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BUREAU OF ENTOMOLOGY—BULLETIN No. 83, Part I.

L. O. HOWARD, Entomologist and Chief of Bureau.

PRACTICAL INFORMATION ON THE SCOLYTID BEETLES OF NORTH AMERICAN FORESTS.

I. BARKBEETLES OF THE GENUS DENDROCTONUS.

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY,
Washington, D. C., March 31, 1909.

SIR: I have the honor to transmit herewith manuscript of the first part of a proposed bulletin of this bureau, to be entitled "Practical Information on the Scolytid Beetles of North American Forests."

The present part is entitled "Barkbeetles of the Genus Dendroctonus," and deals with the more practical results of extensive investigations by Doctor Hopkins between 1891 and 1908, and of those conducted by him and under his immediate supervision by field and office assistants of this Bureau, Messrs. W. F. Fiske, H. E. Burke, and J. L. Webb. It relates to the most destructive enemies of the coniferous forests of North America, gives practical methods for their control, and serves as a supplement to Technical Series No. 17, Part I, the two publications together making a very complete technical and popular monograph of the genus Dendroctonus, the major part of which is based on original research. It is believed that these contributions will mark an important era in the history of forest entomology in America, and should be of special value to the systematic and economic entomologist and to students of forest entomology. This part should be of exceptional interest and value to practical foresters in the management of National and State forests, as well as to private owners of forests. The illustrations are mainly reproduced from Technical Series No. 17, Part I.

I recommend the publication of this manuscript as Bulletin No. 83, Part I, of the Bureau of Entomology.

Respectfully,

L. O. HOWARD,
Entomologist and Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE TO BULLETIN.

During the writer's investigations of extensive insect depredations in the forests of West Virginia, from 1890 to 1902, he was forcibly impressed with the importance of the forest-insect problem in connection with any future efforts toward the successful management of the forests of this country, and was thus led to give special attention to the subject. It was soon realized that among the principal groups of insect enemies of forest trees the scolytid bark and wood boring beetles must occupy first rank, both in economic importance and systematic interest. Subsequent investigations in West Virginia, in connection with the work of the West Virginia Agricultural Experiment Station, and in all of the principal forest regions of the country, in connection with the work of the Bureau of Entomology, have served to confirm these first impressions.

In these investigations special efforts have been made to acquire information on the habits and seasonal history and other facts relating to the various species, and to collect an abundance of material for systematic study, all to form a basis for conclusions in regard to the principal enemies of American forests and practical methods for their control.

The results of these investigations will be published in the two series of bulletins issued by the Bureau of Entomology. Those relating to the purely technical or systematic side of the subject, and of more direct interest to the systematic and economic entomologist and the general student of entomology, will be published in the technical series, while those of special interest to the economic entomologist, the student of forest entomology, the technical and practical forester, the owner of private forests, the manufacturer of forest products, and the public generally will be included in the regular, economic series of bulletins. The bulletins of each series are to be issued in parts, each part relating to a special group or genus as the work thereon is completed, thus avoiding the otherwise necessary delay in publication. A full index will be published to accompany each completed bulletin of several hundred pages.

A. D. H.

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I. BARKBEETLES OF THE GENUS DENDROCTONUS.

By A. D. Hopkins,
In Charge of Forest Insect Investigations.

INTRODUCTORY.

The first part of this bulletin supplements Technical Series No. 17, Part I, of this Bureau, in giving facts of practical interest and importance on a group of barkbeetles which contains the most destructive enemies of the principal coniferous forest trees of North America.

To avoid the too frequent repetition of technical and common names in the text or in footnotes, the species number is used, referring to the corresponding number in a classified list of technical and common names in Plate I.

The list of publications, in which references are to be found to some economic feature of one or more species, is arranged in chronologic instead of alphabetic order, so that the reference in the text is to the year in which the particular article referred to was published, as well as to the author's name. A more extensive bibliography is found in Technical Series No. 17, Part I.

HISTORICAL.

The name "Dendroctonus," which means *killers of trees*, was proposed in 1836 by Dr. W. F. Erichson to designate a genus of beetles which was then represented by two described species—the European spruce beetle (No. 21) (see Plate I) and the black turpentine beetle (No. 22). Between that time and 1897 ten more North American species, as at present recognized, were added, one (No. 18) by Kirby in 1837, one (No. 17) by Mannerheim, 1843, one (No. 23) by Le Conte, 1860, one (No. 4) by Zimmerman in 1868, two (Nos. 12 and 20) by Le Conte in 1868, one (No. 7) by Chapuis in 1869, one (No. 1) by Le Conte in 1876, one (No. 8) by Dietz, 1890, and one (No. 24) by Blandford in 1897. The writer has added twelve (Nos. 2, 3, 5, 6, 9, 10, 11, 13 to 16, and 19) North American species, but none has been added from any other part of the world. Therefore the genus is now represented by 23 species from North America and one from Europe.

The European species was early recognized as a destructive enemy of spruce and other coniferous trees, and much information has been published relating to its habits, life history, distribution, and methods of control.

Previous to the year 1891 only two species had been recognized in this country as depredators on forest trees. The black turpentine beetle had been referred to by Olivier, 1795, and the red turpentine beetle by Harris, 1826 to 1862, and by other writers, as enemies of pine, and the eastern spruce beetle (No. 14), under the name of another species (No 18), was recognized as a destructive enemy of the spruce in the northeastern United States and southeastern Canada and was the subject of special investigations and reports by several authors. In 1891 the writer found that the southern pine beetle (No. 4) was the cause of the death of pine and spruce timber over extensive areas in West Virginia and adjoining States, and it was the subject of special investigations and reports (Hopkins, 1892 to 1899). It was also mentioned in publications by Chittenden (1897), Schwarz (1898), and others.

In 1899 the writer made observations on the destructive habits of the western pine beetle (No. 1), the red turpentine beetle (No. 23), the mountain pine beetle (No. 9), and the Douglas fir beetle (No. 13), and observed the habits of the Sitka spruce beetle (No. 17). In 1900 the destructive work of the eastern spruce beetle (No. 14) in northwestern Maine was investigated, and in 1901 investigations were made on the Black Hills beetle (No. 10) and its depredations in the Black Hills of South Dakota were investigated.

Since July, 1902, many trips have been made by the writer to different sections of the country in general, and special investigations made of the work of one or more of the species of this genus, as noted further on, under "Basis of information," following the account of each species. Messrs. J. L. Webb, H. E. Burke, and W. F. Fiske, assistants in forest insect investigations, working according to the plans and under instructions of the writer, have given special attention to the study of the seasonal history, habits, etc., of the species found during their active field work.

Mr. Webb spent two seasons (1902 and 1906) in the Black Hills National Forest, principally in the study of the Black Hills beetle (No. 10) and its work and in conducting experiments with trap trees; one season (1904) in the San Francisco National Forest, giving special attention to species 2, 3, and 8, and one season (1905) in central Idaho, studying the western pine beetle (No. 1) and in conducting experiments with trap trees. He also spent the season of 1906 in the Black Hills to complete the investigations on the Black Hills beetle and the season of 1907 in the national forests of southern New Mexico and Arizona in general field work.

Mr. Burke spent three seasons (1903, 1904, and 1905) in western and northwestern Washington in general forest insect investigations, and made observations on the Sitka spruce beetle (No. 17) and the Douglas fir beetle (No. 13). He also made special trips to Idaho and South Dakota in 1904 to determine certain facts relating to the western pine beetle (No. 1) in Idaho and the Black Hills beetle (No. 10) in South Dakota. In 1906 he spent the greater part of the season in the Yosemite National Park, under instructions to make special studies of the mountain pine beetle (No. 9), the western pine beetle (No. 1), and the red turpentine beetle (No. 23), and in 1907 he made observations on the southwestern pine beetle (No. 2), the Black Hills beetle (No. 10), and other species in the forests of Utah.

Mr. Fiske gave special attention to the investigation of the southern pine beetle (No. 4) and its work, experiments with trap trees, etc., during his general investigations of forest insects in the South Atlantic and Gulf States during the seasons of 1903, 1904, 1905, and 1906, and studied the seasonal history and habits of the black turpentine beetle (No. 22) and the red turpentine beetle (No. 23)—the latter in the mountains of North Carolina. In the fall of 1906 he made observations on the eastern larch beetle (No. 12) and the redwinged pine beetle (No. 18) in northwestern Michigan, and in the spring of 1907 he made observations on species 4 and 22 in Texas and on species 2, 3, 5, 8, 13, 15, and 23 in southern New Mexico.

This field work by the writer and his assistants has resulted in the accumulation of a mass of material in specimens and notes which has served as a basis for the preparation of this part of the bulletin.

Considerable material has also been received from officials of the Forest Service, together with information in regard to the location and extent of depredations, and from owners of private forests and other correspondents in different sections of the country who have notified us of troubles affecting the timber and have responded to our requests for specimens and detailed information in regard to the character and extent of the depredations.

DESTRUCTION CAUSED BY THE BEETLES.

The results of our investigations have clearly shown that some of the species of this genus of beetles are the most destructive enemies of the coniferous forest trees of North America. As examples, we have only to cite the well-known depredations by the eastern spruce beetle (No. 14) in the northeastern United States and New Brunswick during the past century (Hopkins, 1901*a*), the widespread destruction of pine and spruce by the southern pine beetle (No. 4) in West Virginia and Virginia in 1891 and 1892 (Hopkins, 1899*a*), the destruction of a large percentage of the timber in an entire National Forest by the Black Hills beetle (No. 10) within the past ten years (Hopkins, 1902*b* and 1905), and the depredations by the western pine beetle (No. 1) in Idaho, Oregon, and California (Webb, 1906), and by the mountain pine beetle (No. 9) in Wyoming, Montana, Idaho, Oregon, Utah, and California noted in the present paper.

CHARACTER AND EXTENT OF DEPREDATIONS.

Living healthy trees are attacked by swarms of the adult beetles, which enter the bark on the main trunk and excavate their egg galleries for a distance of a foot or more through the inner, living bark. This weakens the vitality of the tree, and in addition the larvæ hatching from the eggs mine through and destroy the bark intervening between the egg galleries, thus completely girdling the trees and causing their death. The amount of timber killed in this manner during the past century has been enormous. That known to have been killed by these beetles in West Virginia, New England, and the Black Hills National Forest alone amounts to many billions of feet of the best pine and spruce, to say nothing of the less conspicuous depredations each year scattered through the forested sections of the Rocky Mountain, Cascade, Sierra, and Coast regions, and of the Southern States. Very conclusive evidence has also been found that some of the great denuded areas in the Rocky Mountains region supposed to have been caused by forest fires were primarily caused by one or more species of Dendroctonus. From our present knowledge of the facts and evidence it is probable that if the timber destroyed by these insects in the United States during the past fifty years were living to-day its stumpage value would be more than $1,000,000,000.

POSSIBILITIES OF CONTROL.

The results of our investigations, experiments, and practical demonstrations make it clear that wherever private forests or State or National forests are under organized management for fire protection and economic utilization the control of these insects is often a less difficult and less expensive problem than that of controlling forest fires. In fact, wherever there is a sufficient demand for the timber, and where facilities for the utilization of the trunks of the infested trees within a specified time exist, the desired control may often be brought about and maintained practically without cost or even at a profit, especially if the action be taken before the depredators have spread over extensive areas.

If, when first discovered, the depredations of the beetles have already involved an extensive area, or if they are neglected until a large percentage of the timber is killed, their artificial control will be as difficult and expensive as that of a neglected forest fire. Furthermore, if the depredations occur in an inaccessible section of the forest or where the conditions as to labor and other facilities are unfavorable for necessary action, nothing more can be done toward the control of the beetles than under the same conditions in controlling a fire. But with the rapid extension of modern forest management, lumbering operations, and working plans into the principal public and private forests, and especially with the adoption of fire-control regulations under an organization of fire patrols and rangers, there will be no excuse for neglecting the insects.

THE BEETLE PROBLEM AS IMPORTANT AS THE FIRE PROBLEM.

In certain sections of the country and in certain National Forests where the more destructive species of beetles are present and a constant menace to the standing timber, the beetle problem is undoubtedly as important as the forest-fire problem, and therefore demands the adoption and organization of beetle-control work, which, with little or no additional force and equipment, can be conducted by fire patrols and forest rangers.

The evidence of destructive beetle work is not quite as distinct as is the evidence of fire, and can not be seen quite so far, but a clump of yellow-top or red-top trees can be seen for a long distance, and upon closer inspection the pitch tubes and boring dust on and around the trunks of living trees are sufficient danger signals to demand that the required action be taken to prevent widespread depredations.

There is one great advantage in the requirements for successful beetle control over those for fire control, viz, there is usually a period of six to ten months in which to utilize or otherwise dispose of the affected timber to destroy the broods of beetles in the bark, while a fire requires immediate attention.

DISTINCTIVE CHARACTERS OF THE GENUS.[a]

The beetles of the genus Dendroctonus (see figs. 1, 2, 3, etc.) are distinguished in the adult stage by their cylindrical, somewhat elongate to stout bodies, broad and prominent heads, nearly round to oblong-oval and transversely placed eyes behind the base of each antenna, the last with an elongate, clublike basal joint (scape) followed by 5 short joints (funicle) and terminated by a broad club which is thickened at the base and flattened toward the apex, and

[a] See also Technical Series No. 17, Part I, for technical descriptions of genus, species, etc.

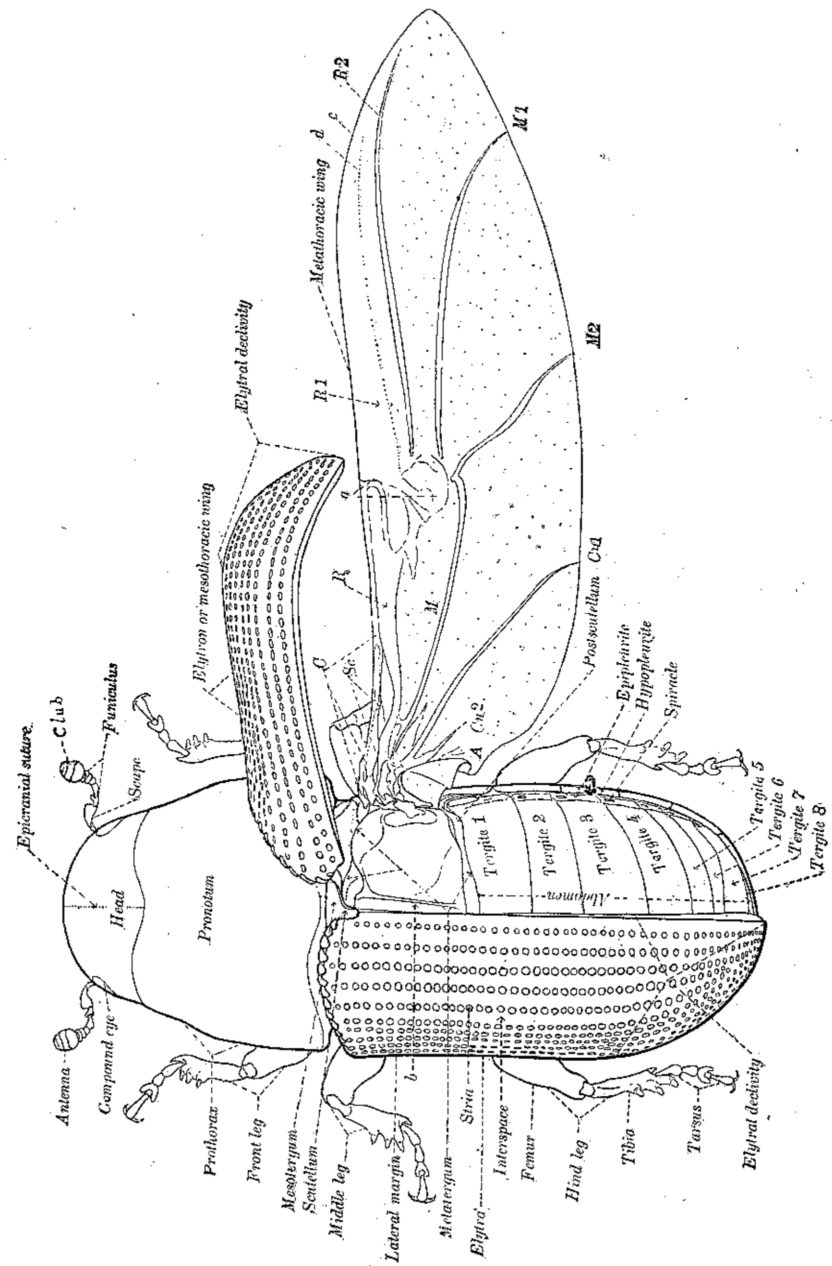


FIG. 1.—The red turpentine beetle (*Dendroctonus valens*). Adult, dorsal aspect, greatly enlarged: *a*, Median fold; *b*, scutellar groove; *c*, costal margin; *d*, inter-radial fold; *Sc*, subcosta; *R*, radius; *R1*, radius 1; *R2*, radius 2; *C*, costa; *M*, media; *M1*, media 1; *M2*, media 2; *Cu1*, cubitus 1: *Cu2*, cubitus 2; *A*, anal. (Author's illustration.)

has three to four closely connected joints defined by curved lines. The front of the head has a distinct middle elevation toward the base of the mandibles, called the epistomal process (see figs. 2, 3). The pronotum is slightly more than half to slightly less than half as long as the elytra, which have fine to coarse rugosities between rows of obscure to distinct punctures.

The diagram, Plate I, gives the technical and common names of the beetles of the genus, and shows how the different species fall into natural primary and minor divisions according to certain structural characters and peculiar habits.

ADULT CHARACTERS.

In the species of Division I the pronotum is somewhat elongate and as broad as the elytra, and in those of Division II the pronotum is shorter and is usually narrower than the elytra.

In species 1 to 8 (subdivision A) the body is somewhat slender, and the pronotum is but slightly narrowed toward the head, which in all but species 3 (comprising subsection b^1) has a frontal groove and two frontal elevations. In species 1 and 2 (section a^1) the elytra are without long hairs, while in species 3 to 8 (section a^2) there are long hairs toward and on the declivity.

In species 9 to 11 (subdivision B) the body is stouter and the pronotum is distinctly narrowed toward the head, which is without frontal groove or elevations. In species 9 and 10 the punctures of the pronotum are moderately coarse and deep, while in species 11 they are shallow and usually fine, with the surface more shining.

In species 12 to 21 (subdivision C) the punctures of the pronotum are of irregular size, while in species 22 and 23 (subdivision D) they are regular.

In species 12 and 13 (section a^3) the striæ of the elytral declivity are deeply impressed, and the interspaces are convex, while in species 14 to 21 (section a^4) the striæ are but slightly or not at all impressed and the interspaces are flat or but slightly convex. In species 14 to 19 the striæ of the elytral declivity have obscure to fine punctures, while in species 20 and 21 the strial punctures are coarse and distinct. Species 22 and 23 are easily distinguished by their large size, evenly punctured pronotum, which is subelongate and almost as broad as the elytra, and by the very large and prominent head.

EXTERNAL SEXUAL CHARACTERS.

In species 1 to 8 (subdivision A) the females are distinguished by a transverse, rather broad, elevated ridge across the pronotum near the anterior margin, moderately broad head, and moderately large mandibles. The males are without the transverse ridge across the

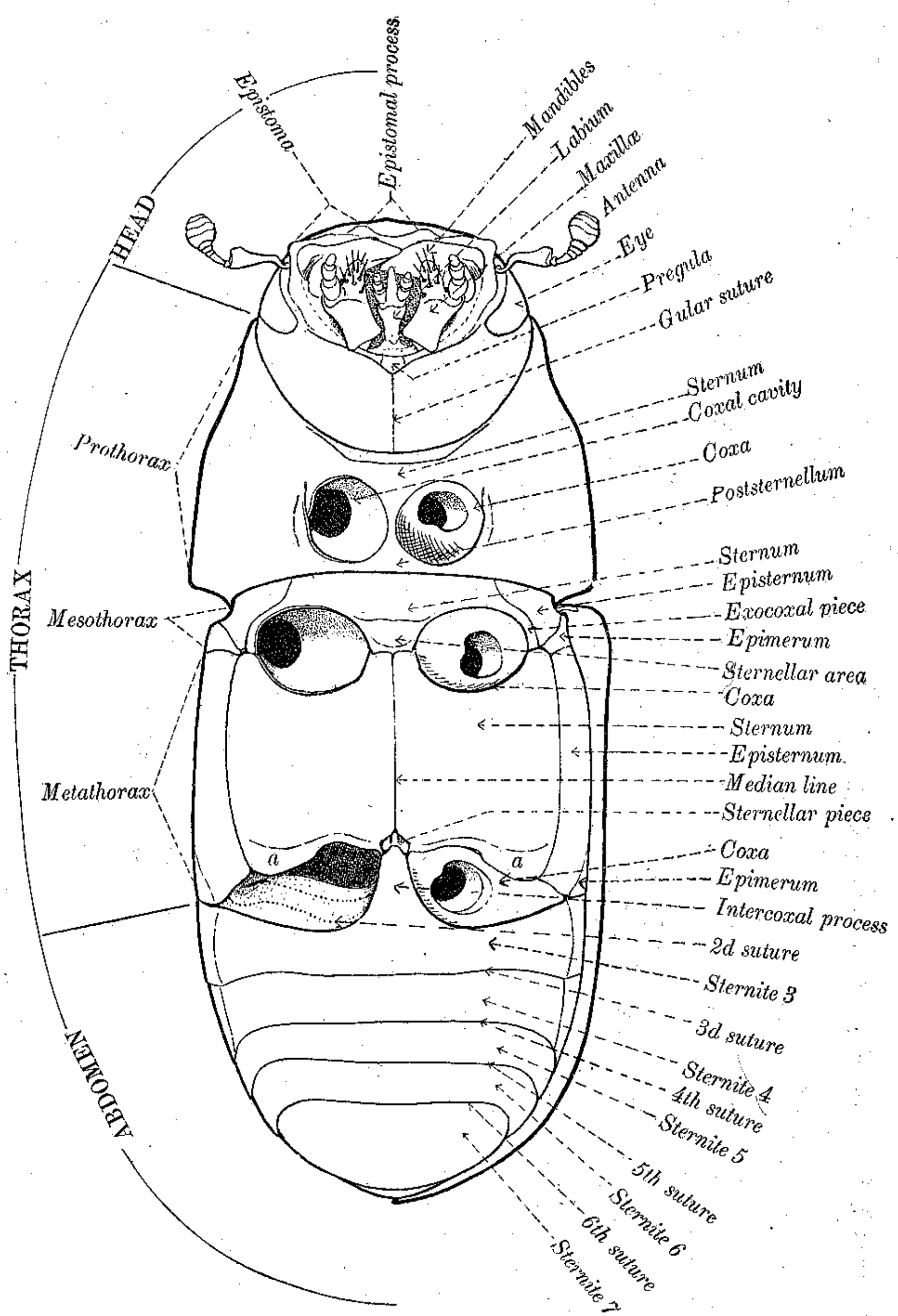


FIG. 2.—The red turpentine beetle. Adult, ventral aspect, greatly enlarged: *a*, Sternellar area. (Author's illustration.)

pronotum; but the frontal groove and tubercles are usually more distinct, the head broader, and the mandibles stouter.

In species 9 to 11 (subdivision B) the females have the declivity of the elytra somewhat flattened and shining and the interspaces with

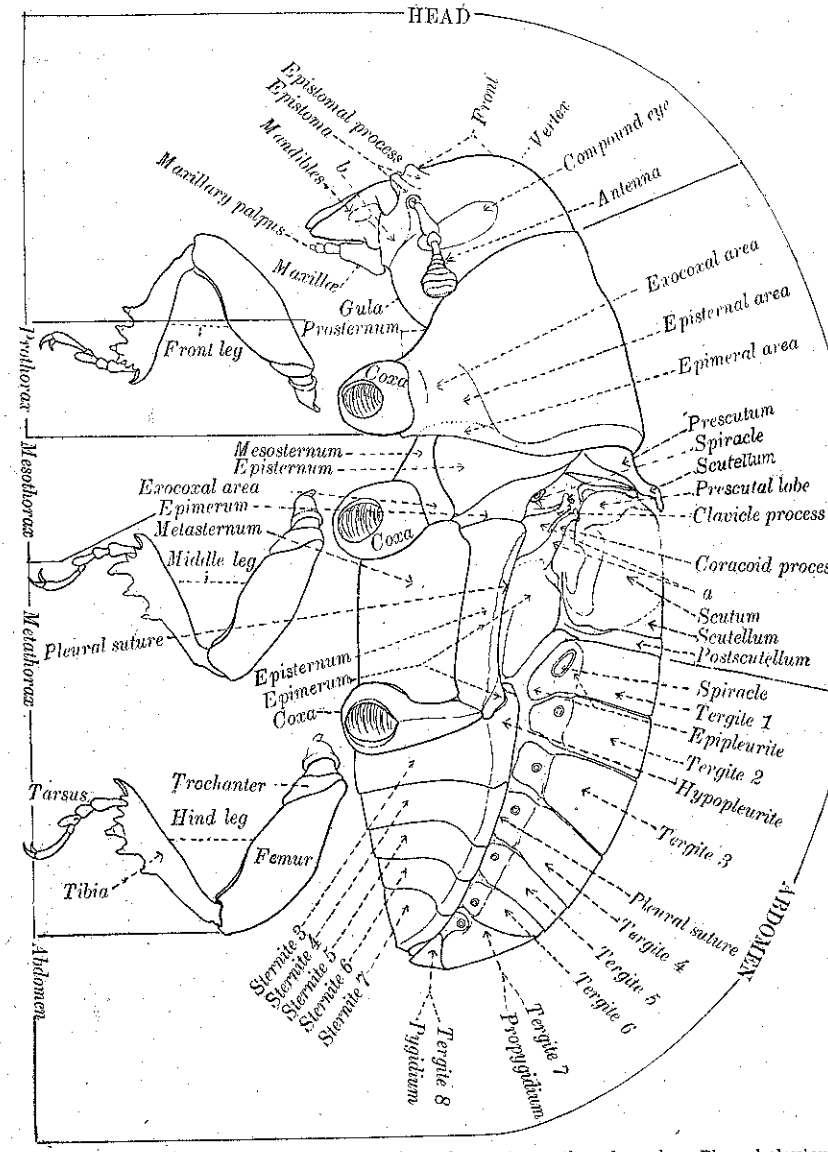


FIG. 3.—The red turpentine beetle. Adult, lateral aspect, greatly enlarged: *a*, Pleural clavicula; *b*, pregena. (Author's illustration.)

small granules and sometimes punctured. In the males the declivity is more convex, the interspaces have coarser granules, the head is broader, and the mandibles are stouter.

In species 12 to 21 (subdivision C) the sexes are easily distinguished by the differences in the declivity of the elytra. In the females the striæ are more distinctly impressed and the interspaces more convex and roughened. In the males the striæ are much less or not at all impressed and the interspaces are shining, smooth, and often punctured.

In species 12 and 13 (section a^3) the striæ are deeply impressed in both sexes; but in species 14 to 21 (section a^4) they are rarely impressed in the males.

In species 22 and 23 (subdivision D) the sexes are less distinctly defined by external characters. In the females the antennal club is broader, stouter, and more compressed; the head is narrower and the mandibles are smaller, while the reverse is true in the males.

THE EGG.

The eggs of the majority of the species have been observed and apparently show no differences except in relative size, corresponding with the size of the adults. They are slightly oblong, rounded at the ends, pearly white, and shining.

THE LARVA.

The larva (fig. 4) is a stout, cylindrical, yellowish-white, footless grub with a yellowish shining head. The body is deeply and closely wrinkled, as shown in the figure.

In species 1 to 11 the dorsal surface of the 8th and 9th abdominal segments are smooth, without chitinous plates, and the ventral prothoracic lobes are more or less prominent.

In species 1 and 2 the front is without a median elevation.

In species 3 to 7 the front has a more or less rounded convex elevation.

In species 9 to 11 the front has a transverse roughened elevation, slightly more elevated toward the sides.

In species 12 and 13 the dorsal surface of the 8th and 9th abdominal segments is without chitinous plates.

In species 14 to 23 one or both have distinct plates.

In species 14, 15, 17, and 19 the 8th and 9th abdominal plates are without prominent spines. The frontal elevation, when present, is transverse.

The larvæ of species 16 to 18 and 19 have not been observed.

Species 21 has a roughened plate on the 9th segment, but none on the 8th.

In species 12 the front is without a median elevation, but in species 13 there is a distinct transverse, rugose, median elevation, more elevated toward the sides.

In species 14, 15, and 19 the front has a transverse elevation, but in 17 it is absent or indistinct.

In species 22 and 23 the dorsal plates of the 8th and 9th segments have prominent spines, and the front of the head is without elevations.

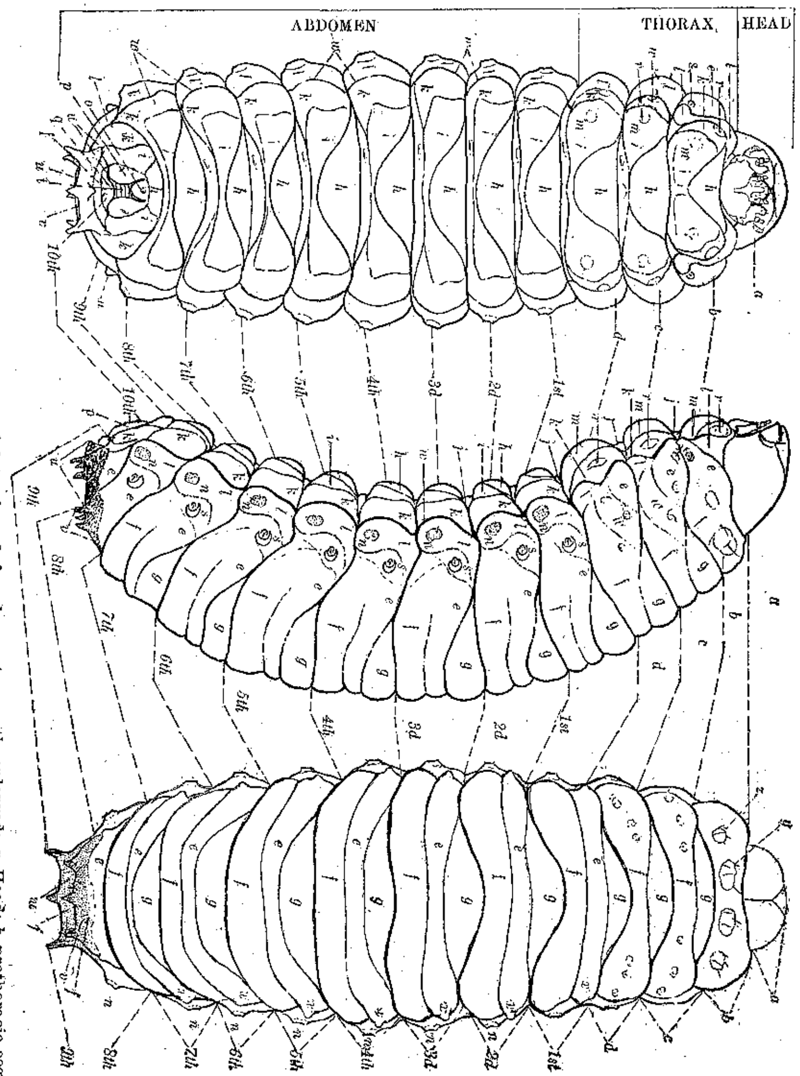


FIG. 4.—The red turpentine beetle. Larva, ventral, lateral, and dorsal aspects, greatly enlarged: *a*, Head; *b*, prothoracic segment; *c*, mesothoracic segment; *d*, metathoracic segment. Lobes: *e*, Scutal; *f*, scutellar; *g*, prescutal; *h*, sternal; *i*, sternellar; *j*, poststernellar; *k*, hypopleural; *l*, epipleural. *m*, *m*, Foot calli; *n*, *n*, epipleural calli and tubercles; *o*, infraanal lobe or sternite of the 10th segment; *p*, paranal lobe or 10th pleurite; *q*, supraanal lobe or tergite of the 10th segment; *r*, hypopleural callus; *s*, spiracle; *t*, anal opening; *u*, dorsal plate of 9th segment with scutellar spines; *v*, dorsal plate of 8th segment with scutellar spines; *w*, pleural suture; *x*, spiracular tubercles; *y*, prothoracic dorsal plate; *z*, prothoracic lateral plate. (Author's ill.)

THE PUPA.

The pupa (fig. 5) is of the general color of the larva, but is of the general form and size of the adult, with the legs and wing pads folded beneath the body and the abdominal segments exposed. The 9th segment has two prominent fleshy spines, and the other segments are with or without dorsal, lateral, and pleural spines, which vary in size among the different species from very smooth to quite coarse and prominent.

In species 1 to 5 and 8 to 11 the vertex or front of the head is grooved, with prominent or small fleshy spines situated at each side of the groove.

The pupæ of species 6 and 7 have not been observed.

In species 1 to 5 and species 8 the elytral pads are smooth and the abdominal segments have small lateral spines or tubercles.

In species 1 and 2 the vertex of the head is faintly grooved, the spines are small and widely separated, and the front and middle femora are without apical spines or granules.

In species 3 the vertex is faintly grooved, the spines are very small, and the front and middle femora have apical granules.

In species 4, 5, and 8 the vertex is broadly grooved, the spines are moderately small and widely separated, and the front and middle femora have small apical tubercles.

In species 9, 10, and 11 the elytral pads are roughened, with sparsely placed granules. The head has the vertex deeply grooved and the spines prominent, and the abdominal segments have very long lateral spines. In species 9 and 11 the front and middle femora have two apical spines each, while in species 10 they have one each.

In species 12 to 23 the vertex is either faintly impressed or convex, with an acute granule at each side and one or two on each side on the front. The elytral pads are smooth, and the abdomen has more or less prominent lateral spines.

In species 12 and 13 the vertex of the head is faintly impressed or grooved, and the front and middle femora are without granules or spines.

In species 14 to 23, so far as observed, the vertex is convex, and the femora have small apical granules.

EGG GALLERIES, LARVAL MINES, AND PUPAL CELLS.

(See figures of work.)

In species 1 to 11 the egg galleries are winding to straight, with individual larval mines concealed or exposed in inner bark and with the pupal cells either in the outer or in the inner bark.

In species 1 to 8 the egg galleries are winding, nearly transverse to oblique; the larval mines short, not in groups; and the pupal cells are in the outer bark. In species 1, 2, 5, 6, 7, and 8 the larval mines are concealed, while in species 3 and 4 they are exposed in the inner bark.

In species 9 to 11 the egg galleries are longitudinal, slightly winding to straight. The larval mines are short and usually in groups,

and both the pupal cells and larval mines are exposed in the inner bark.

In species 12 to 23, so far as observed, the egg galleries are longitudinal, straight to slightly winding, with the larval mines either in groups or connected, or they form a broad common chamber, and all are exposed in the inner bark. The pupal cells are located at the

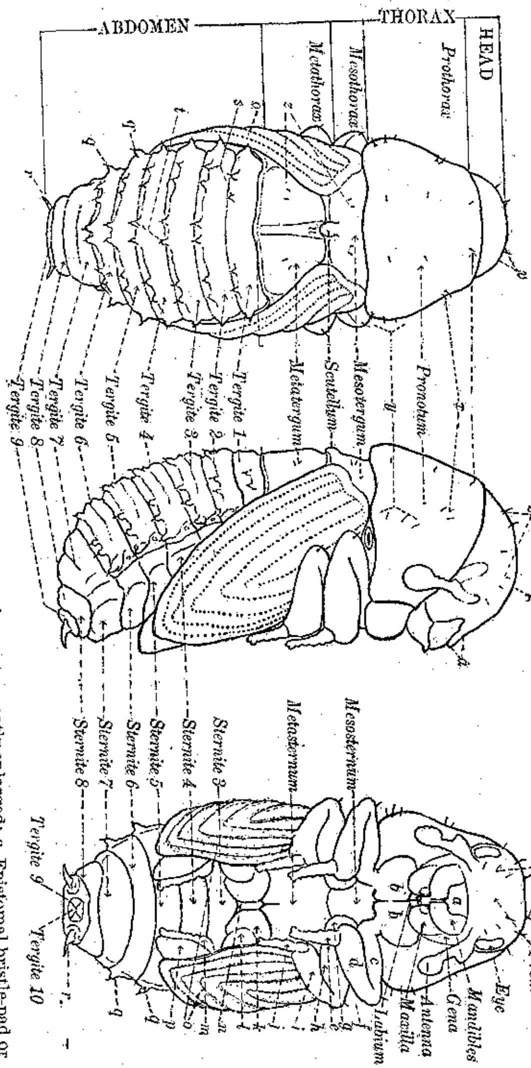


FIG. 5.—The red turpentine beetle. Pupa, dorsal, lateral, and ventral aspects, greatly enlarged: a, Epistomal bristle-pad or pseudo-labrum. Anterior leg: b, b, Coxa; c, femur; d, tibia; e, tarsus; f, apical spines of femur. Middle leg: g, Coxa; h, femur; i, tibia; j, tarsus. Posterior leg: k, Coxa; l, femur; m, tarsus. n, Sternellar or intercoxal area; o, elytral pad; p, wing-pad; q, pleural spines; r, caudal spine or 9th pleural; s, lateral spines; t, dorsal spines; u, scutellar groove; v, frontal spines; w, dorsal spines of pronotum; x, lateral spines of pronotum; y, pleural spines of pronotum; z, mesotergal and metatergal spines. (Author's illustration.)

end of the larval mines or in the larval chambers and are usually exposed.

In species 12 to 13 the egg galleries are straight or slightly winding, sometimes branched, the larval mines are in groups and exposed in the inner bark, and the pupal cells are exposed or concealed.

In species 12 and 13 the egg galleries are long, longitudinal, straight, or slightly winding, sometimes branched, and moderately broad; the larval mines are long, independent of each other from the start, winding, and more or less regular.

In species 14 to 21, so far as observed, the egg galleries are broad, moderately long, straight, irregularly branched at terminals, and usually with an inner gallery through the packed borings of the finished egg galleries; the larval mines are long, connected toward the egg gallery, independent and irregular, or forming a broad larval chamber.

In species 14, 15, and 17 the larval mines are connected toward the egg gallery and separated toward the middle and outer ends.

In species 19 and 20 the larvæ excavate a common or social chamber, sometimes with independent mines extending from the edges.

In species 22 and 23 the egg galleries are broad to very broad, short to very long, and straight or slightly winding, and the larval mines form very large common chambers, with the pupal cells in the chamber or at the ends of short independent mines extending from the edge of the chamber.

DISTRIBUTION.

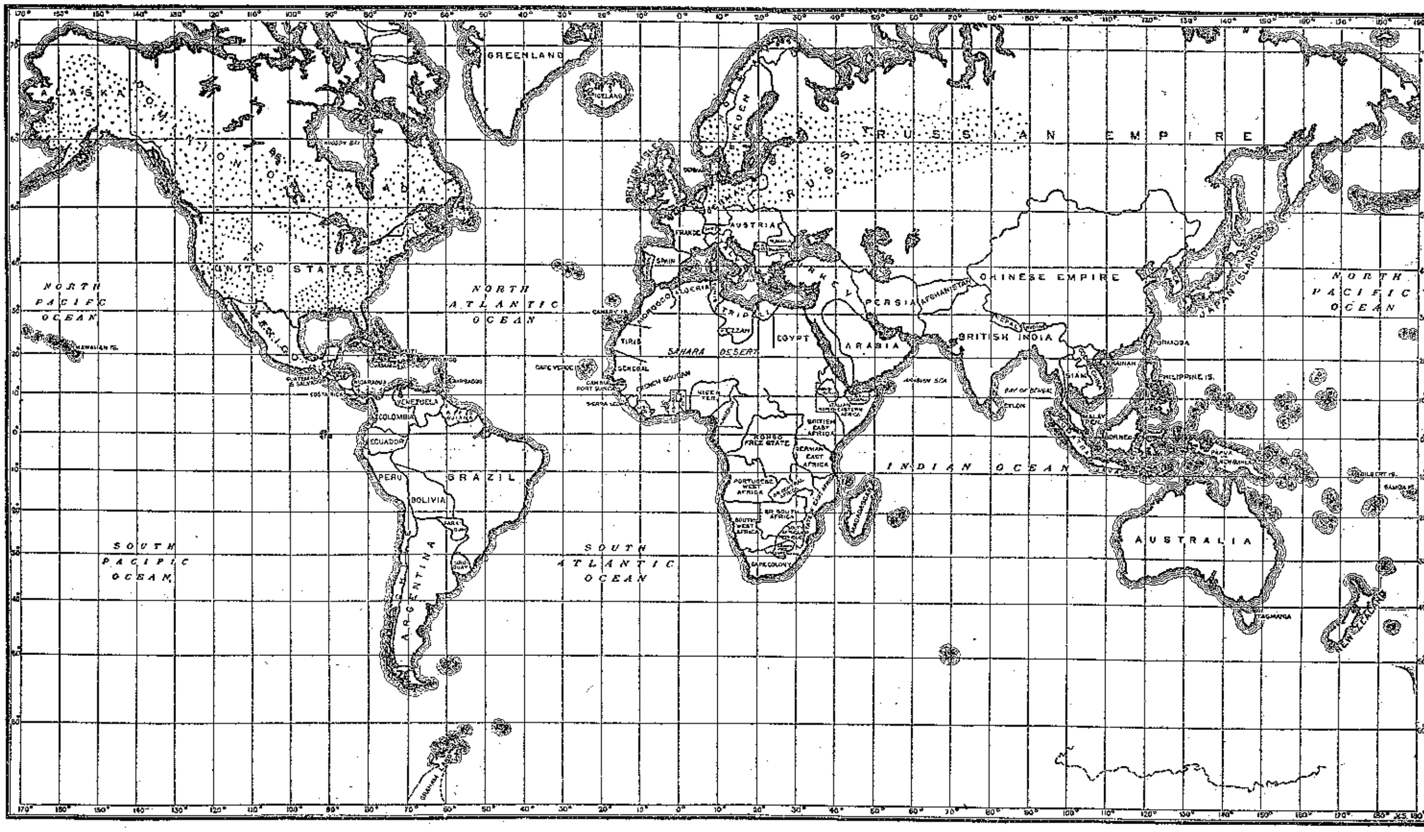
The distribution of the species of Division I is from the South Atlantic States to Mexico and Central America, and northward into the Rocky, Sierra Nevada, and Cascade mountains to British Columbia.

Species 1 occupies the region of the western yellow pine west of western Montana and southern Idaho, southward to Santa Barbara County, Cal., while species 2 occupies the Rocky Mountains region south of central Colorado and central Utah, into southern California and northern Mexico.

Species 3, 5, and 8 occupy practically the same region as species 2, while species 4 occupies the region of yellow pine, loblolly pine, and longleaf pine south of Pennsylvania and westward into Texas, and species 6 and 7 occupy the pine regions of the mountains of southern Mexico.

Species 9 occupies the region of silver pine, lodgepole pine, and sugar pine north of Colorado and Utah and westward into the Sierra Nevada and Cascade mountains.

Species 10 occupies the region of the Rocky Mountain variety of the western yellow pine and limber pine above an altitude of 6,000 feet, from western South Dakota southward through Wyoming, Colorado, and Utah to southern New Mexico and Arizona, while species 11 occupies the Jeffrey-pine region from the mountains of San Bernardino County, Cal., to northern California, and probably into Oregon.



MAP OF THE WORLD, SHOWING DISTRIBUTION OF THE GENUS DENDROCTONUS. (AUTHOR'S ILLUSTRATION.)

The species of Division II range from Guatemala northward to Alaska, eastward to the Atlantic coast, and across northern Europe and Russia into Siberia.

Species 12 occupies the regions and sections of eastern larch from northwestern West Virginia, northward and westward, while species 13 occupies the region of the Douglas fir, bigcone fir, and western larch from southern New Mexico and Arizona to Ventura County, Cal., and northward into British Columbia.

Species 14 occupies the region of red spruce from the high mountains of Pennsylvania northward and from New Brunswick to northwestern Michigan, and probably northwestward to the 100th meridian.

Species 15 occupies the region of Engelmann spruce from the white spruce in western South Dakota westward, and north of southern New Mexico.

Species 16 occupies the white-spruce region in Alaska, and species 17 the Sitka-spruce region from southern Oregon to Sitka.

Species 18 occupies the Lake Superior region; species 19 the region of lodgepole pine from central Colorado northward probably into British Columbia; species 20 the regions of red spruce from the mountains of West Virginia into New York; while species 21 occupies the spruce and pine regions north of central Europe in Denmark and through Russia to eastern Siberia.

Species 22 occupies the region of pitch pine, Virginia pine, yellow pine, loblolly pine, and longleaf pine from Long Island, New York, east of the Allegheny Mountains, southward to Florida and Texas, and west of the mountains from the Little Kanawha River probably through Kentucky and Tennessee, while species 23 occupies the regions of pine timber from the Atlantic to the Pacific north of the South Atlantic and Gulf States and south into the mountains of Guatemala. Species 24 is described from Guatemala.

The distribution maps (figs. 11, 14, 17, etc.) show the known and probable ranges of each species, the known range being indicated by large dots and the probable range by small dots.

The distribution of the genus is shown on a map of the world (Pl. II.)

HOST TREES.

In Division I the species confine their attack to pine and spruce, but principally to the pines.

Species 1 confines its attack to the western yellow and sugar pine, and is a destructive enemy of both. Species 2 attacks the western yellow pine, but, so far as observed, is much less destructive than its northern and western neighbor. It has also been found in the Douglas fir, but this is evidently an abnormal habit.

Species 3, 5, and 8 are usually associated with No. 2 in the western yellow pine, but none of them has been especially destructive, although independently or collectively they are capable of being so. Species 4 attacks all of the pines and spruces within its range, and while it caused widespread devastation in its northern range during 1891 and 1892 its destruction of timber within its southern range, so far as observed, is comparatively moderate.

The species of subdivision B are the most destructive insect enemies of western pine forests. Species 9 attacks the western white pine, silver pine, sugar pine, lodgepole pine, and western yellow pine, and is exceedingly destructive in certain localities throughout its range, especially to the silver pine, sugar pine, and lodgepole pine. Species 10 attacks the Rocky Mountain variety of the western yellow pine, limber pine, white spruce, and Engelmann spruce, but confines itself principally to the yellow pine and is exceedingly destructive, as has been conclusively demonstrated in the Black Hills Forest Reserve of South Dakota and in numerous localities in Colorado. Species 11 attacks the Jeffrey pine and western yellow pine, but principally the former, to which it is quite destructive.

The species of Division II attack pines, spruces, larches, and Douglas-fir, and some of the species are very destructive to living timber.

Species 12 confines its attack to the eastern larch. There is no positive evidence that it is primarily destructive to living timber, but it evidently contributes to the death of trees defoliated by the larch worm. Species 13 confines its attack principally to the Douglas fir, but is also found in the bigcone spruce and western larch. In the northwestern section of its range this species is not especially destructive, but in its eastern and southern range it is very destructive to the Douglas fir.

Species 14 attacks the red spruce, black spruce, and white spruce, and from time to time during the past century it has been exceedingly destructive to the red spruce in Maine and New Brunswick. Species 15 attacks the Engelmann and evidently the other spruces of the Rocky Mountain region. There is conclusive evidence that it has caused widespread devastation of matured spruce during the past fifty years, and it is now quite aggressive in some localities. Species 16 has been found in the white spruce, but nothing more is known of its habits. Species 17 attacks the Sitka spruce, but there are no records to indicate that it has been primarily destructive to living timber. Species 18 lives in the white pine, but nothing further is known of its habits. Species 19 attacks living lodgepole pine and Engelmann spruce, but it is not known whether or not it is primarily destructive. Species 20 was found in the living bark on a red-spruce stump in West Virginia, which is all that is known of its habits.

Species 21 is recorded as attacking spruce and pine principally, and as sometimes attacking larch, and fir (Abies), and is recognized as a destructive enemy.

Species 22 attacks the different species of pine within its range and has also been found in spruce. It is sometimes destructive to living trees, but more often is simply injurious to the base of the trunks in causing basal scars. Species 23 attacks all of the pines and is sometimes found in spruce and larch. It rarely causes the death of trees but causes serious damage to the base of living trees, resulting in the common defect known as basal scars and fire wounds.

EVIDENCES OF ATTACK.

In all of the species the first evidence of attack on living trees is the presence of pitch tubes on the trunks, mixed with reddish borings, or the presence of reddish boring dust in the loose bark and around the base of the trees. Later the fading, yellowish, or reddish condition of the foliage is conspicuous evidence of the barkbeetles' destructive work.

Successful attacks by species 1 to 8 are followed by a rapid death of the trees. The leaves fade in a month or two and turn yellow and reddish before winter. Successful attacks by species 9 to 11 are followed by a slow death of the trees. While the trees attacked during the summer will have the bark on the trunks killed, the leaves will not turn yellow until the following May.

Attacks by species 12 and 13 are not as a rule indicated by pitch tubes, but the reddish boring dust in the crevices of the bark, in the loose bark, and around the base of the trunk of Douglas fir or larch is quite conclusive evidence of their presence. Douglas fir attacked in the summer will have the leaves fading and turning pinkish in the fall and winter, and reddish in the spring. The leaves on the larch probably fall before they fade, although some of them may remain on the trees after the normal time for them to fall.

In species 14 and 15, pitch tubes and red boring dust, mixed with resin, on the trunk and around the base, are evidences of attack. The trees attacked in the early summer will shed their green needles before fall. Those attacked later in the summer will have the bark on the trunks killed before winter, but the leaves may remain green until growth starts in the spring, when they will fall. Thus in May and June one often finds the ground beneath the infested trees covered with the green needles. After the leaves have fallen the bare twigs will cause the tops of infested trees to present a reddish appearance.

Species 18 to 20 appear to confine their attack to or toward the base of the trees, where large pitch or gum tubes are formed, indicating their presence. In Europe, species 21 sometimes attacks the trunk at points some distance above the base, where the large pitch or gum tubes indicate their presence.

Species 22 and 23 nearly always attack the base of the trees, where the very large pitch tubes and masses of pitch indicate their work. When the main trunk is infested by these species to a sufficient extent to kill the trees, the evidence of infestation is found in the large pitch tubes and yellow foliage of the dying trees.

SEASONAL HISTORY.

The important features in the seasonal history of these beetles are the hibernation or overwintering of the broods, the beginning of activity in the spring, the emergence and flight of the adults, the beginning and ending of the period of principal attack, the period of larval development, the principal period of transformation from the larvæ to the pupæ and adults, the beginning and ending of the period of emergence, and the number of generations annually.

Certain features in the seasonal history of all of the species are similar, but as a rule each species or series of closely related ones has peculiarities which are more or less distinctive. A knowledge of these facts, therefore, is of prime importance as a basis for advice relating to the exact species involved in a given trouble and the successful methods of control.

The broods of all of the species pass the winter as adults and larvæ in the bark of the trees, logs, or stumps attacked during the preceding spring, summer, or fall. All excavate galleries through the inner living bark in which to deposit eggs, and the larvæ of all feed on the inner bark; all become more or less active as soon as the weather conditions are favorable in the spring, especially the larvæ and overwintered parent adults, the former extending their larval mines and the latter their egg galleries. The principal differences in seasonal history are brought out in the following references to the general features of the different species and in the detailed discussion under each species farther on.

In species 1 and 2, under average conditions, there is one complete generation and a partial second during the season of activity.

In species 1 the first attack is made during the last week in June and first week in July, and the more advanced broods develop and begin to emerge about the last of August, but are not all out before cold weather. The first eggs of the second generation are deposited about the first of September, but the broods do not develop beyond the larval stage before hibernation begins in October. In species 2 the seasonal history is practically the same as in species 1, except that the attack and subsequent stages begin a month earlier. The attack begins during the last of May, and the advanced broods begin to emerge during the latter part of July.

In species 3 there is but one generation annually in the more advanced broods, while the more retarded ones may pass through two winters before they complete their development and emerge. The adults begin to emerge, attack other trees, and deposit eggs toward the last of June, but the broods do not develop before hibernation begins in the fall.

Species 4 has two or three generations annually in its northern range. In the intermediate range, represented by Tryon, N. C., there are three or four generations, while in the more southern range there may possibly be five generations, with activity continuing during the warmer days of winter. Under average conditions the first attack is made about the middle of May, and under favorable conditions the resulting brood develops to adults and emerges in about sixty days.

Species 5 evidently has a seasonal history similar to species 2

In species 8 there is but one generation annually. The attack begins in June, and the broods do not emerge until the following June to August, or later.

In species 9, 10, and 11 there is but one generation annually, and the seasonal history of each is quite similar to that of the others. The first attack is made during the last week in July or first week in August, and the broods do not develop and emerge until the following July and August.

In species 12 and 13 there is a single generation annually. The first attack is made in April to May, and the broods emerge the following April to July.

In species 14 and 15 there is but one generation annually. The first attack is made in June, and the broods do not emerge until the following June to August. In species 17 the attack begins a month earlier. In the European species (No. 21) the first attack is made in May and June, and the broods emerge the following May to August.

In species 22 and 23 there is but one generation annually. The attack is made during the first warm days in March to April, and the broods emerge the following March to September, or later.

INFLUENCES OF LATITUDE AND ALTITUDE ON SEASONAL HISTORY.

The beginning and ending of the hibernating period vary somewhat among the different species, and in each species there is considerable difference at different latitudes and altitudes within its range. Within the area of a given State or section of the country this difference in the beginning or ending of a given period in the seasonal history of a species can be estimated after the date of beginning is determined for a given season in a given locality. In the spring of a given year the average difference in the time of beginning activity, emergence, flight, attack, etc., at the same altitude, will not vary much from four days later for each degree north, or four days earlier for each degree south, while at the same latitude there will be a difference of about four days for each 400 feet difference in altitude—four days later for each 400 feet higher, and four days earlier for each 400 feet lower. Thus a difference of 7½ degrees of latitude at the same elevation would mean a difference of about thirty days in the beginning of activity or any other event, depending on a given average temperature, while a difference of 3,000 feet in altitude at the same degree of latitude would cause an equal difference in these phenological events.

In the fall of the year the beginning of hibernation and other events will be earlier northward and later southward at localities of the same elevation, or earlier at higher altitudes and later at lower altitudes in the same latitude.

Of course there are exceptions to these rules, especially in regions like that of California, where remarkably abnormal conditions as to influence of altitude and latitude prevail, as also in the case of southern and northern exposures, sandy dry soils, and wet clayey soils or bogs. In such cases the estimates must be corrected so as to allow for three or four days later for the beginning of activity, etc., under average colder conditions, or three or four days earlier for average warmer conditions. The best indication of the rate of difference between two localities is found in the average difference in the dates of opening of the buds or flowers of some indigenous species of forest trees common to both localities, and especially of a species of conifer subject to the attack of a given Dendroctonus beetle.

A knowledge of the facts relating to this principle is of especial importance as a basis for recommending or executing beetle-control policies, since *success depends largely on a knowledge of the proper time to begin and end certain timber-cutting or barking operations for the destruction of the broods of the beetles.*

When, as is usually the case, the seasonal-history data have been collected at different latitudes and altitudes within the range of the species, the discussion under each species is based on a probable average. But when the data have been collected in one locality the discussion relates to that locality, and the probable differences are estimated for other localities. While there is yet much to be determined in regard to the rate of difference between different localities at the same latitude or elevation in the same region and the influence which different latitudes and altitudes exert on different species, sufficient evidence is at hand regarding some of the species of this genus and the regions occupied by them to warrant certain preliminary conclusions as a basis for action and further study.

HABITS.

HABITS OF PARENT ADULTS AND OF IMMATURE STAGES.

All of the species of Dendroctonus will breed to a greater or less extent in the living and dying bark of stumps and logs, and in injured and weakened trees. Some of them show a preference for trees in weakened condition, while others show a preference for healthy trees. *All of those studied, however, have demonstrated their ability to attack healthy trees and kill them whenever the individuals of a species occur in sufficient numbers to overcome the resistance of the tree.* The habit of swarming, or of congregating in one locality and concentrating their attack on groups of trees within a forest, is one of the more striking features in the habits of these beetles. The part of a tree selected for the attack varies somewhat in the different subdivisions of the genus. The species that are more destructive to the life of a tree attack the middle to upper portion of the trunk, while those that are less destructive attack the trunk toward the base, or even at the roots. The beetles' power to resist the repelling effects of the resin that flows into the freshly excavated entrances and galleries in the living bark and to dispose of it by forming pitch tubes at the entrances is most remarkable. This alone demonstrates the ability of these insects to overcome the resistance exerted by a living, healthy tree. The manner of excavating the egg galleries and the directions followed in their extension are quite different among the several species and have a different effect on the tree. The almost transverse, very winding, and closely arranged galleries of species 1, 2, 4, 5, and 6 serve to quickly girdle and kill the trees, while the straight, longitudinal course and parallel arrangement of those of species 9, 10, 11, 13, and 14 result in a much slower, but none the less certain, death of the tree.

RELATION OF HABITS TO SUCCESSFUL CONTROL.

The habits of the broods of larvæ are of special importance in indicating methods of control.

In subdivision A the larvæ of species 1, 2, 5, 6, 7, and 8 excavate their larval mines through the middle layers of the inner bark, so that they are rarely exposed in the inner bark. Those of species 3 and 4 are exposed, but in all of the species of subdivision A the transformations from the larvæ to the pupæ and adults are almost entirely in the outer corky bark, so that in order to destroy the broods of the species of this subdivision the simple removal of the bark is not sufficient; it must be burned or otherwise destroyed.

In the species of subdivisions B, C, and D the larvæ excavate their mines in the inner layers of bark and also transform to pupæ and adults in the inner bark, so that when the bark is removed from the tree they are exposed to the frost or sun and drying winds, which is sufficient to kill them, without the necessity of burning the bark.

It will be seen from the foregoing that the periods in which control operations must be conducted are indicated by the habits and seasonal history of the species involved. In general, the work should be done between the beginning of hibernation in the fall and the beginning of activity in the spring, but in the case of certain species in which there are one or more complete generations within the season of activity, such as species 1, 2, and 4, it may be desirable under certain conditions to dispose of the infested trees during the summer, as well as during the winter, especially during the principal development and summer activity of the first generation of larvæ. In the case of species 9, 10, and 11, the operations may be continued after activity begins in the spring until late in June or the first of July.

SECONDARY INJURIES TO THE TREES.

Some of the losses resulting from secondary injuries or destruction may be mentioned in this connection. One of these which affects the commercial value of the beetle-killed trees is the bluing of the sapwood. This, according to Dr. Hermann von Schrenk, is due to a fungus which finds its way into the wounds and galleries made by the beetles and rapidly penetrates the sapwood to the heartwood, causing at first bluish streaks and later a uniform bluish-gray appearance of the wood. This bluing condition, especially in pine trees infested with species 9 to 11, often prevails long before the leaves of the beetle-infested trees show evidence of decline or death.

Other secondary losses consist in abnormal decay of the sapwood and heartwood, but the greatest losses of this class may come from forest fires started in the beetle-killed timber, which may not only complete the destruction of the old dead and the newly infested timber, but also spread into the healthy forests. But there is one redeeming feature in the destruction of the beetle-infested timber by fire, and that is the widespread destruction of the beetles in the infested trees, thus preventing the rapid extension of their ravages which would otherwise occur.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLES.

It is quite necessary that we should have some general and detailed information in regard to the influences upon the beetles of climate, fires, etc., and how certain methods and practices in the management of a forest, or in utilizing its resources, contribute to the multiplication of the destructive enemies of the living timber, and how certain other methods may contribute to their reduction or destruction. There is considerable difference in this respect between different sections of the country and between different species of Dendroctonus, as mentioned under the more detailed discussion of the several species.

CLIMATIC INFLUENCES.

DROUGHT.

It is the common impression that the death of pine and spruce timber in certain sections of the Rocky Mountain region is primarily due to a weakened condition resulting from drought and that the work of the insects is secondary. Under the influence of exceptionally severe drought during several successive seasons this may be true to a very limited extent, but our observations lead us to conclude that drought does not offer specially favorable conditions for the multiplication and destructive work of barkbeetles. In fact, the reverse is more likely to be the rule, since exceptionally dry conditions appear to be more unfavorable for the development of the beetles than humid conditions. The only exception we have noted in which injury is greater in dry sections than humid ones is that of the Douglas fir. In the more southern range of this tree, where the normal dry character of the climate and soil prevails, it suffers more from the Douglas fir beetle (No. 13) than it does in the Northwest, where, under moist conditions and rich soil, the tree reaches its best development. This beetle is very abundant in the Northwest, yet as a rule it confines its attack to the felled and injured timber and rarely attacks the healthy trees. On the other hand, the western yellow pine suffers more severely in the humid sections than it does in the more arid ones, as demonstrated by the work of the Black Hills beetle (No. 10), which is widely distributed over the eastern section of the Rocky Mountain region, yet has been far more aggressive and destructive in the Black Hills National Forest than in the much drier sections in southern Colorado and northern New Mexico and Arizona, and has continued its depredations in the Black Hills unabated through excessively wet as well as excessively dry seasons.

The western pine beetle (No. 1) is far more abundant and destructive in the northern and more moist climate of the mountains of Idaho, Oregon, and California than is its near relative, the southwestern pine beetle (No. 2) in the drier forested areas of New Mexico and Arizona. The mountain pine beetle (No. 9) is exceedingly destructive to the lodgepole pine at high altitudes and under especially moist conditions. The same may be said of the eastern spruce beetle and the Engelmann spruce beetle. It is evident, therefore, that drought is not an important factor in contributing to the multiplication or destructiveness of this class of enemies.

LOW TEMPERATURE AND SNOW.

While the severe cold at the high elevations in which most of the western species prevail appears to have no detrimental effect on the overwintering broods, we have a striking example of its effect on a northern migration of a southern species, in the complete extermination of the southern pine beetle (No. 4) in the Virginias by the exceptionally cold winter of 1902–3. On the other hand, snows, when sufficiently heavy to break down a large amount of timber, might offer favorable conditions for the multiplication of some of the species like the western pine beetle, the mountain pine beetle, and the Douglas fir beetle.

LIGHTNING.

In certain sections of the country where a great many pine and spruce trees are struck by lightning during the summer months these trees furnish exceptionally favorable conditions for the perpetuation and multiplication of the pine and spruce beetles. Although the constant supply of such trees furnishes also favorable conditions for the multiplication and perpetuation of the natural enemies of the destructive beetles (insects and birds), these enemies are frequently not sufficiently numerous to serve as a natural check, and the living timber is attacked by the broods of beetles which develop in the lightning-struck trees. This is especially true in the Southern States, where a pine tree struck by lightning attracts the beetles to the spot, and they not only enter the injured tree but attack and kill a number of those surrounding it.

WINDSTORMS.

Whenever a windstorm occurring during the period from June to August is sufficiently severe to fell and break a large amount of pine and spruce, favorable conditions may be presented for the multiplication of certain of the destructive beetles, provided they are present in the locality in sufficient numbers to infest the felled timber. This has been demonstrated from time to time in Europe, where beetles with much less aggressive habits than the Dendroctonus beetles have, it is said, been thus enabled to multiply to sufficient numbers to attack and kill the living timber and cause serious extension of their depredations into the healthy forest.

OTHER INFLUENCES AND CONDITIONS.

FOREST FIRES.

While some of the species find favorable conditions for their multiplication in fire-scorched trees, others, like the Black Hills beetle, appear to prefer the uninjured trees. This is due, perhaps, to the fact that if a fire be sufficiently severe to kill large pine trees, the bark on the lower and middle trunk is so scorched and killed that the beetles can not live in it. Spruce, however, may be killed or weakened from injuries to the base and roots by a surface fire, and thus offer especially favorable conditions for the multiplication of the spruce beetles. On the other hand, a forest fire in a forest in which the majority of the trees are infested by broods of beetles and dying from their injuries may contribute to the destruction of the insects and the protection of the remaining living timber.

MATURED TIMBER.

Practically all of the more destructive species show a decided preference for the larger and best-matured trees, and as a rule these are killed first, and the younger timber is not attacked until later, if at all. This is particularly true of the spruce beetles (Nos. 14 and 15), the southern pine beetle in the East and South, the western pine beetle, and the mountain pine beetle of the West.

COMMERCIAL CUTTING.

The cutting of living timber for commercial purposes may offer favorable conditions for the multiplication of some of the species, like the Douglas fir beetle and western pine beetle, but if such cutting, within a range of less than 50 square miles, is more or less continuous, it appears to serve as a protection to the living timber rather than otherwise. On the other hand, local sporadic cutting may bring about more or less serious results. Some species, like the Black Hills beetle, are evidently not attracted from the living trees by cutting operations, while the southern pine beetle in the Southern States is greatly favored by sporadic cutting, especially if carried on during the summer months.

SUMMER CUTTING.

The cutting of healthy trees, or even of living beetle-infested trees, during June, July, and August, in a forest or section where the southern pine beetle, the western pine beetle, the mountain pine beetle, or even the Black Hills beetle, is present, is more or less objectionable from the fact that the beetles are attracted by the odor of the exposed bark and wood and often attack many healthy trees in the immediate vicinity of the felled ones.

WINTER CUTTING.

When any of the more destructive beetles are present in a forest it is important that the principal timber-cutting operations should be carried on during the late fall and winter months, and completed in the spring before the beetles begin to fly. This is especially important when there is a large amount of infested timber to be utilized, because it is necessary to remove the bark from the trunks of such trees or convert them into lumber and burn the slabs before the insects begin to emerge. Winter cutting of living, healthy timber is much to be preferred when species with a single generation, like the mountain pine beetle, Douglas fir beetle, or the spruce beetles, are present, because during the following summer the stumps and slash will serve to attract the beetles away from the living trees. And since the broods would remain in the bark during the following winter they can then be destroyed by burning the slash any time during the following fall or winter. In the Southeast and in the Rocky Mountain region, however, when species with more than one generation annually are present, it may be necessary to burn the winter slash before the first of July, to destroy the broods of the first generation which develop from eggs deposited during May or June.

NATURAL ENEMIES OF THE BEETLES.

Were it not for the natural checks and control of some of the insect enemies of forest trees, the destruction of the forests would evidently be far more continuous and complete, but under the existing warfare between the trees and the destructive beetles and between the beetles and their own enemies, a more or less balanced condition in nature is preserved, so that it is only under exceptional conditions that a species of tree or a species of insect is exterminated.

INSECTS.

The insect enemies of the destructive beetles consist of parasites, predators, and robbers. The parasites are small wasplike insects.[a] The adults lay their eggs on, in, or near the beetle larvæ, and the minute maggotlike larvæ of the parasite, situated either internally or externally, feed on the body fluids and thus cause the death of their victims. When the parasite larva reaches its full development it either changes to a free pupa in the mine of its victim or makes a cocoon in which it goes through its transformation. Therefore the presence of certain of the parasitic enemies of the beetle larvæ is indicated by the presence of their cocoons in the mines, even after their victims have been destroyed and they themselves have emerged.

The principal predators consist of certain adult beetles and their larvæ[b] (see fig. 32), the adults often feeding on the adults of the destructive beetles before or after they enter the bark, and the larvæ feeding on the broods of the beetle larvæ in the bark.

There is another class of predatory enemies of the beetles among the true bugs,[c] which follow the beetles and larvæ into their galleries

[a] Order Hymenoptera, families Braconidæ, Chalcididæ, etc.
[b] Order Coleoptera, families Cleridæ, Histeridæ, Trogositidæ, Colydiidæ, etc.
[c] Family Anthocoridæ.

and mines, and kill their victims by inserting their beaks into their bodies.

The so-called robbers (see fig. 30) consist of large bark-boring grubs or larvæ of long-horned beetles,[a] which sometimes rob the barkbeetle larvæ of their food supply or kill them outright, by destroying the inner bark before the broods of barkbeetles have completed their development. These, however, do not occur so commonly with the more destructive barkbeetles as with those which, like the bark-boring grubs, are in the bark as the result, and not the cause, of the dying condition of the tree.

While some of the Dendroctonus beetles have numerous insect enemies, others have comparatively few. Some of the smaller species, like the southern pine beetle, which often occupy the thin bark on the upper portion of the trunk and branches of the larger trees, and sometimes on young trees, have many parasitic enemies, while others of the small species, as 1, 2, and 5, and the larger species, such as the Black Hills beetle and the Douglas fir beetle, which usually occupy the thick bark, have none at all, or very few.

So far as determined, the southern pine beetle has 11 parasitic and about an equal number of predatory enemies; the eastern spruce beetle has 5 parasitic and 4 predatory enemies, and the eastern larch beetle 6 parasitic and 2 predatory enemies. Of the western species the mountain pine beetle is the only one on which a parasite has been found, but there are four or five predators common to all, which evidently exert quite an important influence in protecting the forests of some sections. With a little assistance on the part of the owner of the forest, this class of beneficial insects will exert a much more powerful influence in preserving a desirable balance among the contending forces, and thus prevent destructive outbreaks of the beetles. This balanced condition appears to prevail at the present time within the range of the southern pine beetle, and with proper attention to local outbreaks of the beetles it could be maintained. However, this whole subject of parasites and predatory enemies of forest insects and their economic relations is one which has not as yet received the attention it deserves. Mr. Fiske gave the matter considerable attention during his field work in forest insect investigations, but his detail to another branch of the Bureau prevented him from continuing it.

BIRDS.

Wherever the Dendroctonus beetles have been found in standing timber the work of woodpeckers has been more or less common, and in some trees quite a large percentage of the beetle broods has been destroyed by the birds. The evidence gathered in Maine a few years

[a] Family Cerambycidæ.

ago indicates quite conclusively that the birds were rendering a most valuable service as a natural check to the multiplication and destructive work of the eastern spruce beetle. The work of birds is common in sections where species 1, 9, and 10 and other western species are prevalent. Yet birds evidently render the greatest service where but few trees are being killed, since their concentrated work may prevent an abnormal increase of the beetles; but where many hundreds or thousands of trees are being killed, the limited number of birds can have little or no effect. Therefore, while the birds are among the foresters' valuable friends, they can not, even with the utmost protection, always be relied upon to protect the forest from its insect enemies. We must remember that there are most complex interrelations between birds, the injurious insects, the beneficial insects, the enemies of the birds, etc., which do not always result in benefit to the forest. In fact it is often quite the reverse. Therefore, in order for the forester or owner of the forest to derive the greatest benefit from the conflict, he must not only direct his efforts toward utilizing as far as possible the natural factors which are contributing to his personal interests, but whenever the enemies of the forest threaten to get beyond natural control he must enter the fight and by radical artificial means force them back to their normal defensive position.

DISEASES OF THE INSECTS.

While evidence has frequently been found of the work of fungous or bacterial diseases in destroying the adults and immature stages of the beetles, the matter will require detailed study by specialists on such diseases before any definite conclusions can be formed in regard to their economic relations or importance.

DISEASES OF THE TREES.

Evidence has been found from time to time that the primary cause of the death of isolated large and small trees and saplings was some fungous disease of the roots and base of the stem, and that the larger trees so affected sometimes favored the multiplication of a destructive insect enemy. Evidence has also been found that certain diseases of the inner bark and sapwood, like the bluing fungus studied by Dr. Hermann von Schrenk,[a] are sometimes very injurious and destructive to the developing broods of the beetles. It is also apparent that this fungus, which is said to depend largely on the wounds made by the beetles in finding its way into the living bark and sapwood of the standing timber, may also contribute to the more rapid and certain

[a] The "Bluing" and the "Red-Rot" of the Western Yellow Pine, with Special Reference to the Black Hills Forest Reserve. By Hermann von Schrenk. Bul. 36, Bureau of Plant Industry, 1903.

death of the trees. Therefore this interrelation between plant diseases and insects must often be considered in our efforts to locate the primary cause of a trouble.

It has been conclusively determined, however, that *when the beetles occur in sufficient numbers, they are entirely independent of the aid of other factors or the influence of their enemies, and that they attack and kill perfectly healthy timber over extensive areas.*

SECONDARY ENEMIES OF THE TREES, AND DEPENDENTS, GUESTS, ETC., OF THE DESTRUCTIVE BEETLES.

As soon as the attack of one of the destructive beetles causes a weakened or dying condition of a tree, such a tree becomes at once the breeding place of many other species of barkbeetles and bark and wood boring grubs which can not attack healthy trees. These secondary enemies of a tree are dependent on the more aggressive Dendroctonus beetles or on other factors that may cause a similar weakened or dying condition of the trees. Some of them render special service to the destructive beetles by attacking the twigs, the branches, and the unoccupied bark on the upper and lower portions of the trunk, and thus aid in bringing about the certain death of the tree. There are some insects which live in the galleries with the adult beetles, in the relation of guests, others as scavengers, etc., so that it is always important to distinguish which are the real primary enemies, which are secondary, which are beneficial, and which are neutral in their relation to an affected tree.

GENERAL METHODS OF CONTROL.

While the subject of control is treated under the special discussion of each species, there are some general principles and features which should be mentioned in this connection, especially such as relate to the infestations of standing timber by the broods of the destructive beetles.

HABITS AND SEASONAL HISTORY AS SUGGESTING METHODS OF CONTROL.

Any systematic plan or method for the destruction and control of these beetles, in order to be least expensive and most successful, must be based on a knowledge of the habits and seasonal history and many other essential features relating to the particular species, or group of allied species, involved in a given problem. The principal facts of importance in this connection are as follows: (*a*) It is the normal habit of all of the species to infest the bark on the main trunk of the larger to medium sized trees; (*b*) in all species the developing broods of larvæ live in the inner bark; (*c*) some of the species, as in subdivision A, enter the outer dry bark to transform to adults, while others, as in subdivisions B, C, and D, transform in the inner bark; (*d*) the broods of all of the species pass the winter in the bark of the infested trees and remain there until they develop to the winged stage, when they leave the then dying or dead trees to fly and attack the living ones; (*e*) the developed broods of beetles usually emerge from the trees before the leaves are all dead, or certainly by the time the leaves have all changed to the reddish-brown color and begin to fall or have entirely fallen from the branches. (See fig. 25.)

DESTRUCTION OF THE BROODS.

Since the trunk of the tree is the principal part of attack, we have only to direct our efforts to the infested bark on the main trunk, and adopt the method of killing the broods which, under local conditions and facilities, is the most practicable and efficient.

In species 1 to 8 removing the infested bark, and burning or otherwise destroying it, is necessary to kill the developed broods of larvæ, pupæ, and adults which may be located in the outer bark.

In species 9 to 23 the removal of the infested bark without burning is all that is necessary. The time to do the work in both cases is from the time activity ceases in the fall until two or three weeks before the normal time for the winged adults to begin to emerge and fly.

BARKING THE STANDING TREES TO KILL THE BROODS.

The bark may be removed from the standing trees by means of suitable tools (see figs. 57, 58), and the trees left until it is convenient to fell and utilize them. Thus, during the period in which these operations must be done, the labor should be directed exclusively to the removal of bark. If necessary, the barked trees may be left standing for several years without the value of the wood becoming impaired; otherwise their utilization may immediately follow the completion of the barking operations. Whenever the conditions are favorable for the immediate disposal or utilization of the infested timber by sale, free use, or otherwise, the timber may be barked as it is felled and the barked log may be converted into lumber at any time during the year, within the required period.

DESTRUCTION OF THE BROODS WITHOUT REMOVING THE BARK.

The destruction of the broods without removing the bark may be accomplished by several different methods: (*a*) By converting the logs into lumber and burning the slabs; (*b*) by placing the logs in water; (*c*) by piling the trunks and scorching the bark sufficiently to kill the broods; (*d*) by scoring the upper side of the felled trunks to allow the water from rain or melting snow to penetrate the inner bark and thus destroy the broods; (*e*) by transporting the infested trunks a sufficient distance (20 to 50 miles or more away) from the forest and away from any living spruce or pine, so that the beetles emerging from them will find no trees to attack.

ATTEMPTS AT COMPLETE EXTERMINATION OF THE BEETLES UNNECESSARY.

As a rule, it is not only useless but unnecessary to attempt the complete extermination of one or more species of the beetles within a given forest. It is necessary, however, to so reduce and weaken their forces that they can not continue an aggressive attack, thus leaving them to depend upon weakened and felled trees for their support and to occupy a defensive position against their natural enemies.

It must be kept in mind that the beetles must occur in great numbers in order to be successful in their attack on healthy trees. If their number is reduced and kept below that required for killing trees they can do no harm. Therefore in the case of a destructive outbreak it is necessary to destroy only from 50 to 75 per cent of the beetles in order to bring them under complete control.

REQUISITES FOR SUCCESSFUL CONTROL.

The principal requisites for success in dealing with these beetles are: (*a*) Prompt recognition of evidences of their presence before they have extended their depredations beyond a few scattering clumps or patches of trees; (*b*) positive identification of the species involved; (*c*) prompt action in adopting the proper method of control; and (*d*) reliance on expert advice relating to the essential features in the habits and seasonal history of the insects, on which the action is based.

HOW TO CHECK AND CONTROL AN EXTENSIVE INVASION.

If the depredations by species 9, 10, 13, 14, or 15 have spread over a large area and there is yet a large amount of living timber or adjacent healthy forests to be protected, a careful survey should be made in September, October, or November, for the purpose of locating the areas and localities of new infestation in which the trees were attacked during the summer and fall and which, at the time of survey, contain living broods. The areas of principal infestation and the larger patches of infested trees should be designated on a map, and estimates made of the total amount or percentage of timber affected. This will form a basis for definite plans and the organization and equipment of a sufficient force to do the required work within the specified time designated for each species. Then, if regular logging operations can be directed and concentrated upon the principal areas so that a large percentage of the timber can be cut, barked, or otherwise treated before the broods begin to emerge, the desired control may be effected with little additional expense, or even at a profit. If this method can not be adopted, the force should be directed to removing as large a percentage as possible of the infested bark from the standing infested trees or from those felled for that purpose. The first work should be done in the principal areas and larger patches. The work should be planned and executed with the object of destroying the greatest possible number of broods for the time and labor involved; that is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from three or four trees as could be done in the same time by removing all of the infested bark from one tree, the former procedure is far preferable.

HOW TO CONTROL A LIMITED ATTACK.

Whenever it is determined that one or more species is attacking and killing small patches of timber in a given locality or forest of greater or less extent and that the bark of the living and dying trees contains living parent adults and developing broods, prompt and, if necessary, radical action should be taken before the adults begin to emerge and fly.

HOW TO MAINTAIN CONTROL.

IN STATE AND NATIONAL FORESTS.

In State and National forests, and in all other forests in which there is an organized force of rangers and fire wardens or patrols, each officer should be furnished with the necessary instructions for the location of beetle-infested trees and with equipment and directions for taking the necessary action whenever the conditions demand it. It has been demonstrated that any intelligent ranger or manager can become proficient in locating and marking infested trees with comparatively little instruction in addition to that already published or conveyed in special recommendations.

It is not necessary that every isolated infested tree should be treated, but it is of especial importance that all groups of infested trees should receive prompt attention.

IN PRIVATE FORESTS.

Private forests should receive the same attention as reserves, but this is often far more difficult on account of intervening forests, where the owners either can not or will not give the matter the required

attention. While in exceptional cases it may be advisable to have laws governing the treatment of timber infested with a dangerous pest, such laws should be based on expert advice and should apply to the more extreme and well-known cases only as a last resort. It is probable that in most cases legislation will not be necessary, and that more ultimate good will result without than with such laws, especially when it can be made clear to the owner that his personal interests demand that he take the proper action and that when necessary his neighbors will render assistance, as is done in the case of a forest fire.

INACCESSIBLE AREAS.

There are yet large inaccessible areas in the East and West where it will not be practicable or possible to control the depredations by these beetles, and which therefore must be left to natural adjustment. While under natural control the matured timber will be lost, it will usually be replaced by young growth, so that under normal conditions the forest will be perpetuated. Under exceptional conditions and combinations of detrimental influences, such as insects, fire, and drought, extensive areas may, however, be completely denuded, never to be reforested under natural conditions. This has doubtless happened in very many denuded and bare areas in the Rocky Mountain region, which were at one time heavily forested.

TRAP-TREE METHOD OF CONTROL.

The well-known attraction of many species of European barkbeetles to weakened, dying, and felled trees suggested to some of the earlier writers on forest insects a method of barkbeetle control which since that time has been widely recommended and under certain conditions and for certain species of beetles has been successfully practiced. It is the so-called trap-tree method, in which living trees are deadened or felled at the proper time or season to attract the insects and induce them to breed in the bark, where they can be easily destroyed by removing the latter or burning the entire tree. Experience and observations indicate, however, that while this method is successful in attracting many species of bark and wood boring insects it does not always attract those which are the most destructive to the living trees, or at least not in sufficient numbers to justify its general recommendation and adoption.

Among the Dendroctonus beetles there are a few species which are attracted to weakened and dying trees and to the stumps, logs, and tops of recently felled living trees. These are species 1, 2, 4, 12, 13, 22, and 23 and, to a more limited extent, species 14 and 15, but extensive experiments have indicated quite conclusively that the Black Hills beetle, the most destructive species of all, can not be successfully attracted to trap trees and that it actually prefers to attack healthy living trees.

The Mountain pine beetle is attracted to a greater or less extent to felled and fire-scorched trees, but will at the same time attack near-by living ones, as will all of the other species. It is therefore under exceptionally favorable conditions only that this method would be sufficiently successful to warrant its adoption as a means of controlling this class of beetles. These exceptions would be as a rule on a very limited scale, as is referred to under the special discussion of some of the species.

One of the objections to the trap-tree method of combating the Dendroctonus beetles is in the fact that a few living trees deadened or felled in the midst of a healthy forest where the destructive species are present may, as has often been demonstrated, not only attract the beetles to the trap trees but to the near-by healthy trees, thus inducing instead of preventing a destructive outbreak.

INTRODUCTION AND PROTECTION OF NATURAL ENEMIES.

The introduction and protection of natural enemies of these barkbeetles is a subject of special interest and one that should receive attention in the future, especially in the line of investigations and experiments to determine facts on which to base reliable conclusions. In the case of a destructive insect which has been introduced from another country it is plain that if its natural enemies did not come with it they should be introduced; but with native insects it is quite a different proposition and will require much detailed investigation before the results from transfers and introductions can be predicted with any degree of certainty. The protection of natural enemies already present is, however, worthy of special consideration. If, for example, certain parasites and predatory insects are abundant in the bark of the infested trees and certain methods of procedure are adopted for combating the destructive beetles which will at the same time allow the beneficial insects to escape, it will naturally operate against the enemy. But if, on the other hand, the beneficial insects are destroyed along with the destructive ones it may have the opposite effect.

The parasites usually attack the broods beneath the thinner bark, like that toward the top and on the larger branches of the large trees or the trunks of the small ones. Therefore, whenever the parasites are common, it will be best simply to remove the infested thicker bark and leave the thinner bark for the parasites.

Burning the infested bark on the trees or immediately after it is removed will destroy the beneficial insects with the injurious ones, but if the bark be removed in the early fall or early spring and left for several days before burning (if burning is necessary), many of

the beneficial insects will escape. Or, if it is not necessary to burn the bark, practically all will escape, and thus assist in destroying the broods left in the tops of trees and those in scattering trees. It is always important, therefore, to determine whether or not the natural enemies are present in sufficient numbers to make it worth while to adopt special precautions for their protection.

Wherever woodpeckers are common in a forest they may aid greatly in destroying the broods of barkbeetles in the scattering clumps and isolated trees, especially if the beneficial insects are scarce. If, on the other hand, the beneficial insects are common, the birds may feed on them and do as much harm as good. The protection of the birds, however, should be maintained, because even if they are harmful at times they evidently more than compensate for it in the general service they render to the forest.

IMPORTANCE OF SYSTEMATIC FORESTRY.

After all, success in the control of these beetles and of forest insects in general depends more upon good forest management, perhaps, than upon anything else relating to the practical phases of the problem, for without some organized system of management very little can be accomplished toward the successful utilization of available information or methods of control. It is equally true, however, that unless the available knowledge relating to the insects and the principles of their control is understood and properly utilized in forest management and lumbering operations, nothing will be accomplished, and the depredations and great losses of valuable timber will continue.

SOME RESULTS OF EFFORTS TO CONTROL BEETLE DEPREDATIONS.

It is only within recent years that any detailed work has been done on the forest insects of North America, and the possibility of controlling their depredations is not generally recognized, even among foresters. Organized efforts and definite results were not, therefore, to be expected, yet we have a few examples which may serve as demonstrations of what can be done. In 1900 the eastern spruce beetle was killing a large amount of mature spruce in northwestern Maine. This was investigated and the concentration of the logging operations in the infested sections was recommended. This recommendation was adopted, and with little or no additional expense sufficient numbers of the infested trees were cut the first winter, and the logs floated out in the spring, to check the ravages of the beetles, and, so far as can be learned, up to the present time very little timber has since died in that section as the result of insect attack.

In 1905 the Black Hills beetle was killing patches of timber in the vicinity of Colorado Springs and Palmer Lake, Colorado, as it did in the beginning of the attack in the Black Hills of South Dakota, in 1897, but through the efforts of the late Gen. William J. Palmer and others, sufficient numbers of infested trees were felled and barked on private land and in the adjoining National Forest during 1905 and 1906 to destroy a large percentage of the beetles in the entire vicinity. Careful inspection during the fall and winter of 1906 and 1907 indicates that the pest is now under complete control within a radius of some hundreds of square miles.

The successful control of another serious outbreak of the Black Hills beetle in 1906 on an extensive private estate in southern Colorado was effected through the efforts of the owners in having some 500 infested trees felled and barked within the necessary period to destroy the broods. A large percentage, but not all, of the infested timber was thus treated. This was so successful that not a single infested and dying tree could be found when the area was inspected in 1908. In this, as in the other case, considerable unnecessary expense was involved in the burning of the bark and tops, but the utilizable timber was more than enough to pay all expenses. It is evident that in this case a destructive invasion was prevented, and that more than a million dollars' worth of timber was protected.

The most striking example of success in control of the Black Hills beetle was reported in time for mention in this connection. Mr. W. D. Edmonston, a forest ranger, detailed from the Forest Service to the Bureau of Entomology to work under the instructions of the writer in the location and reporting of evidences of beetle infestation in the National Forests of Colorado and adjoining States, reported in May, 1907, that the pine timber was dying on a large estate not far from Idaho Springs, Colorado, and the adjoining National Forest. He was instructed to make more detailed examinations, after which he reported that some 65,000 feet of timber on the estate were found to be infested by the Black Hills beetle, and that unless the ravages were checked at once the timber not only on this estate but on the adjoining estates and National Forest would be killed. The owner of the property was advised by this bureau to take radical action according to a special recommendation and detailed instructions relating to a necessary control policy. No action was taken, however, before the first of the following July, and therefore not in time to prevent the beetles from swarming from the infested trees and extending their ravages. In December, 1907, Mr. Edmonston was instructed to make another examination of the timber, when he found that his prediction was being fulfilled. He reported that instead of 65,000 feet of infested timber, there was nearly four times as much timber involved in the new infestation, or over 250,000 feet.

The owner was again notified in December, 1907, of the serious character of the outbreak, and the suggestion made that if the logs from the infested trees were converted into lumber and the slabs burned before the next May, it would result in the protection of the remaining living timber. Immediate steps were then taken to carry out the original recommendations. Mr. Edmonston gave instructions to the manager of the estate in locating and marking the infested trees and in the essential features in the methods of utilization to destroy a sufficient number of beetles to check the infestation, and he also marked infested timber on the adjoining estate and National Forest. In May, 1908, Mr. Edmonston reported that the larger clumps of infested trees on the estate had been converted into lumber and the slabs burned, and that those on the adjoining estate and National Forest had been cut and barked. In November, 1908, Mr. Edmonston was instructed to make another inspection of the forest on the estate and surrounding area, and on December 1 he reported as follows:

> Nothing could be more satisfactory than the results obtained by the cutting of the infested timber on the estate. Your recommendations and instructions submitted to the owner, and carefully followed by the manager of the estate, have clearly demonstrated that insect infestation can be controlled and at no expense to the owner of the timber involved; in fact, a very satisfactory price was realized, resulting in a net profit, I understand, of $5 per thousand feet, board measure, on the 240,000 feet cut. This, of course, does not include the profit of the milling operations, but for the logs sold at the mill, after deducting the expenses of cutting and logging. The sawmill was owned and operated by an Idaho Springs firm, and the manufactured article sold in that town. I spent six days on the estate—November 18 to 23. After a very thorough examination of the timber, I found only three infested trees, isolated individuals, over a mile from where the large clumps of infested trees were cut. With the exception of those three trees there is no new infestation on the estate. I also examined the adjoining lands, but no new infestation was observed. The infested trees which I marked in December, 1907, had all been cut and barked. On the Pike National Forest, contiguous to the first-mentioned estate, where, you will remember, I marked some clumps of infested trees, no new infestation was found—not one tree. I found that all the infested trees I marked had been cut and barked. Ranger Kelso had charge of this work, and it has been quite thoroughly done.

This most gratifying result demonstrated two important facts: One, that a very extensive outbreak by one of the Dendroctonus beetles can be controlled without expense, and even at a profit, whenever the conditions are favorable for the utilization of the infested timber; the other, that the essential details, recommendations, and expert advice can be sucessfully carried out by a manager of a private forest and by the rangers of National and State forests. It also indicates quite conclusively that the widespread depredations in the Black Hills National Forest could have been prevented with very little expense to the Government if the matter had received prompt attention in 1901, when the first investigations were made and recommendations submitted. But, through the lack of public appreciation of the importance of the problem at the time, and the lack of sufficient authority and funds later, it was allowed to extend beyond practical control, and in consequence a large percentage of the timber on the entire National Forest has been killed.

DETAILED INFORMATION ON THE SPECIES.

The discussions on the following pages relate to more detailed information on each species.

In the first paragraph, under the English and technical name, will be found a brief summary of the distinctive characters of the species, its seasonal history, habits, distribution, and evidences of attack. This is to facilitate preliminary identification by the reader, and is followed by a more detailed account of the seasonal history, habits, and economic features as a basis for the recommendations and proper application of methods of control, and closed with references to the investigations and identifications on which the statements are based. The fact that the species are discussed more or less independently necessitates some repetition of statements relating to seasonal history, habits, and methods of control. In view of the fact, however, that a bulletin of this kind is used mainly as a reference work, in gaining information on a special insect or subject, as it is required, such repetitions are to a certain extent necessary.

GENERAL EXPLANATION OF DESCRIPTIVE AND OTHER TERMS.

While the illustrations will show the parts designated by technical or semitechnical names, there are other terms used in the discussion of seasonal history, habits, etc., which may need some explanation for the general reader.

Brood.—The term "brood" refers to the progeny of a single pair, or the individuals hatching from the eggs in a single egg gallery.

Generation.—By a "generation" is meant all of the broods that are the offspring of the adults of the overwintering broods, except the overwintered parent adults, which may be parents of the overwintered broods, and also of broods from eggs deposited by them in the spring. Another exception is in the retarded individuals which pass more than one winter in either the larval or adult stage.

All the progeny of the overwintered broods may be said to comprise a complete generation. If all of this progeny complete their development between the time the first eggs are deposited in the spring and the close of the same season of activity, and emerge from the trees, it may be referred to as constituting a complete seasonal generation. If another set of broods develops to maturity from eggs deposited by the adults of the first generation of the season, it will form a complete second generation, and so on. If, however, only

parts of the broods complete their development and emerge during the first season, and the others remain over until the next season, it will be a partial development of a seasonal generation. If all of the broods develop and emerge within twelve months from the time the first eggs were deposited, it is referred to as a complete annual generation.

Hibernation.—The term "hibernation" as here applied relates to the period in the seasonal history of the broods from the time general activity ceases in the fall until the time it begins again in the spring. In southern localities there may be considerable activity (feeding and development) of the broods during the warmer days of winter, so that hibernation used in this connection does not mean that the broods are entirely dormant and inactive, but that for the greater part of the time they are.

Overwintering stages.—The overwintering stages are those of the hibernating broods.

Overwintered broods.—The term "overwintered broods" relates to all stages which have passed the winter in the bark of the infested trees, whether active or not. It is, therefore, a better term to use for the barkbeetles than "hibernated broods."

Activity of overwintered broods.—By the "activity of overwintered broods" is meant the feeding, development, transformation, emergence, flight, etc., from the time general activity begins in the spring among the broods which have overwintered in the bark. This activity may extend over several months and overlap the activity of broods of one or more generations. The parent adults that attack the tree too late in the fall to complete their egg galleries usually continue their work of extending the galleries and depositing eggs when activity begins the following spring. Some of the parent adults that have completed their egg galleries in the fall may also live over winter and excavate new galleries when activity begins in the spring. The overwintered broods of young adults include those that transformed to adults before activity ceased in the fall and passed the winter in the pupal cells where they transformed. These are usually the first to emerge and fly in the spring, but sometimes they remain in the bark until the majority of the broods are fully developed. Among the overwintered broods of larvæ there may be all stages from very young or small larvæ to fully developed ones. The latter will begin activity by transforming to pupæ. The immature larvæ begin their activity by feeding and extending their larval mines. Under normal or favorable conditions, the majority of the immature stages of some species will have completed their development and transformed to adults before the overwintered young adults in the same tree have begun to emerge, so that nearly all of them may leave the trees about the same time, but there are always certain trees in which the conditions are not so favorable for normal development. There are also broods from eggs deposited by overwintered parent adults, so that the period of development and emergence of all of the overwintered broods is prolonged and irregular. In fact, some of the overwintered individuals of certain species may not complete their development and emerge until the second season of activity. These retarded broods are not of much economic importance, but they introduce an element of confusion in defining the limits of a given generation. On the other hand, periods of normal or principal development, transformation, and emergence of the broods are of especial economic importance, since a knowledge of them is quite essential for successful control.

Seasonal history.—According to the writer's interpretation, the seasonal history of an insect is the history of the broods of the species from the beginning of activity in the spring of one year to the end of the hibernating or overwintering period in the spring of the next year.

Life history.—The term "life history," as frequently employed, is synonymous with seasonal history, but to be more exact it is the history of an individual from the egg to maturity and death, including its natural enemies, environment, or any other phenomena affecting its life.

Egg gallery (fig. 7, etc.).—The egg gallery is the burrow made by the adult beetles, along the sides of which the eggs are deposited.

Larval mines and pupal cells (figs. 19, 22, etc.).—The larval mines are the food burrows made by the larvæ. The pupal cells are cavities excavated by the larvæ at the end of the larval mines, in which to transform to the pupæ and adults.

Food burrow.—A food burrow is one excavated into the living bark by the adult beetles for the purpose of obtaining food.

Entrance burrow (figs. 79, 99).—The entrance burrows are the holes made by the parent beetles through the outer and inner bark preliminary to excavating the egg galleries.

Ventilating burrows (figs. 79, 99).—Ventilating burrows are the vertical burrows located at frequent intervals in the roof of the egg gallery and extending outward to or near the surface. They are utilized by the parent adults as a place in which to turn around, or in which to pack the boring dust, or through which to eject the dust, as the case may be.

Exit burrows or exit holes (figs. 8, 22).—The exit burrows or exit holes are the clear-cut holes in the outer bark through which the adults of the new broods emerge from the tree.

Boring dust (figs. 79, 99, etc.).—The sawdustlike borings ejected from the egg galleries or packed in them and in the larval mines is referred to as boring dust.

Pitch tubes (figs. 8, 9, 100).—The resin or gum expelled by the beetles from the entrance burrows is often formed into more or less regular masses with a hole through the middle, thus suggesting the name "pitch tubes."

Infested trees.—Trees containing living parent adults or developing broods are referred to as "infested trees."

Fading tops.—The fading or noticeably paler green of the foliage of infested trees is referred to as "fading tops."

Sorrel tops.—The yellowish foliage of trees dying from the attack of the beetles is termed "sorrel tops." It must be remembered that a certain number of the older leaves or needles on the healthy twigs die, turn yellow, and fall each year; therefore this normal condition should not be mistaken for an indication of unhealthy conditions. It is only when the needles of the middle and tip of the cluster turn yellow from the base outward that the dying of the tree is indicated.[a]

Red tops.—The term "red tops" refers to the color of the foliage after the tree is dead, and usually after the broods of destructive beetles have emerged from the bark. This reddish-brown of the adhering pine needles may prevail for one year or more after the trees are dead.

Beetle-abandoned trees.—After the broods of the destructive beetles have emerged from the bark of a tree such a tree is referred to as "beetle abandoned."

Black tops (fig. 25).—The condition of the dead trees after all of the needles have fallen and two or more years after the beetles have left them is referred to under the name "black tops."

Broken tops (figs. 26, 27).—After the trees have been dead four or more years and the tops have broken off they are termed "broken tops."

Sap stain or blue sap (fig. 29).—The discolored condition of the sapwood of infested trees before and after the leaves begin to fade is referred to as "sap stain" or "blue sap."

Sap decay.—After the trees have been dead long enough for the sapwood to be decayed, but the heartwood is yet in a sound condition they are termed "sap decayed."

Heart decayed.—The term "heart decayed" refers to the condition after the trees have become unfit for any practical use.

Millimeters and inches.—One millimeter equals about one twenty-fifth of an inch or about four-hundredths of an inch. Two millimeters equal about one line, or about one-twelfth of an inch. To reduce millimeters to inches, multiply by 0.04; to reduce hundredths of an inch to millimeters divide by 0.04. To reduce lines to millimeters multiply by 2; to reduce millimeters to lines, divide by 2.

[a] Needles injured by climatic conditions have the tip dead and the base green.

sented in the forest-insect collection of the Bureau of Entomology by more than 150 specimens.

This species is closely allied to No. 7, of Mexico, and was at one time thought by the writer to be a variety of it,[a] but recent studies indicate that it is a good species, distinguished by the more shining pronotum, more distinctly narrowed and faintly constricted toward the head, the hairs on the sides toward the base slender and less numerous. Therefore it is thought best to retain it as a good species. It is easily distinguished from the other species associated with it in the same region by its elongate form, larger size, and by the deep frontal groove of the head and stiff, erect, blackish hairs on the declivity.

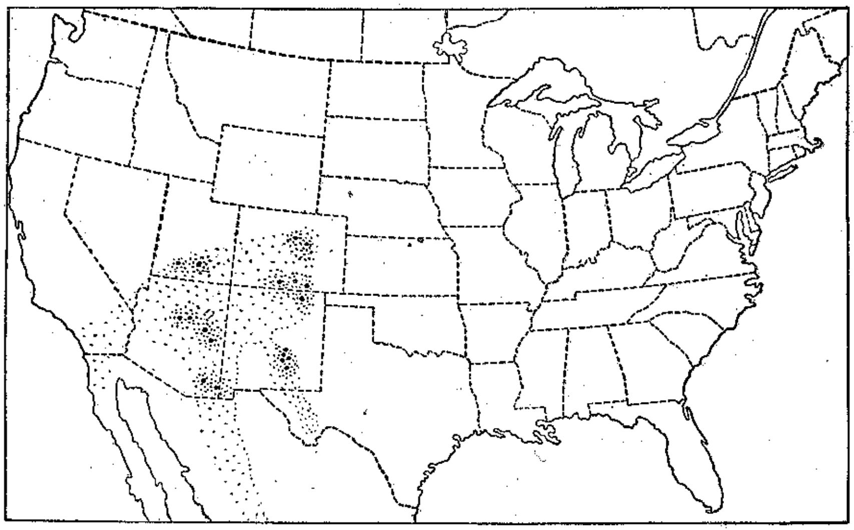


FIG. 43.—The Colorado pine beetle: Distribution map. (Author's illustration.)

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Schwarz, 1902, p. 32; Hopkins, 1903*a*, p. 61; Hopkins, 1904, p. 44; Hopkins, 1905, p. 11; Hopkins, 1906*c*, p. 81; Hopkins, 1909, pp. 101–104.

No. 9. THE MOUNTAIN PINE BEETLE.

(*Dendroctonus monticolæ* Hopk. Figs. 44–50.)

The mountain pine beetle is a stout, black, cylindrical barkbeetle 3.7 to 6.4 mm. long, having the head broad, without frontal groove, but with a short longitudinal impression above the middle; the prothorax short, broad, and punctured, with sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between rows of punctures, the latter usually indistinct on the sides; the declivity slightly impressed each side of the suture, and

[a] Proc. Ent. Soc. Wash., VII, p. 81.

with a few long hairs, the striæ narrow, and the spaces between quite broad and roughened with sparsely placed granules. (See fig. 44.) It attacks injured, felled, and healthy silver or western white pine, western yellow pine, and lodgepole pine, in Montana, western Wyoming, Idaho, Oregon, and Washington; it also attacks sugar pine, western yellow pine, and lodgepole pine in the mountains of Washington, Oregon, and California. It excavates very long, nearly straight to slightly, and sometimes strongly, winding egg galleries through the inner living bark and grooves the surface of the wood (figs. 45, 46). The eggs are placed in approximate groups at short intervals along the sides, and the short and broad to long and slender larval mines are exposed in the inner bark; the larvæ transform to pupæ and adults in separate cells, exposed or concealed in the inner bark. This species is sometimes associated with the western pine beetle in the same tree, but usually it works independently and occupies the greater part of the bark on the main trunks. Infested trees are first indicated by pitch tubes and later by the fading yellow to reddish foliage.

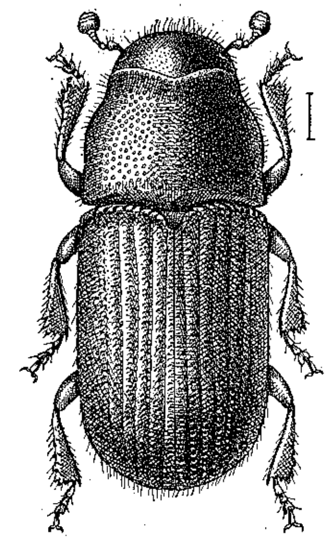

FIG. 44.—The mountain pine beetle (*Dendroctonus monticolæ*): Adult. Greatly enlarged. (Author's illustration.)

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed as larvæ, young adults, and parent adults, in the inner bark of trees attacked the preceding summer and fall, the parent adults in the egg galleries or ventilating burrows, and the broods in the larval mines or pupal cells.

ACTIVITY OF OVERWINTERED BROODS.

As soon as the weather is favorable in April and May the overwintered parent adults extend their incompleted egg galleries or excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge in July. The principal period of emergence is in August, but the retarded broods continue to come out until September, or later. The broods of larvæ begin to transform to pupæ and adults in April and May and continue to do so until September, or later. Some of the larvæ evidently pass the second winter as matured larvæ and adults. The broods from eggs deposited by the overwintered parent adults evidently develop to adults in July and August.

GENERATION.

The overwintered broods of adults begin to attack the trees, excavate galleries, and deposit eggs about the first of August and continue to do so during August and September, until October or later, but the principal period of attack is in August. The larvæ begin to hatch early in August and begin to transform to pupæ and adults in September and October. Under favorable conditions a few adults may emerge late in the fall, but evidently it is the normal habit for the

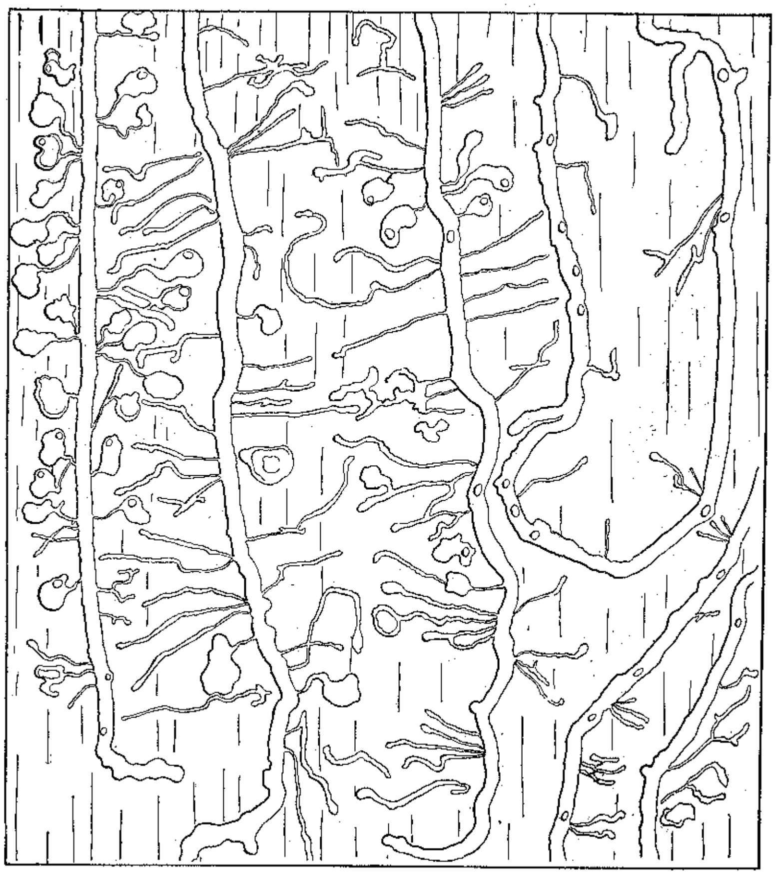

FIG. 45.—The mountain pine beetle: Egg galleries and larval mines in bark. Reduced. (Author's illustration.)

broods of this generation to pass the winter as all stages of larvæ, as adults in pupal cases, and as parent adults, and it is evident that some individuals of the delayed broods do not complete their development until in the fall of the year following and that some of them pass the second winter as parent and young adults. There is, therefore, but one generation annually, with a possible overlapping of the generations of three years during the summer.

HABITS.

This species apparently prefers to attack injured and felled trees, but is often found attacking healthy living ones. It infests at least

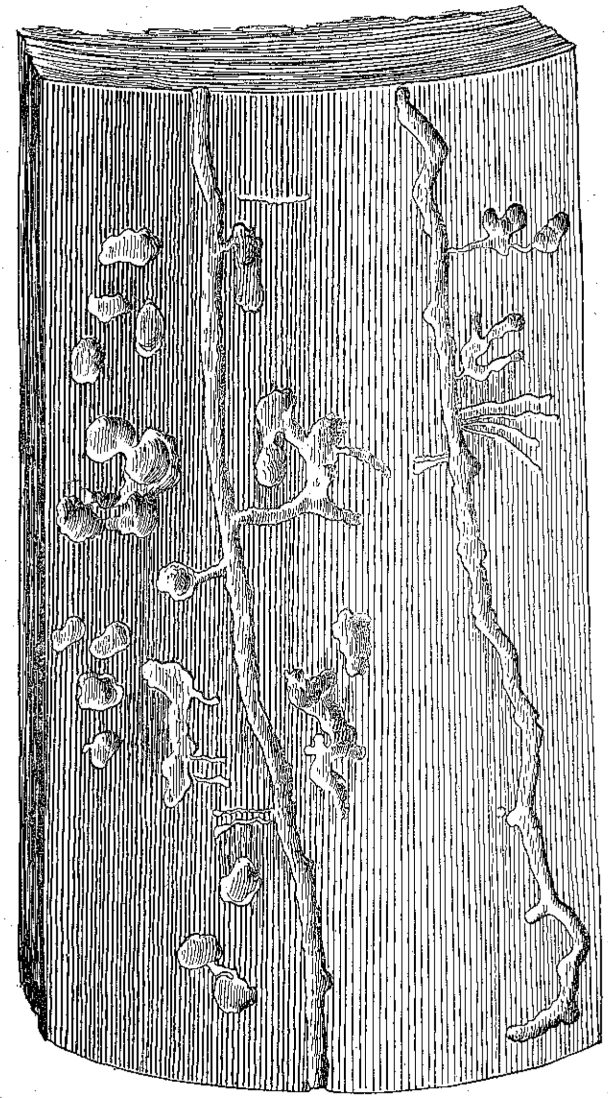

FIG. 46.—The mountain pine beetle: Egg galleries and larval mines grooved in surface of wood. (Author's illustration.)

four species of pine and one species of spruce, and will doubtless be found in other species of pine and spruce growing within its range.

The parent adults excavate their long, nearly straight, or winding, longitudinal galleries through the living inner bark, and groove the surface of the wood of the main trunk. The larvæ excavate short and broad, or long and slender food burrows at right angles to the primary gallery, and usually transform in their individual pupal cells exposed in the inner bark or between the inner bark and wood, the cells marking the surface of the wood. After the new broods of adults become matured, they often bore out the bark intervening between the cells and congregate under the loose bark before they begin to emerge; some of them, however, bore directly out from the transformation cells.

Scarcely anything is known of the flight habits, but this species evidently flies in swarms late in the evening or at night. It is not improbable, however, that, like its near relative, the Black Hills beetle, it may at times swarm during the day.

ECONOMIC FEATURES.

While this species apparently prefers to attack injured and felled trees, it is in some localities often found attacking and killing the living timber over considerable areas. As a rule, the largest and best trees are attacked first, and their egg galleries and larval mines completely girdle the trunks from near the ground up to the middle branches.

The silver pine or western white pine (fig. 47) and lodgepole pine in Idaho and Montana, the sugar pine (figs. 48, 49) in Oregon and California, and especially the lodgepole pine in the Yosemite National Park, and in northwestern Oregon have suffered severely from its ravages.

EVIDENCES OF ATTACK.

The first external evidence of attack on living timber is the presence of pitch tubes on the outer bark of the trunk or of reddish borings lodged in the flaky bark and around the base of the trees with normal green foliage.

The second important external evidence of attack, and of infested trees, is the fading of the foliage in the fall and spring, followed by a yellowish or sorrel-top condition in May to June, and by red-tops during the period from July to September. The internal evidence is found by cutting into the bark and revealing the characteristic galleries occupied by the broods, but positive evidence of attack or infestation by this species is determined only by authentic identification of specimens taken from the bark. Trees attacked for the first time early in August may have the foliage fading late in the fall, but as a rule the foliage remains green until the following spring. The broods begin to emerge by the time the leaves begin to change to the red-top condition, and are all out by the time all of the leaves are dead and red. Exceptions to this rule are frequently found, where only the top or one side of a tree was killed the first year, or when living bark remains toward the base, which is attacked the second year by the overwintered parent adults and young adults from the overwintered broods. But it is safe to conclude that after the leaves are all dead and brown, very few representatives of the broods will be found in the bark.

FIG. 47.—Silver or western white pine killed by the mountain pine beetle in the Priest River National Forest, Idaho. (Original.)

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

The commercial value of the silver pine, sugar pine, and lodgepole pine, owing to the thin sapwood, is often not seriously impaired for many years after the trees die, provided they are not injured by fire, storms, wood-boring grubs, and premature decay. The yellow pine, with its thick sapwood, suffers immediate deterioration owing to the bluing fungus which follows the attack of the beetles, causing the wood to blue long before the leaves begin to fade. Except for the secondary injuries by wood-boring insects, fire, etc., the heartwood of the larger trees will remain sound and valuable for several years. While, however, there may not be a very great loss from leaving the dead timber standing until the heartwood begins to deteriorate, the danger of destruction by forest fires is so great that, in order to insure

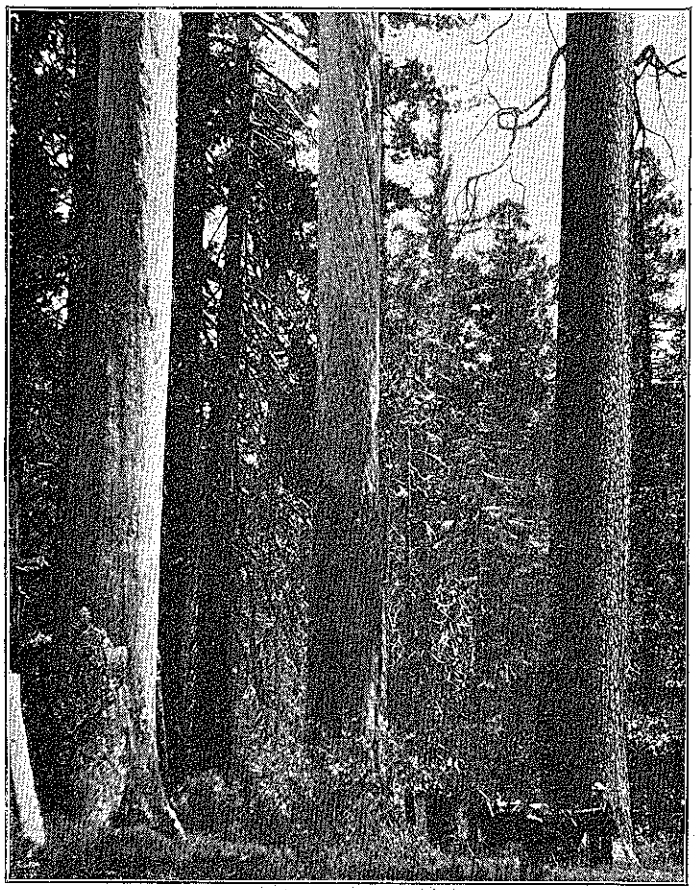

FIG. 48.—Two giant sugar-pine trees killed by the mountain pine beetle, and one dying from recent attack, Yosemite National Park, Cal. Note horse and man by dying tree, indicating diameter of tree at base. Approximate diameter, 8 feet. (Original.)

against complete loss, the attacked and infested timber should be felled and utilized before the broods of the beetle develop and emerge, or within two or three years.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this insect are found in so-called primitive forests with a predominance of mature timber, and where trees are frequently struck by

lightning, broken, or felled by storms, landslides, etc., or injured by fire. Unfavorable conditions for attacks on living timber will be found in areas of vigorous young to matured growth under some system of forest management which provides for the utilization of the old timber and especially that injured by storm, lightning, fire, etc.

FIG. 49.—The mountain pine beetle: Tops of the trees shown in figure 48. (Original.)

METHODS OF CONTROL.

Whenever it is positively determined that this species is killing the timber and that the bark of living or dying trees contains living broods, the principal groups of infested trees should be located and marked during September, and then during the period beginning in October and ending in the following July the infested bark should be removed from the main trunk. The simple removal of the bark, without burning, is sufficient to kill the broods of this species. If large numbers of lightning-struck trees, and those injured by storms or otherwise, become infested during the summer, they should be barked before the succeeding July. The felling and barking of newly-attacked trees during August and September is not to be recommended for this species.

This species, unlike *D. ponderosæ*, is attracted to injured and felled trees, and therefore may be trapped to a limited extent in trees felled during July and August, and may be destroyed by removing the bark any time between October and the following July. This may or may not provide sufficient breeding places in the felled trees and stumps to prevent attacks on living timber.

Whenever it is necessary or desirable to destroy the broods of this insect in the logs, stumps, and tops, the timber sales or timber-cutting regulations relating to living timber should require that if the slash from winter, spring, and summer cutting is to be burned it should be done during the succeeding fall, winter or spring, and that the work be completed before the first of the succeeding July. Summer burning, to destroy the broods of this species, is undesirable and entirely unnecessary if it can be done later.

The regulations relating to infested timber should require that the first work be directed either to removing the infested bark from the main trunks of the standing trees or to felling and barking the trees, or to utilizing the timber and burning the slabs, so that this essential part of the work may be completed within the specified time, after which the logging operations, including the disposal of the barked and old dead timber, or of the living timber, if the last is included in the sale, may be prosecuted until it is time to begin the barking operations the following October, on any new infestation which may appear within the area covered by the sales.

The lodgepole pine, with its very thin bark, offers more favorable conditions for combating this enemy than the thick-barked western yellow pine and sugar pine. While the parent adults may attack the thinner bark on the upper portion of the trunk and on smaller trees, it is only in the thicker bark on the lower portion of the trunk of the medium to larger trees that the broods will reach their best development. Therefore, while many trees may be killed by the beetles, the removal of the infested bark from the lower portion of the trunks of a comparatively few of them may be all that is necessary, and since this bark can be removed from the standing timber the work need not be expensive. In fact, it may be desirable and more practical to give the infested trees to anyone who will bark them within the specified time.

Whenever the infested timber is in the vicinity of streams or lakes the insects may be destroyed by placing the unbarked logs in the

water. Scorching the bark or burning the timber outright, or utilizing it and burning the slabs, may answer the same purpose. It is quite evident that if the infested lodgepole pine be cut in the period from September to February, and the trunks, logs, or trees with infested bark on them crib-piled in the open, the bark will dry sufficiently to kill the broods before they can develop and emerge. Hacking or scoring the bark on the upper side of the logs or felled trunks of the silver pine or sugar pine during December, to let the water in, would doubtless kill the majority of the broods before the time for them to emerge. These suggestions relating to methods of treating unbarked timber should be tried by the foresters and lumbermen and the practical results reported, as should all practical results from the adoption of our recommendations. Failures, as well as successes, should be reported.

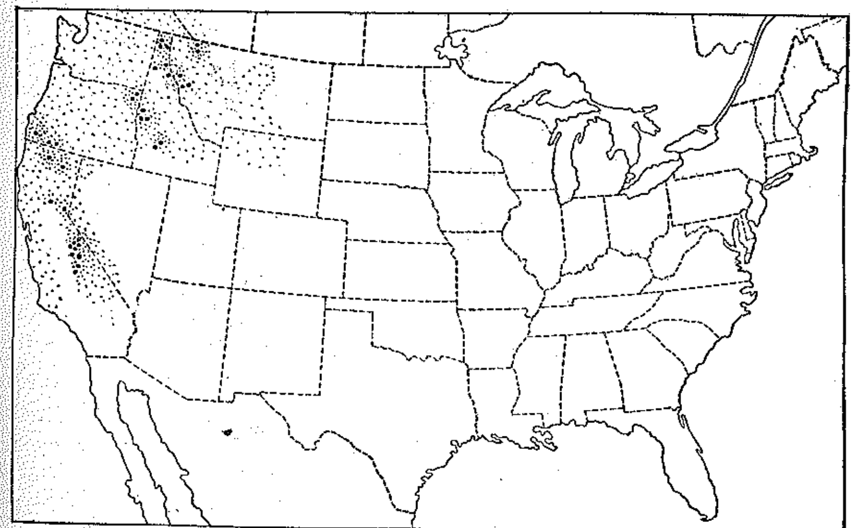

FIG. 50.—The mountain pine beetle: Distribution map. (Author's illustration.)

BASIS OF INFORMATION.

Information concerning this species is based on studies by the writer at Grants Pass, Oregon, and Sand Point and Kootenai, Idaho, in 1899; at Priest River, Idaho, in 1902, and in the Yosemite National Park and Yosemite Valley, California, June, 1904; by Mr. J. L. Webb, at Moscow, Idaho, in 1900; at Centerville, Smith's Ferry, and Collins, and in Boise County, Idaho, June to September, 1905; by Mr. H. E. Burke, at Smith's Ferry, Idaho, October, 1904; at Longmires Springs, Wash., September, 1905; at Wawona, Summerdale, Little Yosemite, Yosemite, Lake Tenaya, Tioga Road, and Soda Springs, Cal., May to September, 1906, and at Joseph, Oregon, and in the Wallowa National Forest, August, 1907. Additional localities, from other collections and through correspondence, are Piedmont and Keystone, Wyo.; Pokegama, Ashland, and Washington National Forest (Portland), Oregon; Columbia Falls, Lewis and Clarke National Forest, Saltese, Missoula, Medicine Bow National Forest, Lolo National Forest (Iron Mountain), and Big Four, Mont.; Coeur d'Alene National Forest and Weiser National Forest, Idaho. It is represented in the forest-insect collection of the Bureau of Entomology by more than 500 specimens, including all stages and work.

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No. 10. THE BLACK HILLS BEETLE.

(*Dendroctonus ponderosæ* Hopk. Figs. 51–59.)

The Black Hills beetle is a stout, black, cylindrical barkbeetle, 4 to 7 mm. in length, with head broad and without frontal groove, but with slight longitudinal impression above or behind the middle; the prothorax short, broad, and punctured, the sides narrowed and slightly constricted toward the head; the elytra with moderately coarse rugosities between the rows of punctures, which are usually distinct on the sides, and the declivity, which bears a few long hairs, slightly impressed each side of the middle line, the impressed striæ narrow, and the interspaces broad and roughened with sparsely placed, coarse granules. (See fig. 51.) The adult beetles attack living and sometimes injured and felled, yellow pine, lodgepole pine, limber pine, Mexican white pine, white spruce, and Engelmann spruce from the Black Hills, South Dakota, to southern Arizona, and westward into Utah, and are very destructive. The parent beetles excavate long, nearly straight, longitudinal egg galleries (fig. 52) through the inner living bark and groove the surface of the wood on the main trunk (figs. 53, 54). The eggs are placed at quite regular intervals, or more often arranged in groups of four or five along the sides. The short, broad larval mines and transformation cells are exposed in the inner bark and mark the surface of the wood; the short, whitish, grublike larvæ (fig. 51) transform to pupæ (fig. 51), usually exposed in the inner bark, and the broods usually work independently of other species and occupy exclusively the greater part of the bark on the main trunks of the trees. The attack causes pitch tubes (figs. 55, 56) on the trunk of the infested trees in the summer and fall, and the leaves fade and turn yellow and red the following season during the period from May to August.

SEASONAL HISTORY.

OVERWINTERING STAGES.

The winter is passed in the inner bark on trees attacked the preceding summer and fall, as parent adults in the egg galleries, all stages of larvæ in the larval mines and transformation cells, and as broods of young adults in transformation cells; but principally as larvæ.

ACTIVITY OF OVERWINTERED BROODS.

As soon as warm weather begins in April and May the overwintered parent adults extend their incompleted egg galleries and

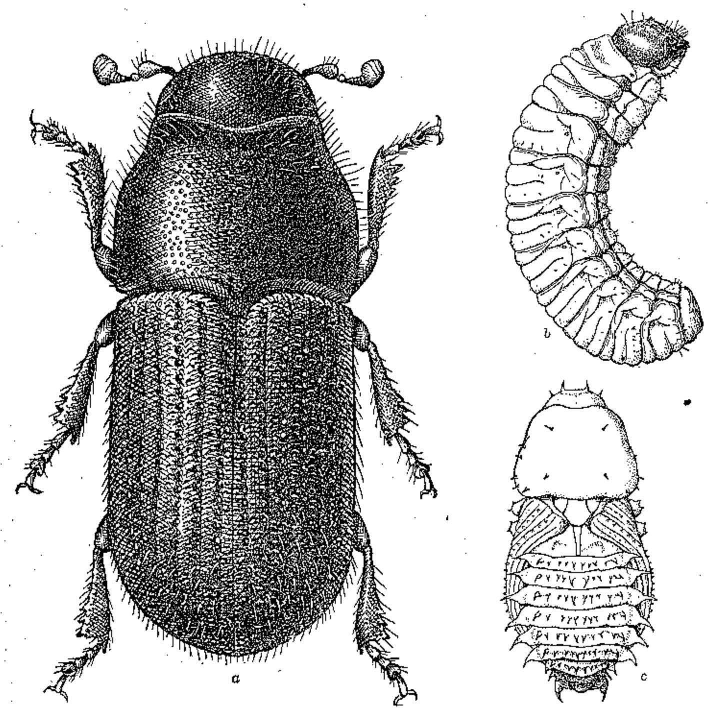

FIG. 51.—The Black Hills beetle (*Dendroctonus ponderosæ*): *a*, Adult; *b*, larva; *c*, pupa. *a*, Greatly enlarged; *b*, *c*, less enlarged. (Author's illustrations.)

excavate new ones in the remaining living bark on the dying trees and deposit eggs. The overwintered broods of young adults begin to emerge from the trees by the middle of July, but the main swarm does not appear until the last of July and first of August. Some of the retarded broods continue to come out until October, or later. The broods of larvæ begin to transform to pupæ and adults about the middle of May, and continue to do so during the period from June until September, or later, and begin to emerge in August.

The broods from eggs deposited by the overwintered parent adults may develop to adults in August and September, but evidently remain in the bark until the next season of activity.

FIG. 52.—The Black Hills beetle: Egg galleries and larval mines. Slightly reduced. (Author's illustration.)

GENERATION.

The overwintered broods of young adults begin to attack the trees, excavate galleries, and deposit eggs toward the last of July; the principal attack is during August, but continues during September and until October, or possibly later. The eggs hatch and the larvæ begin to feed about the first of August. The principal

activity of the larvæ is during the latter part of August, but they continue active until the beginning of hibernation in the fall. The larvæ of a few of the most advanced broods may begin to transform to pupæ and adults toward the last of September and in October, but by far the greater number overwinters in different stages of larvæ with the parent adults. There is, therefore, but one generation each year. It is evident, however, that some retarded individuals from the preceding generation may pass the second winter as young and parent adults. Thus, during the early summer there may be an overlapping of representatives of two and even three annual generations.

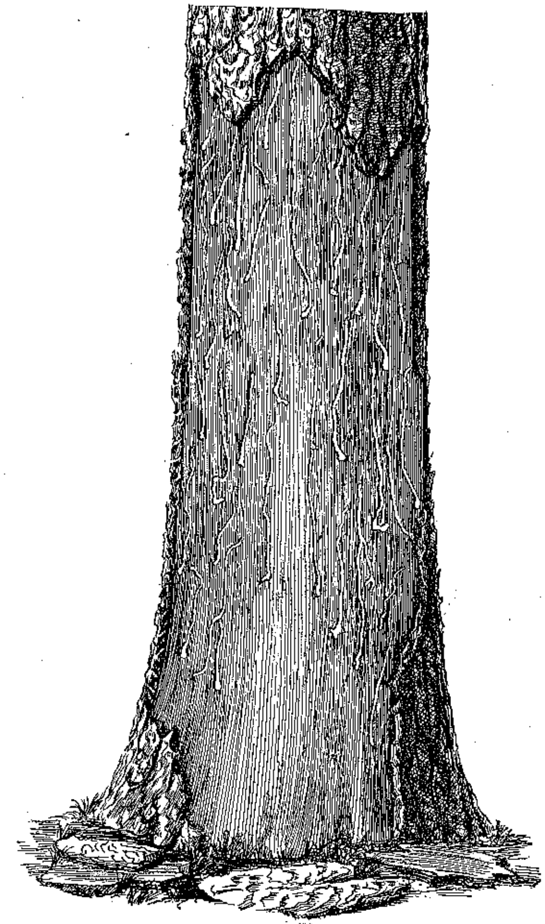

FIG. 53.—The Black Hills beetle: Tree with bark removed, showing egg galleries grooved and marked on surface of wood. (Author's illustration.)

HABITS.

This species apparently prefers to attack living timber, but will breed to a very limited extent in injured and felled trees. It infests at least four species of pine and two species of spruce, and will doubtless attack other pines and spruces (except the "Douglas spruce") growing within its range. It prefers the western yellow pine, or bull pine.

The largest and best trees are usually attacked first, but after these are killed it will attack and kill the medium to small trees and even saplings 8 or 10 feet high or only a few inches in diameter.

The parent adults excavate their long, nearly straight, longitudinal egg galleries in great numbers through the inner bark, where they often closely parallel each other. The larvæ excavate short and broad or long food burrows at right or oblique angles to the egg galleries through the intervening bark, and transform to pupæ and adults in individual cells at the farther end or toward the middle of their larval mines, which are exposed in the inner bark when it is removed from the tree. Both the egg galleries and larval mines cause marks and grooves on the surface of the wood. After the new broods of adults become matured, they burrow through the intervening bark between their cells, and congregate in the general

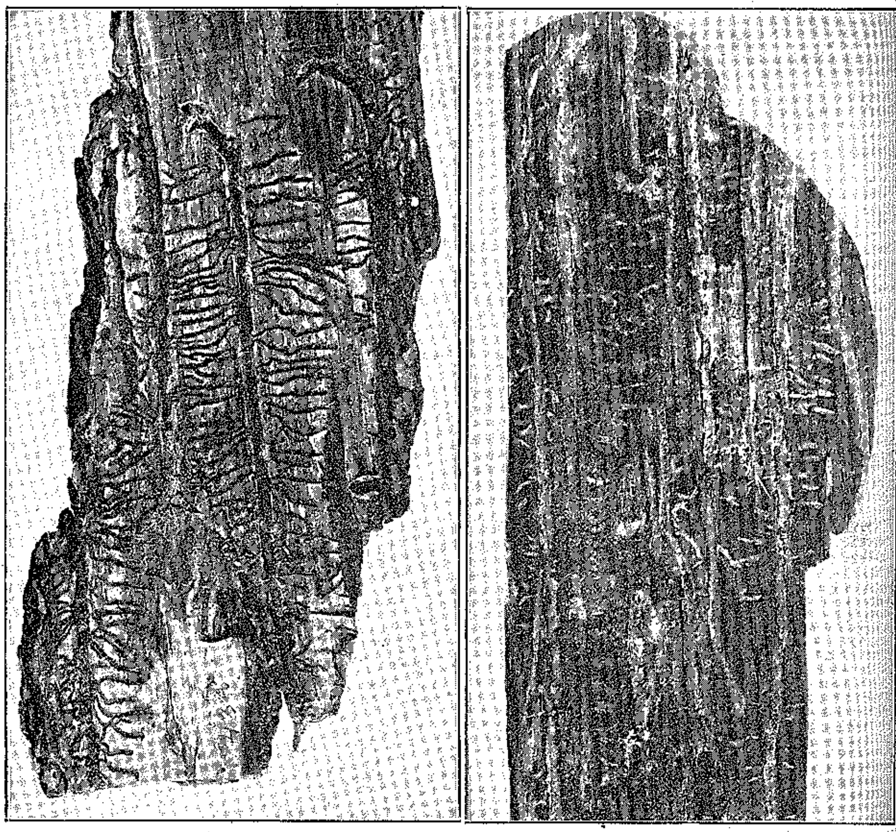

FIG. 54.—The Black Hills beetle: Galleries in bark and marked on scoring chip. About one-third natural size. (Author's illustration.)

cavity thus formed, until the proper time for them to emerge, when they all come out and fly in swarms to attack the remaining living timber.

Sufficient information relating to the flight of this species has been secured to indicate quite conclusively that it flies in swarms during the day, and probably at night.

ECONOMIC FEATURES.

This species apparently differs from all of the others in its decided preference for living timber, in which it excavates its egg galleries in such a manner as to kill the tree and make the conditions favorable for the development of its broods. It is, therefore, a primary enemy of the first importance, especially as related to the western yellow pine in the eastern section of the Rocky Mountain region south of eastern Montana. It has destroyed a vast amount of the best timber in the Black Hills National Forest of South Dakota, and is threatening the destruction of practically all of the best timber there, as well as much of the reproduction. It is also destructive to the pine in Colorado, New Mexico, and Arizona. There is evidence that extensive forests have been destroyed in Colorado by this beetle and by resulting forest fires during the past fifty or seventy-five years.

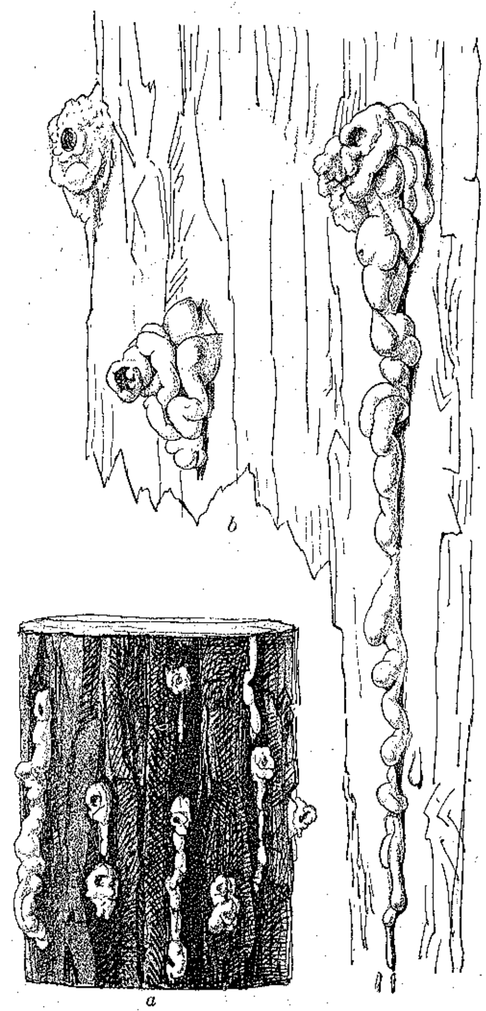

FIG. 55.—The Black Hills beetle: *a*, Pitch tubes on surface of bark, reduced; *b*, same, two-thirds natural size. (Author's illustration.)

EVIDENCES OF ATTACK.

The first evidence of attack and infestation on living timber is the appearance of pitch tubes on the bark of the main trunk; or, in the absence of these, of reddish borings lodged in the loose bark and on the ground around the base of the trees. This is usually the only external evidence from the time the trees are attacked in the summer and fall until the following spring. Sometimes during the winter, and especially in the period from April to June, the more noticeable evi-

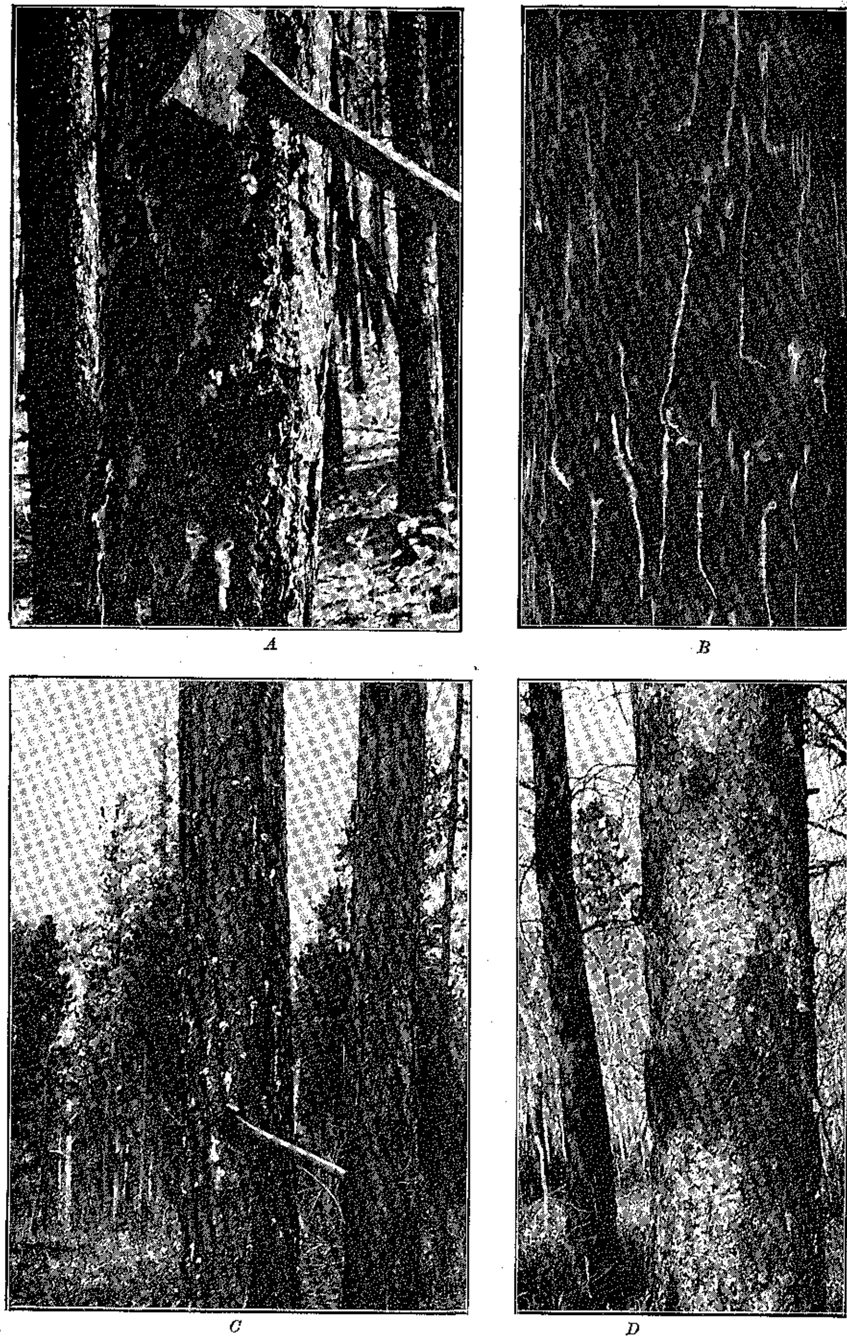

FIG. 56.—Work of the Black Hills beetle in the Black Hills National Forest: *A*, Small freshly attacked fine tree, showing pitch tubes. *B*, Marks of primary galleries on surface of wood when bark is removed. *C*, Freshly attacked tree, showing pitch tubes; near tree not attacked. *D*, Dead tree, showing where outer bark has been removed by woodpeckers. (Author's illustration.)

dence is found in the fading foliage which begins to change to sorrel tops in May and June and to red tops in July and August. The finding of these conditions within the region occupied by this species will indicate destructive work by barkbeetles, but positive evidence of the presence of this species can only be determined by cutting into the bark and finding the characteristic galleries and mines occupied by authentically identified beetles. As a rule, the broods have left the trees by the time the leaves are all dead, and sometimes before the leaves have changed from yellow or sorrel to red. Exceptions are frequently found when but one side or the top of a tree is killed the first year and the remaining living bark is infested with broods of the next. It is safe to conclude, however, that after the leaves are all dead and brown, very few living examples of this species will remain in the bark.

EFFECTS ON COMMERCIAL VALUE OF THE WOOD.

Owing to the thick sapwood of the western yellow pine, the commercial value is reduced for certain purposes by a bluing condition, which affects it soon after the trees are infested by the beetles in August and September and long before the leaves begin to fade. The heartwood of large trees is not usually reduced in value for several years after the trees die, provided they do not suffer from subsequent injury by storm, fire, wood-boring insects, or premature decay. If left standing, however, with the bark on, until the branches and tops begin to fall, the loss from decay may be complete. On the other hand, if the bark be removed from the trunks of the standing trees, the heartwood will remain sound for many years longer.

The danger, however, of the total destruction of the dead timber by forest fires is so great that in order to insure against such losses, and at the same time destroy the broods of insects, the insect-killed timber should be utilized before the insects emerge.

FAVORABLE AND UNFAVORABLE CONDITIONS FOR THE BEETLE.

Favorable conditions for the multiplication and destructive work of this species are found in somewhat isolated forests with a predominance of large mature timber. Unfavorable conditions for destructive outbreaks will be found in forests, isolated or not, which are kept under a system of forest management or regulations which provide for the utilization of the mature timber and the barking of trees injured by lightning or dying from any cause, before the broods of insects develop in the bark and emerge.

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METHODS OF CONTROL.

Whenever it is positively determined that this species is attacking living pine timber in a given locality and that the bark of living and dying trees contains living parent adults or developing broods, active and radical measures should be promptly adopted for its control.

The simple removal of the infested bark from the main trunks of the trees, without burning it, is sufficient to kill the broods of this species, provided the work be done between the first of October and the first of June. If, in the case of a moderate outbreak, the larger clumps or patches of infested trees and the more accessible scattering ones in the worst affected sections of a forest are thus treated, it should serve to bring the pest under control the first year, but in the case of a very extensive outbreak this may require two or three years or more.

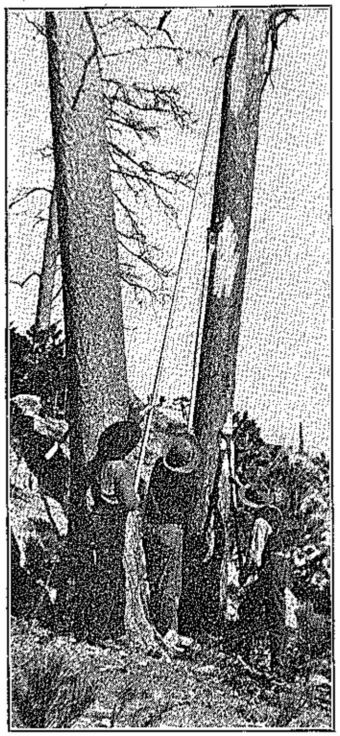

FIG. 57.—Removing bark from trunk of standing tree with special barking tool having handles of different lengths, to destroy broods of the Black Hills beetle. (Original.)

If all of the infested trees can be barked or utilized and the slabs burned without much additional expense, it may be best to do so, but where, for any reason, this can not be done within the specified time, the work should be planned so as to insure the barking or utilization of all of those in the larger patches, or an aggregate of 75 per cent of the infested trees to each square mile.

If the bark be removed from the standing trees (figs. 57, 58), an aggregate of 75 per cent or more of the actually infested bark should be removed from all of the trees, or all of the infested bark should be removed from 75 per cent of the trees. *The work should be planned and conducted with the object of destroying the greatest possible number of insects for the labor and time expended.* That is, if there are more infested trees than can be barked within the specified time, and five or six times as many insects can be killed by removing half of the infested bark from the standing trees as can be done in the same time by felling one tree and removing all of the bark, the former is far preferable, remembering that it is not necessary to exterminate the enemy,

but that it is necessary to reduce its numbers beyond the power of doing harm.

The removal of the infested bark from at least the lower half of the standing trees offers many advantages over felling the trees for the purpose of barking all of the trunk. More insects can be destroyed in the standing trees within a given time and the barked standing timber may be left standing until suitable facilities can be provided for its utilization; thus, if necessary, all of the specified time for the destruction of the insects may be devoted exclusively to the removal of the bark.

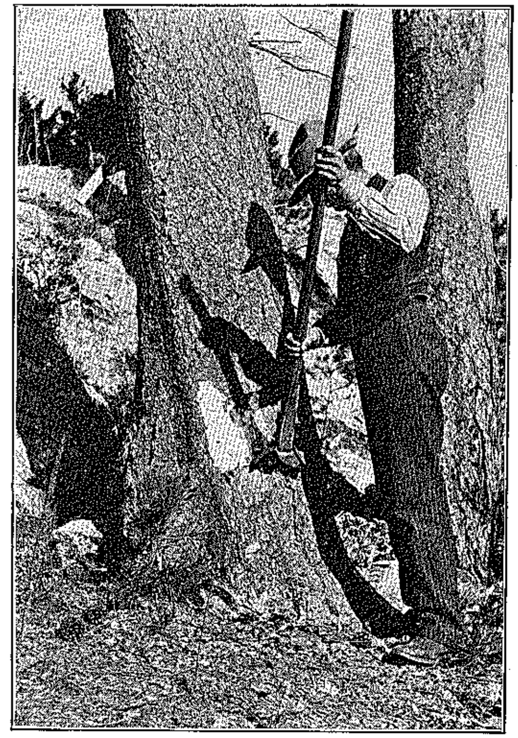

FIG. 58.—Removing bark from base of trunk of standing tree with special barking tool, to destroy broods of the Black Hills beetle. (Original.)

The barking of newly attacked trees in August and September is not to be recommended for this species. Trap trees are of little or no service in combating it and continued timber-cutting operations appear to have little or no influence in checking its ravages on living timber.

Recent reports of conditions in the vicinity of Colorado Springs, where a large percentage of the infested timber was barked in 1905 and during the winter and spring of 1906, indicate most successful and satisfactory results. (See also other references to successful control, pp. 36–38.)

The depredations in the Black Hills have been so extensive that little or nothing has been accomplished toward the control of the beetle, owing to lack of sufficient funds and other facilities for adopting the radical measures necessary to accomplish anything of importance.

(For additional information, see Bulletin No. 56, Bureau of Entomology, of which the above is a partial revision.)

BASIS OF INFORMATION.

The data on this barkbeetle have been secured through investigations by the writer in the Black Hills National Forest, September, 1901, August, 1902, and June, 1903; at Vermejo, N. Mex., May, 1903; at Flagstaff, Ariz., May, 1904; in the Pike National Forest and in the vicinity of Colorado Springs, Colo., October, 1905, and June, 1906, and in the vicinity of Fort Garland, Colo., June, 1906; by Mr. J. L. Webb, in the Black Hills National Forest, South Dakota, May to October, 1902, and April to September, 1906; in the Chiricahua National Forest, Arizona, June to September, 1907; by Mr. H. E. Burke, at Nemo, S. Dak., November, 1904; at Kamas, Panguitch, and Panguitch Lake, Utah, June to September, 1907; by Mr. W. D.

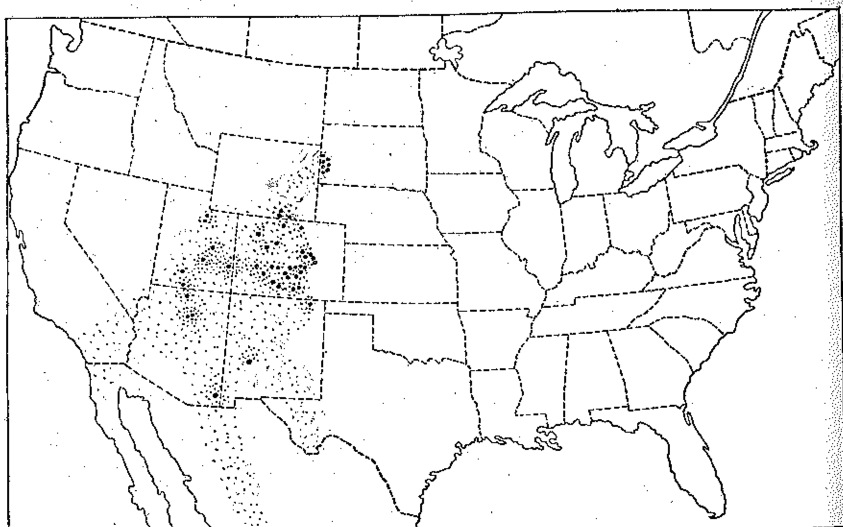

FIG. 59.—The Black Hills beetle: Distribution map. (Author's illustration.)

Edmonston, at Larkspur, Colo., July, 1906; at Brookvale, Sequache, Poncha Springs, San Juan National Forest, Wagon Wheel Gap, Cochetopa National Forest, Monte Vista, White River National Forest, Uncompahgre National Forest, and Colorado Springs, Colo., January to December, 1907; in the San Isabel National Forest, at Hahns Peak and Clarke, in the Gunnison National Forest, the Hayden National Forest, the La Salle National Forest, the Ouray National Forest, the Pike National Forest, the Routt National Forest, the San Juan National Forest, the Wet Mountains National Forest, and the White River National Forest, Colorado (12 national forests), and at Encampment and Downington, Wyo., in 1908. Additional localities through correspondence and other collections are Palmer Lake, Cat Mountain, Trinchera Estate, Fort Collins, Pine, and the Medicine Bow National

Forest, Colorado; Fredonia, Ariz.; Kanab, Escalante, Provo, Aquarius National Forest, Utah, and at Keystone, Wyo. It is represented in the forest-insect collection of the Bureau of Entomology by more than 10,000 specimens.

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No. 11. THE JEFFREY PINE BEETLE.

(*Dendroctonus jeffreyi* Hopk. Figs. 60, 61.)

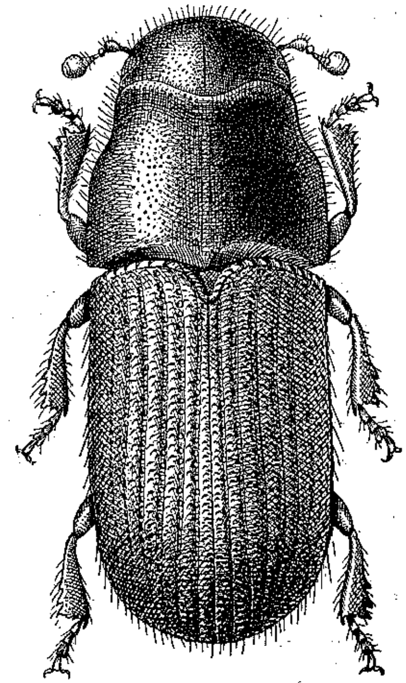

FIG. 60.—The Jeffrey pine beetle (*Dendroctonus jeffreyi*): Adult. Greatly enlarged. (Author's illustration.)

The Jeffrey pine beetle is a stout, black, cylindrical barkbeetle 6 to 8 mm. in length; the head broad, convex, with faint grooves behind and usually in front of the middle; the prothorax stout, broad, shining, the sides suddenly narrowed toward the head and the punctures fine; the elytra with moderately coarse rugosities between the rows of punctures, which are distinct on sides, the declivity with a few long hairs, the striæ on grooves narrow, and the intervening spaces broad and roughened with coarse granules. (See fig. 60.) It attacks living and dying Jeffrey pine and yellow pine, in the Yosemite National Park and San Bernardino County, California. It excavates long, nearly straight, egg galleries through the inner bark, and grooves the surface of the wood; the larval mines extend from the sides, exposed in the inner bark. The stout, whitish, grublike larvæ transform to pupæ and adults in cells at the end of the burrows, and the broods occupy the bark on the main trunk. The infested trees are indicated by pitch tubes on the trunks in the summer and fall, and during the following May to August by the fading and yellowish foliage.

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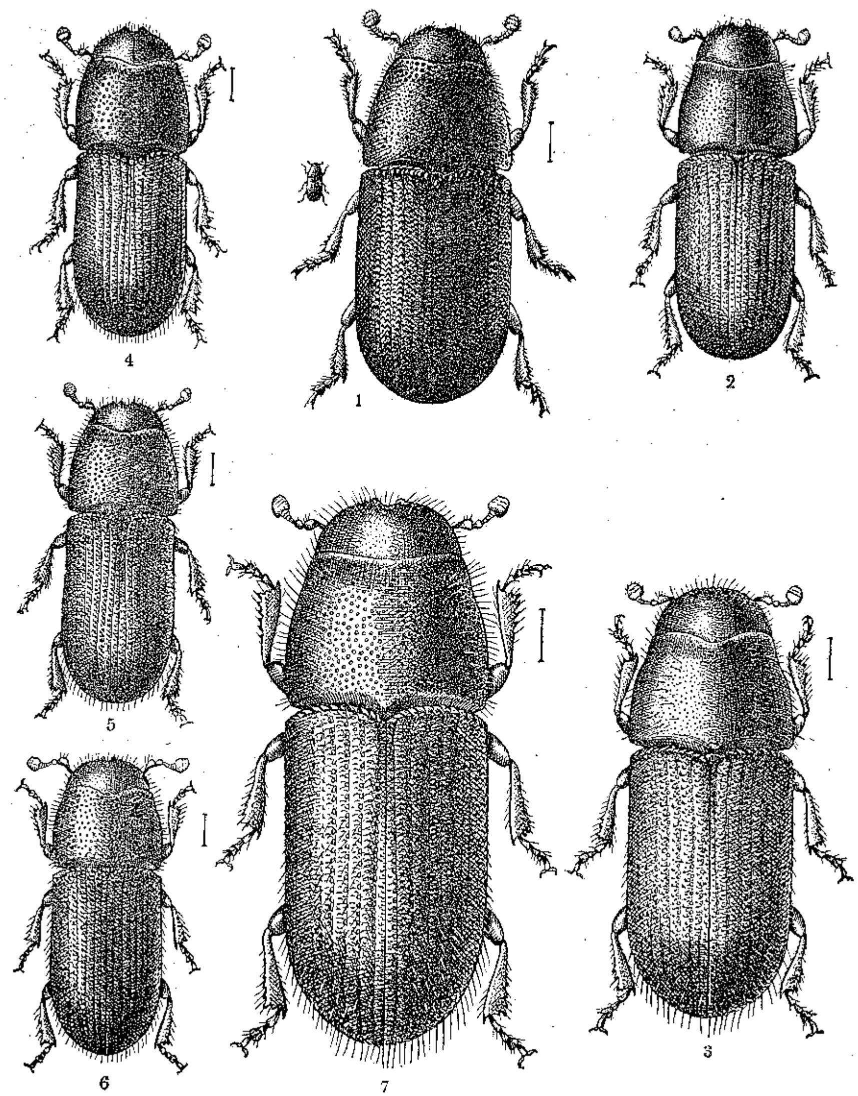
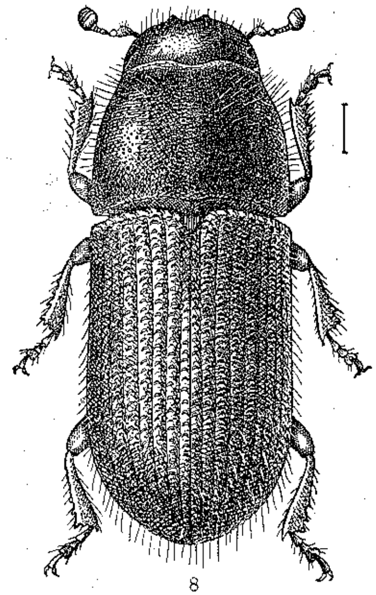


DENDROCTONUS ADULTS.

Fig. 1.—*D. brevicomis.* Fig. 2.—*D. barberi.* Fig. 3.—*D. convexifrons.* Fig. 4.—*D. frontalis.* Fig. 5.—*D. arizonicus.* Fig. 6.—*D. mexicanus.* Fig. 7.—*D. parallelocollis.* (Original.)



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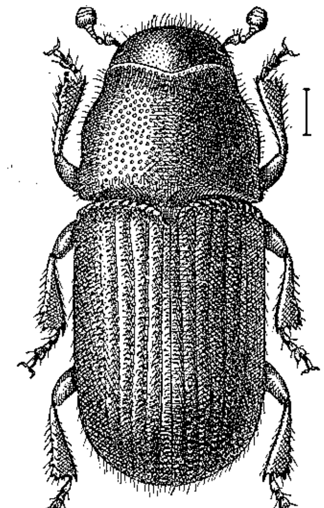

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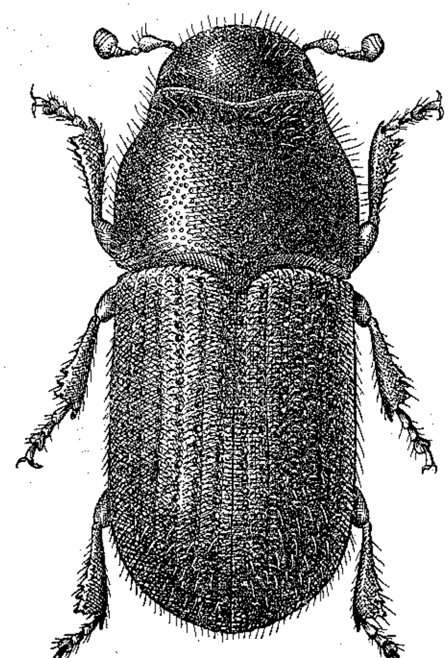

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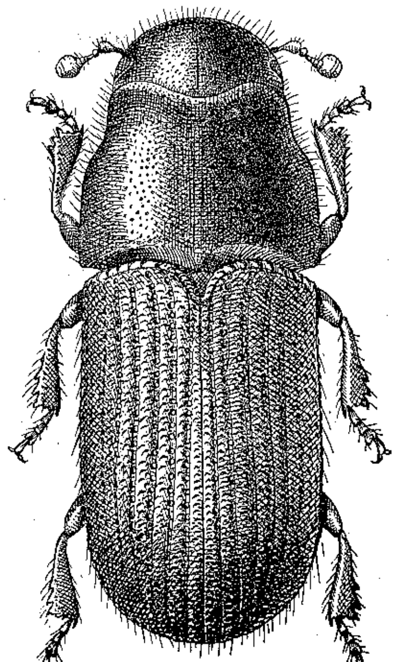

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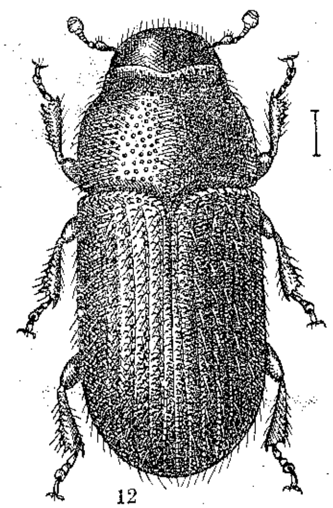
DENDROCTONUS ADULTS.

Fig. 8.—*D. approximatus.* Fig. 9.—*D. monticolæ.* Fig. 10.—*D. ponderosæ.* Fig. 11.—*D. jeffreyi.* (Original.)



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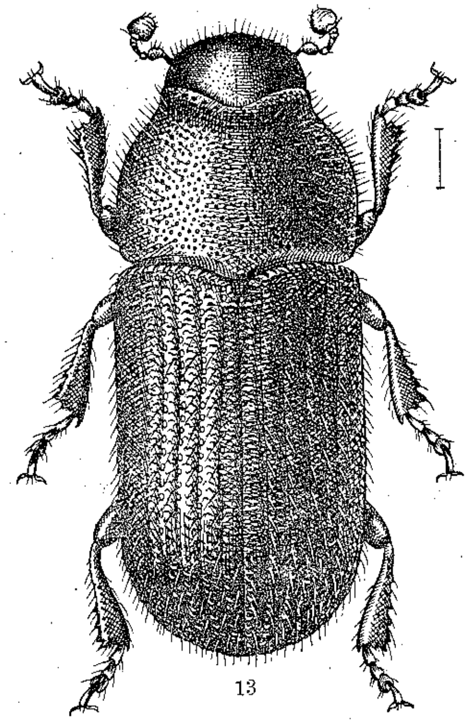

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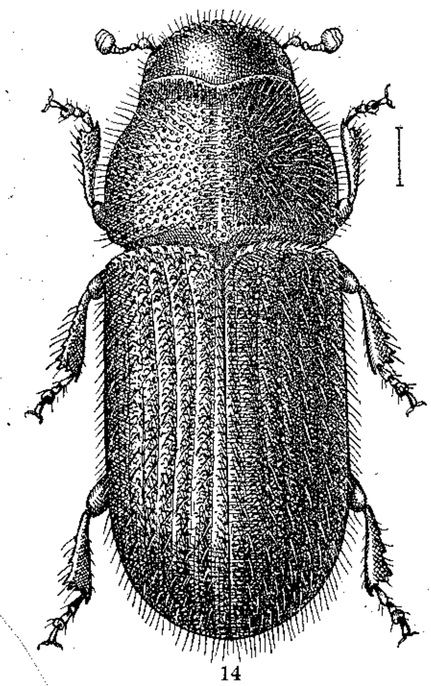

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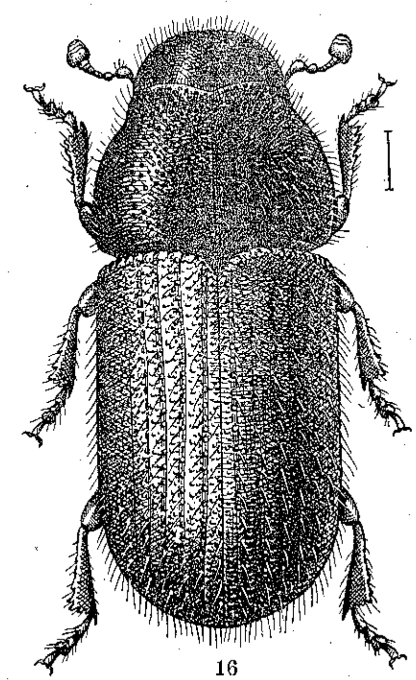

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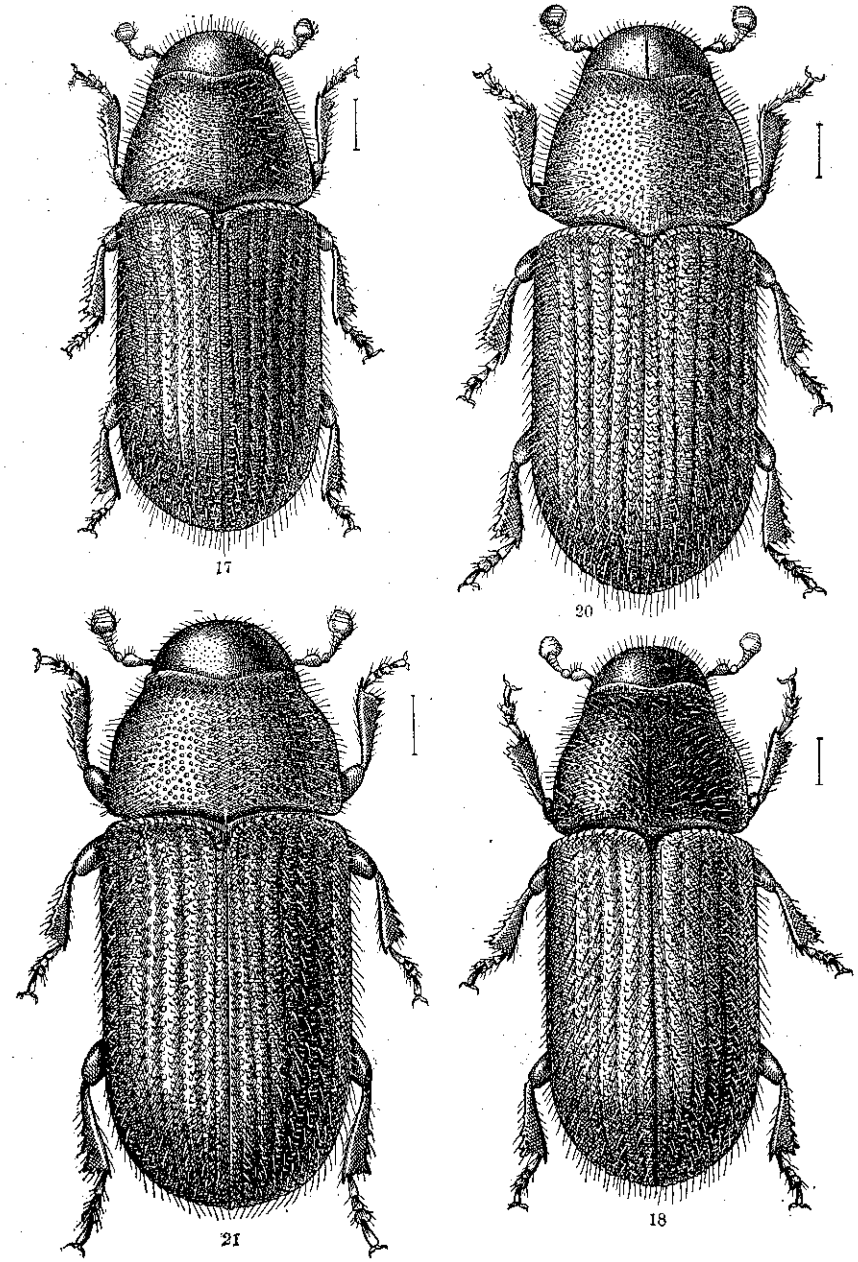
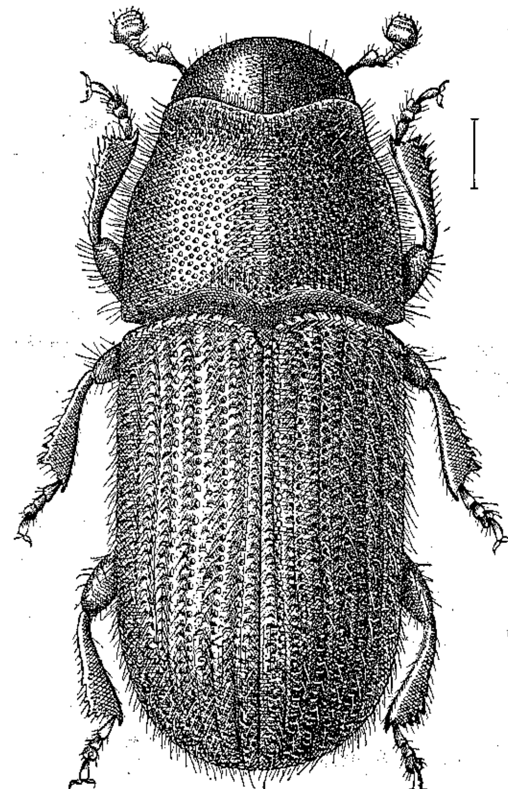
DENDROCTONUS ADULTS.

Fig. 12.—*D. simplex*. Fig. 13.—*D. pseudotsugæ*. Fig. 14.—*D. piceaperda*. Fig. 16.—*D. borealis*. (Original.)



DENDROCTONUS ADULTS.

Fig. 17.—*D. obesus*. Fig. 18.—*D. rufipennis*. Fig. 20.—*D. punctatus*. Fig. 21.—*D. micans*. (Original.)



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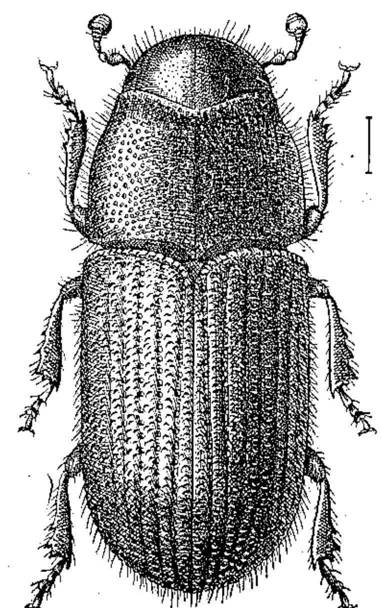

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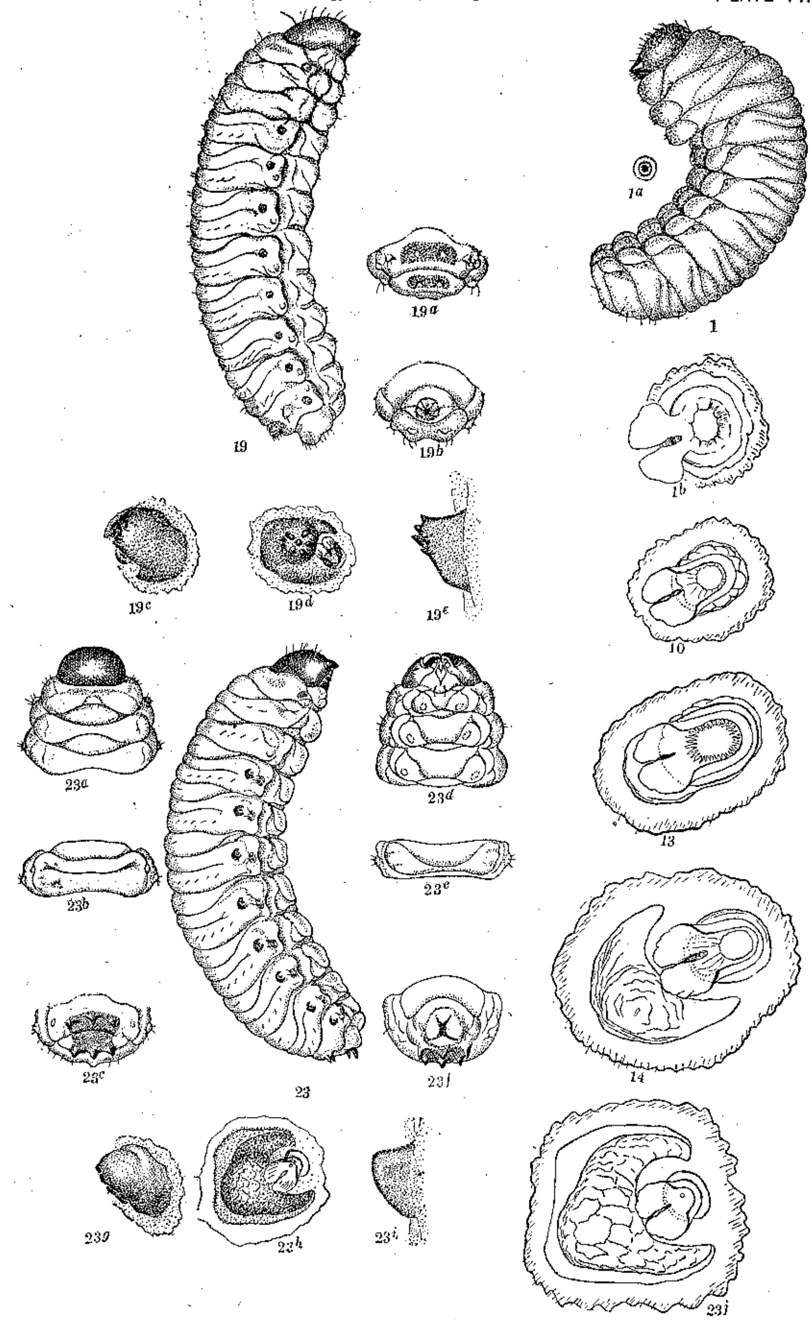
DENDROCTONUS ADULTS.

Fig. 22.—*D. terebrans.* Fig. 23.—*D. valens.* (Original.)



DENDROCTONUS LARVÆ.

Fig. 1.—*D. brevicomis;* 1*a*, spiracle, enlarged; 1*b*, spiracle, greatly enlarged, showing simple bifid processes. Fig. 10.—*D. ponderosæ*, spiracle, greatly enlarged. Fig. 13.—*D. pseudotsugæ*, spiracle, greatly enlarged. Fig. 14.—*D. piceaperda*, spiracle, greatly enlarged. Fig. 19.—*D. murrayanæ;* 19*a*, dorsal aspect of abdominal segments 8 and 9, showing plates; 19*b*, anal aspect; 19*c*, 19*d*, and 19*e*, different aspects of spiracular tubercle, much enlarged. Fig. 23.—*D. valens;* 23*a*, dorsal aspect of thoracic segments; 23*b*, dorsal aspect of abdominal segments; 23*c*, dorsal aspect of abdominal segments 8 and 9, showing armed plates; 23*d*, ventral aspect of thoracic segments; 23*e*, ventral aspect of abdominal segment; 23*f*, anal aspect of abdominal segments 8, 9, and 10; 23*g*, 23*h*, 23*i*, different aspects of spiracular tubercles, moderately enlarged; 23*j*, spiracle and spiracular tubercle, greatly enlarged. (Original.)