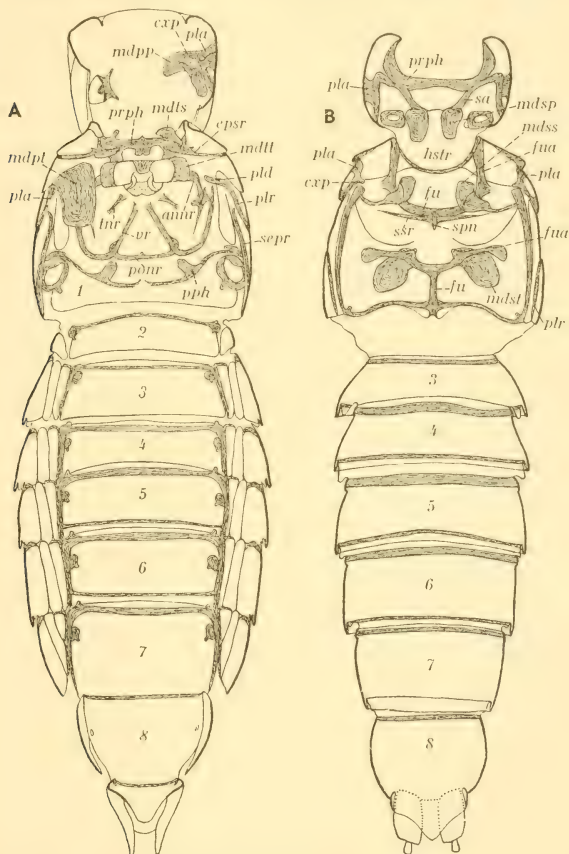

FIG. 5.—Endoskeleton of trunk of *Creophilus villosus* (Grav.).
A, endoskeleton of the dorsum. B, endoskeleton of the venter.

tending between the anterior notal wing processes (fig. 4 A, *anp*), and posteriorly at the sides to the prescutoscutellar suture (*pss*), and more or less united to the prephragma. On the midline this phragma

bears a longitudinal ridge (*ppr*), and a rounded posterior lobe next to it on each side (*ppl*). The ental side of the posterior notal wing processes (*pnp*) of the scutum bears a small transverse phragma of unknown homology.

The endotergites of the metathorax are much more extensive than those of the mesothorax. The most conspicuous are the two **V**-ridges (figs. 4 F, 5 A, *vr*) converging anteriorly near the center of the segment. These mark the lateral boundaries of the scutellum but are not marked on the ectal surface by definite sutures. Posteriorly each **V**-ridge seems to coalesce with a transverse apodeme, the posterior notal ridge (*ponr*), which is formed from the posterior edge of the scutum and scutellum and extends from the base of one wing to the base of the other. Just laterad of the anterior end of the **V**-ridge is a short transverse apodeme called the transverse notal ridge (*tnr*). The central part of the anterior edge of the prescutum bears a lobate phragma, the prephragma (*prph*), which is more or less connected laterally to the large muscle disk (*mdtt*). The prescutoscutal suture (*psss*) marks the invagination of the anterior notal ridge (*annr*), which extends around to the base of the wings, where it approaches a small apodeme supporting the axillary process (*axp*). The posterior part of the postnotum (*pn*) bears a transverse suture (*acs*) marking a long apodeme, the postphragma (*pph*), which supports the postnotal articulations (*pna*) and is expanded into a pair of lobes which project over the posterior ends of the **V**-ridges and appear to be more or less connected with the posterior notal ridge (*ponr*).

The endopleurites are present in all three of the thoracic segments. Since the pleuron of the prothorax is greatly reduced and united with the trochantin, it is this combined sclerite that bears the pleural apophysis. This is a large crescentic process which projects under the inflexed hypomera. There is an oval sclerotization on the ental surface of the peritreme, but this is a structure of the endopleuron of the mesothorax.

The endopleurites of the mesothorax are very small. The pleural apophysis (fig. 5 B, *pla*) is formed between the episternum and the epimeron and projects into the coxal cavity to form the pleural coxal process (*cxp*). An apodeme also extends from the pleural apophysis along the posterior edge of the episternum or pleuron to the region of the muscle disk of the endotergites and to the base of the elytra.

The endopleurites of the metathorax are relatively much more developed than those of the mesothorax. The pleural apophysis (fig. 5 A, *pla*) is composed of a pleural ridge (*plr*) formed between the episternum and the epimeron along the pleural suture, and an ental ex-

tension, the pleuradema (*pld*). The dorsal edge of the sternepimeron bears the sternepimeral suture (fig. 3 A, *seps*), which marks the invagination of the sternepimeral ridge (fig. 5 A, *sepr*). Apparently arising from the cephalic end of the episternum is the very large pleural disk (*mdpt*) which extends posteriorly, overlapping the base of the wing.

The endosternites of the prothorax consist of a broad prephragma (fig. 5 B, *prph*) and the sternal apophysis (*sa*). The prephragma arises from the anterior edge of the basisternum (fig. 3 A, *bs*) and forms the ventral border of the anterior foramen (*afor*). It extends the width of the basisternum and unites with the sternal apophysis entad of the sternonotal suture (*sns*). From each lateral corner of the furcasternum (*fs*) arises a sternal apophysis which extends along the lateral edge of the sclerite to unite with the prephragma and the pleural apophysis. Near the base of each sternal apophysis is the large muscle disk (*mdsp*).

In the mesothorax the sternum bears a transverse ridge on its posterior margin. This ridge is the furca (fig. 5 B, *fu*) and has two anterior projections, the furcal arms (*fua*). The two muscle disks (*mdss*) apparently arise from the furcae also. The spinisternum (fig. 3 A, *ss*) also bears a small transverse ridge (fig. 5 B, *ssr*) with a median cariniform projection, the spina (*spn*).

The metathoracic endosternites (fig. 5 B) are more properly termed the furca than those of the mesothorax. The prominent part is the median bar (*fu*) arising from the posterior border of the sternum and projecting anteriorly in the interior of the thorax. In approximately the middle of the metathorax it divides into two lateral branches, the furcal arms (*fua*), each of which bears a large muscle disk (*mdst*). A narrow ridge is formed on the ental surface of the caudal and lateral margins of the sternum, extending anteriorly to the region of the pleural coxal process of the mesothorax.

THE APPENDAGES OF THE THORAX

THE WINGS

The elytra are highly modified wings of the mesothorax. They have a horny texture and considerable rigidity but are not used in flight. They are held apart at an angle with the body to allow freedom of motion of the wings, but when at rest are laid along the dorsum of the mesothorax and metathorax, meeting along the midline. They serve as covers for the wings, but are so small in this species that the wings must be folded transversely under them several times.

The elytron is irregularly oval in outline (fig. 6 F), with a straight mesal edge that fits against a similar edge of the opposite elytron, and an oblique anteromesal edge that fits against the side of the "scutellum" of the mesothorax. The two outer angles are broadly rounded. The greater part of the surface is flat and even, but the sides become
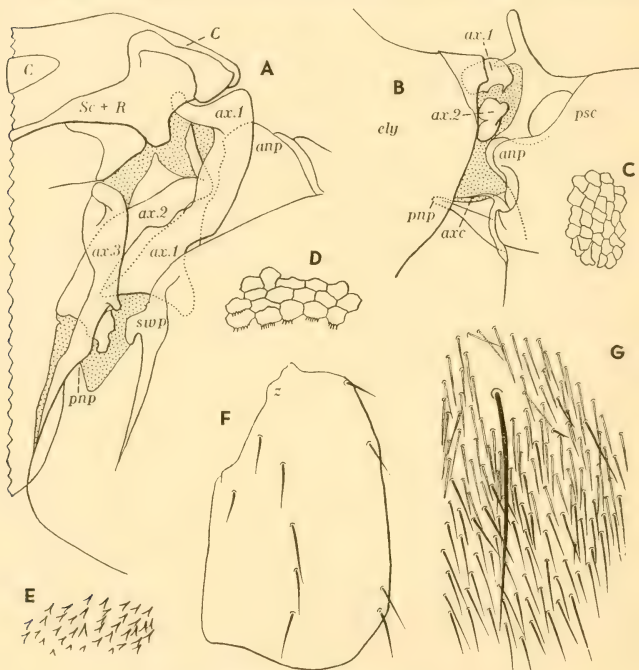

Fig. 6.—Morphology of the wing bases and elytra of
Creophilus villosus (Grav.).

A, base of hind wing, showing axillary sclerites. B, base of elytron. C, D, E, details of elytral sculpture. F, right elytron (smaller setae omitted). G, detail of three types of setae of elytron.

very convex, being deflexed somewhat onto the lateral aspect of the body.

The entire surface is densely covered with setae (fig. 6 G) of rather uniform size, and bears also a few much longer setae (figs. 6 F, G) placed in a regular pattern. There are three series of these setae: One along the lateral margin of the deflexed area, of four or five setae;

another along the axis of the disk, of three to six setae; and the third of one to three setae along the scutellar margin. Each seta is set in a puncture at the center of a small smooth area, so that it is somewhat isolated from the surrounding smaller setae. The dense smaller setae are of two colors, pale and black. They are arranged in fairly definite groups, thus giving rise to the black and white markings of the elytra. Rather frequently interspersed among the setae are several types of pores or punctures which appear to be glandular.

Certain parts of the surface are sculptured in various ways (fig. 6 C, D, E). The point indicated at *z* in figure 6 F probably forms part of the articulation of the elytra with the mesonotum and appears to be very finely scaly (fig. 6 C). This area extends for a short distance on both the dorsal and ventral surfaces of the elytron, and the scales grade off anteriorly into minute points (fig. 6 D, E).

The elytron articulates with the mesonotum by means of the two wing processes (fig. 6 B, *anp, pnp*). The connecting membrane bears two irregular, very lightly sclerotized areas, which have been interpreted as the first and second axillary sclerites (*ax. 1, ax. 2*). The axillary cord (*axc*) proceeds from the margin of the scutellum. As the actual movement of the elytron is rather slight, the whole articulating mechanism is much less developed than that of the hind wings.

The hind wings (fig. 7 A) are well developed, being nearly as long as the entire body. The wing is approximately one-third as wide as long, with a distinct and heavily sclerotized hinge just proximad of the stigma, and a large separate anal lobe. The venation is greatly reduced and not easily homologized. The following scheme is tentatively adopted here.

The most conspicuous vein is the one arising from the articulation with the first axillary sclerite (fig. 6 A, *ax. 1*) and extending to the hinge, enclosing a narrow costal area. This vein is the subcosta united with the radius (fig. 7 A, *Sc, R*). It is apparently double, as shown, the anterior and the basal parts representing the subcosta, the distal part being chiefly radius. The costa is anterior to the subcosta but is rather indefinite. It is represented by an oval area (fig. 7 A, C, and 7 D) near the base of the wing and by the anterior basal edge of the wing. The base of the subcosta articulates with the first axillary sclerite (fig. 6 A), but the costa is the only part of the wing that could come in contact with the anterior notal wing process (*anp*). The sub-basal area (fig. 7 D) appears to be a raised sclerotic plate bearing numerous setae. It is surrounded by membranous areas and does not touch the margin of the wing. This is the only part of the wing bearing true setae.
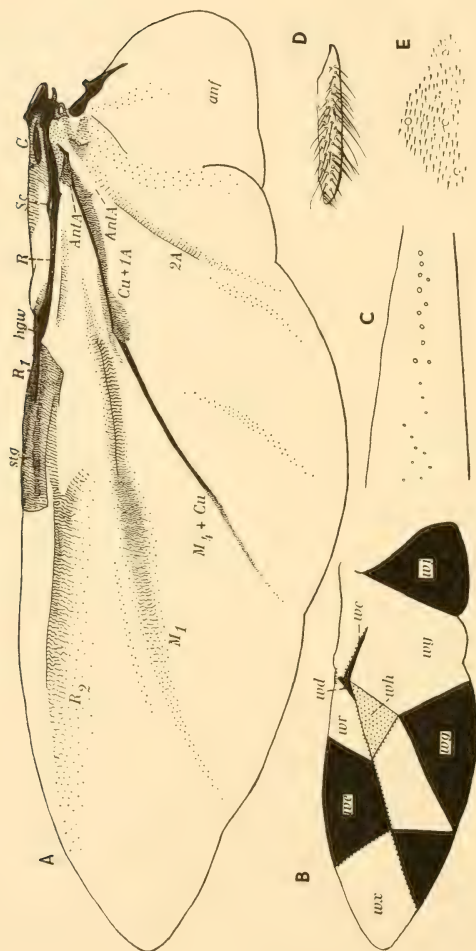
Fig. 7.—The wing of *Creophilus villosus* (Grav.).
A, left wing. B, diagram of folding pattern. C, detail of base of radius vein. D, sclerotized plate of costa vein. E, detail of microtrichia of wing surface near the base.

The base of the subcosta overlies the basal part of the radius as shown in figure 6 A, and a short distance from the base it divides into two parts. The anterior of these is the subcosta. It is continued distally nearly to the hinge but is covered by the radius except near the base where they overlap somewhat. Near the point at which the subcosta passes under the radius, the posterior edge of the radius has a small projection which approaches a projection from the cubitus and is interpreted as the anterior arculus ($AntA$). Apparently in nearly all beetles the radius is characterized by the presence of tiny pores on the dorsal surface near the arculus. These pores (fig. 7 C) appear immediately distad of the separation of the radius from the subcosta. They serve as a ready means of identifying this vein. The radius typically arises from the second axillary sclerite, but here the base is united with the subcosta and its union with the second axillary is not apparent, though they do approximate each other. The radius is extended distally to form the large rectangular stigma (stg) near the middle of the anterior margin. A disconnected branch of radius (R_2) extends from near the stigma toward the tip of the wing, but it is rather indefinite and not strongly sclerotized.

Posterior to R_2 is another indefinitely sclerotized area which represents the first branch of the media (fig. 7 A, M_1). Its basal part is entirely lost, and the only other branch that remains of the media is considered to be united with the distal part of the cubitus ($M_4 + Cu$).

The cubitus is a definite vein extending from the anterior arculus (fig. 7 A, $AntA$) diagonally across the wing. Its distal part is united with M_4, and its proximal part with the first anal vein. There is a distinct angle between these proximal and distal parts, and this point approaches rather close to the base of M_1. The anterior arculus is on the dorsal edge of the base of the vein, and just distad of this on the ventral edge is the anal arculus ($AnlA$). The cubitus is supposed to arise from the third axillary sclerite, but this connection is not apparent in this form.

The anal veins are all very indefinite. The first anal is apparently united with the proximal part of the cubitus (fig. 7 A, $Cu + 1A$). This is the vein that forms the anal arculus, which extends toward the second anal vein. The second, third, and fourth anals are merely darker streaks in the wing membrane. It is apparently the third (or the second branch of the second) that marks the anal fan (anf).

The surface of the wing is marked by streaks of darker color, whereas the hinge (fig. 7 A, hgw) and the stigma (stg) are very dark and opaque. The entire surface of the wing, both dorsally and ventrally, is covered with minute points or setulae which grade off on the

posterior and anal areas into tiny rounded or truncated conical projections. In the costal area also they are replaced by minute rounded tubercles. Along the posterior margin of the wing these setulae are frequently twice as long as on the surface, but they are still minute and are merely processes, not setae.

The wing is articulated to the metanotum by means of the two notal wing processes (figs. 4 F, 6 A, *anp, pnp*) and the three axillary sclerites (*ax. 1, ax. 2, ax. 3*). Figure 6 A shows the relations of these parts to the wing. The united subcosta and radius ($Sc+R$) is the only vein that is prominent at the wing base, and it forms a definite articulation with the first axillary sclerite (*ax. 1*). Near the base of the first and second axillaries is a process of the scutum which evidently forms a condyle for the base of the second and middle portion of the third axillaries. This is tentatively designated the scutal wing process (*swp*) as it has apparently been unnoticed heretofore.

<p style="text-align:center">THE LEGS</p>

The legs are composed of five main divisions, the coxae, trochanters, femora, tibiae, and tarsi. The first four divisions consist of a single segment each, the tarsus consisting of five subsegments or tarsomeres, the last of which bears the pretarsus and its ungues.

The anterior legs (fig. 8 F) are short and stout and very densely covered with setae. The coxa (*cx*) is rather cylindrical and fusiform. Its proximal end articulates with a proximal process of the trochantin by means of a condyle (fig. 8 H, *cxa*) and with the distal end of the trochantin by a somewhat indefinite projection (*tra*). The distal end of the coxa bears the articulation of the trochanter (fig. 8 F, *tr*) upon its ventral side. This articulation (fig. 8 G) is a large membranous area with several rather indefinite projections which serve as condyles. The dorsal and anterior surfaces of the coxa are densely set with slender setae, even more densely than shown in figure 8 F, but the ventral and posterior surfaces are glabrous and impunctate, with the following exception. Along the posterior edge of the ventral face, from the middle to the distal end, is a row of long and slender setae. The punctures are small and placed in a regular series at first, but distally are crowded and somewhat irregular. Some of the setae attain a length equal to half the width of the coxa. The dorsal vestiture is also denser near the distal end of the coxa.

The trochanter of the prothoracic leg (fig. 8 F, G, *tr*) is rather elongate and somewhat triangular. It is immovably attached to the base of the femur, thus forming the articulation of the latter with

FIG. 8.—Morphology of the legs of *Creophilus villosus* (Grav.).

A, ventral aspect of tarsus of prothorax. B, ventral aspect of pretarsus of pro-
thorax. C, dorsal aspect of tarsus of prothorax. D, comb of setae and calcar from
anterior side of tibia of prothorax. E, comb of setae and calcar from posterior
side of tibia of prothorax. F, prothoracic leg. G, trochanter of prothoracic leg.
H, articulations of base of coxa of prothoracic leg. I, metathoracic leg. J, claw
of metathoracic leg. K, coxa and trochanter of mesothoracic leg.

the coxa. The trochanter articulates with the coxa by means of two rather indefinite condyles (*a, c,* and *a, a*) which permit a dorsoventral movement only. The distal two-thirds of the exposed surface bears numerous moderately long setae, and the area at *z* (fig. 8 G) has a very few large pores which are quite distinct from the setigerous punctures.

The femur (fig. 8 F) is the largest segment of the leg. It tapers somewhat distad and bears a large tubercle on its ventral proximal margin. The proximal end is obliquely truncated and is immovably united to the trochanter by a flat surface. The distal end bears a dorsoventral groove in which the tibia articulates. This groove is known as the gonytheca (*gony*). The proximal dorsal tip forms an acutely rounded projection which appears to articulate to some extent with a socket on the outer edge of the coxa. The posterior surface of the femur is moderately densely set with setae, more sparsely proximad and dorsad. The setae of the anterior surface are similarly arranged, being very dense along the tubercle, very sparse on the basal dorsal part, and entirely lacking from a narrow strip along the ventral face, which is outlined on both the anterior and posterior faces by an irregular longitudinal series of more closely placed setae. Another series, of more widely spaced setae, extends along the dorsal face into two smooth areas. The setae are somewhat longer and more dense near the dorsal apical margin and show some tendency to serial arrangement across the tip. With transmitted light one may observe the minute pores which occur in clusters of two to five about the base of each seta. The surface is extremely finely and irregularly, but linearly and longitudinally, striate in great part.

The tibia is the fourth segment of the leg. In the prothoracic leg (fig. 8 F, *tb*) it is shorter than the femur and about one-half as thick, expanding slightly toward the apex. It articulates with the femur by means of a rounded head on its proximal end, which fits into the groove or gonytheca of the femur (*gony*) and is held there by a pair of condyles on each side. This head is somewhat curved toward the femur, allowing the tibia to lie along the ventral edge of the femur at rest. The distal end of the tibia is rather rounded and membranous. It bears the tarsus and the two tibial spurs as well as numerous very stout heavy setae around the tip. The spurs are known as the calcaria (*cal*). They are inserted within the membranous area of the tip, but are apparently merely slightly modified setae. The larger one is inserted on the posterior side of the tarsus and the smaller one on the anterior side, both of them slightly ventrad of the middle. The tip is nearly circled by two series of very large and heavy setae, one on

the anterior and one on the posterior face. Those of the posterior series
(fig. 8 E) are longer and more slender than those of the anterior series
(fig. 8 D), but the latter series contains more setae (about 12) and
extends farther across the tip. The main part of the tibia bears two
types of setae. The most conspicuous is the large thick and blunt
setae similar to those of the terminal series but shorter and some-
what more regular in outline. They occur scattered sparsely on the
posterior aspect, there being perhaps 15 in all, but there are none on
the anterior face. The other type is the smaller tapering setae which
form the normal vestiture. They are sparse on the posterior aspect,
none occurring close to the proximal end, and they approximate the
length of the larger terminal series on the distal portion, being gradu-
ally smaller toward the base. The anterior aspect and the dorsal
portion are clothed with these finer setae similarly to the posterior
face, but the ventral aspect of the tibia is very much more densely
clothed. The base of nearly all of these setae is surrounded by a group
of two to four pores as on the femur, and the anterior face is sup-
plied with additional scattered pores. The surface of the tibia is very
minutely transversely strigulose in contrast to the femur, which is
longitudinally striate.

The tarsus of the prothoracic leg (fig. 8 F, *tar*) is rather loosely
united to the tibia. The latter bears a rather large terminal membranous
area into which the basal segment of the tarsus, the so-called metatarsus,
is inserted. There are two rather indefinite condyles on the tarsus,
one anterior and one posterior, but no definite corresponding condyles
have been observed on the tibia. The tarsus consists of five tarsomeres
or tarsites, of which the first four are greatly expanded into trans-
verse plates (fig. 8 A, C). The first and second are approximately the
same size, the next two decreasing successively in width and length.
On the dorsal aspect each of these four tarsomeres is broadly emargi-
nate anteriorly, whereas the anterior margin of the ventral side is
expanded in a broad curve forming a large flat plate. The space be-
tween the dorsal emargination and the ventral plate is membranous
and receives the base of the next segment (fig. 8 C). The fifth tarso-
mere is elongate, nearly three times as long as wide, and is inserted
upon the dorsal side of the preceding tarsomere similarly to the others.
It is expanded rather strongly and regularly toward the apex and
is rather cylindrical in form. On its distal end the fifth tarsomere bears
a pair of claws (fig. 8 B, *un*) and an expanded membranous lobe carry-
ing a small ventral plate, the unguitractor plate (*utr*). The claws (fig.
8 J) are slightly compressed dorsoventrally, rather strongly curved
and tapering, and they articulate with the rounded end of the dorsal

surface of the last tarsomere. From the proximal end of the unguitractor plate arises the tendon of the retractor muscle of the claws (*xt*). The unguitractor plate is rather quadrate, tapering proximally into the tendon, and is partly inserted into the end of the last tarsomere. Its distal end is somewhat indefinitely produced into an unsclerotized area bearing two large setae. This is the empodium.

The dorsal aspect of each tarsomere (fig. 8 C) bears a few scattered moderately long but fine setae, and the ventral side of the fifth segment is similarly clothed. The ventral aspect of each of the first four tarsomeres (fig. 8 A) is very densely set with long fine hairs, which are absent from the basal portion of each tarsomere. These four tarsomeres are thus united into a single hairy pad. The two setae on the empodium have been called parempodia (Hayes and Kearns, 1934) and are stated to arise from conspicuous trichophores on the empodium. They are, however, perfectly normal setae, and it is doubtful whether they have any such significance as is implied to them. Their insertion is very inconspicuous as is usual on such lightly sclerotized areas.

The mesothoracic legs are longer than the prothoracic legs but not quite as long as the metathoracic ones. As they are similar to the others in structure and general arrangement, they are treated briefly and not figured completely.

The coxa of the mesothoracic leg (fig. 8 K) is shorter and ovate. It is strongly convex and somewhat excavated on the ventral aspect to receive the base of the femur at rest. The proximal end is slightly produced on the outer side to form the coxal condyle (*cxa*), which articulates with the pleural coxal process. The trochantinal articulation is situated near the center of the proximal end and is retracted to form a concavity that receives the end of the trochantin. The distal end of the coxa is deeply grooved to receive the trochanter. The anterior lip of the groove forms a rounded condyle that articulates in a small socket on the trochanter. The ventral side of the latter is prolonged proximad into the coxa, forming a large muscle attachment. The anterior aspect of the coxa is somewhat more densely clothed than the prothoracic coxa, but the vestiture is practically restricted to the inner or mesal half, only a very few scattered setae occurring on the concavity laterad of the line *y*. The distal end of the posterior aspect also bears a few setae similar to the anterior side. At the tip of the inner face the setae form a long dense brush, and the punctures are so close as to merge with one another.

The trochanter is moderately densely set with long setae on the ventral and anterior sides. Each of the punctures has one or more

relatively large pores close to it. The posterior face is more sparsely punctured than the anterior.

The femur of the mesothoracic leg is slightly longer and considerably thicker than that of the prothorax. The anterior aspect bears numerous moderately long setae which are much sparser at the base and much shorter along the dorsal edge. The posterior face is glabrous but is extremely minutely longitudinally striate. The ventral part of the gonytheca bears a few scattered short setae.

The tibia of the mesothoracic leg is very similar in form to that of the prothoracic leg. It is nearly one-half again as long and exceedingly roughly sculptured. The terminal combs of setae are very similar, and the other vestiture differs chiefly in being longer and more dense. The large blunt setae are longer and more irregular in shape and much more abundant. The calcaria are similar to those of the metathoracic leg (fig. 8 I).

The tarsus is almost exactly similar to that of the metathorax (fig. 8 I). It is very slightly shorter and bears more of the large terminal dorsal setae on each tarsomere.

The metathoracic legs (fig. 8 I) are longer and slightly stouter than the other legs, but the sculpture and vestiture are not as evident as on either of the others. The coxa (*cx*) is short and very transverse, being rather globular medially with a narrow lateral extension that bears the pleural articulation (*cxa*), which is rather indefinitely associated with the tip of the episternum. The median proximal part forms the articulation with the metasternum. The median distal part articulates with the trochanter (*tr*) by two sets of condyles, one anterior and one posterior. The anterior aspect is sparsely clothed with moderately fine setae which become denser and larger toward the apex. There is a slight concavity extending diagonally across the coxa from the median anterior angle and this irregular band is impunctate. The posterior aspect is glabrous except for the median and apical areas which are clothed similarly to and continuously with the anterior parts. The caudal or ventral edge of the transverse lateral part is slightly concave and bears an irregular row of small setae.

The trochanter (fig. 8 I, *tr*) is rather oval in form with its proximal ventral part extended into the interior of the coxa for muscle attachment. It is immovably attached to the posterior side of the proximal end of the femur as in the other legs. Its anterior surface is moderately closely set with small setae, among which are a few of the tiny pores. The posterior aspect is glabrous except for a few setae which are continued around from the anterior side. The femur of the metathoracic leg (*fm*) is tapered to a blunt point proximally and truncated

distally. The gonytheca is rather broad and extends half way down the ventral side as a distinct groove. This groove bears an irregular row of short setae. The anterior surface is clothed with moderately long setae, rather more sparse at the base and longer around the apex. These are also more densely placed ventrad along the edge of the ventral groove. The posterior surface (fig. 8 I) bears a few small setae along the border of the ventral groove, and near the apex a few which are continued around from the anterior side. There is also a series of longer close-set setae along the distal truncated margin, which is continued onto the dorsal margin also. This posterior surface is also very minutely longitudinally striate.

The tibia (fig. 8 I, *tb*) is rather slender, cylindrical, and somewhat regularly expanded distad. Its apex bears a complete circle of large setae very similar to those on the prothoracic tibia (figs. 8 D, E) but the calcaria are much larger and more conspicuous. The anterior vesti-ture is rather dense and the setae long. It is much denser toward the apex and the dorsum. The large thick setae are scattered irregu-larly over the surface, there being perhaps 10 or 12 present. The posterior surface (fig. 8 I) is more sparsely clothed and lacks entirely the larger setae except in the apical series. There is a dorsal series of four or five of the larger setae. The calcaria are unequal in length, the posterior being much the longer, and nearly as long as the first tarsomere. Their surface has an irregular scaly appearance.

The tarsus of the metathoracic leg (fig. 8 I, *tar*) is nearly as long as the tibia, five-segmented like the others, and very nearly cylindrical. The first tarsomere is elongate, nearly as long as the next three to-gether, the latter decreasing in length slightly among themselves distally. The fifth tarsomere is somewhat shorter than the first and bears two claws and the empodium, which are very similar to those of the prothoracic leg (fig. 8 B). Each of the first four tarsomeres is a little more extended ventrad than dorsad and therefore is in-serted apparently a trifle more on the dorsal aspect. They are rather densely clothed with small setae except for the base of the distal four, and the surface of the first is roughly sculptured. The apex of each tarsomere, particularly ventrally, bears a number of very long setae which often reach to the apex of the succeeding tarsomere. The last one is more sparsely clothed with the longer setae and bears the two long setae on the empodial end of the unguitractor plate.

THE ABDOMEN

The abdomen (fig. 9 A) or third region of the body is composed of a series of 10 segments, of which the last two form the genitalia.

Each of the first eight segments bears a pair of spiracles in the tergum, and each one except the eighth has one or two paratergites on each side between the tergite and the sternite.

The first segment is more closely united to the thorax than to the abdomen (fig. 3 A, *tt. 1*). The sternite of this segment is not present, the tergite (fig. 9 A, *tt. 1*), one paratergite on each side (*ptt. 1*), and the large spiracles (*sp. 1*) composing the tergum. The tergite is wider than any of the other tergites and is expanded laterally to nearly twice the length at the middle. Anteriorly it is closely united to the post-notum of the metathorax and posteriorly is rather widely separated from the tergite of the second segment. The surface is not marked by any sutures and is rather lightly sclerotized. A narrow strip along the lateral margin (*y, y*) is somewhat elevated and rather densely clothed with setae. This area is wider posteriorly, and the setae are long in front but becoming much longer posteriorly. The punctures are separated by two to four times their own width and are interspersed with tiny circular nonsetigerous punctures. The remainder of the surface except near the midline is sparsely set with very small setae in small punctures, with scattered nonsetigerous punctures also. The surface is finely strigulate except at the middle, where the posterior area is very densely and finely, but strongly, muricate. This murication is continued onto the membrane behind the tergite and expands somewhat laterally. On the ental surface of the tergite the strigulae are serrate on the posterior edge over nearly the entire surface.

The paratergites (fig. 9 A, *ptt. 1*) of the first abdominal segment consist of a single broad plate on each side of the tergite. They are about one-half as long as the lateral margin of the tergite and are nearly quadrate. Anteriorly each is deeply emarginate to receive the end of the spiracle (*sp. 1*). The paratergites are clothed similarly to the lateral parts of the tergite except that the setae are a little shorter and are densest in front. The posterior margin is unclothed but bears the scattered small punctures similarly to the rest.

The spiracle of the first abdominal segment (fig. 9 A, *sp. 1, D*) is the largest spiracle on the body. It is about twice as long as wide and occupies the anterior half of the lateral margin of the first tergite. It is formed of an oval plate with a large irregularly oval aperture, which is almost completely closed by two series of narrow branching lobes along the sides, which project in one plane over the aperture and, by means of their very dense covering of minute hairlike projections, form a sieve plate over the whole aperture. These microscopic points
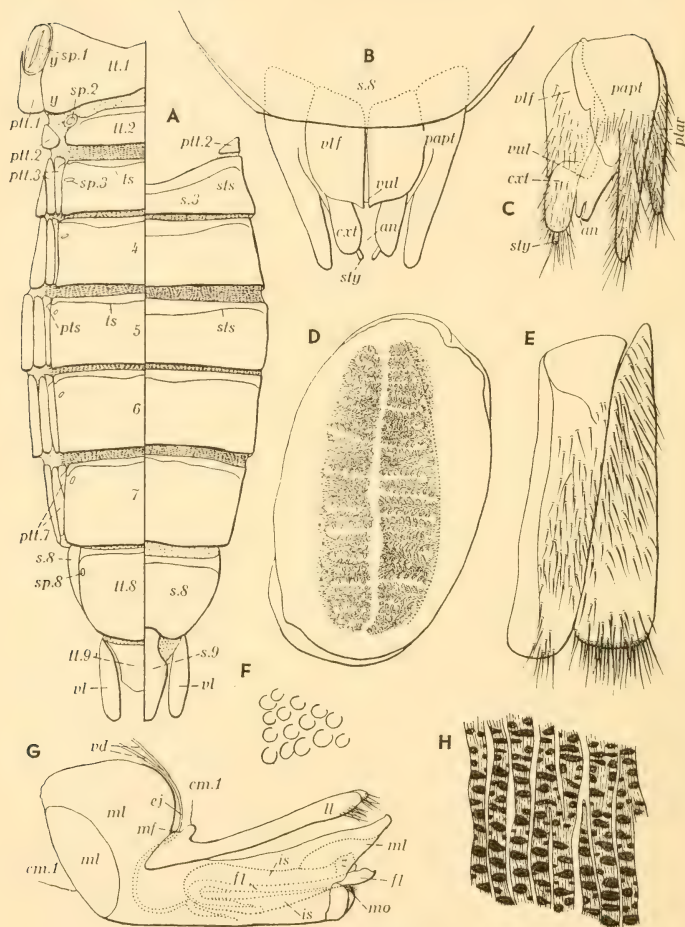
Fig. 9.—Morphology of the abdomen and genitalia of
Creophilus villosus (Grav.).

A, dorsal and ventral aspects of abdomen of male. B, dorsal aspect of female genitalia. C, lateral aspect of female genitalia. D, spiracle of first abdominal segment. E, paratergites from left side of third abdominal segment. F, sculpture of inner side of median orifice of male genitalia. G, lateral aspect of male genitalia. H, mosaic pattern of intersegmental membranes.

are placed in tiny circular groups, and these are continued out onto the surface of the plate giving it a striated and spotted appearance.

The second abdominal segment is composed of a small tergite and one small paratergite on each side extending around onto the ventral aspect. The spiracles are more or less united to the tergite.

The tergite of the second segment (fig. 9 A, *tt. 2*) is about equal in width to the succeeding segments but is shorter than any. The segments from two to eight, in fact, increase regularly in length. The shape is somewhat fusiform, and the anterolateral angle is produced to enclose the spiracle. The surface is longitudinally marked by a strong suture parallel to the anterior margin, and the vestiture consists of a small group of long setae at the posterolateral angles and a very few scattered setae along the posterior margin. The surface is very finely transversely strigulose throughout and is rather densely beset with relatively large lageniform pores.

The second segment has one paratergite (fig. 9 A, *ptt. 2*) on each side of the tergite. They are rather wider than long, tapering toward each end and are curved around onto the dorsal aspect. No vestiture or sutures have been observed, but the surface is sculptured similarly to the tergite.

The sternum of the second segment is entirely membranous and unrecognizable.

The anterolateral corners of the second tergite are slightly produced to embrace a small circular sclerite bearing the spiracle of the second segment. This sclerite is the second abdominal peritreme (fig. 3 A, *peri*). The spiracle is approximately one-fourth as large linearly as the first abdominal spiracle but is slightly larger than the following ones. The spiracle is very similar in structure to the first abdominal one, having the processes covered with minute hairs that form the sieve plates.

The membrane separating the tergites of the second and the third abdominal segments bears a minute but very definite pattern of more heavily sclerotized or pigmented areas which are arranged on longitudinal irregularly anastomosing strips separated by clear membranes (fig. 9 H). This type of membrane is found between the tergites of the second to seventh segments and between the sternites of the third to seventh segments. It fades off laterally to normal membrane in the region of the paratergites.

The tergites of the segments three to seven (fig. 9 A), are all nearly rectangular and are marked by a sinuous transverse fold or suture (*ts*) along the anterior margin. Each bears a spiracle near each anterolateral angle and is bordered on each side by a pair of paratergites.

The narrow strip between the fold and the anterior margin bears a very few long, well-separated setae on the caudal margin, except on the seventh segment, where these setae are about twice as numerous. The main part of the tergite has a rather conspicuous vestiture of long setae. These are set in punctures not noticeably larger than the base of the setae, and separated from each other on the median area by from three to five times their own width, but near the sides by slightly less. At the sides of the seventh segment this vestiture is even slightly denser. Anteriorly on each segment the setae become more sparse and leave a narrow irregular impunctate strip just posterior to the fold or suture. Along the posterior margin the setae are arranged in a single series close to the edge. They are close-set, with the punctures anastomosing, and thus form a kind of marginal fringe. These setae are nearly twice as long as the discal ones. This occurs only on the third to sixth segments. The surface of all these tergites is minutely transversely strigulose, and the setae are interspersed with numerous tiny lageniform pores.

The eighth tergite is the last exposed tergite and is broadly tapered and rounded behind. The sculpture and vestiture are similar to the preceding segments, except that the discal setae are less conspicuous, separated by three to five times the width of their punctures, and not arranged in a definite posterior marginal series.

The sternites of the third to seventh abdominal segments (fig. 9 A) are very similar in structure, vestiture, and sculpture, but differ slightly among themselves in form. They decrease in width slightly from the fifth posteriorly, while increasing in length from the third to the seventh. They extend around the lateral aspect onto the dorsum and are marked with an anterior marginal fold or suture (*sts*) similarly to the tergites. This suture is somewhat arcuate and disappears near the side of the ventral aspect. The third sternite (*s. 3*) is narrowed in the middle so that it is about one-half as long at that point as at the sides. The eighth sternite (*s. 8*) is narrowed and rounded posteriorly similarly to the tergite in the female, but in the male is broadly and shallowly emarginate at the middle. Each of these six sternites is clothed very similarly to the tergites. The setae are long and slender, the punctures small and placed at three to five times their own width apart, a little more numerous at the sides of the venter, and arranged in a single closely spaced series along the posterior margin. This series is present on all the sternites from the third to the eighth. The strip anterior to the suture is sparsely clothed, and a narrow line posterior to it is smooth. The longitudinal strigulations are much finer than on the tergites, being very indistinct except on the

strip anterior to the sternal suture. The lageniform pores are very abundant, especially on the posterolateral portions of the ventral aspect of each sternite.

The paratergites (fig. 9 A, *ptt*, E) are narrow longitudinal sclerites on the dorsal aspect between the tergites and the up-turned edges of the sternites. There is one on each side of the first abdominal tergite, one on each side of the second tergite, and two on each side of the segments from the third to the seventh. The eighth segment alone has no paratergites. The first two segments have already been described. The paratergites of the third to the seventh segments are very similar in form and arrangement throughout. The median one is slightly expanded and truncated anteriorly and more or less tapering caudally. The outer one is rather larger posteriorly but rounded, and tapers somewhat anteriorly. On the seventh segment the inner paratergite is much shorter, being only half the usual length and more sharply tapering. All the others are equal in length to the rest of the segment. The inner paratergite of each segment bears a raised line or fold (*pts*) near the anterior end in such a position as to appear to be a continuation of the tergal suture (*ts*).

The endoskeleton of the abdomen consists chiefly of narrow apophyses along the margins of the segments. These are sometimes known as plicae, and MacGillivray has proposed a system of naming them.

Each of the dorsal segments from the second to the ninth has a narrow phragma near the anterior margin which extends along the sides to the posterior angles except on the second, eighth, and ninth segments (fig. 5 A). These phragmata are marked externally by sutures (fig. 9 A) except on the second, eighth, and ninth segments, in which the phragmata are at the anterior edge of the segment. Each spiracle, except those on the eighth segment, has a small roughly circular apophysis on its ental surface. On the fifth and sixth segments there is a very small transverse apophysis just in front of the margin. These are apparently not marked on the exterior.

The tergal or dorsal member of each pair of paratergites has a narrow apophysis along the anterior end and the median edge. This is found only on the third to seventh segments.

The ventral segments from the third to the eighth each have an anterior apophysis similar to the dorsum. A transverse posterior apophysis is present on the third to sixth sternites.

THE GENITALIA

The abdominal segments posterior to the eighth form the genitalia. Owing to special modifications, these are very different in the two

4

sexes. The genitalia of the female (fig. 9 B, C) are comparatively slight modifications of the ninth and tenth segments. The tergite of the ninth segment (*tt. 9*) is the sclerite termed the proctiger by Tanner (1927). The anus (*an*) is borne not at the end of this sclerite but on another lobe beneath this, the dorsal surface of which represents the tenth tergite. The homology of the pair of elongate lobes, called paraprocts by Tanner, which lie along the sides of the true " proctiger " or tenth segment, are not known. They most likely are parts of the ninth tergum which have become separated from the tergite. The sternum of the ninth segment is represented in the two rectangular sclerites (*vlf*) meeting along the midline and called the valvifers by Tanner. These bear a pair of two-segmented appendages composed of a basal coxite (*cxt*) and a stylus (*sty*). This interpretation differs somewhat from that of Tanner, as he considered the valvifers to be the basal segment of the appendages of the ninth segment. The opening of the vulva (*vul*) is behind (entad) and between the apices of the sternal plates. The distal portions of the ninth tergite and the lateral lobes, the valvifers, the coxites, and the styli are clothed with rather long but pale setae. The surface of the membrane about the vulva is finely muricate with rather blunt pustules.

The genitalia of the male (fig. 9 G) are much more highly specialized or modified than those of the female in this species. The several sclerites caudad of the eighth segment of the abdomen but not actually forming part of the aedeagus have not heretofore been considered as part of the male genitalia. Since they correspond rather closely to the parts of the ninth segment in the female, they are here included with the genitalia of the male.

The ninth segment appears to be present as four distinct parts. The median dorsal surface (fig. 9 A, *tt. 9*) is almost entirely unsclerotized but bears numerous setae. This area is assumed to represent the ninth tergite. On each side is an elongate lobe (*vl*), heavily sclerotized and densely clothed with setae, which is interpreted as the appendage of the ninth segment, the valvula. The sternum is occupied by a sagittate sclerite (*s. 9*) which is undoubtedly the ninth sternite. It is densely clothed with setae similarly to the valvulae and the eighth sternite.

The male genital tube consists of a strong median lobe and a pair of united lateral lobes. The median lobe (fig. 9 G, *ml*) has a large bulbous base and bears the median orifice (*mo*) at its distal end. On the ventral side at the junction of the bulbous part and the distal tube is the small median foramen (*mf*) through which passes the ejaculatory duct (*ej*). This duct opens to the exterior through the tip of the flagellum (*fl*), which is somewhat coiled and apparently double

and projects somewhat from the median orifice (*mo*). The internal sac (*is*) is rather large and nearly encloses the flagellum. Its ventral surface is rather coarsely muricate, whereas the dorsal surface is densely set with tiny spines or pointed processes. The internal surface just below the flagellum at the point *z* is sculptured into minute scalelike protuberances (fig. 9 F), while just dorsal to the flagellum is a small lobe projecting from the median orifice and very densely clothed with long but fine hairs or setae. The two lateral lobes are united on the ventral aspect except at the tip. They are very nearly as long as the median lobe and very slender, with a small group of long setae on the dorsal side at the tip.

The outer surface of the aedeagus bears no sculpture or vestiture, except for the frequent very minute pores which traverse the integument.

Comparative Morphology of the Family

The following section is intended to give a brief review of the variation within the family of certain of the more important characters as they are found in the series of species studied. There are very probably many further modifications to be found in other species, but the present study will serve to show the chief types and the general trend of variation.

THE HEAD

The head capsule shows a great many modifications in structure as well as a wide variety of form and sculpture. The proportions of length to breadth are found in all stages from 2:1 to 1:2 (figs. 10, 11). The shape may vary considerably within a single genus or even a single species, or it may be fairly constant in a larger group.

The dorsal surface of the head, or epicranium, is generally not divided by sutures as in more generalized insects. Of the species studied, only *Tachyporus* (fig. 10 C), *Tachinus*, and *Erchomus* (all in the tribe Tachyporini) show any trace of the anterior part of the coronal suture. A few species have a very short part of the suture visible at the posterior margin of the epicranium. These include *Pseudopsis, Paederus, Lathrotropis, Lithocharis, Trachysectus, Pinophilus, Xantholinus, Staphylinus, Philonthus, Cafius, Glenus, Acylophorus* (fig. 11 G), *Quedius, Bolitobius* (fig. 11 F), and *Xenodusa.*

The frontal sutures are complete between the anterior tentorial pits in all the Tachyporinae studied except *Hypocyptus* (fig. 10 D) as well as the Habrocerinae and Oxyporinae. They were also found in this condition in certain Oxytelini and Piestini. The following are noted

in this group: *Trigonurus* (fig. 10 A), *Bledius, Aploderus, Oxyporus* (fig. 11 D), *Habrocerus, Tachyporus* (fig. 10 C), *Tachinus, Erchomus,* and *Bolitobius* (fig. 11 F). However, in none of these species
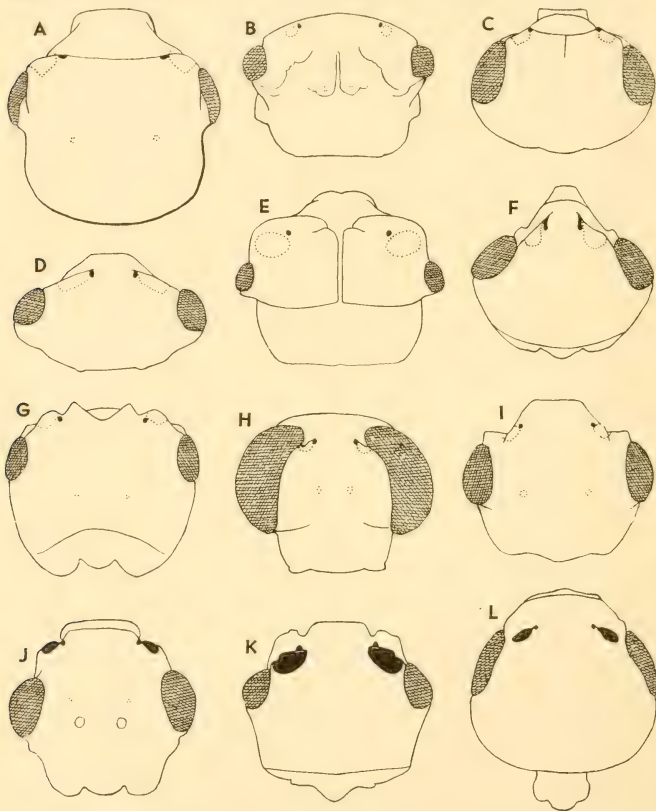

FIG. 10.—Intrafamily variation in the form and structure of the dorsal aspect of the head (continued on fig. 11).

A, *Trigonurus crotchi* Lec. B, *Micropeplus punctatus* Lec. C, *Tachyporus jocosus* Say. D, *Hypocyptus longicornis* (Payk.). E, *Leptochirus mexicanus* Er. F, *Aleochara lata* Grav. G, *Platystethus americanus* Er. H, *Stenus sculptilis* Csy. I, *Proteinus limbatus* Mäkl. J, *Pelecomalium testaceum* (Mann.). K, *Xenodusa sharpi* Wasm. L, *Lorinota cingulata* (Lec.).

is there any evidence of the presence, as a sclerite, of the frons. This sclerite is normally bounded laterally and posteriorly by the frontal sutures and anteriorly by the frontoclypeal or epistomal su-

ture, or, if this suture is absent, approximately by a line drawn between the anterior tentorial pits. Since in these forms the frontal sutures unite to form a nearly straight line, it is obvious that the true
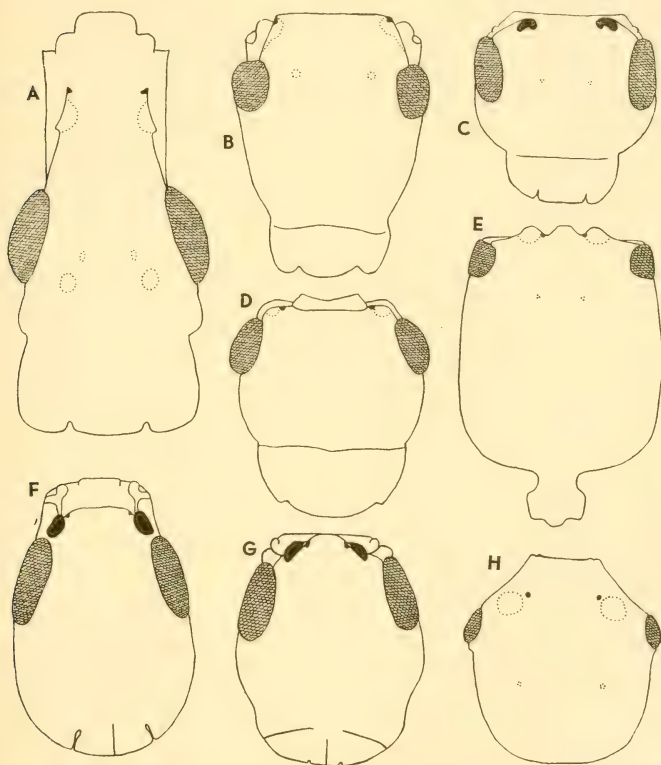

FIG. 11.—Intrafamily variation in the form and structure of the dorsal aspect of the head (continued from fig. 10).

A, *Tanyrhinus singularis* Mann. B, *Hesperobium pallipes* (Grav.). C, *Philonthus aeneus* (Rossi). D, *Oxyporus lateralis* Grav. E, *Metoponcus varians* Shp. F, *Bolitobius cinctus* (Grav.). G, *Acylophorus flavicollis* Sachse. H, *Osorius mundus* Shp.

frons is undifferentiated from the other parts. The area anterior to the tentorial pits is therefore the postclypeus. A portion of the hypostomal suture or epicranial arm is sometimes present, extending

from the tentorial pit toward the eye, as is *Tanyrhinus* (fig. 11 A) and *Philonthus* (fig. 11 C). A definite postclypeal area is present in *Tanyrhinus* (fig. 11 A), *Leptochirus* (fig. 10 E), *Osorius* (fig. 11 H), *Hypocyptus* (fig. 10 D), *Lorinota* (fig. 10 L), etc.

The posterior part of the epicranium is frequently marked by a transverse suture which is believed to be the occipital suture. It is generally rather short and disappears on the lateral aspect, but it may extend onto the ventral surface, as in *Oxyporus* (fig. 12 D) and *Philonthus* (fig. 12 J). In *Aploderus* (fig. 12 E) it even unites with the gular sutures below. The following show this suture in some form: *Platystethus* (fig. 10 G), *Aploderus* (fig. 12 E), *Gastrolobium*, *Hesperobium* (fig. 11 B), *Paederillus, Paederus, Lathrotropis, Stilicus, Trachysectus, Orus, Astenus, Xantholinus, Staphylinus, Ocypus, Philonthus* (fig. 11 C), *Cafius, Glenus, Acylophorus* (fig. 11 G), *Quedius, Oxyporus* (fig. 11 D), *Bolitobius, Liparocephalus, Xenodusa* (fig. 10 K), *Aleochara* (fig. 10 F), and *Baryodma*. It should be noted that *Paederillus littorarius* is the species having the suture, whereas *P. pugetensis* apparently does not. Of the major subfamilies, only Omaliinae and Steninae are not represented in this list.

The head is frequently suddenly constricted behind at the point to which it may be inserted into the prothorax. This point is frequently but not always at about the region of the occipital suture. Extreme examples of constriction are *Metoponcus* (fig. 11 E) and *Lorinota* (fig. 10 L).

The position of the antennal fossa varies considerably and has been used extensively in classification schemes. Since the anterior arm of the tentorium is invariably closely associated with the antennal fossa, and the tentorial pits mark the posterior boundary of the frons or frontal region, it follows that the antennae are never inserted " under the margin of the front " or " at front of front " or " upon the front," but can only be situated at some point along the anterior margin of the vertex. In the cases in which the postclypeus is completely lacking, the antennae will be inserted along the anterior margin of the head. In those cases in which the postclypeus is present but does not reach the eyes, the antennae will be inserted at the lateral corners of the vertex, usually near the eyes. In those cases in which the postclypeus is large and attains the eyes, the antennae will be inserted into the upper surface of the epicranium, between the eyes. In the first group are to be found all the Paederinae and Staphylininae, including *Hesperobium* (fig. 11 B), *Metoponcus* (fig. 11 E), *Philonthus* (fig. 11 C), and *Acylophorus* (fig. 11 G). In the second group are all the Micropeplinae, Omaliinae, Oxytelinae, Habrocerinae, and Tachyporinae, in-

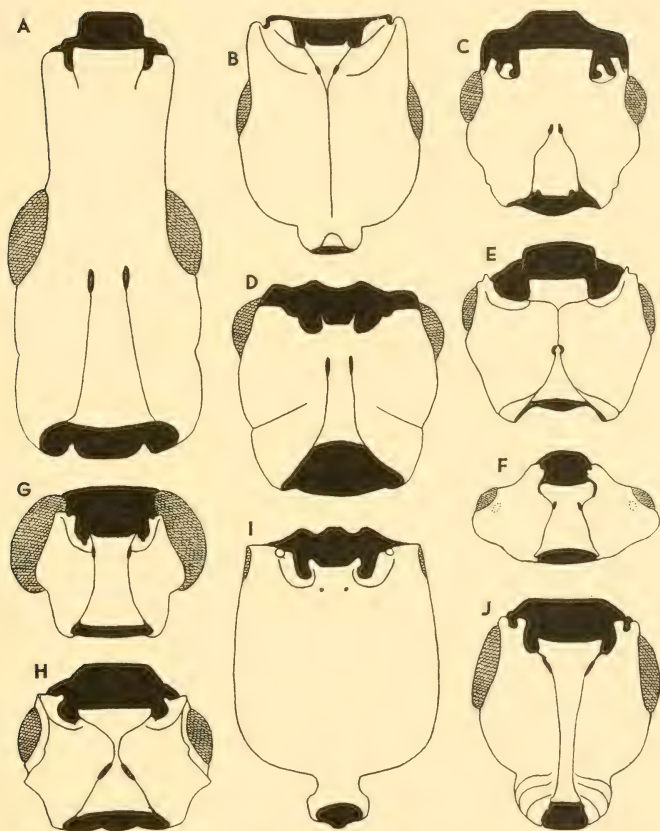FIG. 12.—Intrafamily variation in the form and structure of
the ventral aspect of the head.

A, *Tanyrhinus singularis* Mann. B, *Astenus discopunctatus* (Say). C, *Eumalus nigrella* (Lec.). D, *Oxyporus lateralis* Grav. E, *Aploderus linearis* Lec. F, *Hypocyptus longicornis* (Payk.). G, *Stenus sculptilis* Csy. H, *Lathrimaeum pictum* Fvl. I, *Metoponcus varians* Shp. J, *Philonthus alumnus* Er.

cluding *Micropeplus* (fig. 10 B), *Pelecomalium* (fig. 10 J), *Tanyrhinus* (fig. 11 A), *Proteinus* (fig. 10 I), *Leptochirus* (fig. 10 E), *Platy-stethus* (fig. 10 G), *Osorius* (fig. 11 H), *Oxyporus* (fig. 11 D), *Hypocyptus* (fig. 10 D), *Tachyporus* (fig. 10 C), and *Bolitobius* (fig. 11 F). In the third group are all the Steninae and Aleocharinae, including *Stenus* (fig. 10 H), *Xenodusa* (fig. 10 K), *Lorinota* (fig. 10 L), and *Aleochara* (fig. 10 F). It should be noted that *Acylophorus* shows a tendency toward the second group, whereas *Hypocyptus* seems to approach the third group.

The compound eyes are normally situated at the sides of the head but frequently slightly more on the dorsal aspect than on the ventral. They vary greatly in size, as in *Stenus* (fig. 10 H) and *Leptochirus* (fig. 10 E). They are so far as observed always complete and undivided and never more than slightly emarginate at any point. The facets vary considerably in relative size and in convexity, and may be interspersed with fine hairs, as in *Liparocephalus*.

The opening from the eye into the interior of the head is the ocular foramen. It is generally much smaller than the eye itself because of the development of the oculata. The ocular foramina are indicated in figure 12 F by two small dotted circles near the eyes. Ocelli are present in one subfamily—the Omaliinae. They appear to be entirely characteristic of this group, being found only here and in all the members except one genus which is doubtfully retained. This genus, *Vellica*, has not been available for study. The ocelli are situated on the vertex, one on each side, between or behind the posterior parts of the compound eyes. In dried specimens they usually appear as pale convex protuberances, but in slide preparations are visible only as lighter spots in the wall of the vertex where the sclerotization is less thick or the pigment less evident. The ocelli are indicated in the drawings by solid lines and must not be confused with the ends of the dorsal arms of the tentorium, indicated by dotted lines. *Tanyrhinus* (fig. 11 A) and *Pelecomalium* (fig. 10 J) illustrate these organs.

The anterior tentorial pits as already stated mark the position of the epicranial arms or frontal sutures. Since the frons is apparently always missing in this family, a line between the anterior tentorial pits may be taken as the line of fusion of the postclypeus and vertex. The tentorial pits are always situated near the antennal fossae, usually at their mesal or anterior corners. They may be situated at some point on the surface of the epicranium before or between the eyes. They are shown in the figures as black spots but are seldom, if ever, visible from the exterior in dry specimens. Their actual location is to be

determined only by following the anterior tentorial arms to their anterior extremity.

The ends of the dorsal arms of the tentorium are likewise invisible from the exterior in unprepared specimens. By following the dorsal arms the point of insertion is determined. This point is indicated in the figures by a tiny circle of dots, and it is found on the vertex generally between the eyes, one on each side of the center. In many species the dorsal arms apparently do not reach the vertex. These include *Acylophorus* (fig. 11 G), *Oxyporus* (fig. 11 D), *Hypocyptus* (fig. 10 D), *Tachyporus* (fig. 10 C), *Bolitobius* (fig. 11 F), *Xenodusa* (fig. 10 K), *Lorinota* (fig. 10 L), etc.

The ventral aspect of the head, similarly to the dorsal, is considerably modified by the obliteration of sutures and the consequent fusion of primitive elements. The vertex extends around behind the eyes and is continuous with the genae, if present, and sometimes with the median gular area and the postgenal area.

In the forms already listed as possessing an occipital suture, the vertex is separated by it from the occiput and to a greater or less extent from the postgenae, which are continuous with the occiput. Where no occipital suture is present the vertex, occiput, and postgenae are all united to form the epicranium. The postoccipital sutures are said to be the most constant of all the head sutures. However, this suture is not evident on any of these species (except possibly *Philonthus,* fig. 12 J) until it reaches the ventral side of the head and becomes the gular sutures.

The gular sutures are formed by the relative anterior migration of the posterior tentorial pits and normally extend from the foramen magnum to the base of the labium, separating the ventral aspect into three parts. Enclosed between these sutures is a sclerite known as the gula. Stickney states that it is always complete in the Staphylinidae, but even under the present interpretation the additional material proves the contrary to be the case. The gula may be considered to be complete when it extends from the foramen magnum to the tentorial pits, where it unites with the submentum.

The gula has been found to be incomplete in 13 of the species used in this study. Three types of conditions are found among these 13. In some the gula is separated from the pits by the meeting of the gular sutures on the midline, as in *Leptochirus, Bledius, Osorius, Gastrolobium, Stilicus, Astenus* (fig. 12 B), *Xantholinus, Staphylinus,* and *Cafius.* Some have the gular sutures incomplete posteriorly, such as *Paederillus, Lathrotropis,* and *Trachysectus.* One species, *Metoponcus* (fig. 12 I), shows no sign of the gular sutures at all; the posterior

tentorial pits, however, are located in this species near the base of the labium and indicate a possible relationship with the supposedly closely related *Xantholinus,* in which the sutures are confluent on the midline.

THE APPENDAGES OF THE HEAD

The intrafamily variation in the antennae is considerable, but these variations are mostly rather superficial and are not very constant within the subfamilies. Omitting the aberrant *Micropeplus* (fig. 13 M), in which the antenna is only nine-segmented with a much enlarged terminal segment, the forms are either 10- or 11-segmented. In the former group are the Hypocyptini (fig. 13 N) and two genera of the Aleocharinae (*Oligota* and *Decusa*). All other members of the family examined have the antennae clearly 11-segmented.

Figure 13 shows some of the variations in form of the antennae. The method of insertion of the second segment into the first determines the amount of movement possible as well as the amount of geniculation. Strongly geniculate antennae are found in *Acylophorus* (fig. 13 L), *Osorius* (fig. 13 K), and some of the Paederini (subtribe Cryptobia). Great variation is found in the shape of the basal segment, as well as in its size and method of insertion in the antennal fossa.

The vesture of the antennal segments ranges from the large sparse tactile setae of figure 13 I to the dense minute pile indicated on the distal segments of figure 13 H. No segment anywhere has been observed that is entirely without vesture, though on some (as fig. 13 L) it may be exceedingly minute and indistinct. The exceedingly minute vesture is generally accompanied by numerous pores, which give a glandular appearance to the surface (fig. 1 B). The extent of this type of vesture is rather definite in each species and varies considerably throughout the family. In some it is distinctly confined to certain segments, but in others diminishes gradually from the apex and becomes indistinct on the basal segments. In *Micropeplus* only the terminal (ninth) segment is so clothed. *Creophilus* has this type of vesture on the last five segments; *Hadrotes* on the last six. Those with it on the last seven include *Tanyrhinus, Leptochirus, Glenus, Bolitobius,* and *Aleochara.* Those with it on the terminal eight segments include *Oxytelus, Xantholinus, Philonthus,* and *Quedius.* The following have it on all but the two basal: *Gastrolobium, Lathrotropis, Hesperobium,* and *Pinophilus.* From this it can be seen that the vesture of the antennae is not stable within certain tribal limits, and in some cases even in smaller groups there is considerable variation.
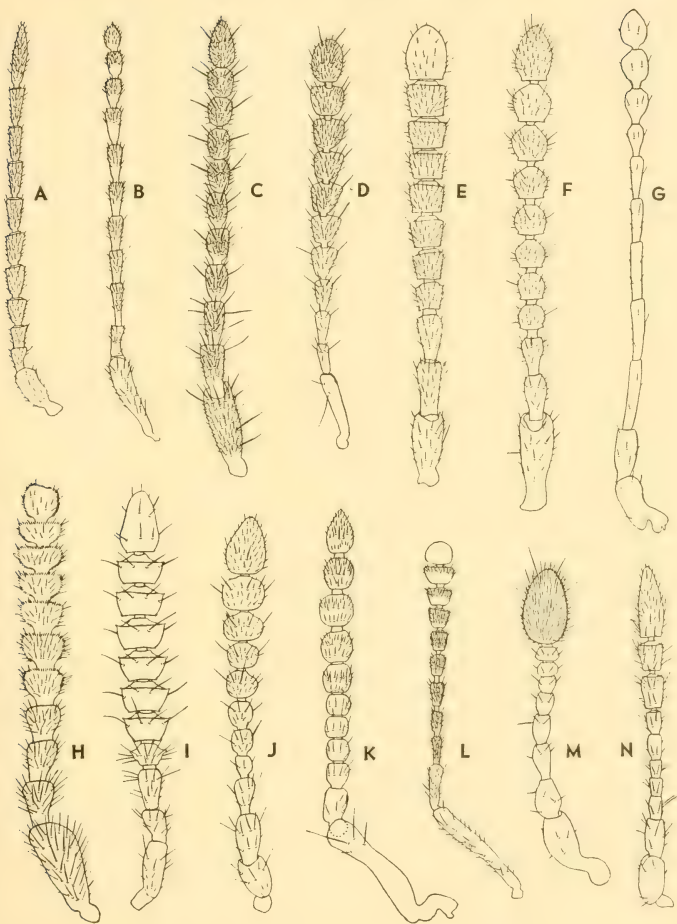
FIG. 13.—Intrafamily variation of the antenna.

A, *Xenodusa sharpi* Wasm. B, *Gastrolobium bicolor* (Grav.). C, *Lithocharis ochracea* (Grav.). D, *Bolitobius cinctus* (Grav.). E, *Lorinota cingulata* (Lec.). F, *Aploderus linearis* Lec. G, *Stenus sculptilis* Csy. H, *Glenus flohri* Shp. I, *Aleochara lata* Grav. J, *Phloeocharis subtilissima* Mann. K, *Osorius mundus* Shp. L, *Acylophorus flavicollis* Sachse. M, *Micropeplus punctatus* Lec. N, *Hypocyptus longicornis* (Payk.).

The considerable variation in the form and relative size of the
labrum is very hard to classify because of the large number of slight
variations which grade from one to the other. Figure 14 shows a few
of the types. The presence of the membranous processes, such as on

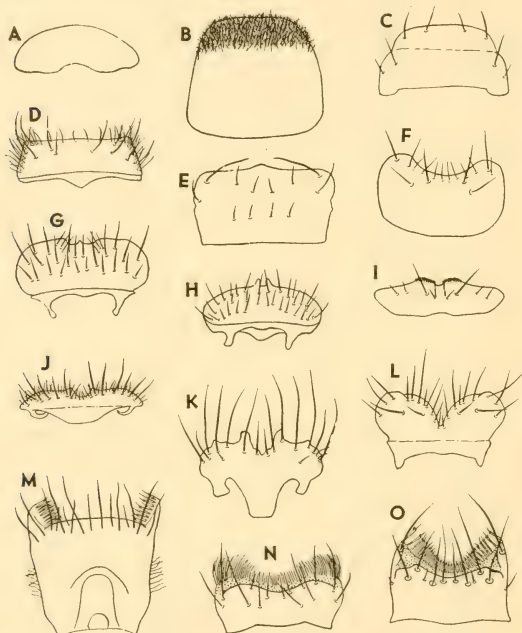

FIG. 14.—Intrafamily variation in the labrum.

A, *Stenus sculptilis* Csy. B, *Xenodusa sharpi* Wasm. C, *Micropeplus punctatus*
Lec. D, *Liparocephalus brevipennis* Mäkl. E, *Pseudopsis obliterata* Lec. F, *Tany-
rhinus singularis* Mann. G, *Lithocharis ochracea* (Grav.). H, *Stilicus angularis*
Er. I, *Astenus discopunctatus* (Say). J, *Pinophilus parvipennis* Csy. K, *Trachy-
sectus confluentus* (Say). L, *Lathrotropis jacobina* (Lec.). M, *Osorius mundus*
Shp. N, *Tachinus limbatus* Mels. O, *Platystethus americanus* Er.

Osorius (fig. 14 M) and *Platystethus* (fig. 14 O), is definite and
usable, as well as the entirely glabrous character of *Stenus* (fig. 14 A).

The variation in the form and structure of the mandibles is ex-
tremely great. Every gradation is found between massive blunt types
with a large molar area, such as *Micropeplus* (fig. 15 C), and the very
slender acute type without mola, such as *Astenus* (fig. 15 L). In some
the terminal tooth is the only one present, as in some species of *Geo-*

dromicus, Pelecomalium (fig. 16 A), *Tanyrhinus, Lathrimaeum, Proteinus* (fig. 15 A), *Trigonurus, Osorius, Tachyporus, Bolitobius* (fig. 15 H), *Xenodusa* (fig. 15 D), and *Lorinota*. In others from two
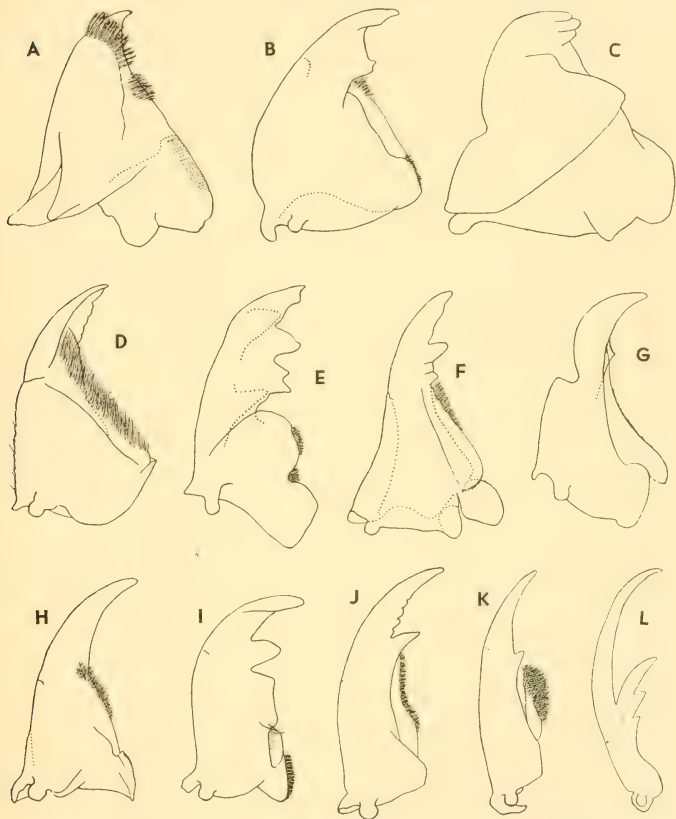
FIG. 15.—Intrafamily variations of the mandibles (continued on fig. 16).

A, *Proteinus limbatus* Mäkl. B, *Phlococharis subtilissima* Mann. C, *Micropeplus punctatus* Lec. D, *Xenodusa sharpi* Wasm. E, *Leptochirus mexicanus* Er. F, *Aploderus linearis* Lec. G, *Oligota esmeraldae* Csy. H, *Bolitobius cinctus* (Grav.). I, *Pseudopsis obliterata* Lec. J, *Liparocephalus brevipennis* Mäkl. K, *Glenus flohri* Shp. L, *Astenus discopunctatus* (Say).

to many teeth may be produced, placed either near the tip or at any point along the inner face. One species, *Oxyporus* (fig. 16 H), has a very small isolated tooth near the outer margin of the mandible

at the middle. The condyles are fairly constant in position. The ventral one is a rounded protuberance and is located on the proximal end of the ventral side near the outer angle. In *Oxyporus* (fig. 16 H) this condyle is situated much nearer the inner edge. The dorsal articulation is sometimes a definite rounded acetabulum but frequently is only a hollow curve along the face of an irregular projection. The prostheca offers considerable variety in form, size, and position. It is
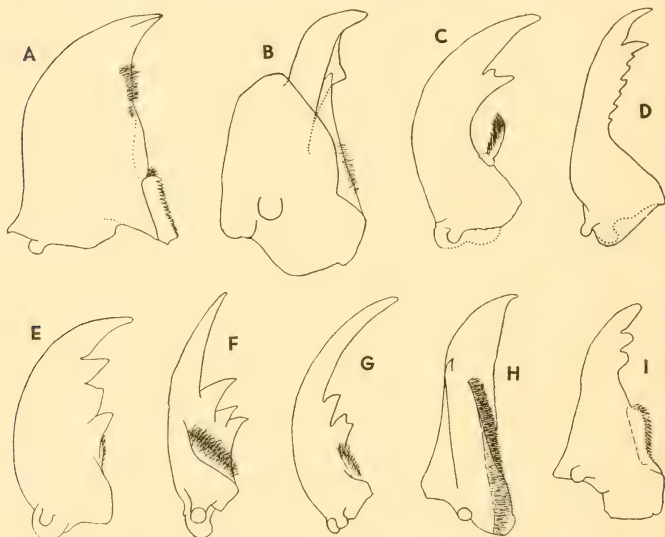
FIG. 16.—Intrafamily variation of the mandibles (continued from fig. 15).

A, *Pelecomalium testaceum* (Mann.). B, *Hypocyptus longicornis* (Payk.). C, *Paederillus pugetensis* Csy. D, *Stenus sculptilis* Csy. E, *Lithocharis ochracea* (Grav.). F, *Acylophorus flavicollis* Sachse. G, *Hesperobium pallipes* (Grav.). H, *Oxyporus lateralis* Grav. I, *Bledius monstratus* Csy.

apparently lacking in *Micropeplus* (fig. 15 C), *Astenus* (fig. 15 L), and *Stenus* (fig. 16 D). In *Glenus* (fig. 15 K), *Paederillus* (fig. 16 C), and *Creophilus* (fig. 2 F) the prostheca is a definite projecting lobe with numerous minute hairlike processes, while in many other species it is apparently represented by a more or less definite row or area of processes proceeding from the surface of the mandible or a groove thereon, such as in *Pelecomalium* (fig. 16 A), *Proteinus* (fig. 15 A), *Acylophorus* (fig. 16 F), *Oxyporus* (fig. 16 H), *Bolitobius* (fig. 15 H), and *Xenodusa* (fig. 15 D).

The maxillae present a rather large amount of variation in form and of modification from the typical arrangement of parts. The typical form has been described for *Creophilus* (fig. 2 G).
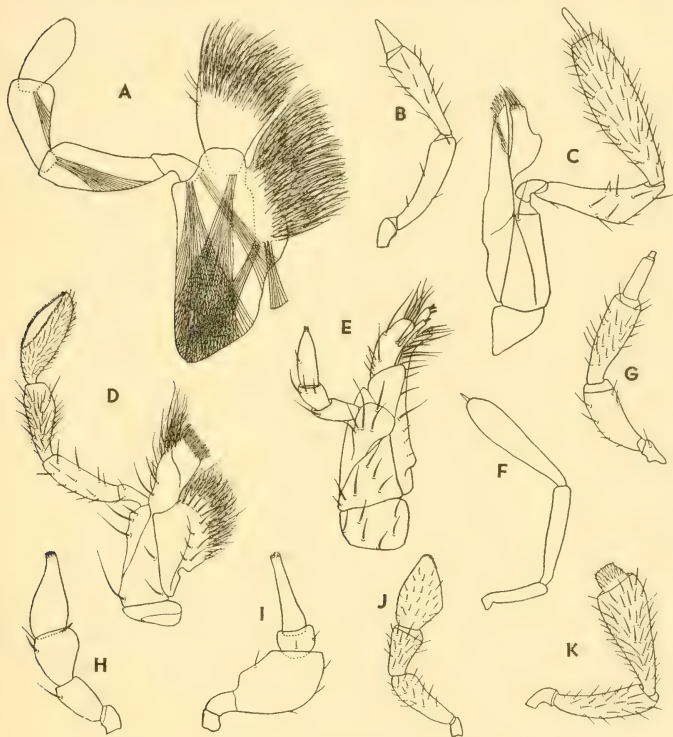
FIG. 17.—Intrafamily variation in the maxillae and the maxillary palpi.

A, musculature of maxilla of *Thinopinus pictus* Lec. B, palpus of *Gastrolobium bicolor* (Grav.). C, maxilla of *Hypocyptus longicornis* (Payk.). D, maxilla of *Pinophilus parvipennis* Csy. E, maxilla of *Osorius mundus* Shp. F, palpus of *Stenus sculptilis* Csy. G, palpus of *Baryodma bimaculata* Grav. H, palpus of *Acylophorus flavicollis* Sachse. I, palpus of *Micropeplus punctatus* Lec. J, palpus of *Pelecomalium testaceum* (Mann.). K, palpus of *Paederus lactus* Er.

The relative sizes of the cardo, stipes, galea, and lacinia are subject to much variation. The subfamily Staphylininae is very homogeneous, there being little variation in any parts from *Creophilus* and *Thinopinus* (fig. 17 A). In some species the lacinia is more elongate and

extends distad almost or quite as far as the galea. These forms generally have both these structures less hairy and frequently armed with spines. Of the species examined *Geodromicus, Pelecomalium, Leptochirus, Eumalus, Trigonurus,* all the Oxytelini, Steninae, Paederinae (fig. 17 D), Staphylininae (fig. 2 G), Oxyporinae, Tachyporini, and Bolitobiini have the lacinia much shorter than the galea, whereas it is elongate in *Micropeplus, Tanyrhinus, Lathrimaeum, Phlococharis, Pseudopsis, Osorius* (fig. 17 E), *Habrocerus, Hypocyptus* (fig. 17 C), and all the Aleocharinae.

The maxillary palpi are four-segmented in all the species except *Aleochara* and *Baryodma* (fig. 17 G), in which there is a small additional fifth segment. With the exception of *Stenus* (fig. 17 F), the first segment is always small and geniculate. It is apparently immovably united to the second segment, at least in *Thinopinus* (fig. 17 A). Any of the succeeding segments may be much expanded, as the second in *Micropeplus* (fig. 17 I), the third in *Hypocyptus* (fig. 17 C) and *Paederus* (fig. 17 K), or the fourth in *Pinophilus* (fig. 17 D). Occasionally the fourth is longer than any of the others, as in *Acylophorus* (fig. 17 H) and *Osorius* (fig. 17 E), but more frequently it is greatly reduced, as in *Gastrolobium* (fig. 17 B), *Hypocyptus* (fig. 17 C), and *Stenus* (fig. 17 F). In *Paederus* (fig. 17 K) the terminal one is short, truncated, and strongly compressed.

In nearly every labium studied the mentum and submentum are the only heavily sclerotized parts. The submentum is continuous with the gula between the tentorial pits and is generally separated at the sides from the postgenae by the submental sutures. These sutures may be complete from the base of the mentum to the tentorial pits, they may be incomplete either anteriorly or posteriorly, they may be united on the midline for a distance in front of the pits, or they may be entirely lacking. They are complete in *Lathrimaeum* (fig. 12 H), *Stenus* (fig. 12 G), *Astenus* (fig. 12 B), *Hypocyptus* (fig. 12 F), and all others not listed in the three following categories. The anterior ends of the sutures have disappeared to a varying extent in *Pseudopsis, Trachysectus, Orus, Philonthus* (fig. 12 J), *Cafius, Creophilus, Ocypus, Thinopinus, Hadrotes, Glenus, Acylophorus, Quedius, Tachinus, Tachyporus,* and *Erchomus.* They are visible only at the anterior end in *Tanyrhinus* (fig. 12 A). In *Trigonurus, Bledius, Platystethus, Oxytelus, Aploderus* (fig. 12 E), and *Osorius* they have become united in front of the tentorial pits so that the submentum is a wholly distinct sclerite. The sutures are apparently entirely lacking in *Micropeplus, Eumalus* (fig. 12 C), *Metoponcus* (fig. 12 I), and *Oxyporus* (fig. 12 D).

The mentum is frequently united to the submentum between the projecting anterior corners of the latter. It is usually trapezoidal in form but may be variously lobed in front, as in *Leptochirus* (fig. 18 G), *Oxyporus* (fig. 18 A), and *Liparocephalus* (fig. 18 E). It frequently bears a few large setae and is nearly always sparsely set with large pores.
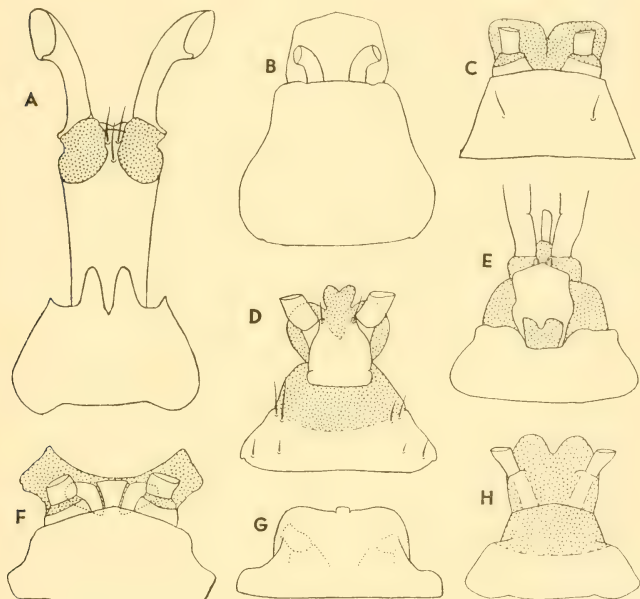
Fig. 18.—Intrafamily variation in the form and structure of the labium. (Only the basal segment of the palpi shown.)

A, *Oxyporus lateralis* Grav. B, *Osorius mundus* Shp. C, *Lathrimaeum pictum* Fvl. D, *Baryodma bimaculata* Grav. E, *Liparocephalus brevipennis* Mäkl. F, *Trigonurus crotchi* Lec. G, *Leptochirus mexicanus* Er. H, *Gastrolobium bicolor* (Grav.).

The prementum is frequently only partly sclerotized. In *Trigonurus* (fig. 18 F) there are three small triangular sclerites lying in the membrane between the paraglossal lobes; in *Osorius* (fig. 18 B) there is a single large quadrate plate anterior to the base of the palpi; in *Oxyporus* (fig. 18 A) the entire basal part of the prementum is sclerotized as a long plate; and in other forms there is more or less sclerotization of the area between the mentum and the base of the palpi. The

palpigers may not be differentiated from the rest of the prementum, and are frequently entirely membranous. Frequently there are no glossal or paraglossal lobes visible, as in *Osorius* (fig. 18 B) and *Leptochirus* (fig. 18 G), but in some forms they appear to have united into a pair of lobes or even a single lobe, as in *Lathrimaeum* (fig. 18 C) and *Gastrolobium* (fig. 18 H), whereas in others there are both glossae and paraglossae distinct, as in *Baryodma* (fig. 18 D). In *Liparo-cephalus* (fig. 18 E) there is a united glossa or ligula which is prolonged into a cylindrical sclerotized piece projecting cephalad for nearly half the length of the first segment of the palpi.

Any of these parts may occasionally bear large setae or minute setulae. It must always be borne in mind in examining the labium that the hypopharynx almost invariably is furnished with a pair of lobes bearing combs of setae which project up behind the paraglossae and are likely to be mistaken for them. They are always membranous like the paraglossae, and the distinction between them is sometimes difficult to make.

The number of segments in the labial palpi is said to vary from one to four. None have been recorded with less than three except from the subfamily Aleocharinae, and the only examples with four are there also. In almost no cases are there definite articulations between the segments of the palpi, each one being united to the next by a relatively wide area of membrane. Frequently also the segments are rather indefinitely sclerotized but usually sufficiently so to prevent any difficulty in counting them.

No specimens have been studied which have only one segment in the labial palpi. One species has been observed with two-segmented palpi. This is *Liparocephalus* (fig. 19 B), in which the basal segment is partially divided into two. It is evidently an intermediate step in the formation of either the three-segmented from the two-segmented condition or the reverse. The closely related genus *Diaulota* frequently shows both the extremes and all the intermediate steps in a single lot of the one species.

The three-segmented condition of the labial palpi is almost universal throughout the family, but a great deal of variation in form is apparent. As a rule the labial palpus cannot be said to be filiform, though certain segments may be slender in certain species. The basal segment may be longer than either of the others, as in *Habrocerus* (fig. 19 E) and *Stenus* (fig. 19 C), or shorter, as in *Hypocyptus* (fig. 19 F) and *Osorius* (fig. 19 J). It may be rather strongly geniculate as in *Stenus* (fig. 19 C) and *Osorius* (fig. 19 J), or may be large and

cylindrical as in *Aleochara* (fig. 19 A) and *Habrocerus* (fig. 19 E).
The middle segment may be greatly expanded as in *Stenus* (fig. 19 C)
or very short as in *Trigonurus* (fig. 19 H). The terminal segment is
generally small and narrow as in *Stenus* (fig. 19 C), *Hypocyptus* (fig.
19 F), and *Paederus* (fig. 19 I), but is greatly expanded in *Oxyporus*
(fig. 19 D) into a very large, compressed, obconical body.
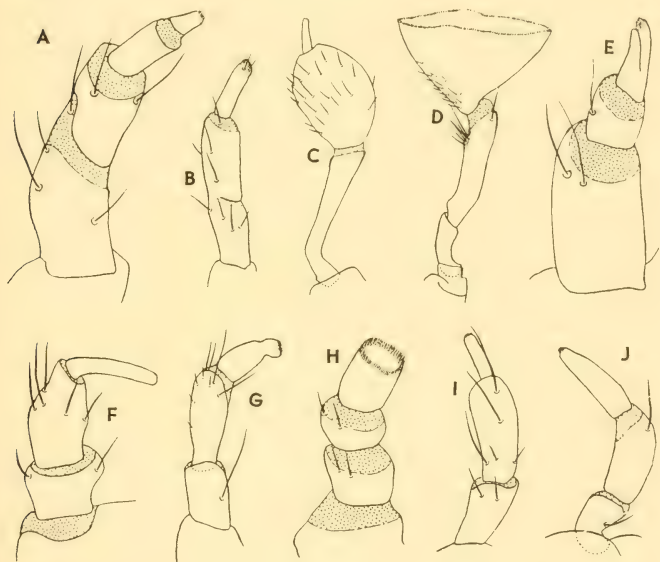
FIG. 19.—Intrafamily variation in the labial palpi.

A, *Aleochara lata* Grav. B, *Liparocephalus brevipennis* Mäkl. C, *Stenus
sculptilis* Csy. D, *Oxyporus lateralis* Grav. E, *Habrocerus schwarzi* Horn. F,
Hypocyptus longicornis (Payk.). G, *Pinophilus parvipennis* Csy. H, *Trigo-
nurus crotchi* Lec. I, *Paederus laetus* Er. J, *Osorius mundus* Shp.

A four-segmented labial palpus was found only in *Aleochara* (fig.
19 A). The palpi of other Aleocharinae are said to be similar.

THE THORAX

A great deal of variation is exhibited in the shape of the pronotum
(figs. 20, 21). It is hard to classify the types, as nearly all gradations
are to be found and nearly every genus or even species is somewhat
different from its near, as well as from its more distant, relatives.
Figures 20 and 21 show some of the forms that occur. Almost any
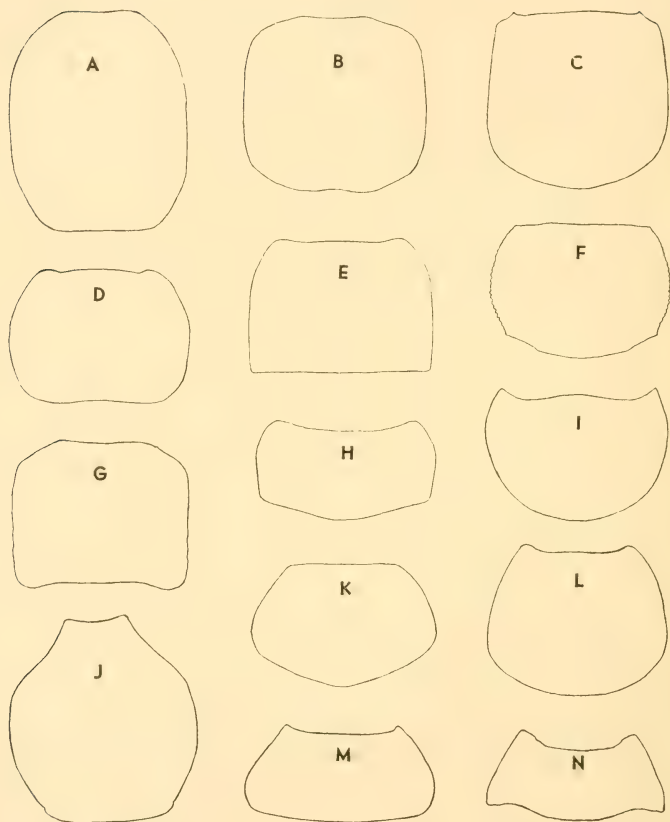
Fig. 20.—Intrafamily variation of the pronotum (continued on fig. 21).

A, *Lathrotropis jacobina* (Lec.). B, *Lithocharis ochracea* (Grav.). C, *Ocypus ater* (Grav.). D, *Felecomalium testaceum* (Mann.). E, *Trigonurus crotchi* Lec. F, *Pseudopsis obliterata* Lec. G, *Leptochirus mexicanus* Er. H, *Proteinus limbatus* Mäkl. I, *Platystethus americanus* Er. J, *Stilicus angularis* Er. K, *Aleochara lata* Grav. L, *Acylophorus flavicollis* Sachse. M, *Tachyporus jocosus* Say. N, *Micropeplus punctatus* Lec.

of these may be found in any of the larger subfamilies. It is obvious
that the shape of the pronotum cannot be used in the higher classifica-
tion. In certain groups it is useful in generic and specific segregation.

The inflexed portion of the pronotum is generally closely united
with certain elements of the ventral surface and will be discussed in
the section dealing with the prosternal area.

The ventral aspect of the prothorax affords a considerable amount
of variation in structure. The fundamental condition is frequently
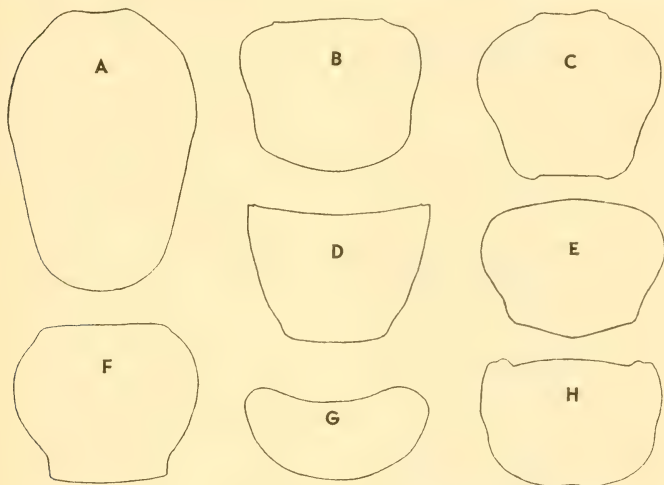
Fig. 21.—Intrafamily variation of the pronotum (continued from fig. 20).

A, *Metoponcus varians* Shp. B, *Cafius lithocharinus* Lec. C, *Lorinota cingu-
lata* (Lec.); D, *Osorius mundus* Shp. E, *Liparocephalus brevipennis* Makl.
F, *Geodromicus brunneus* (Say). G, *Hypocyptus longicornis* (Payk.). H,
Aploderus linearis Lec.

obscured by the reduction of sclerites and the obliteration of sutures,
but several important characters are available.

The amount of inflection of the pronotum varies somewhat, but
the size of the postcoxal lobe is more important and usable. These
lobes tend to close the coxal cavities behind, being almost successful
in *Leptochirus* (fig. 22 F). In *Lithocharis* (fig. 22 B) and *Xantholinus*
(fig. 23 D) they are lacking entirely.

The sternum varies greatly in length. The longest exposed area
occurs in *Leptochirus* (fig. 22 F), but the large posterior lobe of

Astenus (fig. 23 A) surpasses it somewhat though covered by the coxae. *Aleochara* (fig. 22 A) has the shortest and most reduced sternum. This structure is often produced posteriorly between or under the coxae. *Trigonurus* (fig. 22 D) has a very small projection,
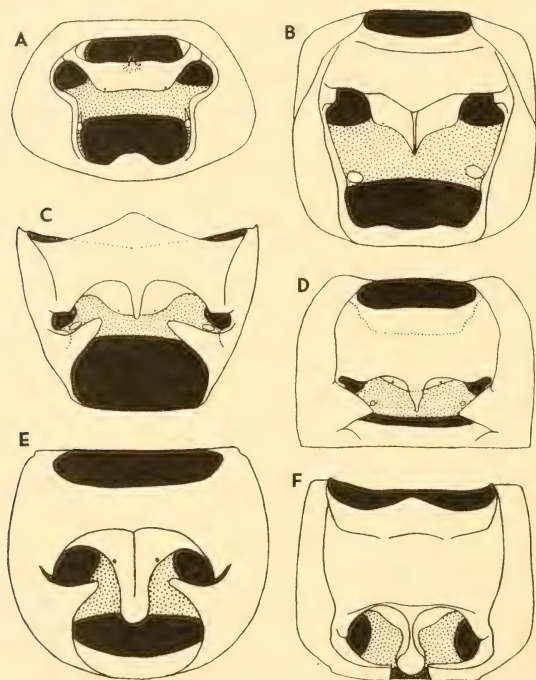
Fig. 22.—Intrafamily variation in the form and structure of the prosternal area (continued on fig. 23).

A, *Aleochara lata* Grav. B, *Lithocharis ochracea* (Grav.). C, *Osorius mundus* Shp. D, *Trigonurus crotchi* Lec. E, *Bledius monstratus* Csy. F, *Leptochirus mexicanus* Er.

while the extreme development is reached in *Astenus* (fig. 23 A) and *Pinophilus* (fig. 23 B). In these last two the prosternal lobe reaches the lobes of the inflexed pronotum, thereby closing the coxal cavities behind. In *Pinophilus* this closure is completed by the actual fusion of the sternal lobe to the underside of the lateral lobes.

In *Xantholinus* (fig. 23 D) and *Metoponcus* there is a pair of large triangular sclerites anterior to the sternum and lying free in the edge of the anterior foramen. They occur in no other group and are said to be present in only a few genera of the Xantholinini.

The spiracles of the mesothorax normally lie in the intersegmental membrane in the vicinity of the pronotal lobes. They usually lie in the
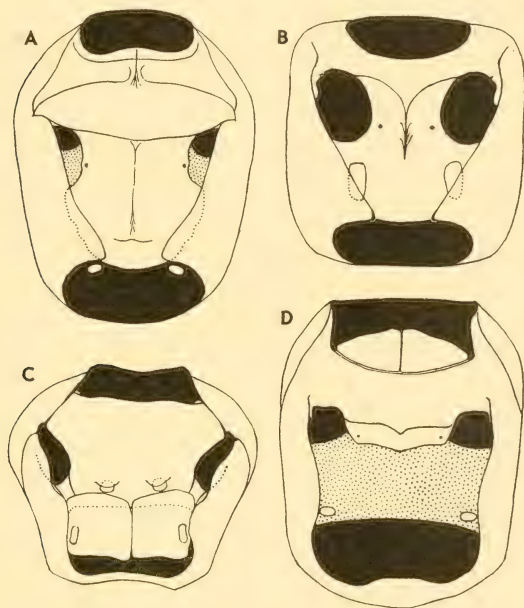
Fig. 23.—Intrafamily variation in the form and structure of the prosternal area (continued from fig. 22).

A, *Astenus discopunctatus* (Say). B, *Pinophilus parvipennis* Csy. C, *Lorinota cingulata* (Lec.). D, *Xantholinus picipennis* Lec.

unsclerotized membrane as in *Lithocharis* (fig. 22 B) and *Trigonurus* (fig. 22 D), but are incorporated into the posterior lobe of the prosternum in *Pinophilus* (fig. 23 B). In *Aleochara* (fig. 22 A) they are surrounded by the small peritremes, while in *Lorinota* (fig. 23 C) these sclerites are so large as completely to close the coxal cavities behind.

The shape of the elytron is almost as individual as that of the pronotum (fig. 24). It is impossible to classify these organs by form,
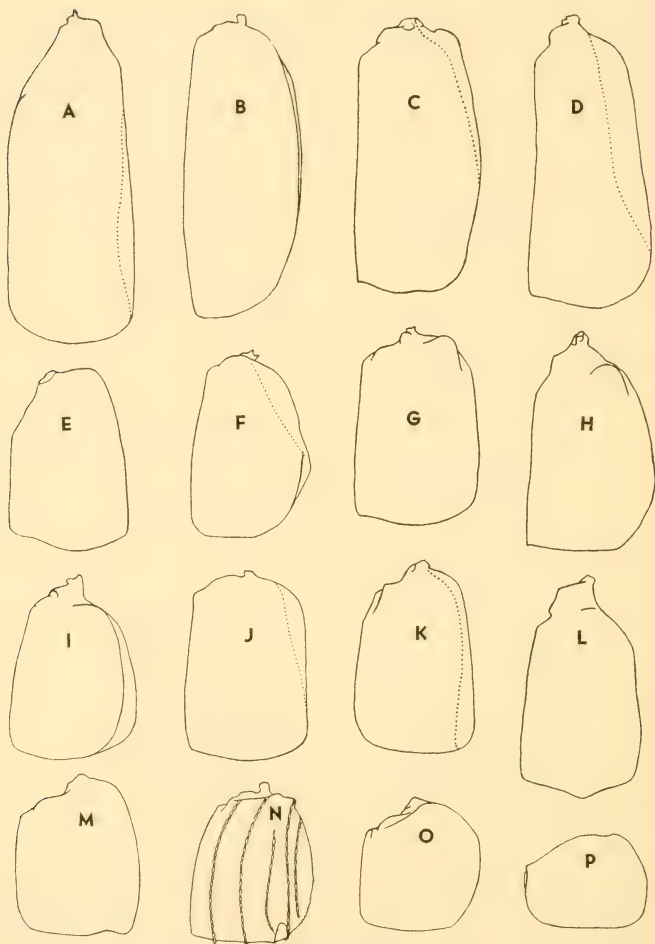
Fig. 24.—Intrafamily variation of the elytra.

A, *Metoponcus varians* Shp. B, *Tanyrhinus singularis* Mann. C, *Trigonurus crotchi* Lec. D, *Geodromicus brunneus* (Say). E, *Acylophorus flavicollis* Sachse. F, *Proteinus limbatus* Mäkl. G, *Oxyporus lateralis* Grav. H, *Osorius mundus* Shp. I, *Bledius monstratus* Csy. J, *Tachyporus jocosus* Say. K, *Platy-stethus americanus* Er. L, *Paederillus pugetensis* Csy. M, *Xenodusa sharpi* Wasm. N, *Micropeplus punctatus* Lec. O, *Aleochara lata* Grav. P, *Liparo-cephalus brevipennis* Mäkl.

but the series shows the range from the long slender types of *Meto-poncus* and *Tanyrhinus* to the short transverse one of *Liparocephalus*.

The extent of deflection of the sides of the elytra depends in great part on the convexity of the thorax. In many species this area is rather abruptly deflexed and of considerable size (figs. 24 D, F, K). This area has frequently been called the epipleurae, but if this term be used, it should be borne in mind that it is a convenient name for a region rather than for a definite morphological unit. The epipleuron is occasionally separated from the discal portion of the elytron by a raised line as in *Bledius* (fig. 24 I) and *Tanyrhinus* (fig. 24 B). The epipleuron may bear a distinct line parallel to the outer margin. This is called the pleural fold by Casey but is more properly termed the epipleural fold, although its exact significance is not known.

In most of the Xantholinini, such as *Metoponcus* and *Xantholinus,* the so-called elytral suture or median edge of the elytron is somewhat abnormal. The thickness of the elytron along this edge is gradually diminished so that the whole edge appears to be beveled. This beveled surface is smooth and unclothed and usually less heavily pigmented than the rest of the elytron. These two edges overlap one another when the elytra are at rest. No special morphological significance is attributed to this feature as it is only a slight modification of the normal suture.

The structure of the sterna of the mesothorax and metathorax is influenced to a large extent by the size, shape, and position of the coxal cavities of the mesothorax. The actual points of insertion of the coxae may be widely separated (fig. 25 C) or close together (fig. 25 B) without changing the relation of the parts. In these two examples the more widely separated ones are still confluent on the midline, whereas the approximate ones are separated by the two sternal processes.

It should be understood that in speaking of the coxal cavities, one is referring to the entire depression occupied by the coxae. This depression is bounded anteriorly by the mesosternum and generally is set off posteriorly by a line on the metasternum. The floor of this depression is made up of the deflexed portions of the mesosterna and metasterna, and it is generally more or less elevated in the middle to form a ridge between the two coxal cavities. However, unless the actual surface of the two sterna meet on the midline or are closely approximated, the cavities are considered to be confluent. The posterior border of the two cavities is usually marked by a line which is common to both and delimits anteriorly the process of the metasternum.
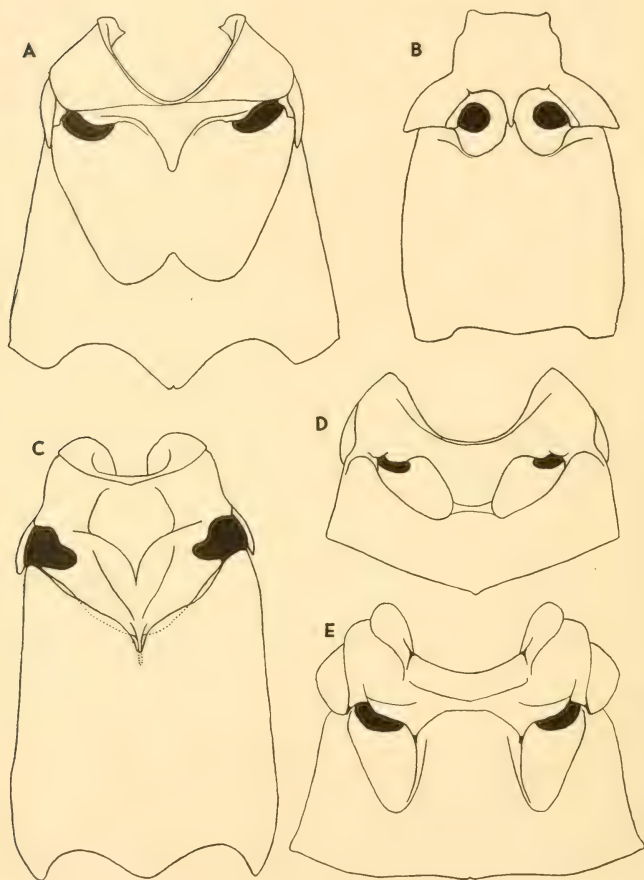
Fig. 25.—Intrafamily variation in the structure of the mesothoracic and metathoracic sterna.

A, *Ocypus ater* (Grav.). B, *Leptochirus mexicanus* Er. C, *Metoponcus varians* Shp. D, *Hypocyptus longicornis* (Payk.). E, *Oxyporus lateralis* Grav.

The most common situation in this family is for the two cavities to be confluent on the midline. That is, the processes from the mesothorax and metathorax do not meet. In nearly all cases, however, the mesothoracic process projects more or less between the coxae. This group includes *Geodromicus, Pelecomalium, Lathrimaeum, Proteinus, Eumalus, Pseudopsis, Bledius, Oxytelus, Aploderus, Osorius*, all the Paederinae, *Metoponcus* (fig. 25 C), all the Staphylinini (fig. 25 A), Xanthopygini, and Quediini, *Habrocerus*, and *Liparocephalus*.

In *Stenus, Hypocyptus* (fig. 25 D), and *Aleochara* the mesothoracic process attains the metasternum, thereby separating the coxal cavities without the aid of a metathoracic process.

This situation is just reversed in *Platystethus* and *Oxyporus* (fig. 25 E), in which the metathoracic process attains the mesosternum and separates the cavities.

Frequently, however, the two processes meet midway and take equal part in the separation. In this group are the following species: *Micropeplus, Leptochirus* (fig. 25 B), *Trigonurus, Phloeocharis, Tachyporus, Tachinus, Erchomus, Bolitobius, Oligota, Xenodusa, Lorinota,* and *Baryodma.*

The mesosternum is usually very short and not separated from the pleural areas. Considerable reduction has taken place in some of the pleural sclerites, but in some species they are distinct and separate.

The metasternum may be very short and transverse as in *Hypocyptus* (fig. 25 D) or rather elongate as in *Metoponcus* (fig. 25 C). In general it is deflexed anteriorly to form most of the floor of the coxal cavities, but in *Metoponcus* this part is formed by the inflexed portion of the mesosternum, and the metasternum has a narrow emargination at the middle which receives a slender process of the mesosternum.

The metasternum is always completely separated from the metapleurites. It is variously emarginate posteriorly to fit the coxae of the metathoracic legs, and generally shows the articulations of the coxae at the middle.

THE LEGS

The greater part of the large amount of variation in the legs is due to the relative sizes of the parts rather than to any fundamental differences in structure. The presence or absence of calcaria or other setae and the variation in number of tarsal subsegments or tarsomeres constitute the principal structural differences.

The musculature of the leg of *Thinopinus* (fig. 26 A) is very similar to that of a typical insect leg as given by Snodgrass (1927). It is not known whether there is any large amount of variation in other members of the family.

The number of tarsomeres varies from three to five. In some cases the number differs on the same individual—the so-called heteromerous condition. The great majority of species in this family have five tarsomeres in each tarsus. This condition is found throughout the subfamilies Omaliinae, Oxytelinae (except Oxytelini), Steninae, Paederinae, Staphylininae, Oxyporinae, Habrocerinae, and Tachyporinae (except Hypocyptini).

The exceptions include *Micropeplus* and the Oxytelini with three tarsomeres in each tarsus, *Hypocyptus* and *Oligota* with four, *Liparocephalus* with four in the front and middle tarsi and five in the posterior tarsi, and *Lorinota* and *Xenodusa* with four in the front tarsi and five in the middle and posterior ones. *Aleochara* and other aleocharinids have all the tarsi with five tarsomeres. Thus it can be seen that the heteromerous condition is restricted to certain aleocharinids, and that five is the normal number. It might be noted that in certain aleocharinids individuals may be found on which the two tarsi of one pair differ. They show the actual fusion or division of the tarsomeres taking place at the present time.

The claws are simple in all the species studied. They vary somewhat in proportions and curvature, but are all similar to the ones shown (fig. 8 J, etc.).

Several species have been found to have a few very curiously modified setae (fig. 26 L) along the ventral edge of certain of the segments. In *Pelecomalium* they occur on the fore legs in a long line on the tibia and in a small group at the middle of the ventral edge of the femur, and on the middle legs similarly on the tibia and three or four on the trochanter. In *Lathrimaeum* they are situated on both the fore and middle legs in a double row on the tibiae and a few on the trochanters. In *Proteinus* they occur only on the middle legs, a very few near the tip of the tibia and on the trochanter. These setae are very distinct and easily recognizable. On the dorsal extremity of the anterior tibia of *Phlococharis* is situated a single seta of unusual shape. It is short and stout, resembling considerably those of figure 26 L. The fore tibiae of *Bledius* are much expanded and bear a large number of very heavy short setae (fig. 26 E).

The union of the femur to the trochanter is subject to considerable variation. In some the trochanter is attached to the side of the femur, and in some to the truncated end (figs. 8 F, 26 B, C, D, H, K). The
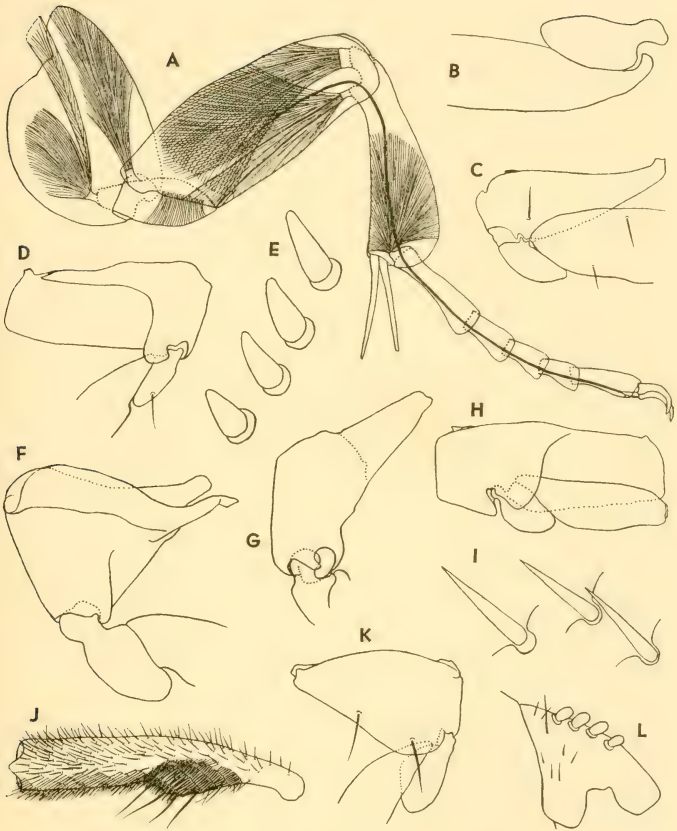
Fig. 26.—Details of the structure of the legs.

A, musculature of the middle leg of *Thinopinus pictus* Lec. B, trochantero-femoral joint of posterior leg of *Bolitobius cinctus* (Grav.). C, posterior coxa of *Oxytelus sculptus* Grav. D, posterior coxa of *Erchomus ventriculus* (Say). E, group of setae from anterior tibia of *Bledius monstratus* Csy. F, posterior coxa of *Paederus laetus* Er. G, posterior coxa of *Stenus sculptilis* Csy. H, posterior coxa of *Hypocyptus longicornis* (Payk.). I, group of setae from middle coxa of *Tachinus limbatus* Mels. J, anterior tibia of *Lathrotropis jacobina* (Lec.). K, posterior coxa of *Habrocerus schwarzi* Horn. L, group of setae on middle trochanter of *Proteinus limbatus* Mäkl.

situation is frequently very different on different legs of the same specimen, but the one from the same thoracic segment of different species can be compared.

The present subfamily classification of the Staphylinidae is based largely on the shape of the posterior coxae. These segments are classified as globose, conical, triangular, or transverse, and a distinction is often attempted between coxae that attain the pleural pieces of the metasternum and those that do not.

In all the species studied, and indeed almost necessarily so from a functional viewpoint, the posterior coxae have articulations in two places. Morphologically the more important of these is the pleural articulation which is situated at the lateral extremity of the coxa and at the posterior end of the metathoracic pleurites. This is the most fundamental point in the coxal area and the articulation is probably never lost. The coxa has also a second articulation with the sternum, usually near the midline. Frequently the lateral parts of the coxa are covered by the sternum and are more or less invisible from the exterior. It is, then, the exposed portion which has given rise to the above classification, but obviously this is not a fundamental separation.

The differences between coxae that are " small and globose " (fig. 26 G), those that are conical (fig. 26 F), those that are triangular (fig. 26 K), and those that are transverse (fig. 26 C, D, H) are matters of degree and form a continuous series. It should be possible to find a more consistent and fundamental character to express the apparent differences.

There seem to be three distinct types of coxal structure. In many species the coxa is conical or triangular without expansions beyond the lines connecting the three articulations. In others the side of the coxa is expanded laterally and caudally into a plate which lies underneath the femur and below (dorsad) the level of the sternum. In the third group there is an upper lamella of the coxa which is expanded laterally and posteriorly into a plate which is nearly at the level of the sternum and completely covers the lower portion of the coxa. These three are the only morphological types recognized.

The following species belong to the first group, having the coxa not expanded laterally and caudally: *Osorius, Stenus* (fig. 26 G), the Paederinae (fig. 26 F), the Staphylininae, and possibly *Liparocephalus*. These are the ones generally said to have the coxae conical or triangular.

The second group, those having the coxae expanded laterally and caudally into a plate that is partly covered by the femur in repose, frequently also have a slight expansion over the base of the tro-

chanter but not extended laterally. It includes *Micropeplus,* the Omaliinae, all the Oxytelinae except *Osorius, Hypocyptus* (fig. 26 H), *Tachyporus, Tachinus, Erchomus* (fig. 26 D), *Bolitobius,* and all the Aleocharinae except possibly *Liparocephalus.* These are chiefly the forms said to have the coxae transverse.

The third group contains only *Habrocerus* (fig. 26 K). The coxa is rather triangular, but the upper surface is broadly expanded into a lamella which covers part of the femur in repose and extends laterally clear to the pleural articulation.

Micropeplus appears to be distinct from all the others in the presence of a narrow separate strip extending from the trochanteral articulation to the pleural one. It may be a secondary separation from the coxa but is entirely unique.

THE ABDOMEN

The abdomen of Staphylinidae is composed of 10 segments in all the species studied. In all cases the first segment is represented only by the tergite and rarely a paratergite on each side behind the spiracle (fig. 9 A, *ptt. 1*).

The second segment may be entirely membranous, as is apparently the case with *Micropeplus.* It may be represented by a tergite alone, as in *Trigonurus, Phloeocharis, Osorius, Stenus, Gastrolobium, Hesperobium, Paederillus, Paederus, Lathrotropis, Hypocyptus, Liparocephalus, Xenodusa, Lorinota, Aleochara,* and *Baryodma.* A pair of small paratergites is present at the sides in *Geodromicus, Tanyrhinus, Lathrimaeum, Pseudopsis, Creophilus* (fig. 9 A) and all the Staphylinini, *Glenus, Acylophorus, Quedius, Oxyporus, Habrocerus, Tachyporus, Tachinus, Erchomus, Bolitobius,* and possibly *Oligota.* Besides these sclerites the following also have some sclerotization of the sternite: *Pelecomalium, Proteinus, Eumalus, Xantholinus,* and possibly *Metoponcus.* The greatest development of this segment, however, is in the tribe Oxytelini. The species of this tribe have all the sclerites completely developed so as to appear identical with the succeeding segments in structure.

The third, fourth, fifth, sixth, and seventh segments are very similar in structure. They each have a normal tergite and sternite and usually one or two paratergites on each side. Only *Leptochirus, Eumalus,* and *Osorius* are entirely without paratergites, and the following have only one on each side: *Micropeplus,* all the Omaliinae (fig. 27 D), *Proteinus, Trigonurus, Phloeocharis, Pseudopsis, Stenus,* and *Habrocerus.* All the other species examined have two paratergites

on each side of the segments from three to seven. Figure 9 A shows the normal form of these sclerites. Modifications are chiefly in size, distinctness of the sutures, and vestiture. *Xenodusa* has the paratergites modified to form the hairy lobes or trichomes (fig. 27 B) which project over the succeeding segment.
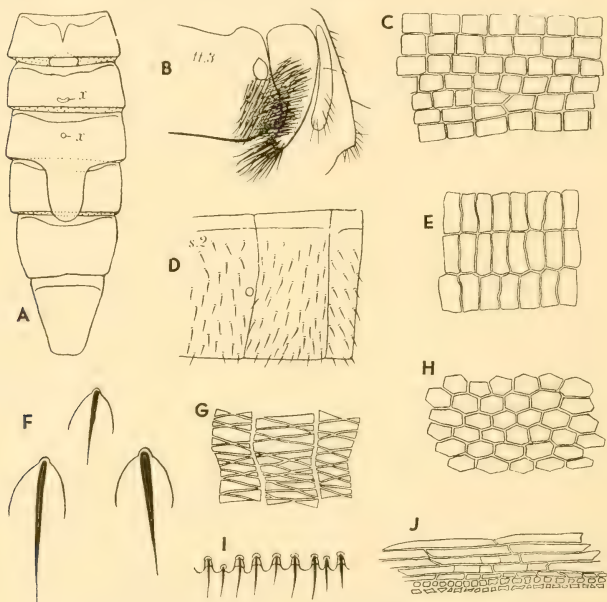
Fig. 27.—Details of the structure of the abdomen, and the intrafamily variation in the pattern of the intersegmental membranes.

A, ventral aspect of abdomen of *Gastrolobium bicolor* (Grav.). B, paratergites and trichome of *Xenodusa sharpi* Wasm. C, pattern of intersegmental membrane of *Lathrotropis jacobina* (Lec.). D, paratergite of *Geodromicus brunneus* (Say). E, pattern of *Paederus laetus* Er. F, group of setae from sternite of *Bolitobius cinctus* (Grav.); G, pattern of *Xantholinus picipennis* Lec. H, pattern of *Stenus sculptilis* Csy. I, posterior margin of sixth tergite of *Acylophorus flavicollis* Sachse. J, pattern of *Osorius mundus* Shp.

The membranes between these intermediate segments are usually marked in a definite pattern with minute spots of regular shape and deeper color. They appear to be actual sclerotizations in the membrane. These patterns are fairly constant in the various groups. The most frequent pattern is one of small rectangular areas arranged either in transverse or in longitudinal rows or both, often changing from

one to the other in a single membrane (fig. 27 C, E). This pattern is found on *Micropeplus*, all the Omaliinae, all the Paederinae, *Oxyporus*, and *Bolitobius*.

Two species have a definitely hexagonal pattern (fig. 27 H). They are *Leptochirus* and *Stenus*. In *Eumalus*, *Pseudopsis*, and *Osorius* (fig. 27 J) the areas are very small and angular in shape and grade into elongate transverse pieces near the edges of the membrane.

The subfamily Staphylininae is characterized by a pattern of ir-regular-sized areas arranged in longitudinal bands separated by clear membrane (fig. 9 F). *Xantholinus* and *Metoponcus* differ somewhat in having the areas strongly angular and frequently triangular or lozenge-shaped. *Acylophorus* is more or less intermediate between these and the typical form for the subfamily, and *Quedius* is marked only with longitudinal rows of very small spots.

Oxytelus and *Bledius* have a pattern very similar to that shown in figure 9 H except that the bands run transversely. In *Aplodcrus* and *Platystethus* there is no actual pattern, as the minute dots appear like an even stipple.

In some of the membranes appear perfectly clear even under a fairly high magnification. These include *Proteinus*, *Trigonurus*, *Habrocerus*, *Hypocyptus*, *Tachyporus*, *Tachinus*, *Erchomus*, and all the Aleochari-nae studied.

Various modifications of form and vestiture are found on the ab-domen, but these are not very constant and are frequently modifica-tions of only one sex. The large posterior lobes on the fifth seg-ment of certain males of *Gastrolobium* (fig. 27 A) and the circular or crescentic groups of setae and pores on the same species are ex-amples of sexual modifications. These groups of setae (fig. 27 A, *x*) are called foveae in the literature and consist of a circle or band of setae set in moderate sockets and completely surrounded by a large number of pores which give a very rough appearance to the surface.

The discal setae of *Bolitobius* (fig. 27 F) do not have a definite socket but are set into the apex of a **U**-shaped area marked only by a fine line on the surface. The posterior margins of the intermediate segments of *Acylophorus* (fig. 27 I) are crenulate with the depressions much deeper on the ectal surface than on the ental. A rather large seta is set at the anterior end of each depression.

The eighth segment is composed of only a tergite and a sternite. The tergite bears a spiracle similarly to the preceding segments and generally is narrower and rather strongly tapering. The eighth seg-ment is usually considered to be part of the genitalia. In the case of the female it is therefore treated in that connection, but in the males

it is more convenient to restrict the discussion of the "genitalia" to the consideration of the genital tube or aedeagus alone. For this reason the eighth and ninth segments of the males will be discussed briefly here.

The posterior border of the eighth segment is frequently modified in the male. This modification may take the form of lobation, emargination or incisure, abnormal vestiture or sculpture, etc. It is generally the last visible segment of the abdomen, though it may be so far retracted within the preceding segments as to be invisible.

The ninth segment is represented by a tergite, a sternite, and two small lateral plates bearing the valvulae or gonapophyses. The gonapophyses are present only in the subfamily Staphylininae excepting the Xantholinini. In the other species studied the lateral plates (morphologically the bases of the segmental appendages) are present, generally large, and frequently appear much like gonapophyses but without any sign of basal articulation. In some species these two plates are joined by a narrow or wide bridge on either the dorsal or the ventral aspect. The species in which these lateral plates are thus united include *Geodromicus, Pelecomalium, Tanyrhinus, Lathrimaeum, Stenus, Gastrolobium, Hesperobium, Lathrotropis, Stilicus, Trachysectus, Hypocyptus, Tachyporus* (fig. 28 D), and *Bolitobius*. The species examined in which these sclerites are not united include *Trigonurus, Phlococharis, Bledius, Oxytelus, Metoponcus, Xantholinus, Xenodusa, Lorinota, Aleochara,* and *Baryodma*. The greatest amount of union was found in *Bolitobius* in which the long sclerite formed is obviously dorsal. On the other hand in *Tachyporus* the union is said by Muir (1920) to be ventral, and the present observations confirm this.

A very much more remarkable modification than any other is found in the eighth and ninth segments of *Habrocerus* (fig. 28 E). The spiracles of the eighth segment are the most important landmarks and are situated on the dorsal aspect (sp. 8). According to the interpretation of Muir (1920), which differs somewhat from that of Weber (1911):

. . . . the eighth segment is highly modified and consists of four pieces. A large pair of pleural plates, on which the eighth spiracles are situated, embrace the lateral area, and from the apex of each a large, spine-like style arises; the dorsal aspect consists of a very short tergite, and the sternite consists of a large plate more heavily chitinized round the edges. . . . . The lateral portion of the eighth tergite articulates with the lateral edges of the sternite and also articulates in a depression at the base of the pleural plates. . . . The ninth segment is highly modified and shaped like an oat. The distal and visible portion consists of a pair of pointed and slightly curved lobes connected in a V-shaped piece on the dorsal aspect; the basal and internal portions consist of a mem-

branous plate chitinized along the edges. On the ventral aspect at the meeting of the lobes there is a small trident body attached to a rod which lies free within the segment. . . . . . The anus opens on a membrane between the lobes; the rectum can be protruded.

Since Muir's figures of *H. capillaricornis* agree essentially with the structure of *H. schwarzi*, a discussion of his interpretation in the light of the present material seems to be justified. The large pleural plates are in the present species membranous except for a framework of sclerotic rods or struts. The spiracles lie on the dorsal aspect of these and identify them as paratergites. The transverse piece behind these and articulating with them probably does represent the tergite, but it is completely fused with the ventral plate by means of the sclerotized bars. The trident body appears in this species to be distinct from the ninth segment, and the lateral parts seem to articulate with the middle one and with the end of the supporting rod. The membranes forming the aedeagus are practically invisible in this specimen.

THE GENITALIA

The male genital tube in this family is characterized by the high state of specialization, by the modification of the median lobe for the evagination of the internal sac by blood pressure, and by the absence of a basal piece. Some of the most extreme modifications occur in the lateral lobes, which are always present and usually separate.

The most frequent type of genitalia is that represented in figures 9 G and 28 J, K. It consists of a strong sclerotic tube with a bulbous base, and a median foramen small and situated ventrally at the junction of the tube and bulb and between the base of the lateral lobes. The lateral lobes may be united into a plate basally but form two narrow lobes which usually lie along the median lobe. This type has been found in the following species: *Geodromicus, Pelecomalium, Lathrimaeum, Eumalus, Trigonurus, Phlococharis* (fig. 28 J), *Creophilus* (fig. 9 G), *Staphylinus, Ocypus, Philonthus* (fig. 28 K), *Cafius, Hadrotes, Acylophorus,* and *Quedius.* It seems to characterize the subfamily Staphylininae except for the tribe Xantholinini.

The Xantholinini are said by Sharp and Muir (1912) to be " one of the most highly specialized forms of Coleoptera." The two species studied do not show the complicated structure of the tip of the aedeagus of Sharp and Muir's species but are rather simpler than many others. In *Xantholinus* (fig. 28 F), according to Sharp and Muir (1912):

. . . . the bulbous median lobe is of an extreme form, being egg-shape, with a small membranous distal portion to which the greatly reduced lateral lobes are attached. The median lobe is formed of dorsal and ventral sclerites, round, and
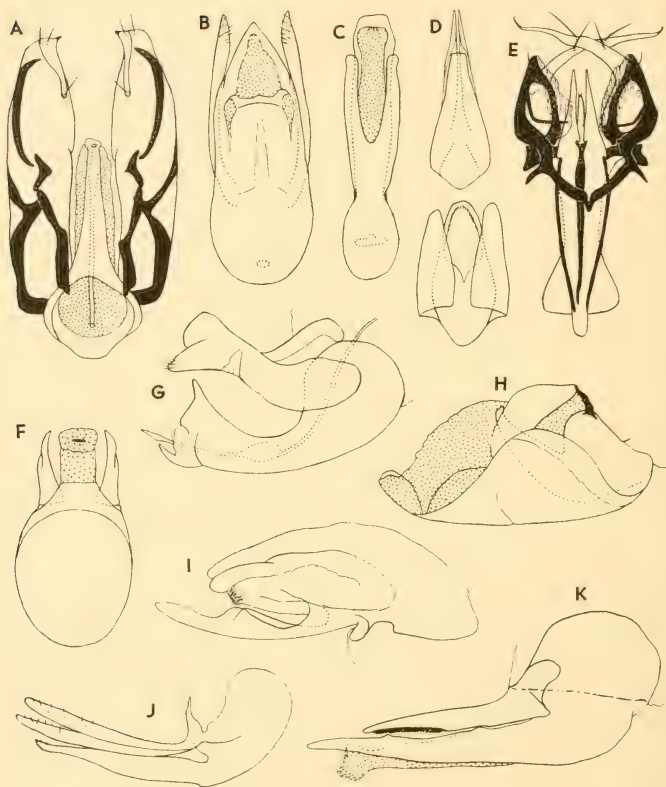
Fig. 28.—Intrafamily variation in the genitalia of the male.

A, *Hypocyptus longicornis* (Payk.). B, *Stenus sculptilis* Csy. C, *Micropeplus punctatus* Lec., ventral aspect. D, ninth segment and genital tube of *Tachyporus jocosus* Say, dorsal aspect. E, eighth and ninth segments and genital tube of *Habrocerus schwarzi* Horn, dorsal aspect. F, *Xantholinus picipennis* Lec., dorsal aspect. G, *Liparocephalus brevipennis* Mäkl., lateral aspect. H, *Xenodusa sharpi* Wasm., lateral aspect. I, *Lathrotropis jacobina* (Lec.), lateral aspect. J, *Phlococharis subtilissima* Mann., lateral aspect. K, *Philonthus aeneus* (Rossi), lateral aspect.

connected by a semi-membranous band; the median orifice is at the distal end, and the median foramen slightly in front (or basal) on the ventral face. These two openings are separated only by a chitinous plate formed by the basal part of the lateral lobes which are extremely reduced.

This description of *Xantholinus glabratus* (p. 499) is equally applicable to our species, *X. picipennis*. In *Metoponcus* the basal part of the median lobe is much more elongate and the lateral lobes are more slender than in *Xantholinus*.

In some forms there are more heavily sclerotized bars or struts in the median and lateral lobes. They are apparently strengthening or supporting structures and frequently articulate with each other. In *Hypocyptus* (fig. 28 A) the lateral lobes each bear three of these structures, articulating with each other and with a fourth pair connected to the median lobe. This latter pair is thought to be the pair of median struts mentioned by Sharp and Muir (1912). The lateral lobes are present on all forms examined. In *Xantholinus* (fig. 28 F) and *Metoponcus* they are very small and not specially modified. In *Cafius* they are also rather short but are otherwise similar to the other Staphylinini. *Hypocyptus* (fig. 28 A) represents the greatest development of these organs in point of size.

In *Micropeplus* (fig. 28 C) the lateral lobes arise from the sides of the median lobe and unite for a short distance on the dorsal surface. They are flat and unmodified and do not extend as far as the tip of the median lobe.

The genitalia of the female consist of the eighth, ninth, and tenth segments of the abdomen and their appendages. The eighth segment is present as a distinct tergite and sternite; the ninth segment is membranous except for a pair of three-segmented appendages and occasionally a sternal sclerite; and the tenth segment is represented only by the tergite. This is substantially the characterization given by Tanner (1927) for beetles in general.

The members of the Staphylinidae for the most part appear to be different from any forms studied by Tanner in the amount of reduction and loss of parts. Only a very few of the species included in the present study have any coxites or styli, the valvifers are absent in at least one species, and the paraprocts are frequently lacking. The one Staphylinid studied by Tanner, *Creophilus villosus,* is one of the very few which possess all the typical structures.

The eighth tergite and sternite are generally not specially modified in the female. They are broadly rounded as in *Oxyporus* (fig. 29 A) or truncated as in *Aleochara* (fig. 30 E). The only outstanding exceptions are in the subfamily Tachyporinae, where there are very
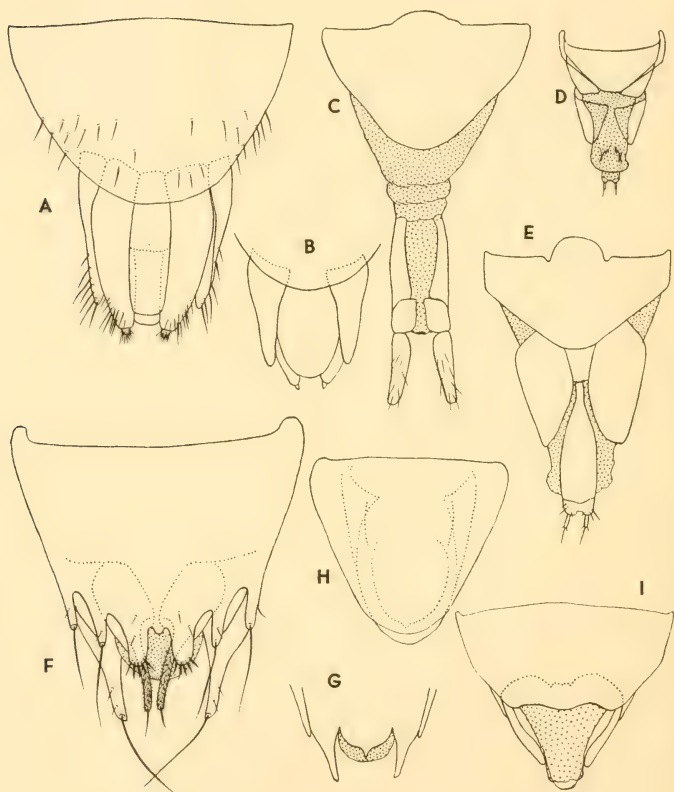
FIG. 29.—Intrafamily variation in the genitalia of the female
(continued on fig. 30).

A, *Oxyporus lateralis* Grav., ventral aspect. B, same, dorsal aspect. C, *Geo-dromicus brunneus* (Say), ventral aspect. D, *Lathrimaeum pictum* Fvl., dorsal aspect. E, same, ventral aspect. F, *Tachinus limbatus* Mels., ventral aspect. G, same, dorsal aspect. H, *Trigonurus crotchi* Lec., ventral aspect. I, *Oxytelus sculptus* Grav., ventral aspect.

great modifications of the posterior border of both these sclerites. In *Tachinus* the tergite (fig. 29 G) is divided into three lobes. The two outer ones are slender, and each bears a very long seta at its apex. The median process is semicircular but produced into a sharp point at the middle. In other species this median process may be much longer than the lateral ones, or it may itself be bifid or even trifid. The
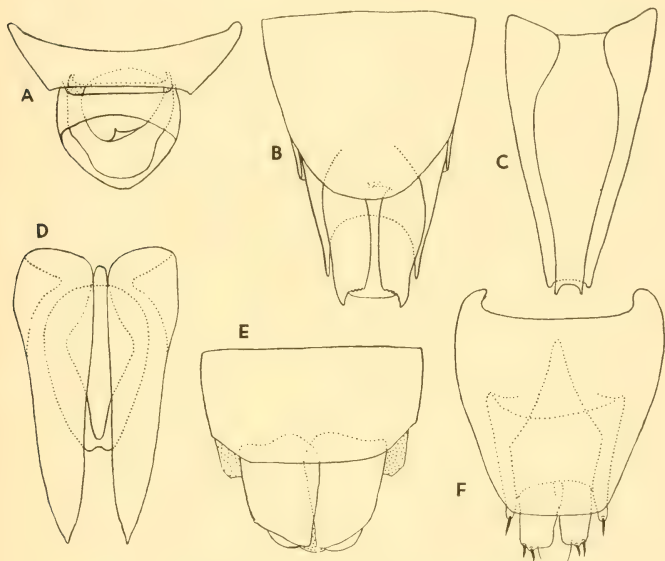
Fig. 30.—Intrafamily variation in the genitalia of the female
(continued from fig. 29).

A, *Micropeplus punctatus* Lec.; B, *Stenus sculptilis* Csy.; C, *Pinophilus parvipennis* Csy.; D, *Paederus laetus* Er.; E, *Aleochara lata* Grav.; F, *Pseudopsis obliterata* Lec. All ventral aspects.

sternite is even more highly modified in *Tachinus* (fig. 29 F). The border is divided into six lobes of about equal length, but considerably shorter than the lateral lobes of the tergite. The outer pair on each side are rather slender, and each bears a long seta at the apex. The two median lobes are wider, and each bears a brush of six very straight short setae.

The ninth tergite and sternite are said to be nearly always membranous (Tanner, 1927). The only exceptions recorded by him are

two species with a sclerotized tergite and one with a sternite. In the present family there are apparently several more exceptions in the sternites. *Paederus* (fig. 30 D) has a distinct sagittate sternite of the ninth segment which lies between and under the large valvifers. *Pinophilus* (fig. 30 C) appears to have a large sternite also.

In practically every species examined there is a pair of large sclerites on the ventral surface which are interpreted as the valvifers. In most cases, therefore, it is found that the coxites are entirely lacking. Complete coxites with styli are found in all the Staphylinini, Xanthopygini, Quediini, and Oxyporinae studied, and also in all the Omaliini. This latter tribe is very different from the others, however, in that the genitalia are much elongated and have large membranous areas between the sclerites. The first group includes *Creophilus* (fig. 9 B, C) and *Oxyporus* (fig. 29 A, B). The Omaliini examined in this regard were *Geodromicus* (fig. 29 C), *Tanyrhinus*, and *Lathrimaeum* (fig. 29 D, E). In *Oxyporus* there are apparently no styli on the coxites. In *Geodromicus* the coxites are two-segmented but lack styli. In *Lathrimaeum* the valvifers appear to be fused to form an elongate median ventral sclerite, bearing apically the two small coxites and their styli.

The sternite of the tenth segment is entirely membranous in all members of the family, but the tergite is represented by a large broad sclerite, the proctiger (figs. 9 C, 29 B). Apparently only a few species possess the appendages of the ninth segment called the paraprocts by Tanner. They are present in *Creophilus* (fig. 9 B, C) and other Staphylininae, in *Oxyporus* (fig. 29 A), in *Lathrimaeum* (fig. 29 D, E), and probably others.

In *Oxytelus* (fig. 29 I) the entire ventral aspect of the ninth and tenth segments is membranous. The dorsal side is composed of a wide proctiger and a pair of narrow lobes at the sides. *Micropeplus* (fig. 30 A) is still more reduced. At first sight the eighth tergite and sternite appear to be part of the genitalia, but the tergite bears a pair of tiny but distinct spiracles. The genitalia form a more or less circular structure without any definite sclerites.

DISCUSSION

VARIATION AND RANGE OF STRUCTURE

Though it has often been said that the beetles, and even the entire class of insects, are characterized by a remarkable degree of uniformity of structure, a beetle almost always being immediately recognizable as a beetle, yet it is equally true in both the order and the

entire class that there is an amazing variety of divergence in the less
fundamental characters. The family Staphylinidae, being one of
the largest natural families of animals, is remarkably homogeneous
in general habitus and form, but presents considerable range of varia-
tion in many of its structures.

In a group of this size it is to be expected that certain characters
which are constant in one series of species will be more variable in
others. This is found frequently to be the case. A certain subfamily
shows a regular development of a given character which thus charac-
terizes it, but the same character may occur scattered here and there
in other groups, being too variable for use in classification.

Before any character can be safely used in classification, it is neces-
sary to know the extent of variation of that character throughout the
group being classified. If it is reasonably constant and varies only
in definite ways and within definite limits, then it can be safely used.
If, on the other hand, it be found to be very variable within small
groups, or to vary through a large number of slightly separated forms,
it can be used only with extreme care or only in certain cases.

The range of variation in each structure or set of structures is
discussed in detail in the section on the comparative morphology of
the family. It may be seen therein that the amount of variation in
the numerous characters differs very greatly.

CHARACTERS AVAILABLE FOR CLASSIFICATION

The existing classification of the Staphylinidae, as has been pointed
out, is based almost entirely upon such characters as can be seen in
pinned specimens and with an absolute minimum of dissection, amount-
ing to no more than the removal of a leg to permit its examination
under a microscope. The study here made reveals a long series of
structures that may be added to the list of available characters.

Obviously, out of the many structures to be seen on the body of
an insect, not all will be of aid in attempting a classification of the
higher groups. Some are apparently usable only for the identification
of species; some appear only in small groups such as genera. Some
are evidently variable, and others, considered in the light of the totality
of structures, seem to have no phylogenetic significance. We are com-
pelled, then, to exercise a certain degree of judgment, based upon an
examination of as many species as possible, in selecting those char-
acters which will probably be significant as affording bases for de-
fining the various categories. Out of the survey here presented the
following list of characters has been selected as offering probably the

6

most significant indications of relationship. That is, they present tangible differences between the various groups, while at the same time they are of sufficient constancy throughout any one or more groups to present an appearance of reliability. It is evident, however, that only an examination of a very large proportion of the species of the family can permit a dependable evaluation. The following are the structural characters suggested:

1. Condition of the coronal suture.
2. Condition of the epicranial arm or frontal sutures.
3. Condition of the clypeal area.
4. Condition of the occipital suture.
5. Position of the antennal fossae.
6. Presence of ocelli.
7. Absence of dorsal tentorial pits.
8. Condition of the gular area.
9. Segmentation of the antennae.
10. Presence of processes on the labrum.
11. Dentition of the mandibles.
12. Condition of the prostheca.
13. Presence of serial pores on the mandibles.
14. Relative size and shape of the lacinia and galea of maxillae.
15. Segmentation of the maxillary palpi.
16. Size and shape of the terminal segments of the maxillary palpi.
17. Shape of the submentum.
18. Shape of the glossae and paraglossae.
19. Segmentation of the labial palpi.
20. Shape of the terminal segment of the labial palpi.
21. Condition of postcoxal lobe of pronotum.
22. Condition of the prosternal area.
23. Enclosure of the front coxal cavities by various means.
24. Condition of mesothoracic peritremes.
25. Presence of corneous plates in the anterior foramen of prothorax.
26. Separation of middle coxal cavities.
27. Condition of elytral suture.
28. Segmentation of the tarsi.
29. Specially modified setae of the legs.
30. Trochantero-femoral joint.
31. Structure and position of the posterior coxae.
32. Condition of second abdominal segment.
33. Paratergites of abdomen.
34. Mosaic patterns of intersegmental membranes of abdomen.
35. Presence of gonapophyses in male genitalia.
36. Condition of lateral plates in female genitalia.
37. Modifications of the aedeagus in the male.
38. Condition of valvifers, coxites, paraprocts, and proctiger in the female genitalia.
39. Modifications of the eighth segment in the female.
40. Condition of the ninth and tenth segments in the female.

The Value of Existing Classifications and Some Suggestions Concerning Them

As far as the present study is concerned, no major changes are indicated in the existing classification of the higher categories of the family. However, there will be numerous changes in position or in the relative degree of isolation of certain groups.

It has been very frequently noted that the conventional statement of a character used in a classification may have no precise morphological meaning except as indicating that some peculiarity exists. Some of these characters are discussed below.

The present subfamily classification, as well as that of all the smaller categories, is to a large extent based on " key " characters. That is, there has generally been in this family no distinction between classification and identification. This has led necessarily to a system based on obvious and readily observable characters, rather than on the ones particularly suited to show the fundamental relationships. Each of these characters has been discussed by itself in the comparative section.

The differences between existing classifications are chiefly those of the differences of opinion regarding the isolation of each group, and the components of it, and are to a large extent due to the use of an insufficient number of categories. Although the family undoubtedly contains several large and homogeneous groups, there are also a number of very isolated and extreme forms which have no very close relatives and are yet obviously members of the family. Some authors tend to unite these with their nearest neighbors, whereas others attempt to show the great divergence by separating them as distinct tribes or subfamilies. The purpose of classification is to show not only the relationships between animals but also the degree of the difference between them.

In European catalogues the genus *Micropeplus* has sometimes been united with the subfamily Omaliinae. More frequently, however, it is given subfamily rank. It seldom shows the typical structure of the family but has several modifications not found elsewhere. It appears to be more isolated from all the other Staphylinids than the extremes of that family are from each other. It is therefore thought probable that it will have to be removed as a separate family. This has already been done by some writers.

In the Leng Catalogue (1920) *Proteinus, Leptochirus, Eumalus, Trigonurus, Phlocacharis,* and *Pseudopsis* are united in the subfamily Piestinae, and thereby are separated from the Oxytelinae. In the catalogue of Eichelbaum (1909) these are all included in the Oxyteli-

nae. They have sufficient characters in common which differ from the
Oxytelini to justify a separation between the two groups. Leng's ar-
rangement is perhaps better for this reason.

Osorius is quite distinct in many respects from the Oxytelini. Its
relationship is perhaps best expressed by an assignment as a tribe in
the subfamily Oxytelinae equal to the rest of the subfamily or the
tribe Oxytelini.

The members of the Xantholinini studied are very distinct from
the rest of the Staphylininae. They differ from the tribe Staphylinini
more than do the members of the tribes Xanthopygini and Quediini,
and perhaps should be more isolated in the system. It may be that
they should rank as a separate subfamily, but this would obscure the
facts of their relationship to the other Staphylininae.

Habrocerus and *Hypocyptus* both differ considerably from the other
Tachyporinae. *Habrocerus* differs perhaps more widely and is prob-
ably correctly placed as a separate subfamily, although its nearest
relatives are the Tachyporini. *Hypocyptus* is more distinct from the
Tachyporini and Bolitobiini than they are from each other, but per-
haps insufficiently so to be isolated in a separate subfamily.

The linear arrangement of subfamilies is unsatisfactory as it pre-
cludes the possibility of showing relationships except in special cases.
No better system has been suggested, and it is merely necessary to
bear in mind the fact that the arrangement is more or less arbitrary.

The classifications in use have been gradually improved to the
point where they seem to reflect the general facts in a true picture.
Minor refinements will probably be necessary for a long time to come,
and the judgment of individual workers will probably indicate many
changes.

LIST OF SPECIES STUDIED

Subfamily MICROPEPLINAE
>   *Micropeplus punctatus* Lec.

Subfamily OMALIINAE
> Tribe OMALIINI
>>   *Geodromicus brunneus* (Say)
>>   *Pelecomalium testaceum* (Mann.)
>>   *Tanyrhinus singularis* Mann.
>>   *Lathrimaeum pictum* Fvl.

Subfamily OXYTELINAE
> Tribe PROTEININI
>>   *Proteinus limbatus* Mäkl.
> Tribe LEPTOCHIRINI
>>   *Leptochirus mexicanus* Er.

Tribe ELEUSININI
> *Eumalus nigrella* (Lec.)

Tribe PIESTINI
> *Trigonurus crotchi* Lec.

Tribe PHLOEOCHARINI
> *Phloeocharis subtilissima* Mann.

Tribe OXYTELINI
> *Bledius monstratus* Csy.
> *Platystethus americanus* Er.
> *Oxytelus sculptus* Grav.
> *Aploderus linearis* Lec.

Tribe OSORIINI
> *Osorius mundus* Shp.

Subfamily STENINAE
> *Stenus sculptilis* Csy.

Subfamily PAEDERINAE
Tribe PAEDERINI
> *Gastrolobium bicolor* (Grav.)
> *Hesperobium pallipes* (Grav.)
> *Paederillus littorarius* (Grav.)
> *Paederillus pugetensis* Csy.
> *Paederus laetus* Er.
> *Lathrotropis jacobina* (Lec.)
> *Lithocharis ochracea* (Grav.)
> *Stilicus angularis* Er.
> *Trachysectus confluentus* (Say)
> *Orus punctatus* Csy.
> *Astenus discopunctatus* (Say)

Tribe PINOPHILINI
> *Pinophilus parvipennis* Csy.

Subfamily STAPHYLININAE
Tribe XANTHOLININI
> *Metoponcus varians* Shp.
> *Xantholinus picipennis* Lec.

Tribe STAPHYLININI
> *Creophilus villosus* (Grav.)
> *Staphylinus cinnamopterus* Grav.
> *Ocypus ater* (Grav.)
> *Thinopinus pictus* Lec.
> *Philonthus politus* (Linn.)
> *Philonthus alumnus* Er.
> *Cafius canescens* Mäkl.
> *Cafius seminitens* Horn
> *Cafius lithocharinus* Lec.
> *Hadrotes crassus* (Mann.)

Tribe XANTHOPYGINI
> *Glenus flohri* Shp.

Tribe QUEDIINI
> *Acylophorus flavicollis* Sachse
> *Quedius limbifer* Horn

Subfamily OXYPORINAE
> *Oxyporus lateralis* Grav.

Subfamily HABROCERINAE
> *Habrocerus schwarzi* Horn

Subfamily TACHYPORINAE
> Tribe HYPOCYPTINI
> > *Hypocyptus longicornis* (Payk.)
>
> Tribe TACHYPORINI
> > *Tachyporus maculicollis* Lec.
> > *Tachinus limbatus* Mels.
> > *Erchomus ventriculus* (Say)
>
> Tribe BOLITOBIINI
> > *Bolitobius cinctus* (Grav.)

Subfamily ALEOCHARINAE
> Tribe OLIGOTINI
> > *Oligota esmeraldae* Csy.
>
> Tribe BOLITOCHARINI
> > *Liparocephalus brevipennis* Mäkl.
>
> Tribe MYRMEDONIINI
> > *Xenodusa sharpi* Wasm.
> > *Lorinota cingulata* (Lec.)
>
> Tribe ALEOCHARINI
> > *Aleochara lata* Grav.
> > *Baryodma bimaculata* (Grav.) ·

ABBREVIATIONS USED ON FIGURES

1A, first anal vein.
2A, second anal vein.
AnlA, anal arculus.
AntA, anterior arculus.
a, condyle.
ab, abdomen.
acs, antecostal suture.
aclp, anteclypeus.
af, antennal fossa.
afor, anterior foramen of prothorax.
an, anus.
anf, anal fan of wing.
annr, anterior notal ridge.
anp, anterior notal wing process.
ata, anterior arm of tentorium.
atp, anterior tentorial pit.
ax. 1, first axillary sclerite.
ax. 2, second axillary sclerite.
ax. 3, third axillary sclerite.
axc, axillary cord.
axp, axillary process.

bp, basal piece of male genitalia.
bs, basisternum.

C, costa vein.
c, condyle.
cal, calcar of tibia.
can, canaliculi.
cd, cardo.
cm. 1, first connecting membrane of male genitalia.
cp, body of the tentorium.
cr, crassa.
ct, coxo-trochanteral joint.
Cu, cubitus vein.
cx, coxa.
cxa, coxal condyle.
cxc, coxal cavity.
cxla, coxal articulation.
cxp, pleural coxal process.
cxt, coxite.

dta, dorsal arm of tentorium.
dtp, dorsal tentorial pit.

e, compound eye.
ej, ejaculatory duct.
ely, elytron.

em, emargination.

emp, empodium.

epi, epicranium.

epm, epimeron.

epm, II, mesothoracic epimeron.

epm, III, metathoracic epimeron.

epms, epimeral suture.

eps, episternum.

eps. II, mesothoracic episternum.

eps. III, metathoracic episternum.

epsr, episternal ridge.

fl, flagellum of male genitalia.

fm, femur.

for, foramen magnum (occipital foramen).

fr, frons.

fs, furcasternum.

fu, furca, sternal apophyses united on median base.

fua, lateral arms of furca.

ga, galea.

ge, gena.

gl, glossa.

gony, gonytheca.

gs, gular sutures.

gu, gula.

hgw, hinge of wing.

hphy, hypopharynx.

hypo, hypomera, inflexed margin of pronotum.

I-III, thoracic segments.

1-10, abdominal segments.

is, internal sac of male genitalia.

ists, intersternal suture.

lb, labium.

lc, lacinia.

ll, lateral lobes.

lm, labrum.

lp, labial palpus.

M₁, first branch of media vein.

M₄, fourth branch of media vein.

mad, dorsal articulation of mandible.

maf, mandibular fold.

mat, mandibular tooth.

mav, ventral articulation of mandible.

mb, intersegmental membrane or conjunctivum.

mbps, membranous area of prescutum.

md, mandible.

mdpp, prothoracic pleural muscle disk.

mdpt, metathoracic pleural muscle disk.

mdsp, prothoracic sternal muscle disk.

mdss, mesothoracic sternal muscle disk.

mdst, metathoracic sternal muscle disk.

mdts, mesothoracic tergal muscle disk.

mdtt, metathoracic tergal muscle disk.

mesp, mesosternal process.

mf, median foramen of male genitalia.

ml, median lobe of male genitalia.

mls, median lobe of scutum.

mo, median orifice of male genitalia.

mp, mandibular pore.

mrn, marginal ridge of pronotum.

mt, mentum.

mtla, episternal articulation of trochantin.

murc, retractor muscle of claws.

musd, muscle disk.

mx, maxilla.

mxa, maxillary articulation.

mxp, maxillary palpus.

nepm, notepimeron.

o, ocellus.

oc, occiput.

ocs, occipital suture.

ol, oculata.

p, pore.

papt, paraproct.

pclp, postclypeus.

peri, peritreme.

pge, postgena.

pgl, paraglossa.

pl, pleuron.

pla, pleural apophysis.

pld, pleuradema.

plf, palpifer.

plg, palpiger.

plns, pleuro-notal suture.

plr, pleural ridge or apophysis.

pls, pleural suture.

pn, postnotum.
pna, postnotal articulation.
pnp, posterior notal wing process.
ponr, posterior notal ridge.
pos, postoccipital suture.
pph, postphragma.
ppl, prephragmal lobe.
ppr, prephragmal ridge.
prf, prosthecal foramen.
prmt, prementum.
prnl, pronotal lobe.
pron, pronotum.
prp, prepectus.
prph, prephragma.
prss, prosternal suture.
prth, prostheca.
psc, prescutum.
pscl, prescutal lobe.
pscs, prescutal suture.
pss, prescutoscutellar suture.
psss, prescutoscutal suture.
pta, posterior arm of tentorium.
ptar, pretarsus.
ptgr, proctiger.
ptp, posterior tentorial pit (gular pit).
pts, paratergal suture.
ptt. 1, first abdominal paratergite.
ptt. 2, second abdominal paratergite.
ptt. 3, third abdominal paratergite.
ptt. 7, seventh abdominal paratergite.
pwp, pleural wing process.

R, radius vein.
R₁, first branch of radius vein.
R₂, second branch of radius vein.

s. I, prothoracic sternite.
s. II, mesothoracic basisternum.
s. III, metathoracic basisternum.
s. 2, second abdominal sternite.
s. 3, third abdominal sternite.
s. 8, eighth abdominal sternite.
s. 9, ninth abdominal sternite.
sa, sternal apophysis.
sart, sternal articulation.
Sc, subcosta vein.
scl, scutellum.
sclp. scutellar process.
sclt, scutellum.
sct, scutum.

scts, scutal suture.
sctt, scutum.
senp, sensory papillae.
sepl, sternepimeral line.
sepm, sternepimeron.
sepr, sternepimeral ridge.
seps, sternepimeral suture.
sg, subgalea.
smt, submentum.
sns, sternonotal suture.
sp, spiracle.
sp. II, mesothoracic spiracle.
sp. III, metathoracic spiracle.
sp. 1, first abdominal spiracle.
sp. 2, second abdominal spiracle.
sp. 3, third abdominal spiracle.
sp. 8, eighth abdominal spiracle.
spe, serial pores.
spn, spina.
sps, sternopleural suture.
ss, spinisternum.
ssr, spinisternal ridge.
sss, spinisternal suture.
stc, sternacosta.
stca, sternal coxal articulation.
stcs, sternacostal suture.
stg, stigma of wing.
st, stipes.
sts, sternal suture of abdomen.
sty, stylus.
swp, scutal wing process.

tar, tarsus.
tb, tibia.
th, thorax.
tn, trochantin.
tnr, transverse notal ridge.
tns, transverse notal suture.
tor, tormae.
tr, trochanter.
tra, distal trochantinal coxal articulation.
trla, coxal condyle of trochantin.
ts, tergal suture of abdomen.
tt. 1, first abdominal tergite.
tt. 2, second abdominal tergite.
tt. 3, third abdominal tergite.
tt. 8, eighth abdominal tergite.
tt. 9, ninth abdominal tergite.

un, claw or ungues.
utr, unguitractor plate.

vd, vas deferens.
vl, valvula.
vlf, valvifer.
vp, ventral piece of male genitalia.
vr, ridge between scutum and scutellum (V-ridge).
vul, vulva.
vx, vertex.

wc, antemedian area.
wd, pivot (distal pivot) area.

we, first costo-apical area.
wg, first anal area.
wh, principal area.
wj, jugal or axillary area.
wr, stigmatal area.
wx, first dorso-apical area.
wy, anal area.

x, point reference.
xt, tendon of retractor muscle of claws.

y, reference to vestiture.

z, reference to sculpture.

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A CADDO BURIAL SITE AT NATCHITOCHES, LOUISIANA

(With Six Plates)

BY
WINSLOW M. WALKER
Formerly Associate Anthropologist, Bureau of
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INTRODUCTION

One of the most important phases of current work in southern archeology consists of the location and excavation of sites that can be definitely proved to have been inhabited by known historic tribes. It is always possible that stratigraphic evidence of earlier occupations may be detected in definite relationship with such known sites. Until more is discovered concerning the nature of archeological remains that may be attributed to the Caddo, Natches, Tunica, Arkansas, Chickasaw, Choctaw, and the several Creek tribes, we shall be unable to draw conclusions as to the part their various ancestors played in the building of the mounds in the Lower Mississippi Valley known to be of pre-Columbian origin. New evidence recently brought to light may now perform this service for the Caddo of northwestern Louisiana.

her knowledge of the country and her contacts with local collectors were especially helpful.

THE FISH-HATCHERY SITE

During the summer of 1931, while the United States Bureau of Fisheries was engaged in preparing the land for a new fish hatchery at a place on Cane River Lake about a mile south of the town of Natchitoches, an ancient Indian burial ground was accidentally discovered. This body of water, formerly a bend of Red River, was cut
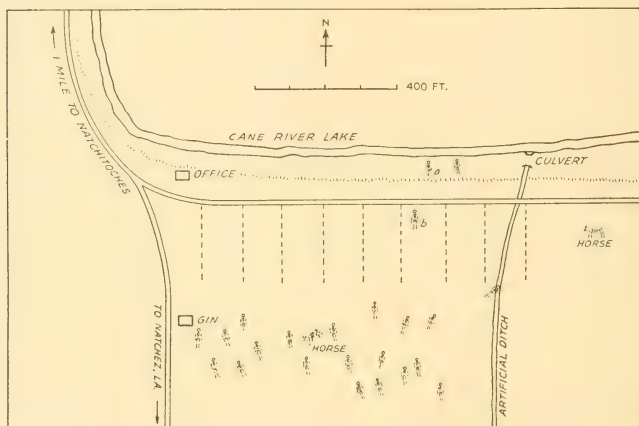
Fig. 1.—Sketch map of burial site on fish hatchery grounds.

off in 1832 and is now a crescent-shaped lake bending sharply toward the east. On the south side its banks rise rather steeply for about 25 feet and then form a flat level plain, which has been the scene of past overflows. The site chosen for the fish ponds of the new hatchery extends east from the highway for about half a mile along this bluff. (See sketch map, fig. 1.)[1]

[1] Dunn (History of Natchitoches, Louisiana Hist. Quart., vol. 3, no. 1, 1920) explains the maze of rivers and bayous in this vicinity by stating that the Natchitoches island known to the early French explorers, about 50 miles long by 3 or 4 miles wide, was formed by Cane River on the west and Rigolette de Bon Dieu on the east. A smaller island was formed between the Ataho or Little River and Rigolette de Bon Dieu. Originally flowing through a channel now referred to as Old River, Red River cut through into Cane River about 1765 and then in 1832 broke into Rigolette de Bon Dieu, which it follows today as far as the town of Colfax.

According to the accounts of the oldest inhabitants interviewed, no mounds ever existed at this particular site, but about the year 1916 human bones were found protruding from the bank at this point, and two skeletons were dug out by Prof. George Williamson, of the Louisiana State Normal School at Natchitoches (fig. 1, *a*). With the burials were some pottery vessels and artifacts, which were sent to the Louisiana State Museum in the Cabildo at New Orleans. One skeleton lying at full length on the back was remarkable for its extremely flattened head. The pottery was found lying near the head. Robert Glenk, curator of the Louisiana Museum, has kindly furnished the photograph of this burial shown in plate 1, figure 2.

When the laborers working at the fish-hatchery site dug a trench leading south from the road at the top of the bank, they discovered another burial at a depth of about 6½ feet in the light-red sandy silt deposited by many overflows. As these bones were unfortunately crushed and thrown out of the trench before any thought was given to their importance, it is impossible to state anything about the original appearance of the burial. West of this trench, 450 to 500 feet south of the river bank, a greater number of burials were found— fully 100, according to the account given by W. A. Casler, the superintendent in charge of the work. He says they were all shallow interments, none deeper than 3 feet below the original ground surface, and all lying extended on their backs. Near the heads of many were pottery vessels in the form of bowls and pots, both decorated and plain, and in some cases glass and shell beads and metal objects as well. Mr. Casler noticed that many of the skeletons had curiously flattened skulls. Most surprising of all was the finding of two horse skeletons, each with a large earthen bowl placed near the head. The bowls were of plain ware about a foot and a half in diameter and half an inch thick. Very few stone or flint artifacts were found with any of the burials.

Through the cooperation of the superintendent and his assistants, it was possible to visit the scene of the discovery before all the preliminary work of scraping and plowing was completed, and thus to uncover one burial virtually untouched. This skeleton (fig. 1, *b*) was found 100 feet south of the river bank, just beyond the road and 175 feet west of the central trench mentioned above. Covered by red sandy silt it lay 2 feet below the surface on white sand in which a few fragments of charcoal were present. The skeleton was that of a woman, lying on the back, head northeast, and arms and hands at the sides. The only objects associated with the burial were two vessels of plain

ware, heavily tempered with shell and poorly fired—a small pot inside of a conical bowl. These had been placed at the right side of the head. The head itself was a remarkable example of extreme fronto-occipital deformation. Measurements taken on the skeleton as it lay gave a length of 5 feet 7 inches, and it was then photographed in situ before any of the bones were removed (pl. 1, fig. 1).

Subsequently the skull and some of the long bones were sent for study to Dr. Aleš Hrdlička, of the U. S. National Museum. The report on them, kindly furnished by Dr. T. Dale Stewart, is as follows:

U. S. N. M. NO. 362447. FEMALE OF ADVANCED AGE. NATCHITOCHES, LA.

Skull.—Complete. Excessive fronto-occipital flattening. Generalized obliteration of the sutures. Whole face broadened to conform with the deformation (pls. 2 and 3). Upper left first premolar lost post mortem; upper second premolars and first and second molars lost ante mortem; remaining teeth show extreme wear; alveolar resorption is advanced.

Skeleton.—Only right humerus, left tibia, first 5 cervical vertebrae, and hyoid. Apparently the suture was medium.

Nothing can be said of the physical type of no. 362447 because of the extreme degree of flattening. Such a type of deformity was probably produced by pressure boards and was not uncommon among the Indians of the Gulf States.

In the Luxembourg Memoire, written evidently before 1718, a description of this process of artificial head flattening is given:

They have * * * the head pointed and almost of the shape of a miter. They are not born so; it is a charm which is given them in early years. What a mother does to the head of her infant in order to force its tender bones to assume this shape is almost beyond belief. She lays the infant on a cradle which is nothing more than the end of a board on which is spread a piece of the skin of an animal; one extremity of this board has a hole where the head is placed and it is lower than the rest. The infant being laid down entirely naked she pushes back its head into this hole and applies to it on the forehead and under the head a mass of clay which she binds with all her strength between two little boards. The infant cries, turns completely black, and the strain which it is made to suffer is such that a white, slimy fluid is seen to come out of its nose and ears at the time when the mother presses on its forehead. It sleeps thus every night until its skull has taken on the shape which custom wishes it to receive.[2]

This particular description was probably based on observations among the Natchez, but it undoubtedly applies to all the southern tribes who practiced head deformation.

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[2] Swanton, J. R., Indian tribes of the Lower Mississippi Valley and adjacent coast of the Gulf of Mexico. Bur. Amer. Ethnol. Bull. 43, p. 54, 1911.

HISTORICAL BACKGROUND

In all probability this burial ground occupies the site or very nearly the site of the ancient Natchitoches village visited first by Henri de Tonti in 1690. This was the southern village of a tribe of the same name mentioned possibly under the form *Nacacahoz* in the Elvas narrative of De Soto's expedition,[3] and found farther up Red River west of the great bend. On February 17, 1690, Tonti arrived after a 5 days' trip, principally overland from the Taensa villages on Lake St. Joseph. He says: " They made us stay at the place, which is in the midst of the three villages called Nachitoches, Ouasita, and Capiche. The chiefs of the three nations assembled, and before they began to speak, the 30 Taencas who were with me got up, and leaving their arms went to the temple, to show how sincerely they wished to make a solid peace * * * I made them some presents in the name of the Taencas." [4]

Further on he speaks of the " Cadadoquis * * * united with two other villages called Natchitoches and Nasoui, situated on the Red River. All the nations of this tribe speak the same language." The Natchitoches village here referred to is this time the upper one, but it serves to show the close relationship existing between this and the other tribes allied with the Caddo.

The next mention of Natchitoches is by Bienville, who, with St. Denis, in April 1700 ascended Red River Valley as far as the Yatasi village. He did not actually visit Natchitoches but stopped at the village of the Souchitionys about a league distant. The Natchitoches, who were settled in cabins along Red River, came with their chief to the French camp to " sing the calumet ", and Bienville gave him a peace pipe and a small present.[5]

A few years later, according to Pénicaut, this tribe came to St. Denis, then commandant of the first French fort on the Mississippi, and asked to be allowed to settle elsewhere, as their corn had been ruined by frequent overflows of Red River. They were permitted to locate near the Acolapissa, at that time living on the north side of Lake Pontchartrain, and remained with them until about 1712. St. Denis had received an order from Lamothe de Cadillac to make a trip over into Mexico to open up trade relations with the Spaniards, and the Natchitoches conceived the desire of returning to their old

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[3] French, B. F., Historical collections of Louisiana, vol. 2, p. 199, 1850.

[4] French, B. F., Ibid., vol. 1, pt. 1, p. 72, 1846.

[5] Margry, P., Découvertes et établissements des Français dans l'Amérique septentrionale, pt. 4, p. 437, Paris, 1880.

lands on Red River. But they reckoned without the assent of their hosts, the Acolapissa. These Indians were loath to see them go, especially as the Natchitoches wished to take with them their women-folk, many of whom had intermarried with the Acolapissa, and a massacre took place in which a great many of the Natchitoches were killed or captured. The survivors, however, escaped into the woods, and later joined St. Denis' party.[6]

Red River at that time formed many large swampy lakes, no longer in existence; and St. Denis and his party, after traversing some of these lakes, came to high land, which he calls " the Bluff of the Cross." This must have been in the neighborhood of the present town of Colfax, since a league higher up the river they came to a branch coming in from the left, which corresponds to the location of the lower end of Cane River. At this point they were met by a party of the Natchitoches, who had traveled overland and with whom was a friendly tribe called by Pénicaut the Doustiany. This tribe had formerly lived near the Natchitoches, but instead of moving with them to the Acolapissa, had remained in the same region, wandering up and down first one side of the river, then the other, living on the products of the chase, fruit, and potatoes.[7]

St. Denis describes the old village of the Natchitoches as being on an island, formed by the separation of the river into two branches, which reunited farther downstream. He assembled the chiefs of the two tribes and distributed grain to them in order that they might replant their devastated fields. He also gave them axes and mattocks, which they used to cut the timber to build two houses for the French in the midst of the Indian village. This was the beginning of Natchitoches Post in 1714, to which in 1717 a fort and garrison were added, under command of M. de Tissenet, and thus the foundations were laid for the oldest permanent settlement in Louisiana, the present town of Natchitoches.[8]

[6] Margry, P., Ibid., pt. 5, pp. 459, 496, 1883.

[7] Margry, P., Ibid., p. 498, 1883.

[8] Swanton considers Pénicaut's narratives as given by Margry and French to be inaccurate in regard to the chronological order of events, being 2 years too early in the description of St. Denis' trip which resulted in the founding of Natchitoches. The dates here given are those of the historian La Harpe (Établissement des Français à Louisiane, pp. 116, 129, 131, edited by A. L. Boimare; New Orleans and Paris, 1831). According to this account St. Denis left Mobile with a party of 30 Canadians on August 23, 1714, for the trip to the Spanish settlements. After stopping long enough to rehabilitate the Indians in their old location on the island of the Natchitoches, as has been recounted, he pushed on into Texas, visited the Hasinai tribes, was carried to Mexico City to appear

The post was visited by Benard de La Harpe on his trip up Red River in 1719; he found there the Yatasi also living with the Natchitoches and Oulchionis (Doustiony). The Yatasi had been induced by St. Denis on his return from Mexico to settle with the Natchitoches about 1716, and yet the three tribes together only numbered about 150 persons. They were all, however, very friendly to St. Denis, a circumstance much in his favor in the course of subsequent events.

The next event of major importance in the history of this site occurred in 1731, when a band of Natchez under the Flour Chief, driven from their stronghold on the headwaters of Black River by Perier, came to attack St. Denis in his fort. That officer was still able to get word out for reinforcements, but before they could arrive from New Orleans, he sallied out with his Indian allies and a few Spaniards from the neighboring presidio of Los Adaes and fought a battle with the Natchez, which resulted in the defeat and almost total annihilation of the latter at a lake a few miles to the south. Charlevoix gives the account of this fight, as told by Sieur Fontaine to De Loubois, the leader of the party sent to succor St. Denis, in the following words:

* * * that the Natchez had been defeated; that the Natchitoches had at the outset wished to attack them, but being only 40 against 200, they had been compelled to retire, and even abandon their village after losing 4 of their men; that the Natchez had seized the village, and intrenched themselves there; that then De St. Denys, having received a reenforcement of Assinais and Attacapas, who were joined by some Spaniards, had attacked the enemy's intrenchments and killed 82, including all their chiefs; that all the survivors had taken flight, and that the Natchitoches were in close pursuit.[9]

Their pursuers caught up with the Natchez at the lake about 3 miles west of Cloutierville, and the sanguinary conflict that took place there is said by Dr. Dunn to have been the origin of the name Sang-pour-Sang (Blood-for-Blood), by which it is locally known. A hill in this vicinity is called by the same name, corrupted in writing to " Sampusanc Hill ", and this may be the source of Sibley's information that

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before the viceroy in June 1715, returned to the Spanish settlements north of the Rio Grande, where he acquired a wife in 1716, pushed on to the Hasinai village in June of that year, and on August 25, 1716, found himself back at Mobile. The following January the Governor, Cadillac, sent a sergeant and six men to take possession of the island of Natchitoches and establish a fort there in order to keep out the Spaniards, who had already set up a presidio at Los Adaes, some 9 leagues to the west, near the modern town of Robeline, La., and were suspected of having cast greedy eyes on the Red River site. The prompt move of the French forestalled the Spaniards in this attempt.

[9] Swanton, Op. cit., p. 250.

the Natchez erected a mound by the side of the lake.[10] The hill is, however, entirely a natural formation, an eastern outcrop of the region of western Louisiana known as the "Kisatchie Wold." But the memory of this event still survives in the name of Natchez Lake and the town of Natchez, just south of Natchitoches.

During the period of Spanish occupation from 1763 to 1803, the village of the Natchitoches continued to increase in importance as a frontier trading post for the Caddo and Hasinai tribes to the northwest. Dr. John Sibley, making the first trip of exploration for the United States up Red River in 1805, reports finding the remnant of the Natchitoches still at its ancient village near the modern town named for them.[11] Soon after this, however, increased pressure by American settlers induced the Indians to move over into Texas, where they joined their kindred of the Caddo confederacy and thus ceased to exist as a distinct tribe.

POTTERY

The pottery from the Cane River Lake burials shows a range of forms including simple conical bowls, cuplike bowls with flaring collars, small jugs, and subglobular bottles with short necks. The bowl of a clay pipe was found with an opening in one side for a stem probably of hollow cane. Unfortunately, very few of these specimens were saved intact, so that it is impossible to state the number that may originally have been present, or the ratio of bowls, pots, and bottles.

The ware is very homogeneous, consisting of a grayish paste, which has a reddish tint on firing and is heavily shell-tempered. No sand or grit has been found in the tempering of any of the pottery. Crude, poorly surfaced, undecorated vessels as well as those showing a high degree of polishing and incised or engraved design are present, the two types often occurring in the same burial. A pebble seems to have been used for the purpose of smoothing the surface, as slight ridges and scratches can be detected, indicating the use of some such agent. This smoothing or burnishing has been carried to various degrees of perfection on different vessels; an example of the high, shining polish achieved on both the interior and exterior of a bowl is shown in plate 5, a.

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[10] Sibley, John, Report of exploration of Red River, included with account of Lewis and Clarke's expedition. Indian Affairs, American State Papers, vol. 1, p. 724, 1832.

[11] Sibley, Op. cit.

One method of producing the shiny-black appearance was to dip the vessel in bear oil after firing. Bushnell observed this process among the Choctaw and describes it thus:

> When thoroughly burned it [the pottery] turns rather dark in color, whereupon it is removed from the fire and immediately immersed in a bowl of grease, which is absorbed by the clay and carbonized by the intense heat. This process causes the pottery to turn black and also adds a certain luster to the surface.[12]

The Chickasaw had a slightly different method of achieving the same result. They placed the pottery over a large fire of smoky pitch pine, which imparted a smooth, black, firm surface to the vessels. They were then rubbed to produce the desired luster. The smoke from burning corn-meal bran was employed by the Cherokee for a similar purpose.[13]

a   b
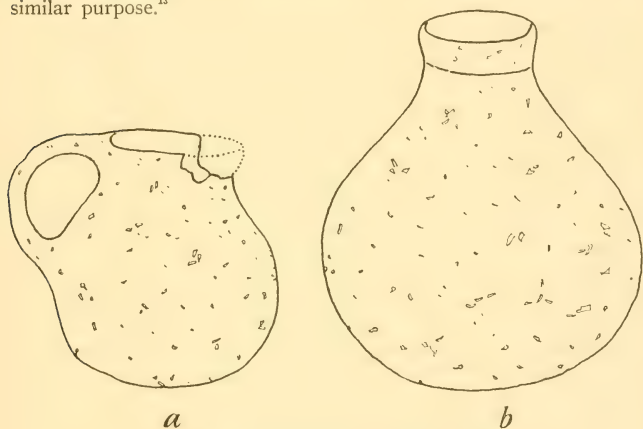
FIG. 2.—Undecorated shell-tempered vessels.

In the undecorated ware the shell particles are large and give a noticeably speckled appearance to the vessels (pl. 4, b, d). Furthermore, the light and dark areas, which give such a pleasing effect, are probably not intentional, but are due to unevenness of firing. This ware is often poorly fired, with the result that when first exposed to the air, it becomes very crumbly. Edward Payne, of Natchitoches, has in his collection two such vessels, a bottle and a small jug or pitcher, the identification of the latter being uncertain because a portion of the rim is missing at the point where a spout would occur if it had formed a part of the vessel (fig. 2). It is 6 inches in height, the

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[12] Bushnell, D. I., Jr., The Choctaw of Bayou Lacomb, St. Tammany Parish, Louisiana. Bur. Amer. Ethnol. Bull. 48, pp. 12-13, 1909.

[13] Williams, S. C., Adair's history of the American Indians, p. 456, 1930.

bottle 10 inches. Neither vessel bears any kind of decoration, except for the shell speckling in the tempering. They were found on a plantation 5 miles east of Natchitoches, when the plow turned them up from a few inches below the surface. Mr. Williamson also has in his collection a few similar pots from the same vicinity.

Decoration on the Natchitoches pottery consists of incised and engraved designs. The simplest technique seems to have been that of merely scratching or incising parallel straight and curved lines in various combinations of the scroll. In some instances this was done after the vessel had dried but had not been fired; in others, after firing had taken place, and in the finest pottery of all, after even the polishing had been completed. These scratches were then gone over with more care, and elaborate designs, through the use of double

a   b
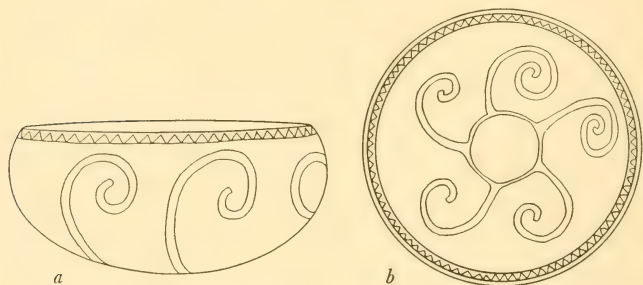
Fig. 3.—Small bowl polished and engraved with scroll-like designs.

and reversed scrolls, spots, and reticulated spaces between them, were produced. The final touch was given by rubbing bright red pigment over the engraved designs, particularly those occurring on a band about the neck, as in the small bowl illustrated in plate 4, a.

Four elements are commonly worked into the pattern of the design, as for example four spiral arms radiating from a disk on the bottom of many of the bowls. On the highly polished bowl shown, these spiral elements extend over the body up to the neck, where a different motif of a zigzag line and large spots is found. But in the less finely finished bottle, shown on the same plate, the area of decoration extends from the neck downward only to slightly below the shoulder. A bowl having five radiating spiral arms in its design is shown in figure 3. Here the rim ornamentation is limited to a narrow band of saw-toothed elements. This bowl is owned by Mr. Casler and came from a shallow grave where there was a flat-headed skeleton.

Merely as a record of negative characteristics, the fact may be mentioned that no pottery was found with any of the following types of ornamentation: Cord markings; punctate, stamped, or rouletted patterns; or painted designs other than the color-filled lines noted.

The only other ceramic object reported from this site was the pipe bowl shown in plate 4, *c*. It measures $1\frac{3}{4}$ inches in height and is made of the same kind of shell-tempered clay except that the particles of shell are more minute than in the pots. In the illustration some scratchings appear on the side of the bowl that might be mistaken for a design, but they appear on closer inspection to be only accidental.

As has been mentioned the ware from Natchitoches is very homogeneous, and no suggestion of stratification has been found at the Cane River site that would indicate an earlier occupation by people of a different culture, but the presence of European objects in the same graves leads to the conclusion that the pottery is seemingly of late origin and probably represents the climax in ceramic art reached by the potters of that particular tribe.

ASSOCIATED OBJECTS

A few stone axes and flint points were found by the workmen, but nothing definite could be learned about them. Undoubtedly, however, they differed but little from those in the collections of Mr. Williamson and Mr. Payne, as the specimens there exhibited came mostly from the immediate vicinity of Natchitoches. The axes are grooved near the butt and show various gradations of ground and polished surfaces. The celts are of both the long, pestlelike type and the flat, broad type. Notched and stemmed forms predominate among the chipped flint arrow and spearpoints. They are made of several kinds of colored flint, including novaculite from southwestern Arkansas, although much of the flint could have come from the small boulders and pebbles carried down by the river. In shape these artifacts range from tiny, serrated, sharp points to large, broad, leaf-shaped blades or spearpoints with short stems. Some rather unusual types also occur, such as notched and stemmed points with a second pair of notches on the blade, and a few small delicate forms with only a single barb, or with distinctly recurved barbs. Some of these have a slight resemblance to certain fish scales, particularly to those of the gar-pike. A number of writers have spoken of the Louisiana Indians using fish scales for arrowpoints,[14] and it is just possible that they may have

[14] Swanton, Op. cit., p. 58.

tried to imitate these scales in flint. What the specific use may have been of such points remains a matter of conjecture. Some of these unusual forms are illustrated in plate 6.

Beads were plentiful in the graves. Some of them were made of shell, evidently from the columella of a marine gastropod, cut in a round or cylindrical shape. Others were of glass or porcelain consisting of a kind of white paste, apparently in imitation of the shell beads. Blue glass beads were also found, these last being, of course, European in origin and probably given or traded to the Indians by the French. ·

Metal objects found included a pair of scissors, a few hawkbells of brass, some bracelets of the same material, and a double-pointed iron spike 6½ inches long. The presence of these articles suggests a reason for not finding more cutting and piercing instruments of flint and bone—their place had probably already been taken by the more efficient metal products of the white man.

DISTRIBUTION OF POTTERY TYPES

The most interesting thing about the Natchitoches pottery is its striking resemblance to the beautiful vessels found by Moore at Glendora Plantation and Keno Place on Ouachita River. Comparison of the elaborately decorated bowl shown in plate 5 with some of those illustrated by Moore from the Glendora site brings out this unmistakable similarity. The design on the body of this bowl is almost duplicated in several of the Glendora specimens, but the motif employed on the neck of the vessel shows slight variations. A bowl in the possession of Mr. Casler is very nearly identical with the one shown by Moore.[15] Likewise, the bottles from Natchitoches are similar in shape to those from the Ouachita region, and the same type of incised scroll design occurs.

Professor Beyer, of Tulane University, found in a mound on Red River near the town of Campti an earthenware bottle of this same Glendora type. He states that the mound formed part of an old levee, which had been partly eaten away by the river until fully two-thirds of the original mound had been engulfed. It was estimated to have had a diameter of 50 feet and was 6 feet high at the time Beyer investigated it. Before his visit the site had been dug into by a party of young men who had seen some bones and potsherds protruding from the side of the bank. Beyer's description of the structure of the mound

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[15] Moore, C. B., Antiquities of the Ouachita Valley. Journ. Acad. Nat. Sci. Philadelphia, vol. 14, no. 1, fig. 47, 1909.

states that the bottom consists of a layer of hard dark brown clay 4 feet thick. Resting on this stratum and embedded in red sandy clay were several skeletons, near the heads of which were some pottery vessels. Most of these burials had been disturbed by the previous diggers, and in consequence much of the associated pottery had been destroyed. Only one additional burial was found by Beyer, from which came, presumably, the bottle figured by him in his report.[16] The layer of red clay enclosing the bodies was 18 inches thick, and above it was an ash bed, in which some of the wood had been reduced only to charcoal. Over this was another 10 inches of red clay overlain by still another ash bed. There was very little charcoal in this upper bed. The topmost layer was again red sandy clay, which covered the entire mound, clearly outlined by a black line formed by the decaying vegetation which had been growing on the surface when it had been enclosed in the levee.

The finding of a vessel of this type in a mound is interesting because neither the specimens from Natchitoches nor those from the Ouachita were found in mounds, yet Campti is only a few miles up Red River from the first-mentioned site. It would appear, from the description given of the mound at Campti, that none of the burials in it were intrusive, but positive evidence on this point is lacking because of the previous disturbance of its contents and because of the fact that fully two-thirds of it had caved into the river.

Another instance of the same kind of pottery from Red River Valley is furnished by Jones, who figures two bottles of the Glendora type from a reported burial ground near Shreveport. One of them is a bottle with the characteristic short, bulging neck and squat, subglobular body decorated with scroll designs; the other looks from the illustration as if the bulge on the neck had been present but had been broken off, probably at the time of its discovery.[17]

Moore has found it again farther up Red River at the Battle Place in Arkansas. Here many of the bowls and bottles found bear the typical engraved scroll and spot design, and the bottles likewise have the characteristic Glendora shape, which Moore says represents a conventionalized cup placed on the neck of a bottle.[18]

The northernmost distribution of this type of pottery seems to be along the Arkansas River in the vicinity of Pine Bluff, Ark. Moore

[16] Beyer, G. E., The mounds of Louisiana, II. Louisiana Hist. Soc. Publ., vol. 2, no. 1, pl. 10, 1897.

[17] Jones, C. C., Antiquities of the southern Indians, pl. 28, figs. 3, 4, 1873.

[18] Moore, C. B., Some aboriginal sites on Red River. Journ. Acad. Nat. Sci. Philadelphia, vol. 14, no. 4, p. 569, 1912.

found, at sites near Greer and Douglas, Ark., vessels that show the same unmistakable design elements and technique as the Ouachita specimens. The Douglas vessels came from a mound, but Moore makes it quite plain that the mound was originally built for domiciliary purposes and later used as a cemetery—hence the presence of supposedly Caddo burials, which were probably intrusive at a later date. Most of the pottery from these two sites was of the brightly painted kind found more commonly in the lower Arkansas Valley and the eastern part of the state. This type may have been the work of the historic Arkansas (Quapaw) tribes, as is suggested by the finding of European objects in burials where the painted ware is also present.[19]

The pottery found by Harrington in the southwestern corner of Arkansas and believed by him to be Caddo in origin shows only slight resemblance to that found at the Natchitoches site. The technique of decoration in the use of engraved figures on the " Red River ware " is the same, but there are differences of detail in the shape of the vessels and in certain elements of design, the scroll, for instance, being less frequently employed. But there is a much greater range of variation in the Arkansas vessels in both shape and ornamentation and a greater elaboration of design, which is just what might be expected if we are here dealing with the Grand Caddo tribe, the leader of the confederation of which the Natchitoches and Ouachita were more outlying members.[20]

When the sites farther to the west on Red River have been examined, as is being done by Prof. J. E. Pearce, of the University of Texas, and also those somewhat more to the south of the river, we may expect to find further similarities to the general Caddo ceramic pattern, inasmuch as the Hasinai were known to have been closely affiliated with the Caddo in historic times. Likewise, when more material is available from known sites of the other Caddo tribes, such as the Adai, Yatasi, and Petit Caddo, we may be able to discover other subtypes of this ware here identified as Caddoan.

CONCLUSIONS

The most significant result of the Natchitoches discovery seems to be that we have here a site known from documentary sources to have been occupied by the Natchitoches tribe as early as the end of the

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[19] Moore, C. B., Certain mounds of Arkansas and Mississippi. Journ. Acad. Nat. Sci. Philadelphia, vol. 13, no. 4, p. 543, 1908.

[20] Harrington, M. R., Certain Caddo sites in Arkansas. Indian Notes and Monogr., Mus. Amer. Indian, Heye Foundation, illus., 1920.

seventeenth century, where pottery of a high degree of excellence in manufacture is found associated with objects of unmistakable European origin. This would indicate for the burials a period probably in the early half of the eighteenth century, at the epoch when French influence was at its height in Louisiana. By the time of the Spanish occupation after 1763, it is unlikely that the Indians who had been long in contact with European traders would still have pursued their ancient potter's art with the same skill and craftsmanship that produced the beautiful specimens of pottery found at the Cane River site. Furthermore, none of the vessels from this or the sites at Glendora and Keno Place was found in mounds, and in cases where this type of pottery has been reported from mounds, it has been proved almost without exception that such burials were intrusive in nature. Apparently, therefore, the tribes that had reached this height of ceramic perfection were no longer builders of mounds, if indeed they had ever been such. The close similarity in type between the Red River and Ouachita specimens is explained historically by Tonti's account of finding the " Ouasita " and " Nachitoches " together at the latter's village, and also by LaFon's map of the Territory of Orleans in 1806, on which the old trading path from Natchitoches to the villages on the Ouachita is plainly shown.

These significant chronological data offer a clue that should assist considerably in the interpretation of many of the archeological remains in northwestern Louisiana, southern Arkansas, and northeastern Texas.

1. Burial discovered in 1931.

2. Burial discovered in 1916.

TWO BURIALS AT THE CANE RIVER SITE

ARTIFICIALLY DEFORMED SKULL OF SKELETON SHOWN IN PLATE 1.
FIGURE 1. FRONT AND SIDE VIEWS

TOP AND BOTTOM VIEWS OF DEFORMED SKULL SHOWN IN PLATE 2

UNDECORATED AND CRUDELY INCISED WARE, HEAVILY SHELL-TEMPERED

a, Bowl with red-filled lines on collar; *b*, small undecorated pot found inside bowl; *c*, pottery pipe bowl; *d*, undecorated bowl.

POLISHED AND ENGRAVED VESSELS OF OUACHITA TYPE

Unusual Types of Small Flint Points from the Williamson Collection

Note two gar-pike scales against cards in lower corners.

AERIAL FERTILIZATION OF WHEAT PLANTS WITH CARBON-DIOXIDE GAS

(With Six Plates)

BY
EARL S. JOHNSTON
Division of Radiation and Organisms,
Smithsonian Institution

(Publication 3346)

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INTRODUCTION

Experiments on the carbon-dioxide assimilation of young wheat plants reported by Hoover, Johnston, and Brackett (*3*) [1] covered a wide range of light intensities and carbon-dioxide concentrations. Under the artificially controlled conditions used, it was shown that there was a linear variation of carbon-dioxide assimilation with carbon-dioxide concentration in the presence of excess light over a limited range. With the maximum light intensity, approximately one-fourth that of sunlight on a cloudless summer day in Washington, carbon dioxide became a limiting factor at a concentration of about that of normal air. Since sunlight intensity for a number of hours per clear day is much higher than the highest intensity employed in these experiments, it was thought that interesting and important data might be obtained from experiments conducted with sunlight under more natural conditions out of doors and with the carbon-dioxide concentration surrounding the plants some 3 to 4 times that of normal air.

It is not feasible here to make an extended review of the large amount of work covering the subject of aerial fertilization of plants with carbon dioxide. Many experimenters report beneficial effects. Several sources of carbon dioxide have been utilized, including carbon-dioxide generators, commercial tanks of the compressed gas, scrubbed flue gas, and that arising from animal and plant manures. Both greenhouse and field experiments have been tried. Carbon dioxide from blast furnaces, after being freed of matter injurious to plants and piped to fields where it was allowed to spread over extended areas, caused marked improvement in crop yields. Because of the difficulty of confining the gas over such large areas in open fields, aerial fertilization with carbon dioxide is better adapted to greenhouse work.

Relatively little work on increasing the products of photosynthesis by enriching the air with carbon dioxide has been done in this

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[1] Italic numbers in parentheses refer to list of references at end of paper.

country as compared with such studies in England, France, and
Germany. Cummings and Jones (2), using open cases in the green-
house, liberated the carbon dioxide from sodium-bicarbonate sul-
phuric-acid generators in such a manner that the plants were bathed
in an atmosphere rich in carbon dioxide for 8 hours a day. Closed
cases were not satisfactory, since they subjected the plants to such
abnormal conditions that consistent results were not obtainable. Ex-
periments with a rather wide variety of plants indicated a general
increase in plant production and that plants can use to good advantage
more carbon dioxide than occurs normally in air. The optimum
quantity of carbon dioxide, as found by these authors, for plants
grown in open boxes (26 x 18 inches and 26 inches deep for the
larger plants, and 52 x 28 x 12 inches for the smaller ones) varied
with the plant. For lettuce this quantity was about 300 liters of
carbon dioxide a day. Cummings and Jones further conclude that
the continuity of supply is as important as the total amount.

Arthur, Guthrie, and Newell (1), working at the Boyce Thompson
Institute for Plant Research, Inc., have studied the effects on plant
growth and chemical composition of increased carbon-dioxide concen-
trations in greenhouses and in constantly conditioned rooms. The air
was enriched with carbon dioxide to about 0.3 percent, or 10 times that
of normal air. In addition to sunlight one of the greenhouses received
supplementary artificial light, and one of the rooms had artificial light
only. Several types of plants were used, the small grains being repre-
sented by barley, wheat, and oats. Their spring wheat (variety blue
stem) data are shown in table 1.

TABLE 1.—*Experimental Results on the Chemical Composition of the Aerial
Portion of Wheat [from Arthur, Guthrie, and Newell (1)]*

| | | | Nitrogen (percent dry weight) | | Carbohydrate (percent dry weight) | | | |
	Weight per plant (grams)	Moisture (percent)	Soluble	Total	Acid hydrolyzable	Sucrose	Dextrose	Total
Treatment								
Control greenhouse. No heads produced	3.4	86.4	0.93	3.42	13.56	2.73	2.87	19.16
Greenhouse 1. Straw only.	3.3	76.4	0.47	2.15	15.46	8.07	3.26	26.79
Greenhouse 2. Straw only.	6.3	68.2	0.25	1.16	15.50	20.29	1.88	37.17
24-hour day. Straw only..	1.8	64.6	0.29	1.15	18.11	14.13	2.93	35.17
Greenhouse 1. Heads only.	0.6	71.3	0.60	2.18	25.43	28.07	6.79	60.29
Greenhouse 2. Heads only.	2.1	64.7	0.51	2.11	40.53	10.83	3.12	54.48
24-hour day. Heads only..	0.5	61.5	0.26	1.26	30.01	14.14	3.80	47.95

Greenhouse 1 received 6 hours supplementary light each night from crane.
Greenhouse 2 received same illumination and additional carbon dioxide.
24-hour day plants grown in constant-light room.

As can be seen from the table, the plants that received both additional light and carbon dioxide were heavier and contained a greater quantity of carbohydrates than the control plants. No signs of heading in the control plants were noted at time of sampling, whereas those in greenhouses 1 and 2 had been in head for some time. These authors conclude that:

Small grains, such as barley and spring wheat, in contrast to potatoes, will grow and yield well at a high temperature (78° F.) if given additional light and carbon dioxide. The production of these grains is not favored by low temperature when day length is long and carbon dioxide supply is abundant. The weight per plant of barley increases with day length up to a 19-hour day. Total carbohydrates also increase and nitrogen decreases. The feeding of nitrate was found to make little or no difference in the total percentage of nitrogen in the barley plant, the percentage remaining high only when carbohydrate synthesis was restricted by short days.

EXPERIMENTATION

In the laboratory experiments of Hoover, Johnston, and Brackett, in which growth was entirely under artificial conditions, the wheat plants were confined to a double-walled glass cylinder with their roots extended into a flask of nutrient solution. In the first type of experiments run outside, Marquis wheat was planted in six 8-inch earthenware pots (not glazed) containing a good garden soil. The pots were buried to their rims in wet peat moss placed in a long, narrow cypress box. Cylinders 30 inches in length with conical tops were made from clear cellulose acetate sheeting and so constructed that they fitted into the tops of the pots. The purpose of these cylinders was to confine air of a given carbon-dioxide concentration about the plants. In order to insure a fairly constant carbon-dioxide concentration, the desired air mixture was introduced through a glass tube emerging centrally just above the surface of the soil. Holes cut in the cylinders at the tops just beneath the aprons of the cones provided an exit for the air.

It was thought the flow of air through these cylinders would be sufficient to keep the plants cool. It was soon realized, however, that additional cooling would have to be employed. A means was devised for flowing a thin sheet of water over the outer surfaces of the cylinders. Near the tops of the cylinders small jets of water from copper tubings wet short cloth curtains wrapped around the upper portions of the cylinders. This gave a fairly even distribution of water over the surfaces of the cylinders. Even with this additional equipment, the temperatures within the cylinders were still excessively high on clear days. This was in part due to the high temperature of the tap water used for cooling, which frequently had a temperature of

25° to 28° C. as it came from the pipe line. A further reduction in temperature was brought about by placing a white cloth reflecting surface back of the plants and by operating a movable " half-shade."

A battery of these cylinders is shown in plate 1. They were placed on a small platform about 6 feet above ground and in front of a small frame building that faced south. The flow of water was adjusted by the valves at the top. The waste pipe is shown below. On cloudy days, and at night, the " half-shade " was raised by means of a rope and pulleys.

In the space beneath the platform were located the air and carbon-dioxide flow gauges, the mixing flasks, and the gas tanks. These are illustrated in plate 2. Commercial carbon dioxide of high purity, supplied in heavy steel cylinders, was passed under 15 pounds pressure into a cushion tank and then through a flow gauge into the mixing flask for the proper dilution with air. The air was supplied from the high-pressure compressed-air line from the United States National Museum. It was reduced to 15 pounds pressure and passed into a cushion tank and then into the mixing flask. The proper mixture of air and carbon dioxide was then passed into the cellulose acetate cylinders. The concentration of carbon dioxide in these growth cylinders was checked from time to time by analyses.

Several preliminary experiments were run during the summer of 1933, but the wheat grew so poorly that no definite conclusions could be made other than that the plants receiving the higher concentrations of carbon dioxide grew better than those receiving the lower concentrations. Because of the fact that the plants were too closely confined in the cylinders, where the temperature was abnormally high, and because of the necessity for using a shade and water filter, it was decided to repeat the experiment the following summer after modifying the conditions so as to make them a little less artificial.

On April 14, 1934, Marquis wheat was planted in the six 8-inch pots used the previous summer and in three plots of soil 2 x 2 feet laid off in the yard of the Astrophysical Observatory. The conical tops of the cylinders were removed to minimize the rise in temperature of the air surrounding the plants. Neither the water screen nor the " half-shade " was used. At the corners of two of the 2 x 2-foot plots were placed slotted posts into which sheets of glass 24 x 30 inches in size could be fitted. A plot with glass walls either 30 or 60 inches high could be built up as circumstances warranted. To minimize the removal of carbon dioxide from within these glass-walled plots by air currents, there was laid across the top a frame over which two layers of fly netting were stretched.

POT EXPERIMENTS

The results of the experiments in which wheat plants were grown in pots and enclosed in clear cellulose acetate cylinders are summarized in table 2. The general appearance of the plants in this experiment is shown in plate 3.

TABLE 2.—*Summary of 1934 Experiment with Wheat Grown in Pots*

Data	Pot 1	Pot 2	Pot 3	Pot 4	Pot 5	Pot 6
CO_2 concentration (relative to normal air)	7.1	4.0	1.3	0.9	1.0	1.3
Plants per pot	3	3	3	3	2	2
Average data per plant:						
Number of tillers	10	8	3	2	4	8
Number of stalks	6	6	1	1	2	6
Length of stalks (cm.)	52	54	35	40	43	45
Weight of heads (g.)	1.2	1.2	0.1	0.2	2.3	0.9
Weight of straw	4.8	4.4	1.0	0.7	2.7	3.8
Total weight	6.0	5.6	1.1	0.9	5.0	4.7
No. of grains	4.7	10.7	1.3	3.3	60.5	11.5
Weight of grains	0.134	0.283	0.029	0.050	1.500	0.279
Weight per grain	0.029	0.026	0.022	0.015	0.025	0.024

Culture 3, no forced ventilation.
Culture 4, ventilated by slow stream of air.
Culture 5, not enclosed.

As noted above, Marquis wheat was planted in these pots on April 14. On April 23 the carbon dioxide and air mixture treatments were started. The rate of flow was approximately 2 liters a minute. By May 24 the plants in pot 5 had the best color, although all were slightly yellow, with leaves somewhat rolled. Temperatures on clear, hot days continued to be excessive in these cylinders in spite of the open tops. Heads appeared on plants in pots 1, 2, and 6 by June 11. On July 13 the plants were photographed (pl. 3), and on the 19th they were harvested.

Although the conditions of this experiment were not so ideal as could be desired, a few interesting facts appear from the data in table 2. The number of grains and the weight of grain per plant were much higher in pot 5 than in any of the others. The wheat plants in this culture were not enclosed, but were entirely open to the outside air. The lowest yield in number of grains and in weight of grain per plant occurred in no. 3, where the plants were enclosed in a cellulose acetate cylinder and deprived of forced ventilation. The weight of straw was greatest in the cultures receiving the highest concentration of carbon dioxide. It is to be expected that vegetative growth would be helped by the addition of carbon dioxide, but it is evident that grain production was depressed in comparison with no. 5, the open control, when the number and weight of grain were used as the criteria of measurement. When compared with nos. 3 and 4,

the enclosed controls, the number and weight of grain were greater for the carbon-dioxide-treated cultures.

The weight per grain was somewhat higher for the plants receiving the greater quantity of carbon dioxide. One other point of interest is that these same plants put out a greater number of tillers than the ones treated with less carbon dioxide. Those in no. 6 appear to be an exception.

PLOT EXPERIMENTS

Owing to the poor stand in one of the 2 x 2-foot plots from the planting made on April 14, these three plots were replanted on May 9. Because of this delay, seeds sprouted in the laboratory were used for the second planting. A good stand was obtained by May 14, at which time the carbon dioxide-air mixture at the approximate rate of 2 liters a minute was turned into the glass enclosure surrounding plot A; B served as the enclosed control plot, and C as the open one. On May 17 the glass sides were increased in height from 30 to 60 inches.

The results of this experiment are summarized in table 3. The general appearance and arrangement of these three plots and of the 6-pot experiment described above are shown in plate 4. The wheat in the three plots, harvested July 25, is illustrated in plate 5. The dry weight data were determined after the plants were air dried for about 2 months.

TABLE 3.—*Summary of 1934 Experiment with Wheat Grown in 2 x 2-foot Plots*

Data	Plot A (in glass enclosure)	Plot B (in glass enclosure)	Plot C (open)
Average CO₂ concentration (relative to normal air)	3.8	1.1	0.9
Number of seeds planted	36	36	36
Number of plants harvested	34	33	31
Average data per plant:			
Weight (grams) at harvest	14.52	6.39	3.47
Weight after air drying	8.02	5.00	3.02
Weight of water lost in drying	6.50	1.39	0.45
Number of heads	7.44	4.03	2.74
Weight of heads	2.88	2.51	1.26
Weight per head	0.39	0.62	0.46
Weight of straw	5.14	2.49	1.75
Weight of grain	0.85	1.70	0.77
Number of grains	26.08	57.70	37.52
Weight per grain	0.0326	0.0295	0.0205
Number of grains per head	3.51	14.32	13.68

At time of harvest the total weight per plant of those treated with carbon dioxide was over twice that of the enclosed control plot (B) and over four times that of the open control plot (C). This great difference was due largely to the water content as is evidenced by the dry weights, which, however, still indicate a substantial increase of

the carbon-dioxide-treated plants over both controls. The number and weight of heads per plant are also greater. However, the weight per head and the number of grains per plant are less in the carbon-dioxide-treated plot. The large increase in total weight is due to the weight of straw. Although the weight per grain of the plants on the carbon-dioxide-treated plot was somewhat greater than those of the two control plots, the number of grains per head was much less. This experiment likewise indicates the accelerating effect of carbon-dioxide aerial fertilization on vegetative growth and an apparent depressing effect on grain production.

During the following summer the plot experiment was repeated with one additional treatment. It was thought that if phosphorus and potassium fertilizers were added to one of the carbon-dioxide-treated plots at time of heading, these plants might be improved with respect to their grain production. The general procedure in this experiment was similar to that of the previous year. However, the rate of air flow was increased to about 5 liters a minute, and the enclosed control plot was changed to the east end of the row. The appearance of the plants when harvested is shown in plate 6, and the data are summarized in table 4.

TABLE 4.—*Summary of 1935 Experiment with Wheat Grown in 2 x 2-foot Plots*

Data	Plot 1 (in glass enclosure)	Plot 2 (in glass enclosure; CO_2 added)	Plot 3 (in glass enclosure; CO_2, P, and K added)	Plot 4 (open)
Average CO_2 concentration (relative to normal air)....	0.9	4.6	4.1	1.1
Number of stalks harvested...	83	112	125	114
Total weight (grams) at harvest	230.0	313.0	378.0	144.0
Total weight after air drying..	150.0	177.5	220.0	112.0
Weight of water lost in drying.	80.0	135.5	158.0	32.0
Number of heads............	79	104	117	84
Dry weight of heads........	71.5	77.0	102.0	40.5
Dry weight per head........	0.91	0.74	0.87	0.48
Dry weight of straw.........	78.5	100.5	118.0	71.5
Dry weight of grain.........	54.20	56.15	74.00	25.25
Number of grains............	1,786	1,927	2,419	1,251
Dry weight per grain........	0.0303	0.0291	0.0306	0.0202
Number of grains per head...	22.6	18.5	20.7	14.9

Each plot was planted to 72 grains of wheat, two to the hill, during the first week of April. By April 26 the plants showed a fair start. The glass sides, 60 inches high, were placed around plots 1, 2, and 3, and the carbon-dioxide mixture turned into plots 2 and 3 on April 29. The average carbon-dioxide analyses showed the concentration in plot 2 to be somewhat greater than that of plot 3, the one to which phosphorus and potassium fertilizers were added. This fertilizer combina-

tion was applied in a solution of KH_2PO_4 at four different times after the plants started to head out. The total quantity added was about 10 grams.

When the plants were harvested, the number to the hill could not be determined. For this reason the data have been expressed as total for each plot rather than the average per plant, as in table 3.

On May 10 the leaves of the plants in plots 2 and 3 showed a slight yellowing. This yellowing of the carbon-dioxide-treated plants during their early growth was also observed in the previous year's experiments. Later the plants overcame this initial handicap and outgrew the plants of the control plots. By June 7 plants in plots 1 and 4 had started to head out, but no signs of heading were in evidence in plots 2 and 3 (those receiving extra carbon dioxide) until a day or two later. This was also in keeping with observations made the previous year. By June 27 vegetative growth had practically ceased, and the carbon-dioxide treatments were discontinued.

So far as vegetative growth and the amount of tillering are concerned, this experiment showed a beneficial effect of the carbon-dioxide treatment. The weight of straw was increased, as was also the number of heads produced. Although the weight of grain was greater on the carbon-dioxide-treated plots, the greater number of grains produced reduced the average dry weight per grain of these plots to practically the same value as the enclosed control, approximately 0.03 grams. The number of grains to the head was but slightly greater in the enclosed control plot, whereas in the previous year's experiment it was considerably greater.

SUMMARY AND CONCLUSIONS

Three different experiments were carried out with Marquis wheat to study the effects in sunlight of increased carbon-dioxide concentration (in most cases about four times that of normal air) of the air surrounding the plants during their growth. In one experiment 8-inch pots were used, and in the two other experiments plots 2 x 2 feet were employed. Commercial carbon dioxide of high purity was mixed with the air surrounding the plants. The carbon dioxide was confined to the space about the plants by cylinders of clear cellulose acetate in one experiment and by square glass sides in the others.

The main conclusions to be drawn from these experiments are that air enriched with carbon dioxide (1) increased the tillering of the wheat, (2) greatly increased the weight of straw, increased (3) the number and (4) weight of heads, (5) increased the number of grains

produced, and (6) slightly delayed the time of heading. The weight per grain was practically the same as that of the controls even in the experiment in which phosphorous and potassium fertilizers were added at time of heading.

Great differences in growth were obtained in the plot experiments between the enclosed plants and those grown in the open. The enclosed plants were larger, heavier, and more succulent, and the weight per grain was somewhat greater. In the pot experiment the plants in the open culture (no. 5) grew better than those of the corresponding control (no. 4). There appears to be some evidence, since this pot experiment, of a toxic effect of cellulose acetate. If this is true, it may account for the poorer growth of the plants enclosed in the cellulose acetate cylinders. It would appear that the higher humidity within the enclosed plots was beneficial to these plants. The evidence, however, is not conclusive, since the temperature was also higher within than without the enclosures.

The aerial fertilization of plants with carbon dioxide raises a number of interesting questions. Many of these can be answered, however, by laboratory experiments under controlled conditions. The practical application of this type of fertilization in field experiments and the supply of carbon dioxide in sufficient amounts for practical field work are still unsolved problems, in spite of the work that has been done. Even its application to greenhouse culture requires the utmost precaution. The escape of the gas mixture into a greenhouse is not sufficient in itself, but a recirculating system, as noted by Owen (4) aids materially toward obtaining uniform distribution. While experiments in which carbon dioxide is used as an aerial fertilizer are of important scientific value, the practical application of this type of fertilizer in commercial work is far from being satisfactory, although its application to greenhouse culture appears to be most promising.

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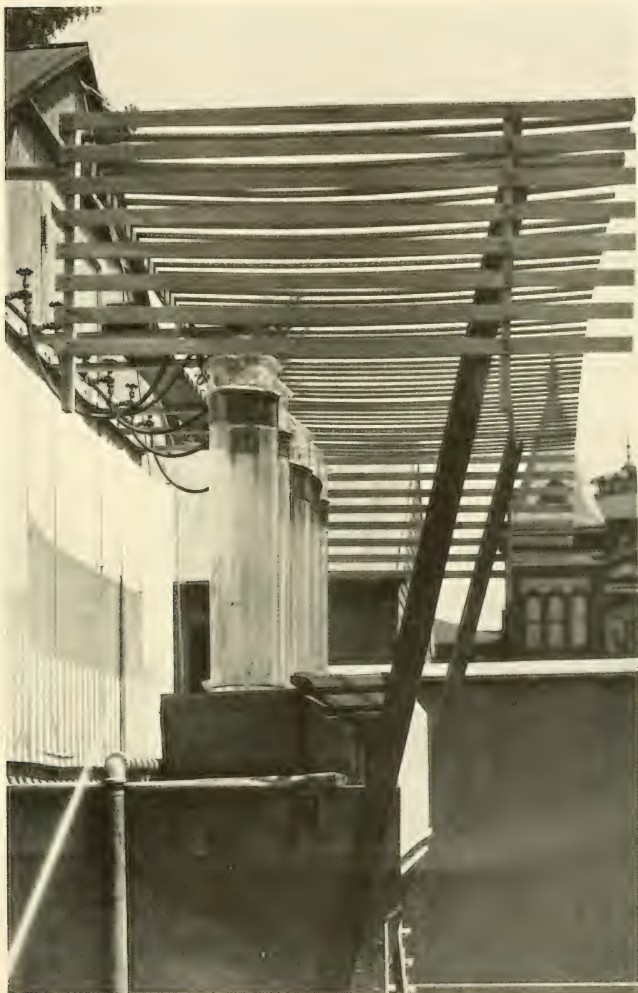
WHEAT CULTURES ENCLOSED IN TRANSPARENT CYLINDERS OF
CELLULOSE ACETATE
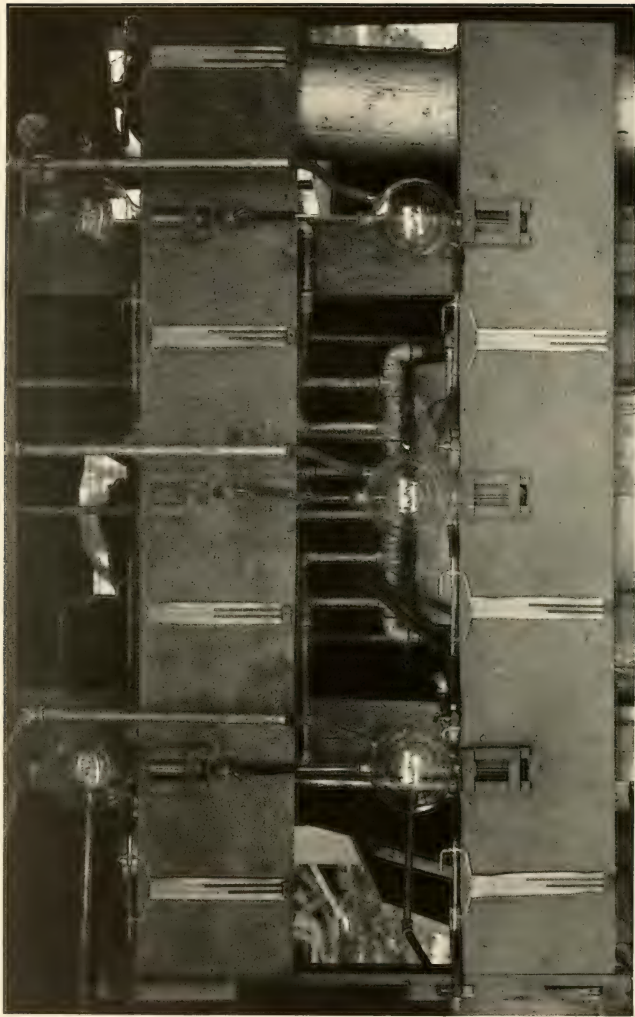
APPARATUS FOR CONTROLLING THE FLOW AND MIXTURE OF CARBON DIOXIDE AND AIR
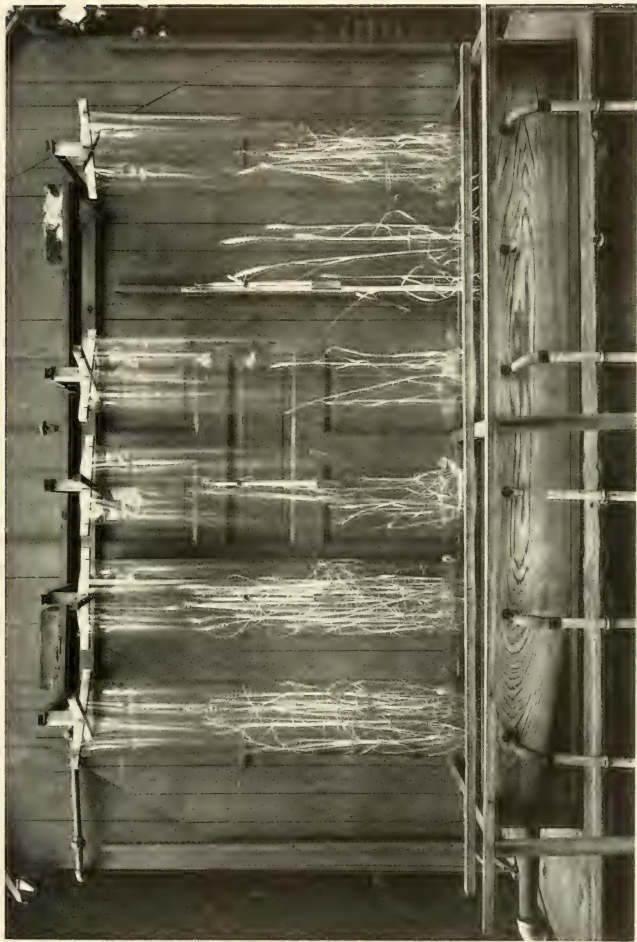
GENERAL APPEARANCE OF WHEAT PLANTS GROWN IN CLEAR CELLULOSE ACETATE CYLINDERS

Cultures are numbered from left to right. (See table 2.)

GENERAL APPEARANCE OF WHEAT POT AND PLOT EXPERIMENTS OF 1934

(See tables 2 and 3 respectively.)
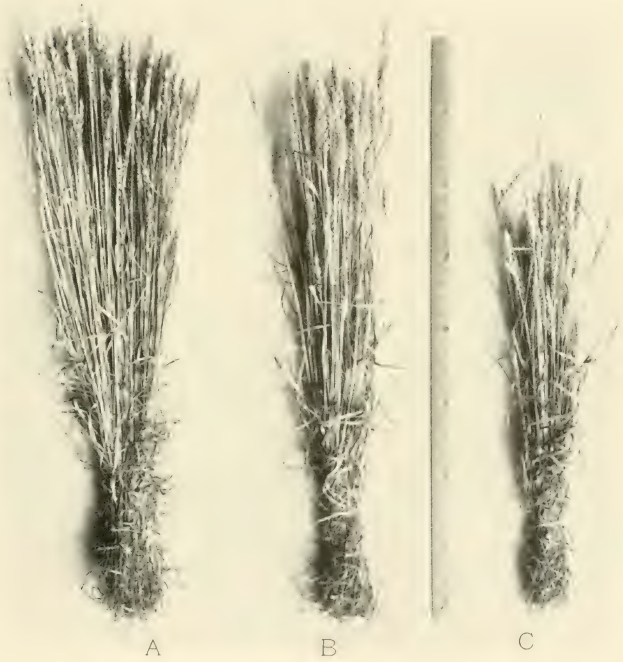
APPEARANCE OF WHEAT HARVESTED FROM THE 1934 PLOT EXPERIMENTS

Average carbon-dioxide concentration relative to normal air was: A, 3.8; B, 1.1; C, 0.0. (See table 3.)
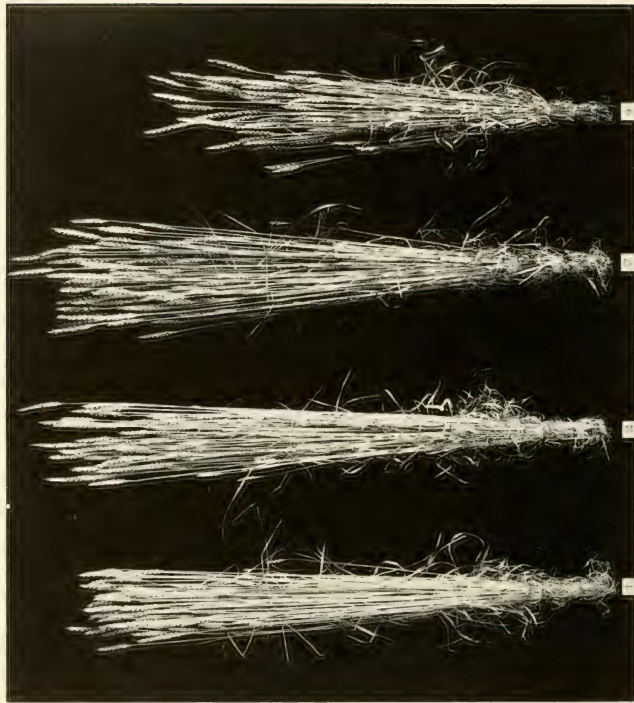
APPEARANCE OF WHEAT HARVESTED FROM THE 1935 PLOT EXPERIMENT

Average carbon-dioxide concentration relative to normal air was: 1, 0.0; 2, 4.6; 3, 4.1; 4, 1.1. (See table 4.)

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THE GENUS
PANSCOPUS SCHOENHERR
(COLEOPTERA: CURCULIONIDAE)

BY
L. L. BUCHANAN
Bureau of Entomology and Plant Quarantine,
U. S. Department of Agriculture

(PUBLICATION 3376)

THE GENUS PANSCOPUS SCHOENHERR
(COLEOPTERA: CURCULIONIDAE)

By L. L. BUCHANAN [1]

Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture

The following descriptions and synoptic keys have been prepared in order that names may be available for several undescribed species of *Panscopus* in the United States National Museum collection, including two submitted for identification by W. W. Baker, of the Division of Truck Crop and Garden Insect Investigations, United States Bureau of Entomology and Plant Quarantine.

Panscopus may be briefly characterized as a group of North American scarred-snout weevils with a prothoracic ocular lobe and a rounded to narrowly elliptic scale in each serial puncture of the elytra. The shape of the serial scale varies considerably, but in only one species (*alternatus* Schaeffer) does it become hairlike. In one subgenus (*Parapanscopus*) there is a well-defined double row of spines at the apex of the hind tibiae enclosing an oblique, narrowly fusiform, subglabrous area (corbellary plate, fig. 2, a). All the species are flightless, and some of them doubtless are in the nature of geographic forms; but their exact status cannot be determined with certainty at present. The rostral length of the descriptions is the straight-line distance between the tips of the closed mandibles and the point where the upper surface of the rostrum meets the globular basal portion of the head. The terms anterior, posterior, dorsal, and ventral, as applied to the surfaces and edges of the leg segments, indicate the relative positions that would be assumed by these surfaces if the leg were extended in a straight horizontal line at right angles to the longitudinal axis of the body.

KEY TO SUBGENERA OF PANSCOPUS

1. Mentum with a single setigerous puncture each side of middle (rarely two); metepisternal suture invisible (fused with metasternum); rostrum above with a scale-covered, sometimes feeble, median carina in about basal two-thirds; species east of 100th meridian.................................2.

Mentum without setigerous punctures; a short length of metepisternal suture almost always visible opposite rear coxa; rostral sculpture variable; species west of 100th meridian..3.

2. Setigerous punctures located on face of mentum, sometimes near sides, and usually about one-fourth distance from apex; basal margin of elytra more or less prominent, especially laterally, the side margin sinuate just behind humerus (sinuation feeble or wanting in *alternatus*); alternate elytral intervals elevated (feebly so in *erinaceus*), the seventh and ninth coalescent some distance from base (about opposite mid coxa); anterodistal edge of hind tibia (in front view) less oblique and with only one well-defined row of spines, the corbellary plate, though often discernible, vaguely defined (effaced in *alternatus*) (fig. 1)........*Panscopus* Schoenherr (sens. str.).
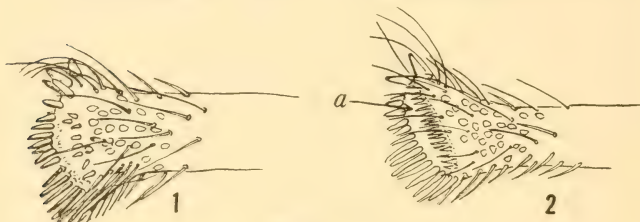
Figs. 1 and 2.

Setigerous punctures located on declivous apical margin of mentum, usually toward sides (not easily seen when mentum is retracted); basal margin of elytra not or hardly prominent, side margins not sinuate; alternate elytral intervals not elevated, the seventh and ninth reaching base independently, or coalescent at base; anterodistal edge of hind tibia more oblique and with two well-defined rows of spines enclosing corbellary plate (fig. 2).

Parapanscopus, n. subg.

3. Both prothorax and elytra with small, shiny tubercles; dorsal scales, in part, usually green; length, 6–10 mm...................*Phymatinus* LeConte.

Elytra without tubercles, the prothorax usually with smaller and less distinctly isolated ones, or rugose tuberculate beneath the scales; dorsal scales not green (except in *johnsoni*); length, 5–9 mm.....................4.

4. Antennal scape, when bisecting eye, reaching its hind margin; dorsum of rostrum and of front subcontinuous in profile; prevailing color dull brownish black ....5.

Antennal scape, which normally is densely coated with scales and setae, not reaching beyond middle of eye; color usually paler brown, or cinereous mottled with brown (more or less green in *johnsoni*); dorsum of rostrum and of front subcontinuous or discontinuous in profile..................6.

5. Female abdomen 4-segmented, its derm not concealed by the vestiture. Male abdomen 5-segmented, hairy and setose, the hairs longer and rather conspicuous in basal concavity; antennal scape hairy or setose; pronotum with usually scanty setae or slender scales, the granular sculpture plainly visible; some of the serial scales on elytral disk elliptical to sublinear and narrower than the punctures...................................*Nocheles* LeConte.

Abdomen of both sexes 5-segmented and densely scaly-setose, the derm concealed except apically; antennal scape rather densely clothed with setae and slender scales; pronotum with broad, usually densely placed scales; serial scales on elytra mostly subcircular and covering, or almost covering, the punctures ....*Dolichonotus*, n. subg.

6. Trochanters without a bristlelike seta; a fine line, marking position of metepisternal suture, usually visible; scales everywhere very dense; alternate elytral intervals costate and setose, even intervals practically nonsetose
Pseudopanscopus Buchanan.

Trochanters with a bristlelike seta; metepisternal suture almost always visible for a short distance only opposite hind coxa (or obsolete); even intervals usually with at least a sparse row of setae....................................7.

7. Elytral intervals flat or subequally convex, the setae, which usually are slender and subacute at tip, about equally developed on all intervals; or, if the setae are evidently more numerous on alternate intervals, some of the serial scales on elytra are slender; rostrum not or faintly carinate; pronotum smooth or rugose-tuberculate...............*Neopanscopus* Pierce.

Alternate intervals elevated (sometimes very feebly so), their setae more abundant than on even intervals; elytral setae blunt (except in *longus*); serial scales on elytra rounded; rostrum often carinate; pronotum more or less rugose-tuberculate and, at middle, usually sulcate..*Nomidus* Casey.

Subgenus PANSCOPUS Schoenherr (sens. str.)

Panscopus Schoenherr, Genera et species Curculionidum, vol. 6, pt. 2, p. 266, 1842. (Monobasic type, as designated by Schoenherr, loc. cit., p. 267, *Barynotus erinaceus* Say, Descriptions of new species of Curculionites of North America, p. 12, 1831.)

An examination of two cotypes of *P. alternatus* Schaeffer shows that this species has been misinterpreted in the literature. The error is corrected in the following key:

1. Each serial puncture of elytra with a hair or seta, none with a rounded scale; alternate intervals costate and setose, the even intervals usually with a sparse irregular row of setae (♀) or practically nonsetose (♂); scape reaching two-thirds to almost entirely across eye at middle; side of elytra at humerus straightly oblique, or at most faintly sinuate; corbellary plate effaced; length, 5.5–7 mm [Black Mountain, N. C. (type locality); Mount Mitchell, N. C. (A. Nicolay)]....................*alternatus* Schaeffer.

Scales of serial punctures oblong to rotund in general, a few sometimes setalike but not hairlike; humeral situation usually distinct; corbellary plate present though poorly defined as a rule and not limited anteriorly by a distinct second row of spines....................................2.

2. All the elytral intervals setose, the alternate intervals, which usually are slightly prominent, with more abundant setae (rarely are the alternate intervals evidently costate and the second and fourth devoid of setae except toward base and apex); front often broadly concave; rostrum wider, its median carina usually coarse and, in profile, distinctly arched; scape reaching one-half to three-fourths across middle of eye; length, 6–7 mm; ♂ un-

known (New Hampshire, New York, New Jersey, Pennsylvania, Mary-
land, District of Columbia, Virginia, West Virginia, Michigan, Wisconsin;
type locality, United States)..........*crinaceus* Say (*carinatus* Pierce).
Alternate intervals distinctly costate and conspicuously setose, the even in-
tervals practically nonsetose; rostral carina less prominent, feebly arched
in profile; scape reaching three-fourths to entirely across middle of eye
(Virginia and southward)..3.

3. Length, 8.5–9 mm; scape reaching or slightly passing hind margin of eye in
♀ (♂ unknown) [Lee County, Va. (type locality) ; Tryon, N. C.]
impressus Pierce.

Length, 6–8 mm; scape a trifle shorter (North Carolina)
impressus thoracicus, n. subsp.

PANSCOPUS (PANSCOPUS) IMPRESSUS THORACICUS, n. subsp.

Panscopus (*P.*) *alternatus* PIERCE, Proc. U. S. Nat. Mus., vol. 45, p. 394, 1913;
BUCHANAN, Proc. Ent. Soc. Washington, vol. 29, p. 27, 1927; not
Schaeffer.

Length, 6.7–7.3 mm; width, 2.7–3.3 mm. Derm black, densely
clothed with striated brown scales, which in general have a dull
coppery tinge, paler on head, rostrum, and vertex of head, and some-
times greenish toward apex of rostrum above; elytra with or without
a few blackish mottlings. Prothorax of male inflated, the sides
strongly rounded.

Rostrum stout, somewhat shorter than prothorax, above densely
scaly, a little wider and more nearly flat than in *alternatus,* the
rather feeble scale-covered median carina not reaching beyond apical
third; front flat to broadly and feebly concave; first and second
funicular segments elongate and subequal, other segments longer
than wide except fifth and sixth, which are usually about as wide
as long. Prothorax a little wider than long in both sexes, about
seven-eighths (♂) and five-sevenths (♀) as wide as elytra; pronotum
with a shallow median sulcus, which is wider and deeper apically,
usually interrupted at middle and sometimes obsolescent basally, the
general surface with small, scale-covered, setigerous tubercles. Elytra
distinctly narrower in ♂, the sides parallel (♂) or slightly rounded
and convergent (♀) from behind the distinct humeral sinuation to
apical third, alternate intervals costate and with a crowded row
(double in places) of long setae; even intervals usually nonsetose, or
second and fourth with a few at base and apex, the sixth occasionally
with a widely spaced row, the serial scales variable in shape, but at
least some of them oblong or ovate (not all subcircular). Fifth
sternite of male with a feeble submedian impression. Ventral edge
of tibiae with a few erect denticulations, strongest on front pair,
feeblest on hind pair.

Type locality.—Round Knob, N. C., June 23, 24, and 26, Hubbard and Schwarz collection; 4 ♂♂, 1 ♀.

Other locality.—Black Mountain, N. C., September 13, Brooklyn Museum collection; 3 ♂♂, whose pin label data are same as on 2 cotypes of *alternatus;* same locality, May 1910, F. Sherman, 1 ♀; same locality, June and July 1912, Beutenmüller, 2 ♂♂, 2 ♀♀ in Casey collection.

Type.—♂, U.S.N.M. no. 50831.

Looks much like *alternatus* from the same region but with prothorax of ♂ more strongly dilated at sides, pronotal sculpture not so rough, rostrum flatter above, and serial scales of elytra much broader. The rostrum is longer than in *erinaceus.* There are at hand single females from Pyziton and Wadley, Ala., and a fragmentary male (the last from a toad's stomach) from Thompsons Mill, Ga., which are more or less closely related to *thoracicus,* but which cannot be definitely associated with any described form.

PARAPANSCOPUS, n. subgen.

Body scaly and setose, the setae slender, narrowly truncate at apex but appearing acute in side view. Rostrum stout, upper surface arcuate and broadly discontinuous with front in profile, moderately widened apically, slightly so basally, thicker at middle than at base, nasal plate not sharply elevated, interantennal fovea or groove usually present; eyes rather small, separated above by basal width of beak, feebly convex, subacute below; scrobe beginning near apex of rostrum becoming rapidly shallower posteriorly and obsolete some distance before eye, arcuate and directed toward lower part of eye or beneath eye; scape setose, or scaly and setose, reaching two-thirds to three-fourths across eye at middle; funicular segments as long as or longer than broad, the first two longer and subequal. Prothorax with feeble ocular lobe; pronotum without median sulcus, though the tubercles are sometimes nearly wanting along a narrow median line; pronotal sculpture tuberculate, the tubercles in *maculosus* indistinct and covered by scales. Elytra of a characteristic ovoid shape, the sides converging posteriorly from a little behind the broadly rounded humeri, intervals with subregular rows of long setae, the serial scales ovate or round, the alternate intervals not costate, the sutural one more or less distinctly vittate, at least on declivity. First abdominal suture arcuate at middle (in female, the male unknown), intercoxal piece wide and subtruncate or slightly advanced at middle, fifth sternite not or very feebly impressed, hind femur nearly reaching apex of abdomen, tibiae

mucronate, ventral edge denticulate, at least on front pair ; third tarsal
segment bilobed.

Type of subgenus.—Panscopus maculosus Blatchley (The Rhyn-
chophora or Weevils of Northeastern America, p. 105, fig. 45, 1916).

1. Length, 5.75-7.75 mm (most specimens between 6 and 7 mm) ; general color
   paler brown, the head and rostrum clothed with cinereous scales and setae ;
   pronotal tubercles normally obscured by scales ; antennal scape clothed with
   fine setae that do not conceal derm ; sutural interval somewhat elevated,
   especially from middle to part way down declivity and here with a double
   row of setae ; pale stripes often present on sutural and base of fifth elytral
   intervals and on middle and sides of pronotum. [Ohio, Kentucky, Illinois,
   Iowa (Nat. Mus.), Missouri (Casey collection), Indiana, New York
   (Blatchley) ; type locality, Posey County, Ind., as subsequently designated
   by Blatchley (Blatchleyana, p. 39, 1930)]............*maculosus* Blatchley.
   Length 6 mm or less ; color darker brown ; pronotal tubercles individually
   distinct ; antennal scape clothed with brown, inclined setae and prostrate
   scales, the latter more or less completely covering derm apically, the scape
   reaching middle of eye ; sutural interval at most just perceptibly elevated
   near top of declivity and here with a few extra setae, elsewhere with a
   single row ; pale markings indistinct..................................2.
2. Prothorax at middle considerably wider than at base, the sides rather strongly
   rounded ; groovelike intervals between the pronotal tubercles more or less
   scaly (Ontario) ....*ovatipennis,* n. sp.
   Prothorax faintly expanded at middle, the sides very broadly rounded ; in-
   tervals between pronotal tubercles almost devoid of scales (Pennsylvania)
   ovatipennis verrucosus, n. subsp.

PANSCOPUS (PARAPANSCOPUS) OVATIPENNIS, n. sp.

Length, 6 mm ; width, 2.8 mm. Derm piceous black to rufopiceous,
antennae and tarsi reddish, body setose and densely scaly, prevailing
color of scales brown with dull, aeneous luster, lighter and in part
greenish on pronotum, vertex of head, and apex of rostrum, a vague
lateral stripe along prothorax behind the eyes and along elytral suture
on declivity paler ; dorsal setae brown and conspicuous ; pronotum
with small, closely set tubercles, most of those on disk isolated
individually.

Rostrum stout, twice as long as thick at middle, feebly arcuate, a
little shorter than prothorax, above with sparse, erect setae, which
form on each side two irregular, longitudinal rows, one lateral and
one each side of median carina, the two rows uniting at side margin
above antennal socket and forming a single row thence to apex, sur-
face transversely convex and densely scaly in basal three-fourths,
flat and sparsely scaly apically, median carina distinct, though obtuse,
in middle half, ending anteriorly at the interantennal fovea, the nasal
plate feeble and merging into the adjacent rather closely punctate

surface; head with a group of erect setae above eye, frontal fovea absent; scape clothed from near base to apex with inclined setae and prostrate scales, the latter setalike and sparser basally, broader and covering derm apically. Funicular segments elongate, the seventh longer than broad. Prothorax transverse (5 to 4), widest a little before middle, base wider than apex, sides distinctly rounded, scarcely constricted apically; pronotal tubercles at sides obscured by the scales, all the tubercles covered by appressed scales (usually 5 or 6), which do not close the seta-bearing puncture at the summit, the setae slender and posteriorly inclined in general. Elytra one-third longer than wide, wider than prothorax (4 to 3), sides progressively more strongly convergent from about basal fifth to apex, disk moderately declivous from about middle to the broadly emarginate base, surface densely clothed with striated scales, the discal intervals faintly and subequally convex, the third and fifth near base slightly more prominent, each interval with a single row of long, slender, inclined setae, the serial punctures not entirely closed by the small, rounded scales. Beneath and legs setose and densely scaly; tibiae rather slender and denticulate on ventral margin, hind pair obsoletely so.

Type locality.—" Hamilton, Canada " (undoubtedly province of Ontario) ; 1 ♀.

Type.—U.S.N.M. no. 50646.

P. ovatipennis looks much like some specimens of *crinaceus,* but there the sides of the elytra are more nearly parallel, the beak wider and flatter, the pronotal tubercles less distinct, the alternate elytral intervals with more setae than the even ones, the elytra sinuate laterally at humerus, etc.

PANSCOPUS (PARAPANSCOPUS) OVATIPENNIS VERRUCOSUS, n. subsp.

Length, 5.7 mm; width, 2.8 mm. Derm rufopiceous (perhaps immature) ; body densely scaly, general color dark brown, with small paler blotches here and there on elytra, a vague pale line on sides of prothorax behind eyes, and a pale sutural vitta on declivity of elytra, the prothoracic scales in part iridescent ; prothorax feebly rounded at sides, the disk with small, closely set but isolated, setigerous tubercles.

Rostrum about twice as long as thick, shorter than prothorax, upper surface broadly and rather strongly discontinuous with front in profile, transversely convex and densely scaly in basal two-thirds, subplanate and sparsely scaly apically, the median carina distinct and extending from the groovelike interocular puncture to the interantennal fovea, nasal plate obsolescent, surface behind it subglabrous and roughly punctate, the erect brown setae arranged in two irregular

rows each side, about as in *ovatipennis*. Scape scaly and setose, funicular segments in general a little shorter than in *ovatipennis,* the seventh about as wide as long. Head with a few setae above eye, some of the scales iridescent. Prothorax slightly transverse (about 10-9), apex not constricted; pronotum with small, scale-covered, setigerous tubercles, those on disk more distinctly isolated than in *ovatipennis* because of the virtual absence of scales in the groovelike network of the interspaces, the scales on tubercles more or less iridescent. Elytra ovoid, about as in *ovatipennis;* discal intervals feebly convex, especially laterally, the third and fifth slightly more prominent at base, the suberect setae in a nearly regular row on each discal interval, the serial punctures rather coarse, the serial scales round and not entirely closing the punctures. Beneath scaly and setose, the fifth sternite (♀) broadly, faintly impressed and rugosely punctate. Legs as in *ovatipennis,* the tibiae denticulate on ventral edge.

Type locality.—Rockville, Pa., March 30, 1909, Kirk and Champlain; 1 ♀.

Type.—U.S.N.M. no. 50832.

Differs from *ovatipennis* in its very feebly expanded prothorax, the more distinctly isolated pronotal tubercles, and the slightly shorter intermediate segments of the funicle.

Subgenus PHYMATINUS LeConte

Phymatinus LeConte, Ann. Mag. Nat. Hist., 1869, p. 382. (Monobasic type, *Tyloderes gemmatus* LeConte, Zool. Rep. Expl. and Surv. . . Route . . Miss. . . to Pacific, p. 56, 1857; type locality, Shoalwater Bay, Wash.)

Specimens of *gemmatus* have been examined from various localities in Washington and Oregon. Recorded from California also in Leng catalog. The majority of the specimens seen have at least part of the dorsal scales green, but a few are grayish white with brownish mottlings, and one specimen is predominantly brown above. The rostrum is relatively long, often being at least three times as long as thick at base.

Panscopus (*Phymatinus*) *sulcirostris* Pierce is a synonym of *Agasphaerops nigra* Horn (see Buchanan, Proc. Ent. Soc. Washington, vol. 29, p. 26, 1927).

Subgenus NOCHELES LeConte (PANSCOPIDIUS Pierce)

Nocheles LeConte, Amer. Nat., vol. 8, p. 453, 1874. Though it is evident that LeConte had no intention of founding a new genus at this time, his statement " in one specimen of *Nocheles* but 4 (abdominal segments) are visible " can be considered as establishing the name. The earliest formal description

of *Nocheles* is by Horn, Proc. Amer. Phil. Soc., vol. 15, p. 54, 1876. Mono-
basic type, *Hylobius torpidus* LeConte, Zool. Rep. Expl. and Surv. . . Route
. . Miss. . . to . . Pacific, p. 55, 1857.]

Panscopidius PIERCE, Proc. U. S. Nat. Mus., vol. 45, p. 394, 1913. (Type of sub-
genus, by original designation, *P. squamosus* Pierce, loc. cit., p. 394.)

In this subgenus the rostrum usually has a fine but distinct median
carina, and the last sternite of the female is broadly and shallowly
impressed.

1. Length, 6.5–8 mm; alternate elytral intervals elevated, rather strongly so in
     ♂, more feebly but still evidently so in ♀; legs piceous black; elytral setae
     longer and more conspicuous, especially on alternate intervals (Rochester,
     Puyallup, and Olympia, Wash.; Portland, Oreg.; type locality, Oregon)
                                                                         torpidus LeConte.
     Length about 7 mm; elytral intervals even, or at most faintly elevated in
     ♂; legs reddish; elytral setae shorter.................................2.
2. Elytral scales apparently a little larger, and broadly overlapping on disk of
     elytra [Hilgard, Oreg. (type locality) ; known from the single ♂ type]
                                                                         squamosus Pierce.
        a. Elytral scales apparently smaller and not or only slightly overlapping.
        [Pullman, Wash. (type locality) ; 6 specimens, ♂ and ♀]
                                                            squamosus var. *dentipes* Pierce.

Several specimens (♂ and ♀) collected by M. C. Lane in the Blue
Mountains of Washington, elevation 6,000 feet, are smaller (about
5.5 mm in length) and probably represent another local variant of
squamosus.

DOLICHONOTUS, n. subgen.

Body elongate, scaly and setose, scales very dense on elytra, the
elytral sides converging posteriorly from behind the rounded humeri,
form unusually slender in male. Rostrum stout, nearly twice as long
as wide at apex, feebly arcuate, medially unicarinate, gradually
widened basally, abruptly widened at about apical fourth so that the
apical portion of scrobe becomes broadly visible from above, upper
edge of scrobe toward apex elevated above the general surface ; scrobe
faintly arcuate, obsolete in basal half or more, beginning practically
at apex of rostrum; scape nearly straight, gradually and feebly
widened apically, first two funicular segments longer, fourth, fifth,
and sixth moniliform, seventh about as broad as long. Eyes very
feebly convex, broadly rounded above, narrowed below, separated
above by a little less than basal width of beak. Prothorax relatively
long, ocular lobe well developed ; pronotum more or less distinctly
sulcate at middle, scales dense, setae slender. Scutellum small, de-
pressed. Elytra with basal margin perpendicular from side to side,
alternate (odd) intervals elevated, more strongly so in ♂, the sutural

costa behind middle more prominent than the others, setae numerous on elevated intervals, sparse or practically wanting on some of the flat intervals; side margin of elytra rather abruptly bent downward behind rear coxa. Beneath and legs setose and densely scaly. Intercoxal piece of first sternite wide and subtruncate. Tibiae mucronate, third tarsal segment bilobed. A short length of the metepisternal suture visible opposite rear coxa.

Type of subgenus.—Panscopus (*Dolichonotus*) *convergens,* n. sp.

♂ and ♀, length about 8 mm; ♂, fifth sternite about two-thirds as long as broad, hind tibia nearly straight, its mucro subacute at tip . . . *convergens,* n. sp.
♂, length 6.5 mm; fifth sternite nearly as long as broad, hind tibia broadly emarginate on ventral margin, its mucro rounded at tip. . . . . *oregonensis,* n. sp.

PANSCOPUS (DOLICHONOTUS) CONVERGENS, n. sp.

Length, ♂ 7.8, ♀ 8.1 mm; width, ♂ 2.8, ♀ 3.3 mm. Derm black to rufopiceous, prevailing color of scales fuscous, ♂ with elytral flanks paler, the elytra of ♀ dull yellowish brown with small, irregular blackish areas. Pronotum feebly sulcate along middle, the sulcus present only toward apex in ♀, interrupted at middle in ♂, the general surface densely scaly and with small, shining black, setigerous tubercles showing through the vestiture; elytral costae with a crowded, double (in places triple) row of stiff, rather coarse, slightly curved setae, posteriorly inclined on disk, more nearly erect on declivity; fifth sternite of ♂ two-thirds as long as broad; hind tibia of ♂ nearly straight, its mucro subacute at tip.

Rostrum one-sixth shorter than prothorax, upper surface continuous with front in profile, broadly convex basally, subplanate apically, above, except at apex, densely clothed with small brown scales and short, curved setae, surface densely punctate, apical one-fifth thinly scaly and rugosely punctate; nasal plate not sharply defined; median carina fine but distinct, and extending from base nearly to antennal socket; rostrum at sides densely scaly in basal half; interocular puncture minute; head finely and densely punctate, the small scales becoming quite slender on vertex, a few subprostrate setae above eye. Prothorax slightly longer than wide (♂) or slightly wider than long (♀), widest before middle, base wider than apex (about 5 to 4), sides broadly rounded, more strongly so in ♀, feebly constricted near base, scarcely so apically; pronotum, except median line, with small, shiny, setigerous tubercles or granules, which are not entirely covered by the scales and some of which are connected by fine, irregular carinae, rest of surface densely and irregularly punctate beneath the scales.

Elytra with rows of well separated punctures, each covered by a sub-circular scale, sides converging from behind humeri, more strongly so in the attenuated male, costae feebler basally, strong apically, the sutural one very prominent at top of declivity, second interval in both sexes with a few setae near base and on declivity, fourth interval same in ♂, but in ♀ with a widely spaced row from base to middle, sixth in ♀ with a similar row its entire length, sixth in ♂ with a few basally and apically; declivity subvertical in ♂, slightly reflexed in ♀. Legs densely scaly, tibiae subcylindrical in basal half, ventral edge in apical half with a few erect denticulations, which are obsolescent on hind legs; in ♂ the posterior face of the hind tibia is more or less flattened in the apical third and slightly hollowed near apex, the two anterior tibiae with a similar but feebler modification, the anterior pair slightly sinuate; ♀ with posterior tibia modified as in ♂, the two anterior pairs nearly simple; posterior femur in ♂ longer and slenderer than the other femora; mucro on posterior tibia of ♂ stout, tapering to apex, and with a short, erect spur at base. First sternite of ♂ rather deeply depressed, the concavity densely clothed with subprostrate setae, rest of abdomen densely scaly and setose, the broad scales confined to about lateral third of the first to fourth sternites and to the latero-anterior part of the fifth, rest of surface with dense, in-clined setae and a few prostrate scales; abdomen of ♀ densely clothed with scales and setae, the fifth sternite with finer vestiture, the first sternite convex, the fifth sternite shorter and more narrowly rounded at apex than in ♂.

Type locality.—Corvallis, Oreg., May 20, 1925, E. R. Buckell, 2 specimens (♂ and ♀).

Type.—♂, U.S.N.M. no. 50647.

The male of this species is the narrowest of any *Panscopus* (sens. lat.). Superficially *convergens* resembles *torpidus* LeConte, but there the scape and abdomen are setose but not scaly, the legs at most thinly scaly, the body form stouter, the hind tibial mucro of male without spur, and the abdomen of female 4-segmented.

PANSCOPUS (DOLICHONOTUS) OREGONENSIS, n. sp.

Length, ♂ 6.5 mm; width, 2.4 mm (♀ unknown). Derm piceous to rufopiceous, prothorax and rostrum blackish. Body setose and densely scaly, general color of scales pale brown, becoming fuscous toward apex of elytra, paler in a short vague humeral line and at sides of pronotum. Elytral sides converging posteriorly from about basal fourth, the general form somewhat less slender than in *convergens*.

Fifth sternite about seven-eighths as long as broad. Ventral edge of hind tibia emarginate.

Rostrum stout, upper surface subcontinuous with head in profile, median carina reaching from base to nasal plate. Antenna about as in *convergens*. Prothorax about as long as wide, widest before middle, sides more strongly rounded than in *convergens,* and slightly constricted near apex, faintly so near base; pronotum medially sulcate, general surface rather densely clothed with broad, striated scales, which toward middle do not entirely conceal the small, shiny black, setigerous tubercles or granules, the latter joined here and there (and especially each side of sulcus), with irregular carinae, the scales denser toward sides. Elytral costae with a crowded row (double for the most part) of posteriorly inclined setae similar to those in *convergens,* second and fourth intervals without setae except near base and apex, sixth with a widely spaced single row, serial punctures and scales about as in *convergens*. Beneath scaly and setose, the abdominal scales dense basally, somewhat sparser on third and fourth sternites, and replaced by inclined setae on apical portion of fifth sternite; intercoxal piece relatively broader and not so deeply impressed as in ♂ *convergens;* femora, especially hind pair, shorter and stouter than in *convergens;* hind tibia broadly emarginate on ventral edge from basal three-sevenths to apex, the posterior face in apical half flattened, shiny, and sparsely setose; mid tibia similarly but more feebly modified, fore tibia sinuate; mid and mid tibiae denticulate on ventral edge; hind tibial mucro ♂ broad, flattened, and faintly curved, the apex rounded.

Type locality.—Forest Grove, Oreg., June 18, 1923; 1 ♂.

Type.—U.S.N.M. no. 50648.

The unusually long fifth sternite, the structure of the hind tibia, and the subspatulate hind tibial mucro distinguish the male of this species from that of *convergens*.

Subgenus PSEUDOPANSCOPUS Buchanan

Pseudopanscopus BUCHANAN, Proc. Ent. Soc. Washington, vol. 29, p. 33, 1927. [Monobasic type, *P. costatus* Buchanan, loc. cit., p. 33; type locality, Chilliwack, British Columbia. Specimens have been examined also from " Was.," Puyallup, Wash. (W. W. Baker), and Seattle, Wash.]

Subgenus NEOPANSCOPUS Pierce

Neopanscopus PIERCE, Proc. U. S. Nat. Mus., vol. 45, p. 397, 1913. (Type as designated by Pierce, loc. cit., *Nocheles aequalis* Horn, Proc. Amer. Philos. Soc., vol. 15, p. 55, 1876.)

1. Pronotal tubercles plainly visible among the scales, the pronotal surface considerably roughened or rugose, with the median sulcus more or less developed; a feeble humeral swelling usually present (between origins of sixth and ninth striae) ; pronotal scales striated; prevailing color cinereous or cinereous mottled with brown (western North America)

aequalis Horn (*cinereus* Horn; *vestitus* Casey).

Pronotal surface smooth and completely covered with appressed, in part nonstriated scales, the median sulcus wanting or faintly indicated; humeral swelling wanting ....2.

2. Length, 6.7 mm; elytral intervals evidently, though rather feebly, convex; elytral setae long (about as in *aequalis*) ; prothorax wider than long, the sides strongly rounded (♀) [Placer County, Calif. (type locality]

squamifrons Pierce.

Length, 4.4 mm; elytral intervals subplanate, the setae short and inconspicuous; prothorax as long as wide (♂) (Placer County, Calif.)

wickhami, n. sp.

PANSCOPUS (NEOPANSCOPUS) WICKHAMI, n. sp.

Length, ♂ 4.4 mm; width, 1.7 mm. Body slender, subparallel, densely scaly, the prothorax as long as broad; color irregularly and feebly variegated brown and cinereous, the scales in part somewhat varnishlike in luster, especially on head, prothorax, and femora; rostrum above densely scaly to apex, only the nasal plate bare, the apical region faintly impressed; surface sculpture of pronotum completely covered by an even coating of flat, closely appressed scales; elytral intervals nearly flat, each with an irregular row of rather fine, short, pale brownish setae, the serial punctures quite widely spaced.

Rostrum practically straight, a little more than twice as long as thick, about five-sixths as long as prothorax, narrowest about middle, gradually and very feebly widened basally, abruptly and strongly so toward apex, upper surface subcontinuous with front in profile, setae above short, scales dense, no indication of carinae through the vestiture. Eyes feebly convex, separated above by basal width of rostrum ; no frontal fovea visible. Antennal scape setose and densely scaly, reaching a little past middle of eye, fourth to sixth funicular segments submoniliform, seventh distinctly broader than long. Prothorax nearly as wide at apex as at base, widest in front of middle, sides converging and just perceptibly sinuate toward base, not constricted apically, ocular lobe distinct; pronotum evenly convex, the setae subprostrate and inconspicuous. Elytra broadly emarginate at base, sides nearly straight and slightly convergent behind the unusually narrow shoulders, surface even, the sutural interval not elevated on declivity; scales in serial punctures rounded, about same size and sometimes same color as the surface scales, the former then scarcely

distinguishable from the latter. Beneath and legs densely covered
with cinereous scales; anterior tibial denticulations distinct, ventral
edge of posterior tibia slightly convex longitudinally and with a few
yellowish spines in addition to the fine hairs. A very short length of
metepisternal suture visible opposite rear coxa.

Type locality.—Truckee, Calif., 5,800 feet, August; Wickham; 1 ♂.
Type.—U.S.N.M. no. 50651.

The small size, narrow form, relatively wide apex of prothorax,
smooth pronotum, and short elytral setae are distinctive features of
this species. The single specimen is the only recorded male in
Neopanscopus.

P. wickhami and *squamifrons* differ from all described *Panscopus*
(sens. lat.) in the smooth coating of scales on the pronotum. Horn's
species *aequalis* is a complex unit that ranges from Colorado, Utah,
Nevada, and California north to Alberta, Saskatchewan, and North
Dakota. Horn's original description calls for " Kansas to British
Columbia."

Subgenus NOMIDUS Casey

Nomidus Casey, Ann. New York Acad. Sci., vol. 8, p. 818, 1895 (Coleoptero-
    logical Notices 6). (Monobasic type, *N. abruptus* Casey, loc. cit., p. 819.)

Including the two described herein, there are now 10 named forms
referable to this subgenus. Though all of them appear to be at least
subspecifically distinct, they are not susceptible of satisfactory dicho-
tomous arrangement on external characters; and it is evident that
some other approach (perhaps through a study of ♂ and ♀ genitalia)
will be necessary to place the classification on a sound basis. The
following key is intended merely as a guide to the original descriptions
of the various forms:

1. Dorsal scales, in part, green; alternate elytral intervals distinctly costate;
    scape setose only, the derm plainly visible; rostrum rather slender, about
    3 times as long as thick at base, and with a fine median carina (at least
    in ♂) [Humtulips, Wash. (type locality) (Pan-Pacific Ent., vol. 11, p. 9,
    1935)] ....*johnsoni* Van Dyke.
    Dorsal scales not green; scape setose and squamose, the derm more or less
    completely covered (the prostrate scales are sometimes slender); rostrum
    usually stouter ....2.
2. Hind tibia more or less bent, its lower edge broadly and feebly convex in
    profile and with some coarse brown or blackish spines in addition to the
    setae (at least in ♀); rostrum above feebly convex in basal three-fourths,
    more nearly continuous with front in profile, rostral carinae wanting or
    feeble ....3.
    Hind tibia nearly straight, its lower edge with setae only (except some speci-
    mens of *tricarinatus*); rostrum a little longer in most species, usually rising

more or less abruptly from head, above in basal three-fourths feebly convex
to subplanate, and usually with distinct median and sometimes lateral cari-
nae (all of which may be obscured by scales)...........................6.

3. Elytral costae faint, scarcely perceptible except near base, and with a mostly
double row of setae; even intervals with a rather closely set row of setae
which is partly double on fourth interval; length, 7 mm (1 ♀) [Inyo County,
Calif. (type locality)]................................*bufo* Buchanan.
Elytral costae evident, though not always strong; setae on even intervals
sparser (except sometimes in *rugicollis*) or wanting..................4.

4. Color brownish black; even elytral intervals nonsetose; rostrum with or
without a median carina; mentum sometimes with a trace of a median
carina; metepisternal suture sometimes obliterated; apical declivity of
elytra distinctly reflexed in profile (in ♀, the ♂ unknown); length, 7.5–9 mm
["Cal." (type locality); Fallen Leaf Lake, Calif.; Easton and Mount
Adams, Wash.] ....*abruptus* Casey.
Color usually paler brown; even elytral intervals with at least a few setae;
a short length of metepisternal suture visible opposite hind coxa; apical
declivity of elytra (♀) subperpendicular or slightly reflexed in profile.....5.

5. Length, 6.25–7.5 mm; mentum with a feeble median carina in apical half;
pronotal rugosities coarser; even elytral intervals setose their entire length
[Mount Adams, Wash. (type locality); Mount Rainier and Easton, Wash.
(W. W. Baker); Mount Hood, Oreg. (M. C. Lane)]..*rugicollis* Buchanan.
Length, 5.25–6.25 mm; mentum noncarinate; elytral costae stronger, elytral
setae longer and in a double or partly triple row on the costae, the flat
intervals sparsely and irregularly setose, or nonsetose except toward base.
[Alta, Utah (type locality); Priest River, Idaho]...*schwarzi* Buchanan.

6. Elytral costae faint, all elytral intervals setose, the setae subsetaceous (about
shape of those in *Neopanscopus aequalis*); denticulations on lower edge of
fore and mid-tibiae strong; rostrum medially unicarinate; apical declivity
of elytra (♀) more strongly reflexed; length, 7.6–8.3 mm (Washington)
                                                              longus, new species.
Elytral costae usually evident, often strong; elytral setae blunt; tibial dentic-
ulations feebler; declivity of elytra (♀) subperpendicular................7.

7. All elytral intervals setose...8.
Even intervals nearly or quite nonsetose...............................9.

8. Length, 5.5–7.5 mm. Prothorax widest in front of middle; rostrum some-
times noncarinate, but usually with a more or less distinct median carina,
and occasionally with lateral ones also [Kaslo, British Columbia (type lo-
cality); Salmon Arm, Kimberly, Vernon, and Grand Forks, British Co-
lumbia; Molson and Tieton, Wash.; Big Fork, Mont.]..*pallidus* Buchanan.
Length, 5–6 mm. Prothorax widest about middle; rostrum usually with three
relatively coarse carinae [Parkdale, Oreg. (type locality); Mount Hood,
Oreg.] ....*tricarinatus* Buchanan.

9. Elytral costae strong; seventh funicular segment only slightly wider than
long; rostrum usually with median carina only; length, 6–7.5 mm (Electron,
Wash.) ....*bakeri,* n. sp.
Elytral costae broader and feebler; seventh funicular segment about twice as
broad as long; rostrum tricarinate; length, 6–6.5 mm [Banff Springs, Al-
berta (type locality); Olds, Alberta (Wickham collection)]..*ovalis* Pierce.

PANSCOPUS (NOMIDUS) LONGUS, n. sp.

Length, 7.6–8.3 mm; width, 3.1–3.8 mm. Relatively elongate; rostrum with a fine median carina; scape setose and scaly, nearly reaching the middle of eye, seventh funicular segment a little longer than broad, fourth to sixth segments not moniliform and about as long as broad; median pronotal sulcus distinct apically, interrupted at middle, and very feeble or obsolescent basally; elytra with alternate intervals not or very little elevated, the setae suberect and finer than usual. Derm blackish or piceous black, the scales dense, cinereous and brown, forming variable and irregular markings which sometimes are oblique, asymmetrical bars on the elytra.

Rostrum stout, feebly arcuate, somewhat more than twice as long as thick, about as long as prothorax, a little longer in ♂ than in ♀, upper surface broadly and shallowly discontinuous with front in profile, subplanate or feebly convex except at the nearly scaleless apical area which is, as usual, more or less impressed between the elevated edges of the scrobes, nasal plate well defined, its apex sometimes produced backward to the interantennal fovea; above densely scaly and with numerous suberect setae, the vestiture cinereous to fuscous and not entirely covering the median carina, which extends from the interantennal fovea to the fine interocular groove, the latter sometimes invisible; scrobe gradually evanescent posteriorly but sometimes nearly reaching the eye as a shallow, sparsely scaly sulcus. Prothorax slightly wider than long in the ♂, somewhat wider in the ♀, base wider than apex (about 5 to 4), sides nearly straight and divergent in about basal two-thirds, then converging and faintly constricted apically; pronotum rugose-tuberculate, the tubercles small and sometimes nearly covered with the dense scales, the summit of each tubercle with a slender, slightly curved seta. Elytra elongate for this subgroup, serial punctures moderately coarse, the setae slender, some of them subacute at tip and appearing bristlelike (much as in *aequalis* and *squamifrons*), sutural and third intervals slightly more prominent than second, at least in apical half, the fourth interval similarly convex in about apical half, the fifth, sixth, and seventh feebly and subequally convex throughout. Setae, in general, more numerous on alternate intervals, where they usually form a confused double or partly triple row; but where the convexity of adjacent intervals is the same, the setae may be almost or quite as abundant on even as on odd intervals. Beneath setose and densely scaly. A short length of metepisternal suture visible opposite rear coxa. Hind tibia nearly straight, the ventral edge hairy but without spines.

Type locality.—Peshastin, Wash., April 8, 1934, W. W. Baker, collector, Truck Crop no. 4995; 1 ♂ and 2 ♀♀. Same locality, April 7, 1934, P. M. Eide; 1 ♀.

Type.—♂, U.S.N.M. no. 50650.

Larger and more elongate, and with finer and more nearly erect elytral setae than in any of the nearly related forms of *Nomidus*. It is closest to *pallidus,* but that species has the prothorax stouter and more coarsely sculptured, the pronotal channel generally broader and deeper, the alternate elytral intervals more prominent, and the even ones with sparser and much stouter setae. In the female of *longus* the depth of the body at the metasternum is about half the length of the elytra; in the stouter female of *pallidus,* this depth is more than half the elytral length.

PANSCOPUS (NOMIDUS) BAKERI, n. sp.

Length, 6–7.6 mm; width, 2.4–3.7 mm, the females longer and stouter than the males. Scales dense, distinctly striated. Derm black, prevailing color of scales cinereous and brown, the pale scales, especially those in the serial punctures of the elytra, often more or less tinged with silvery or pale greenish blue, the brown scales often obscure aeneous and grouped into irregular and asymmetrical elytral brown markings that tend to form oblique bars, some specimens dark, more rarely nearly uniform cinereous; rostrum with a usually distinct median carina (it may be covered by scales) and occasionally faint lateral ones; antennal scape setose and scaly, reaching middle of eye; pronotal channel usually broad and deep apically, narrower and shallower, or sometimes obsolescent, in basal half, rest of surface rugose-tuberculate; sutural (except basally) and alternate elytral intervals costate, and with a crowded, in places double, row of blunt setae, the even intervals without setae except second along middle third of its length in some females.

Rostrum stout, feebly arcuate, somewhat more than twice as long as thick, about as long as prothorax, much thicker and wider apically, upper surface in profile plainly discontinuous with front, densely scaly and sparsely setose except on and behind the well-defined nasal plate, the surface from about apical third to apex usually lightly concave, more broadly and deeply so near apex, the median carina usually rather broad and conspicuous basally but finer or obsolescent beyond middle; interantennal fovea, when present, rather coarse and groovelike; interocular fovea often groovelike, and frequently produced backward onto the head as a very fine groove or smooth line, which

sometimes reaches the vertex; scrobe feebly arcuate, usually obsolescent at about basal third of rostrum; funicular segments 1 and 2 subequal or 1 longer, 4, 5, and 6 submoniliform, 7 a little wider than long. Prothorax one-seventh to one-fourth broader than long, wider at base than at apex, widest in front of middle, side margins irregularly scalloped and nearly straight and convergent to base, shallowly constricted toward apex, the constricting line rather deeply impressed behind the strong ocular lobe and across the prosternum; pronotal tubercles or granules coarse for this group, some of them partially coalescent, normally nearly covered by scales, those on disk often bare at summit, each with a puncture and seta at summit. Elytra with rows of coarse serial punctures each nearly closed by a subcircular scale; costae distinct, that on sutural interval at top of declivity most prominent; declivity in profile perpendicular in female, oblique in male. Beneath and legs setose and densely scaly. Ventral edge of hind tibia nearly straight, clothed with hairs and stiff setae, but without coarse spines. Fifth sternite of ♂, as usual in the genus, longer and more broadly rounded at apex. A short length of metepisternal suture visible opposite rear coxa.

Type locality.—Electron, Wash., W. W. Baker, collector, Truck Crop no. 4971; 64 specimens, mostly taken during June 1933, a few in September and October.

Other locality.—Montesano, Wash., March 30, 1932. W. W. Baker, 1 specimen. Mr. Baker states, in litt., that this specimen may have been washed down from the vicinity of Electron.

Type.—♂, U.S.N.M. no. 50649.

Closest to *ovalis* Pierce from Alberta, but that species has three distinct rostral carinae, the median strong throughout, the space between median and lateral carinae groovelike, the seventh funicular segment strongly transverse, the pronotal tubercles more numerous but smaller, the antennal scape not reaching middle of eye, and the alternate elytral intervals more feebly elevated. The elytral costae of *bakeri,* on the average, are at least as prominent as in any other *Nomidus.* The uniform dark brown color of *ovalis,* as previously recorded by the writer, was the result of discoloration; the type specimen, recently cleaned, proves to be light brown on the disk of the pronotum and elytra, paler at the sides.

GROWTH OF A GREEN ALGA IN ISOLATED WAVE-LENGTH REGIONS

(With One Plate)

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

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INTRODUCTION

The importance of experimentation with isolated narrow ranges of light for the determination of the effectiveness of specific wave lengths on cell multiplication and chlorophyll formation in green algae was manifested in a previous paper by Meier (1934 b). In the research reported in that paper, 11 short wave length cut-off filters were used to transmit light of progressively shorter and shorter wave lengths from one transmitting only deep red, 6000 A, to one at the other extreme, 3700 A, where most of the visible region is included. Chlorophyll was formed in the unicellular green alga, *Stichococcus bacillaris* Naegeli, under all the filters but in best condition where the wave lengths of the blue-violet region were included. A multiplication of algal cells ranging from twofold to fourfold was obtained in the cultures. It was evident that some ranges of wave lengths seemed to inhibit cell multiplication and chlorophyll formation and that others seemed to favor them. Considering the complexity of the bands of radiation from the short wave length cut-off filters, it was clear that the effectiveness of restricted wave-length regions could be determined conclusively by experimentation in the isolated narrow ranges of light such as can be provided by Christiansen filters.

isms, L. B. Clark, and L. A. Fillmen, the successful experiments herein described were conducted under controlled conditions of temperature, humidity, and illumination.

LITERATURE

As discussed by Meier (1934 b) in more detail, some of the earlier investigators including Wiesner (1874), Artari (1899), Teodoresco (1899, 1929), Nadson (1910), and Arthur (1930), who experimented with plants growing under filters of glass and of chemical solutions, as the case may be, without especial attention to the effect of isolated wave lengths, found that their plants displayed more normal development under blue light than in the other colored lights. Teodoresco (1899, 1934) found that green light caused the poorest chlorophyll development in plants.

In his research with *Scenedesmus acutus,* growing under Senebier jars of chemical solutions, Grintzesco (1902) found that the development of the colonies was more active in the blue-violet than in the red-yellow light.

Shirley (1929) grew higher plants in a series of houses covered with glass filters transmitting definite spectral regions. He found the entire visible and ultraviolet solar spectrum to be more efficient for the growth of the plants than any small portion of it used. The blue region was more efficient than the red region.

A. Brooker Klugh (1925), using Wratten light filters whose transmission value he had very nearly equalized, found that *Volvox aureus* and *Closterium accrosum* reproduced most in red light, less in blue light, and not at all in green light.

Funke (1931) grew varieties of *Sempervivum, Ajuga,* and *Glechoma* under glass filters which let through different colored lights equalling in intensity about 25 percent of the energy of diffuse daylight. He found that the development in blue was similar to that in full daylight, red had the same influence as darkness, green produced the same phenomenon as red, or reduced development to a minimum; while in gray (subdued white light) the results were midway between those of red and blue.

Hutchinson and Ashton (1929) irradiated live specimens of *Paramoecium caudatum* in isolated wave lengths of a Hilger monochromatic illuminator operated at a low intensity of illumination. After 24 hours' exposure to the red-yellow (6152-5769 A), blue (4359-4348 A), or near ultraviolet (3663-3132 A), stimulation of growth was observed in *Paramoecia.* Retardation of growth and even death

were observed in the specimens exposed for 24 hours to the green
(4968-4916 A), violet (4078-3821 A), or ultraviolet (3028-2054 A).

Johnston (1932) discusses at length the effect of infrared on the
growth of plants as observed in his own experiments in addition to
the conclusions formulated by other investigators. In general, it is
agreed that if not actually destructive, the infrared region of the
spectrum is of little or no benefit to chlorophyll formation. Burns
(1933) also found infrared radiation detrimental to photosynthesis.

There exists considerable difference of opinion regarding the effec-
tiveness of the various wave lengths. Warburg and Negelein (1923)
have found the maximum chlorophyll assimilation of *Chlorella vul-
garis* to be in the red (6100-6900 A), with a minimum in the blue
(4360 A). Gabrielson (1935) also found assimilation in *Sinapsis
alba* to be greatest in red-orange light and least in the blue-violet.
Dangeard (1927), using Wratten filters, found that growth and mul-
tiplication of green algae, blue-green algae, and diatoms takes place
only in red-orange light, the other radiations affecting the plants as if
they were in complete darkness.

Numerous other scientists could be cited whose work gives rather
contradictory results. The fact that careful scientific workers have pro-
duced contradictory evidence that leads to uncertainties emphasizes
the need for precise quantitative work with isolated narrow wave
length bands of light.

THE PLANT STUDIED

The unicellular green alga *Stichococcus bacillaris* Naegeli has an
elongated cell usually varying from 2 to 2.5 μ in diameter and 4 to
8 μ in length. Multiplication takes place by transverse division of the
protoplast which partially fills the cell and the formation of cross
walls.

Cultures of this alga remain green in the dark for 2 months on
Detmer $\frac{1}{4}$ agar plus 2 percent dextrose, as reported by Meier (1934 a).
The best growing conditions for this alga in an artificial environment
were found by Meier (1934 b) to be in Detmer $\frac{1}{3}$ solution in inter-
mittent light when the cultures were kept agitated to favor more
equal distribution of the cells, multiplication, and a more uniform
lighting condition. It was also found that rubber stoppers serve as
well as cotton plugs in 300 cc flasks containing 100 cc of inoculated
solution for an experimental period of a month. Multiplication of
this alga is proportional to the intensity of illumination, ranging from
3.76 to 34.1 microwatts/mm^2. A higher intensity such as 102.0 micro-
watts/mm^2 checks the growth.

APPARATUS AND TECHNIQUE

The same metal table described by Meier (1934 b) was remodeled and utilized for this experiment. (See pl. 1.) This metal table is constructed with four glass-bottomed water baths, each holding two 300 cc Erlenmeyer flasks. The four water baths are connected to a centrally located thermostated mixing chamber which kept the temperature at 19° C. In order to insure uniform dispersion of the algal cells, a common driving mechanism continually agitates the Erlenmeyer flasks. One of the cultures in each bath is illuminated from below by monochromatic light from a light filter. Mazda projection lamps served as the source of illumination. The other culture in each bath was contained in an Erlenmeyer flask which had been

TABLE 1.—*Percentage Decrease in Intensity During Each Experimental Period of 2 Weeks*

	Experiments		
Filter	2	3	4
Blue			
(4000-5200 A)	33.5	26.5	
Green			
(5000-5600 A)	50.0	27.0	
Yellow			
(5500-6200 A)	40.0	22.5	21.0
Red			
(6000-7500 A)	28.0	17.5	20.0
Infrared			9.5
(8500-12000 A)			10.0

NOTE.—Intensity at beginning of each experiment was 19.5 to 20 microwatts/mm² for each wave-length region.

painted black to prevent the entrance of any light, thus providing a check on the culture conditions in each bath. Each of the successful experiments described here was run for a period of 2 weeks (April 9-23, May 7-21, and June 6-20, 1935), during which the temperature, humidity, and light quality were maintained constant. The cultures were given 12 hours of illumination daily, from 9:30 a. m. to 9:30 p. m. The cells in a drop of .01 cc volume obtained with the aid of a specially calibrated pipette and a microscope slide marked in 2-mm squares were counted microscopically for each culture at the beginning and at the end of the experiment. Nephelometric measurements of the increase of liquid turbidity as an indirect check upon the observed multiplication of cells in each culture were also made as described by Meier (1934 b). The light intensity was 19.5 to 20 microwatts/mm² for each wave-length region at the beginning of each experiment. The intensity dropped during each experiment as recorded in table 1.

The Christiansen filters used were constructed as described by McAlister (1935) and are shown in plate 1 on the low wooden tables by the lamps. The temperatures of the Christiansen filters were recorded twice daily to insure control of the 3 monochromatic beams utilized which were: red, yellow, and green. A Corning heat-resisting red glass filter, "205 percent", was combined with one of the Christiansen filters to give the desired region in the red. Because of the difficulty in obtaining a light source of sufficiently high intensity that would work practically with the blue Christiansen filter, it was
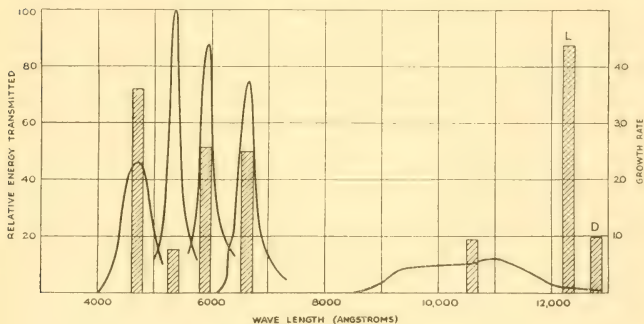

Fig. 1.—A diagram of the growth rate or cell multiplication (columns) super-imposed on a diagram showing the relative energy transmitted by each filter (curves). The columns marked L and D indicate the results of daylight and darkness respectively. The abscissae indicate wave lengths. On the right is a scale of ordinates for the cross-hatched columns representing cell multiplication. On the left is a scale of ordinates representing intensities of the radiation groups. The areas under the curves representing radiation are equal, indicating the equality of radiation stimuli for visible and infrared rays. For full daylight, however, no measurement of the intensity of the radiation stimulus is available, hence the cell multiplication in daylight is not strictly comparable to the other results.

found necessary to use a saturated solution of copper sulfate as a filter. For the infrared cultures, two duplicate Corning heat-transmitting glass filters no. 254 were used. The wave-length regions for the filters are listed in the tables and shown graphically in figure 1. The daylight cultures were grown under natural conditions of day and night in a north window of a room in the Smithsonian flag tower. The dark cultures were grown in a sealed drawer of the same room.

Numerous experiments were essayed for over a year before the three successful ones reported were completed. In experiments 2 and 3, the red, yellow, green, and blue colors, as described above, were tested. The green and blue results checked in both experiments, but

as there still seemed to be some doubt as to the results of the red and yellow filters, a third experiment was run repeating the red and yellow, and with the duplicate infrared filters in place of the green and blue ones.

RESULTS

CELL MULTIPLICATION

The cells in five drops of each culture were counted and the mean was determined. As determined by the microscopic count, there was an average of seven cells in a drop of the initial cultures before treatment. The ratio of the means of the final to the initial cell count of each culture after 2 weeks of exposure to the different wave-length regions is recorded in table 2.

The nephelometric measurement, or the intensity of the light transmitted by each culture, was determined before and after each experiment. The ratio of the final to the initial measurement for each wavelength region is likewise recorded in table 2.

An examination of the cell count ratios and the nephelometric measurement ratios in table 2 shows that the check culture varies less from the treated culture of each region according to the nephelometric measurements than it does according to the cell counts. The cell counts of the check cultures show that darkness had a depressing effect on the cell multiplication, whereas the nephelometric measurements of the check cultures record the turbidity of the solution. Consequently, it hardly seems that the nephelometric measurement ratios should receive as much weight as the cell count ratios. A comparison of the two types of measurement shows that the nephelometric measurement results roughly support the cell count results.

A correction to the nephelometric indications was thought to be advisable, and was made as follows. It appeared that the nephelometric values showed a small increase of turbidity for the liquids which remained in darkness. (See table 2.) As counts showed that such a change was not caused by multiplication of algae, it seemed probably to be due to another cause, not readily ascertained, but no doubt equally operative with the flasks in which the algae were treated with radiation. Hence it seemed proper to divide the nephelometric ratios found in irradiated flasks by the mean nephelometric ratios found in the dark or check flasks before considering the nephelometric evidence as to algal multiplication under radiation. (See tables 2 and 3.)

TABLE 2.—*Growth Measurements* (*final/initial*)

Filter	Cell count ratio — Experiment 2 Check	Treated	Experiment 3 Check	Treated	Experiment 4 Check	Treated	Nephelometric measurement ratio — Experiment 2 Check	Treated	Experiment 3 Check	Treated	Experiment 4 Check	Treated
Blue (4000-5200 A)	0.86	3.6	1.6	3.6			1.4	2.7	1.6	2.8		
Green (5000-5600 A)	0.70	0.76	1.7	0.76			1.2	1.4	1.5	1.0		
Yellow (5500-6200 A)	0.86	2.1	1.6	2.7	1.0	2.9	2.0	2.4	1.7	2.3	1.3	2.3
Red (6000-7500 A)	0.71	1.6	1.0	3.6	0.86	2.3	1.3	1.9	1.7	3.1	1.2	2.1
Infrared (8500-12000 A)					1.1	1.0					1.1	1.1
					0.85	0.86					1.1	1.2
Daylight	0.86	4.5	1.0	4.0	1.1	4.6	1.1	3.9	1.6	4.6	1.4	4.7

TABLE 3.—*Comparison of Nephelometric Measurements with Cell Counts*

Filter	Nephelometric measurements treated/check			Growth rate according to cell count			Mean	
	Experiment			Experiment			Cell Counts	Nephelometric measurements treated/check
	2	3	4	2	3	4		
Blue (4000-5200 A)	1.93	1.75		3.6	3.6		3.60	1.84
Green (5000-5600 A)	1.17	.67		0.76	0.76		0.76	0.92
Yellow (5500-6200 A)	1.20	1.35	1.77	2.1	2.7	2.9	2.57	1.44
Red (6000-7500 A)	1.46	1.82	1.75	1.6	3.6	2.3	2.50	1.68
Infrared (8500-12000 A)		1.00	1.09		1.0	0.86	0.93	1.05
Daylight	3.55	2.88	3.36	4.5	4.0	4.6	4.37	3.26

The means for the three experiments were then determined. (See table 3.) When the means of the nephelometric results are compared with the means of the ratios of the cell counts, the same general result is obtained.

In figure 1, a diagram is given of the cell multiplication for each wave-length region superimposed on a diagram showing the relative energy transmitted by each filter. The columns marked L and D indicate results of daylight and darkness respectively. The blue region produces the greatest amount of increase over the other regions, the red and the yellow show considerable increase, the green gives a decrease, and the infrared shows no change. The daylight, the combination of all the regions of the spectrum, gives the largest increase of all. Since, however, no measurement of the intensity of the radiation stimulation was possible for daylight, the daylight results cannot be considered exactly comparable to those of the filters where the radiation stimuli are known to be equal.

The nephelometric measurement, being a very indirect method of measurement of cell multiplication, since it is based on the turbidity of the solution which doubtless undergoes a change during 2 weeks, should not be regarded as anything more than a check on the results. The cell counts give the definite result of the experiment.

CELL LENGTH

The lengths of 25 cells of each culture were measured and the means were recorded in table 4. The accuracy of the width measurements was not sufficient to show a possible increase of 20 percent. Hence, assuming no increase in width or thickness, but increased

TABLE 4.—*Cell Length (mm) at Completion of Experiments*

Filter	Experiments			Mean	Growth rate or cell count ratio (final/initial)	Assumed total volume
	2	3	4			
Blue (4000-5200 A)	.058	.064		.061	3.60	220
Green (5000-5600 A)	.055	.049		.052	0.76	40
Yellow (5500-6200 A)	.051	.064	.048	.054	2.57	139
Red (6000-7500 A)	.048	.053	.052	.051	2.50	128
Infrared (8500-12000 A)			.050	.050	0.93	47
Darkness	.058	.056	.056	.057	0.99	56
Daylight	.062	.054	.047	.054	4.37	236

length and multiplication of numbers as observed, the volumes of the cultures after exposure were proportional to the numbers in the final column which are the products of the mean length by the growth rate according to the cell count ratio.

These figures indicate that the blue region produced almost as large a volume as did the daylight, and one that exceeds greatly that produced by the other regions. The red and yellow regions also show a large increase in volume, while the infrared and the green cultures are less in volume than those cultures exposed to darkness.

APPEARANCE OF THE CELLS

The cells that had developed in the blue, yellow, and red regions contained beautiful green plastids, even more green than those in the daylight cultures. There were green plastids in the cells of the cultures exposed to the green wave-length region, but a great deal of granular material was also present. In the infrared cultures, the plastids were green, but there were large vacuoles and much granular material present in each cell. The cells grown in the darkness contained faded yellow-green plastids that were shriveled, broken, and in general presented a disintegrated appearance.

SUMMARY

The cell multiplication and cell length of the unicellular green alga *Stichococcus bacillaris* Naegeli were determined after 2 weeks' growth in five isolated wave-length regions of artificial light, in daylight, and in darkness.

Christiansen filters were used for the green (5000-5600 A) and yellow (5500-6200 A) regions; a combined Christiansen filter and a Corning heat-resisting red glass filter, " 205 percent ", provided the red (6000-7500 A) ; a saturated copper sulfate solution gave the blue (4000-5200 A) ; and a Corning heat-transmitting glass filter no. 254, gave the infrared (8500-12000 A). The light intensity was 19.5 to 20 microwatts/mm ^{2} for each wave-length region at the beginning of each experiment.

A multiplication of algal cells of over fourfold was obtained in the daylight cultures by cell counts supported by nephelometric measurements ; over threefold in the blue, and over twofold in the yellow and red regions. The green region proved to be destructive, as there was a decrease in the number of cells ; the infrared region made little change in cell multiplication, the cultures being very similar to those

grown in darkness. The assumed total volume based on cell length and growth rate computations varied in a similar manner.

Cells with beautiful green plastids were found in the cultures grown in the blue, red, and yellow regions as well as in the daylight. The cells exposed to the green region had green plastids but contained much granular material. Those cells exposed to the infrared had large vacuoles and very granular contents but contained green plastids. Colorless cells and cells with faded yellow-green plastids and disintegrated contents were characteristic of the cultures exposed to darkness.

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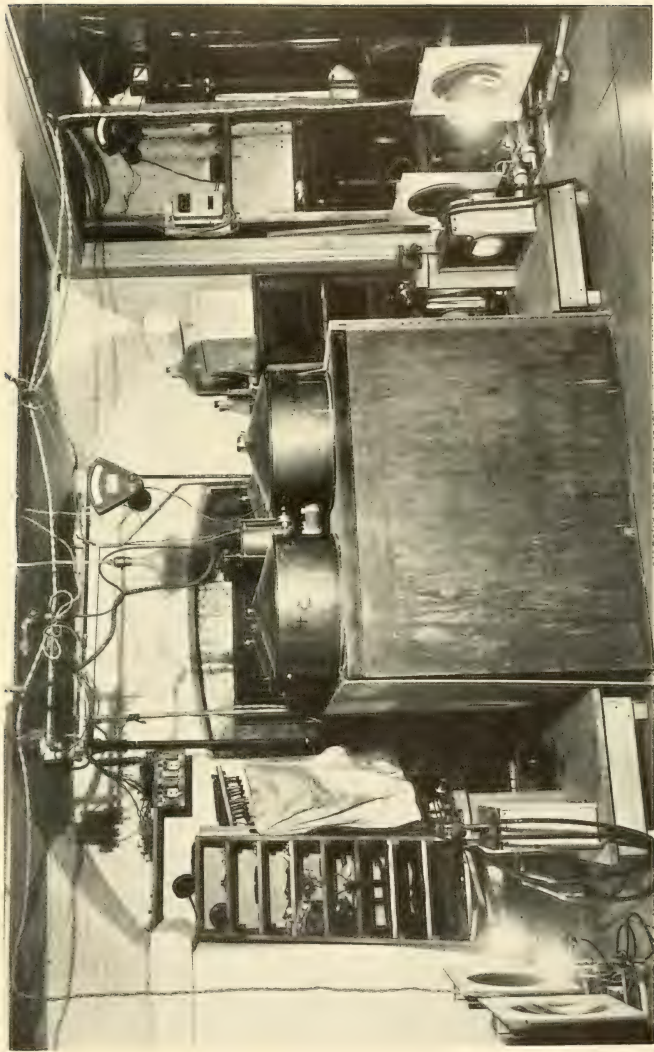
APPARATUS FOR GROWING ALGAE IN ISOLATED WAVE-LENGTH REGIONS. CONDITIONS OF LIGHT INTENSITY, TEMPERATURE, AND HUMIDITY ARE CONTROLLED IN ALL FOUR BATHS