OSSIFICATION IN THE NESTLING HOUSE WREN

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As a necessary preliminary to work on the effects of certain hormones on the time relations of ossification and relative growth in the House Wren (*Troglodytes aëdon aëdon*), it was essential to determine this relationship in normal individuals. This paper in a qualitative manner discusses briefly the first appearance, fusion and articulation of bones in the skeletons of normal nestling House Wrens.

At least four birds for each day in the nest were collected. The birds were killed, the skeleton was stained with Alizarin Red S. and cleared by Dawson's method as given in A. B. Lee's 'The Microscopist's Vade Mecum' (Philadelphia, P. Blakeston's Sons and Co., 1937). There have been numerous articles published concerning this method but the authors have been unable to discover any extensive use of this technique for a study of this kind.

FORE LIMB

O day.—The humerus is a short thick bone with the ends slightly flared. The radius is about the same length as the ulna but thinner, not as heavily ossified, while the ends of the ulna are more flattened than those of the radius. The radiale and ulnare are not present. In the carpometacarpus the third metacarpal is heavier and larger than the fourth metacarpal; the latter is a slender bone while the ends of the third metacarpal are somewhat thickened. The second digit is a minute bone. In the third, both of the phalanges are present, although the distal is much smaller than the proximal. The fourth digit is not present, nor is the second metacarpal. [The three fingers of the hand are regarded as numbers 2, 3, and 4 of the primitive five.]

Third day.—Distal and proximal ends of the humerus are more expanded. The fourth digit and the second metacarpal have appeared.

Fourth day.—Present for the first time is the beginning of the tuberculum ulnare ossi metacarpi.

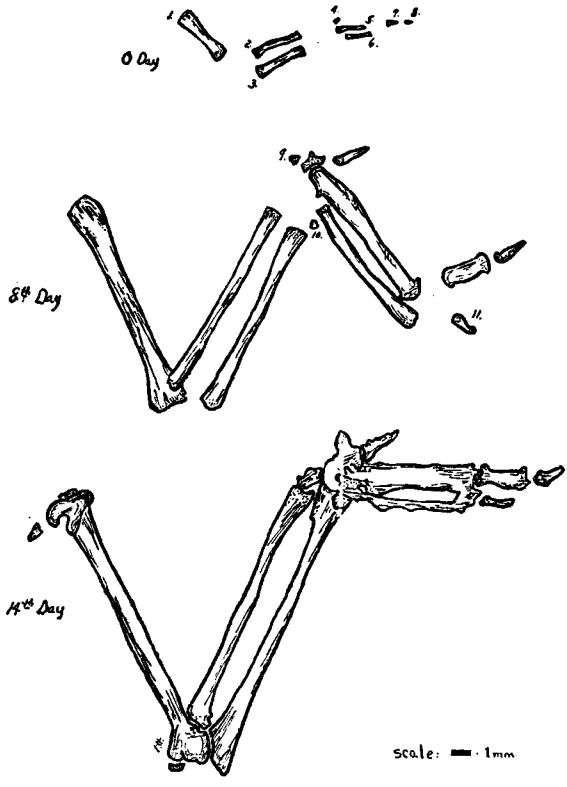
Fifth day.—The tuberosities of the humerus are much more prominent.

Seventh day.—The radial and ulnar bones are present for the first time.

Eighth day.—The tuberculum ulnare ossi metacarpi has united with the proximal end of the third metacarpal. Two small centers of ossification have appeared close to the third metacarpal, and a third

has appeared between the fourth metacarpal and the ulna. The epiphyses of the humerus and ulna have appeared.

Ninth day.—In the humerus the caput humeri is beginning to fit into the glenoid fossa. The fourth metacarpal has developed a slight indentation for articulation with the third metacarpal and the second metacarpal is touching the proximal end of the third metacarpal.

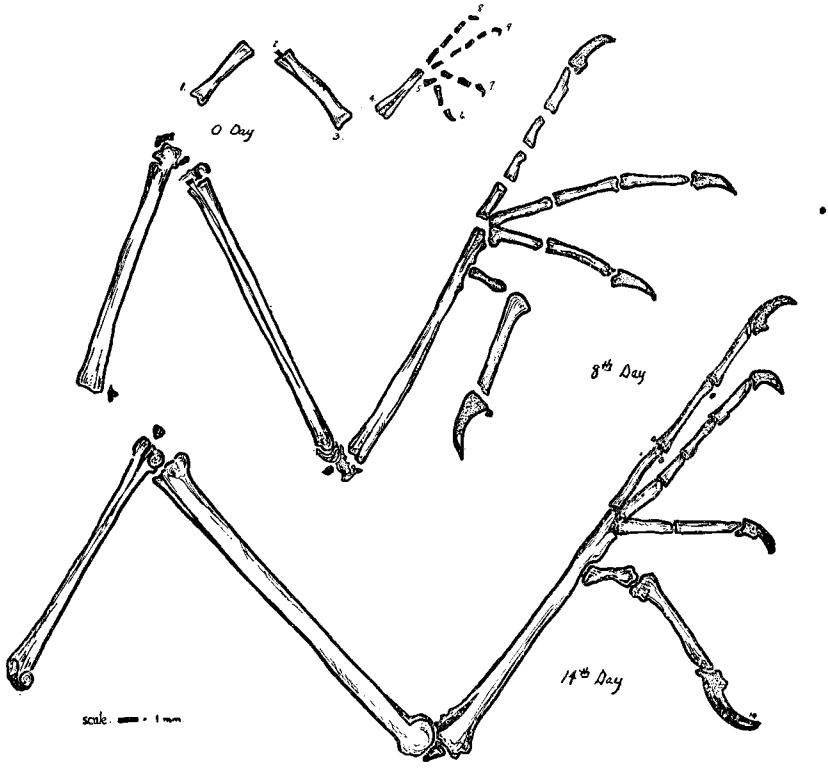


TEXT-FIGURE 1.—Fore limb of nestling House Wren: 1, humerus; 2, radius; 3, ulna; 4, second digit; 5, third metacarpal; 6, fourth metacarpal; 7, first phalanx of third digit; 8, second phalanx of third digit; 9, radiale; 10, ulnare; 11, fourth digit.

Tenth day.—The second metacarpal is beginning to fuse with the preaxial side of the proximal end of the third metacarpal.

Twelfth day.—The head of the humerus has now reached adult proportions. The trochleae are well formed on the humerus. The radius articulates with the humerus and radiale and the proximal end is expanded and concave for articulation with the oblique tubercle.

The proximal end of the ulna articulates with the ulna tubercle of the humerus while the distal end articulates with the radiale, ulnare and head of the third metacarpal. The third metacarpal has fused with the fourth metacarpal. The third finger articulates with the third metacarpal. Fusion of the epiphyses of the humerus is completed and the epiphysis at the distal end of the ulna is fused.

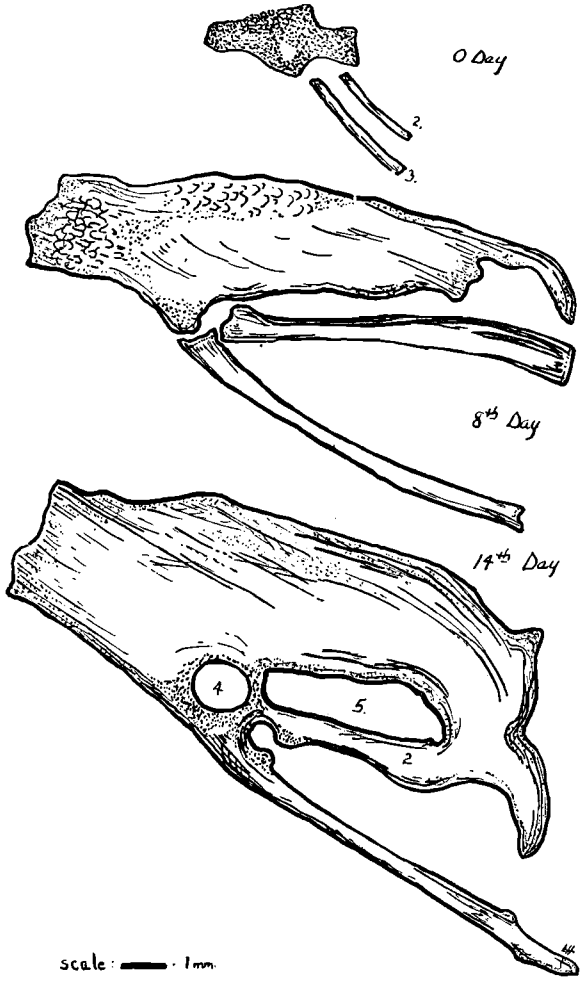


TEXT-FIGURE 2.—Hind limb of nestling House Wren: 1, femur; 2, fibula; 3, tibio-tarsus; 4, tarso-metatarsus; 5, remnant of first metatarsal; 6, first toe; 7, second toe; 8, third toe; 9, fourth toe.

Thirteenth day.—The radius articulates with the oblique tubercle and with the radiale at the distal end. The ulna articulates with the humerus. Two new centers of ossification have appeared at the distal end of the ulna. The radiale articulates with the radius while the ulnare is attached to the third metacarpal. The third metacarpal articulates with the second finger, fourth metacarpal, ulnare and

radiale. The *fourth* metacarpal articulates with the *fourth* finger.

Fourteenth day.—The radius articulates with the humerus and ulna. The radiale articulates with the radius and tuberculum ulnare ossi



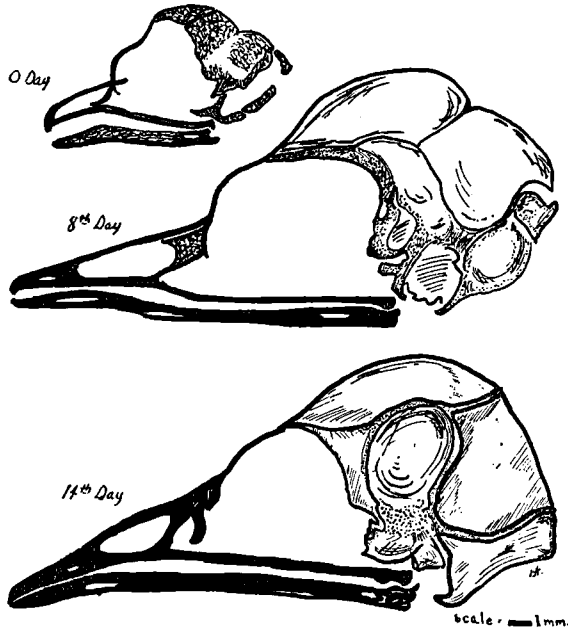
TEXT-FIGURE 3.—Pelvic girdle of nestling House Wren: 1, ilium; 2, pubis; 3, ischium; 4, acetabulum; 5, ilio-ischiac foramen.

metacarpi. The epiphysis at the proximal end of the ulna is fused, as are also the third and fourth metacarpals and the ulnare. The two centers appearing on the thirteenth day have now fused with the ulna. Also, the second metacarpal articulates with the second digit.

SHOULDER GIRDLE

O day.—The scapula is a short stocky bone with the ends expanded. The coracoid is approximately of the same size as the scapula and has about the same amount of ossification. The clavicles are thread-like in thickness and are joined by the minute inner clavicle.

First day.—The coracoid bears hook-like processes on its upper end. These will be part of the glenoid fossa.



TEXT-FIGURE 4.—Skull of nestling House Wren; side view.

Third day.—Three tuberosities, which will articulate the anterior head of the coracoid with the other parts of the shoulder girdle and humerus, are now present.

Ninth day.—The furcula is almost touching the end of the scapula. A head is forming for articulation with the coracoid. A head is also forming on the furcula.

Twelfth day.—The distal portion of the coracoid articulates with the sternum and the proximal end articulates with the scapula to form the glenoid cavity.

Thirteenth day.—The scapula articulates with the humerus, coracoid and furcula.

HIND LIMB

O day.—The femur, tibio-tarsus, fibula, tarso-metatarsus, remnant of the first metatarsal, phalanges and claws are all present. The three bones that have fused to form the metatarsus are still visibly separated at both ends of the bone and only partially fused through the shaft. The first phalanx of the fourth toe is moderately ossified but the three other phalanges are barely distinguishable.

First day.—The proximal end of the femur has begun to develop into the caput femoris while the distal end shows the beginning of the condyle.

Second day.—A small center of ossification develops outside the distal end of the tibio-tarsus.

Fourth day.—Second small center of ossification develops outside the distal end of the tibio-tarsus.

Fifth day.—The metatarsus has an indentation on its inner posterior surface. A third center of ossification has developed at the distal end of the tibio-tarsus.

Seventh day.—The cap at the proximal end of the tarso-metatarsus is visible. The distal head of the tibio-tarsus is beginning to take form by the fusion of the three small bones mentioned above. A small sesamoid bone appears beside the proximal extremity of the tarso-metatarsus.

Eighth day.—Three centers of ossification have appeared at the distal end of the femur and mark the beginning of the patella. A small center of ossification has formed near the distal end of each of the three splints forming the tarso-metatarsus.

Ninth day.—The three centers of ossification that are close to the tarso-metatarsus fuse to form the triple trochlear head which articulates with the second, third and fourth toes. A center of ossification has developed at the anterior head of the fibula.

Tenth day.—The centers of ossification for the patella have fused. The center of ossification at the anterior head of the fibula has fused with the fibula, supplying a surface for articulation with the outer condyle of the femur.

Twelfth day.—A small center of ossification has developed by the cap at the distal end of the femur. The head of the femur now fits into the acetabulum. There are small ossified strands running from fibula to tibio-tarsus. The tibio-tarsus articulates with the anterior head of the tarso-metatarsus. The first metatarsal has joined the tarso-metatarsus. The third digit articulates with the metatarsus and the fourth partially so.

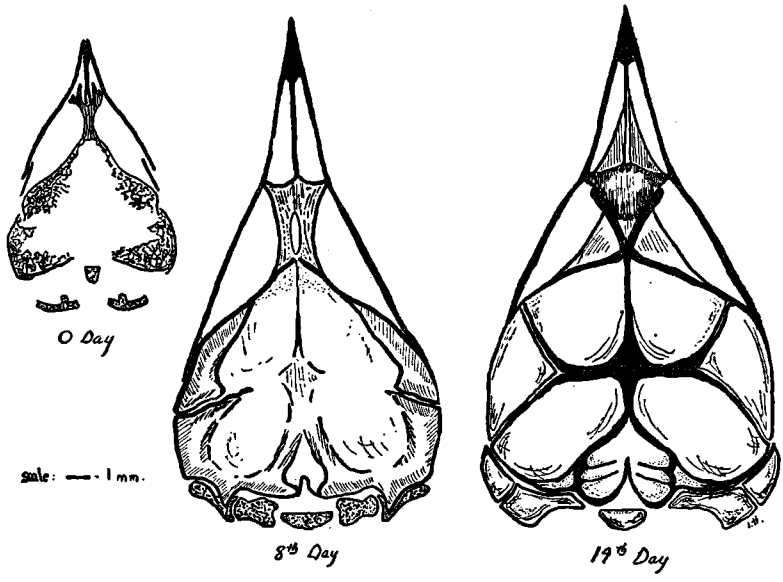
Thirteenth day.—Articulation between phalanges is now complete.

Fourteenth day.—Epiphysis of the femur, tibio-tarsus and tarso-metatarsus join their respective diaphyses.

PELVIC GIRDLE

O day.—The three bones that constitute the pelvic girdle are present. The ischium is the most solidly ossified; beneath the ilium the lumbar vertebrae are easily seen, while the slender pubis is just distinguishable.

Second day.—The pubis is now clearly seen and is approaching the ilium.



TEXT-FIGURE 5.—Skull of nestling House Wren; dorsal view.

Third day.—The ends of the ischium are slightly expanded.

Fourth day.—The heads of the ischium are more expanded and a small head has formed on the anterior end of the pubis.

Sixth day.—Fusion is beginning between the ilium and the synsacrum.

Eighth day.—The three bones of the pelvic girdle have met to form the acetabulum, but the only fusion apparent is between the ilium and the ischium.

Tenth day.—The ilioischiac foramen is just being formed with the fusion of the posterior ends of the ischium and the ilium.

Twelfth day.—The pubis and the ilium have fused at the acetabulum.

Thirteenth day.—The suture between the ilium and the synsacrum is evident and complete fusion of the pelvic bone is accomplished.

THE SKULL

O day.—The occipital shows four centers of ossification. The frontal and parietal are present but very lightly ossified. There are small processes on the temporal for later articulation with the quadrate. In the premaxilla, the lateral halves are completely fused together and the processi frontales are present. There are three main divisions of the maxilla and they are not yet completely fused. The nasal is very faintly ossified while the lacrimal is not present. The palatine appears to be joined to the nasal portion of the sphenoid. The pterygoid is connected with the palatine and the articular facet is beginning to develop. The zygoma is much curved with a slight widening of the posterior end (quadrato-jugal) while the jugal is already fused to the maxilla. The vomer is present but ossification is very slight. In the quadrate development has already progressed toward articulation with the temporal portion of the skull. The inferior maxilla can be seen very faintly. In the hyoid, two small bones are visible with their ends more heavily ossified. There are signs of ossification of the corneal margin of the sclerotic coat.

Second day.—Eye ring is complete but ossification is light.

Third day.—The four divisions of the occipital are still separate. The rostrum is present on the sphenoid. The temporal is joining with the frontal. The lacrimal still is not present. The pterygoid appears to be joined anteriorly to the posterior end of the palatine. The vomer is apparently fused with the rostrum of the sphenoid. In the hyoid a third center of ossification has appeared between the two previously mentioned. The plates of the eyes are much more distinct.

Fourth day.—The ear cavity is beginning to form in the temporal. The premaxilla has fused with the nasal. The pterygoid is fused with the rostrum of the sphenoid. The quadrate is about ready for articulation with quadrato-jugal. The os articulare of the inferior maxilla is beginning to form.

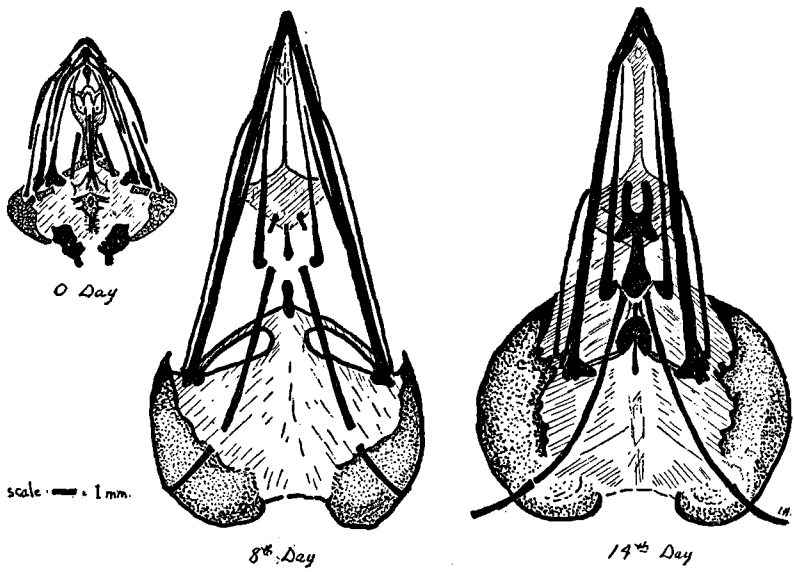
Fifth day.—The sphenoid appears to be connected with the quadrate and is nearly connected with the lateral occipital. The quadrate articulates with the os articulare of the inferior maxilla.

Sixth day.—There is fusion between the parietal and the lateral occipital.

Seventh day.—Pterygoid articulates with the quadrate while the quadrato-jugal is articulating closely with the quadrate.

Eighth day.—The lateral and supraoccipital parts have fused and the occipital is curving around to form part of the ear cavity. The sphenoid appears to be joining with or touching the occipital ventrally. The temporal and quadrate articulate. The palatine appears to be fused with the inner edges of pterygoid. The basi-hyal of the hyoid is present.

Ninth day.—The four parts of the occipital are all fused. Sutures between the two frontals extend down to the nasal bone.



TEXT-FIGURE 6.—Skull of nestling House Wren; ventral view.

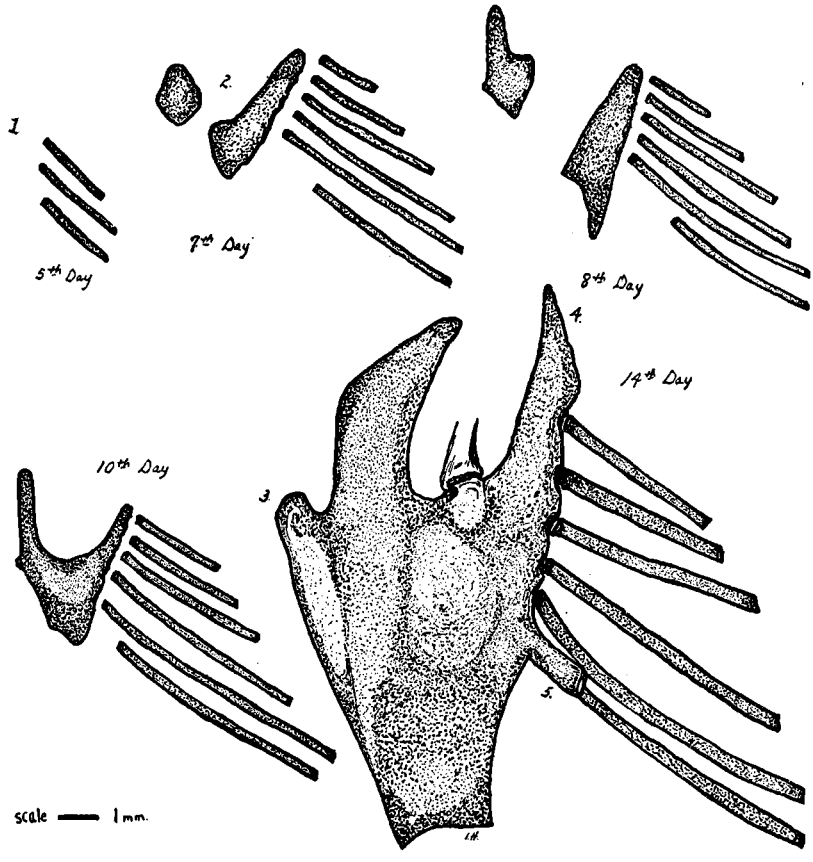
Tenth day.—There is general fusion between temporal, lateral occipital, sphenoid and quadrate. The lacrimal is seen for the first time. Zygoma and jugal articulate and the inferior maxilla articulates with the quadrate.

Twelfth day.—The temporal is fused with the sphenoid. By this time most of the skull bones are completely fused.

VERTEBRAL COLUMN, RIBS AND STERNUM

O day.—In the cervical region there are thirteen small vertebrae, each having three centers of ossification: the right and left halves of the neural arch and the centrum. The vertebrae do not yet articulate with each other. The atlas and axis are not as well formed as the other cervical vertebrae. The seven thoracic vertebrae are larger and

more heavily ossified but in extent of development are like the cervical. Eight ribs are present but unattached. The vertebral end of all but the first rib is slightly divided into the capitulum and tuberculum. In four of the specimens the first rib is difficult to see; in two others,



TEXT-FIGURE 7.—Sternum of nestling House Wren: 1, sternal ribs; 2, first ossification centers of body of the sternum; 3, keel or sternal crest; 4, costal process; 5, xiphisternal process.

it is well formed. No ossified sternum is present. The lumbar and sacral vertebrae are barely visible. In most of the specimens it was impossible to count the coccygeal vertebrae as ossification was not advanced enough.

Second day.—The pygostyle is present. It is not possible to distinguish all the coccygeal vertebrae.

Third day.—The processes of the thoracic vertebrae are developing and transverse processes on the last four sacral vertebrae are present.

Fourth day.—Processes of the cervical vertebrae are developing. The zygapophyses are beginning to develop as separate centers in the cervical region. In the thoracic region fusion of the centra with the transverse processes has taken place. The coccygeals are fused ventrally.

Fifth day.—In the cervical region the neural arch and the centrum are fused ventrally at each side. The atlas is not yet fused on the ventral side but is on the dorsal side. The last thoracic is beginning to unite with the first lumbar vertebra. A center of ossification is present on each side of the sternum and very light ossification is present in the keel. The lumbar and sacral vertebrae are fusing together. Fusion is beginning between the first coccygeal and the last sacral vertebra.

Sixth day.—The atlas is articulating with the axis and the axis is articulating with the next cervical vertebra. Five new centers of ossification have appeared on each side of the sternum. Many of the lumbar and sacral vertebrae are fused.

Seventh day.—The processes of the cervical vertebrae have united with the vertebrae. The atlas is articulating with the single condyle of the occipital. All the lumbo-sacral vertebrae are fused. The sternum has developed another large center of ossification in the keel.

Eighth day.—Fusion of some of the thoracic vertebrae has occurred. The transverse processes are touching the dorsal end of the ribs. Three of the ribs have developed uncinate processes. Another paired center of ossification has appeared in the sternum.

Ninth day.—The fusion of the thoracic vertebrae is still incomplete. Another rib has developed the uncinate process. In the lumbar and sacral vertebrae small processes are being formed dorsally. Fusion of the three bones that form the sternum is beginning.

Tenth day.—Fusion of the sternum is nearly complete.

Twelfth day.—The uncinate processes have joined the ribs and there is a general fusion of all vertebrae.

Thirteenth day.—In the dorsal region the superior processes are articulating with the small part of the rib articulars.

SUMMARY

Ossification of all the bones has begun in the newly hatched wrens with the exception of the second metacarpal, fourth digit, radiale, ulnare, eye ring, lacrimal, uncinate processes of the ribs, pygostyle and sternum.

Of these, the pygostyle and the plates of the corneal margin of the sclerotic tunic appear on the second day, the second metacarpal and the fourth digit on the third day, the radiale and ulnare on the seventh. Uncinate processes begin to develop on some of the ribs on the eighth day and the lacrimal begins on the tenth.

The first center of ossification for the sternum is present on the fifth day with new centers appearing successively until the ninth day, when fusion begins.

Ossification proceeds rapidly, with articulation and fusion almost complete by the time the nestlings are ready to fly.

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