ported by the external bones of the carpal and tarsal series respectively. The reduction of the external digit deprives the external bones in question of their share in the support of the general weight, and consequently relieves them of impact, which now passes through the longer median digits which remain. The median digits, on the other hand, support the radius and tibia through the medium of the carpus and tarsus, and it is these elements, therefore, which function in the use of the limb. We have here an evident illustration of the effect of disuse in effecting the atrophy of an element, and of use in increasing the size and complexity of an adjacent element of the same organism. No other explanation seems possible, for the elements which are reduced and those which are enlarged are subjected in every other respect to the same conditions.

On False Elbow Joints.

By Prof. E. D. Cope, Ph.D.

(*Read before the American Philosophical Society, December 2, 1892.*)

I have in various papers formulated and defended the hypothesis that the peculiar characters of the articulations of the mammalian skeleton are due to mechanical causes operating throughout the ages of geologic time.* I had previously traced the succession of these modifications from simple reptilian types, through various stages, to the highly specialized and mechanically perfect structures seen in the higher Mammalia. The series of forms revealed by paleontologic research is so complete as to leave little doubt in the mind as to the manner and cause of their origin. The theory thus derived, which I have called kinetogenesis, depends for its demonstration on two assumptions. The first is that living osseous tissue is plastic, and is therefore readily modified in its form by impacts, strains, friction, etc. ; and the other is that one which is necessary to all evolutionary hypotheses, that acquired characters are inherited. I do not propose to discuss here the latter proposition, but I desire to offer some evidence in support of the former. Marey tells us,† as a result of a study of pathological conditions of articulations, that "after dislocations the old articular cavities will be filled up and disappear, while at the new point where the head of the bone is actually placed, a fresh articulation is formed, to which nothing will be wanting in the course of a few months ; neither articular cartilages, synovial fluid, nor the ligaments which retain the bone in place."

Specimens demonstrating the truth of this statement of Marey are also

* *Origin of the Fittest*, 1887, p 368 *et seq.*; "The Mechanical Origin of the Hard Parts of the Mammalia," *American Journal of Morphology*, 1889, p. 148.

† *Animal Mechanism*, 1874, pp. 88, 89.

demonstrative of the truth of the doctrine of kinetogenesis. Two such have recently come under my observation—both of them cases of dislocation of the elbow joint. One of these is that of a man (No. 1838, Wistar and Hornor Museum of the University of Pennsylvania), where the cubitus is luxated backwards. The other is that of a horse, where the cubitus is luxated outwards, which I owe to the kindness of Dr. William B. Werntz, Vet., of Philadelphia. These specimens are especially instructive as exhibiting the different effects of different luxations of the same articulation.

Elbow of Man.

The human elbow, for which I am indebted to the authorities of the University of Pennsylvania, is so dislocated as to have allowed little flexion and extension during life, but the radius retained rotary motion. The humeral condyle rests on the ulna anterior to the coronoid process, and the head of the radius is in contact with the posterior side of the external epicondyle. It has resulted in consequence of the abnormal position of the humerus, that a new coronoid process has developed as far anterior to the true coronoid as the latter is anterior to the olecranon; and that a new humeral cotylus has appeared between the two coronoids whose fundus is considerably elevated above that of the old one. In consequence of the contact of the head of the radius, a deep cotylus has been formed on the posterior face of the external epicondyle and adjacent part of the condyle of the humerus, which is well adapted to the radial head. From both of these new cotyli I removed a layer of articular cartilage, and the osseous surface is as smooth and dense as those of normal articulations. The edges of the cotyli are not as smooth as those of the normal, but display the greater or lesser irregularities of unfinished osseous deposit, except the internal border of the radial cotylus of the humerus which is perfectly regular.

Remarkable exostoses accompany the development of the cotyli. The normal humeral cotylus of the ulna is partially filled with rough osseous deposit. The internal epicondyle of the humerus sends a process downwards and posteriorly towards this cotylus, which it does not reach, but projects freely. The external epicondylar region develops three processes of which the posterior and inferior anterior (distal) embrace the head of the radius, forming the posterior and anterior boundaries of the radial cotylus. Two ridges of exostosis of the shaft terminate at the posterior process. The superior anterior process is short, and projects freely distad. But a small portion of the condyle proper retains its articular surface; that is the posterior part of the internal condyle which articulates with the ulna. The remaining surface of the condyles is concealed by irregular bone deposits which quite obliterate its normal form, especially on the posterior (olecranar) surface, where the deposit is thickest and most irregular.

Elbow of a Horse.

I am informed by Dr. Werntz that the horse with dislocated elbow lived for about two years after the accident, in the country, dying of pneumonia. It used the leg (the left one) to a moderate degree, walking on the extremity of the hoof, with the elbow everted.

It results from the dislocation, that the internal part of the head of the radius was in life without opposing humeral surface. The trochlear crest of the humerus rotated inside of the median ridge of the head of the radius ; and the interior roller of the humerus projected freely within the internal border of the head of the radius. The external border of the humeral condyles corresponds to the trochlear groove of the head of the radius, which, of course, it does not fill. Since the internal face of the olecranar process rotates on the external epicondyle of the humerus, it follows that the external face of the olecranar process has no contact and was unused.

The mechanical result of this position of the parts is as follows : The internal side of the olecranar process develops friction on the external surface of the external epicondyle of the humerus. The trochlear crest of the humerus produces the same along the inner side of the median crest of the head of the radius. The expansion of diameter of the internal roller of the humerus produces friction on the internal edge of the head of the radius.

The structural result may be divided into two divisions : *first*, those developed at points of contact of the parts thus abnormally brought together, and *second*, those which appear at points abnormally separated.

Class First. (1) A large new facet is developed on the posterosuperior aspect of the external epicondyle of the humerus (*1a*, Figs. 1 and 3), which lies in an arc continuous with that of the external roller (or condyle), and whose surface is directed downwards and outwards. It occupies the usual position of the external *flexor metacarpi* muscular insertion, which is in the normal humerus a truncate oval, looking downwards and backwards. This surface has been almost entirely removed, the posterior face of the lateral rib of the humerus terminating below in an obtuse acumination, instead of the form described. The form of the new facet is not entirely due to the planing down or absorption of this region. The external epicondylar fossa is filled with exostoses, of which a large one in a superior position contributes material for the inferior part of the new facet. The posterior rib of the humerus is also exostosed so as to present a rough surface of greater transverse extent than in the normal humerus. This mass overhangs the new olecranar facet, forming a guide to its free extremity in rotation, the latter thus running in an open groove. Thus is further luxation in a measure provided against.

(2) The internal half of the humeral facet of the olecranar process is narrowed, and its prominent internal rim rounded off; and it is con-

tinued to the radial articular surface, instead of being separated by an interruption as seen in the normal horse. In extension and flexion the prominent posterior border of the new olecranar facet of the humerus rotates behind the humeral olecranar facet just described. Posterior to this depressed surface there rises an abnormal bony crest which is concentric with the olecranar and humeral surfaces, and serves as a guide in extension and flexion of the crest of the humerus which moves in the surface in front of it, which becomes, through the presence of this crest, an open groove (*1c*, Figs. 4, 5).

(3) A triangular shallow facet is formed on the posterior part of the head of the radius corresponding to the trochlear crest of the humerus (*1f*, Figs. 2, 4).

(4) A corresponding facet appears on the posterior part of the trochlear crest of the humerus, which penetrates the dense layer (*1e*, Fig. 1).

(5) The internal extremity of the humeral surface of the head of the radius is beveled off by the expansion of the internal roller of the humerus, forming a new facet of perfect articular character (*1b*, Figs. 1, 2, 4).

(6) A facet corresponding to (5) is developed on the internal roller at its middle, considered either transversely or anteroposteriorly. It is of an elongate oval form, and its superior portion penetrates the dense layer (*1d*, Fig. 1).

Class Second. (1) The trochlear groove of the head of the radius has nearly closed its anterior and posterior margins by osseous outgrowths, the largest of which, the posterior, so fills it as to support the external part of the external humeral condyle in extension and flexion (*2a*, *2b*, Figs. 2, 4, 6).

(2) Exostoses exist on the external side of the humeral facets of the olecranar process, which fill part of the concave arc of the ulna, necessary for adaptation to the external border of the humerus in its new position (*2c*, Figs. 4, 6).

(3) At the internal and posterior sides of the head of the radius a mass of exostoses causes a considerable thickening of the bone. Its thickness on the internal side is just equal to the free projection of the internal roller of the humerus within the head of the radius. It is not, however, built up to the plane of the head of the radius, and so does not yet support the humerus.

Summary.—As a result of the abnormal action of this luxated elbow we have the following production of new structures. Four complete new facets, viz.: One on the humerus, one on the ulna, one on ulna and radius, and one on the radius. Two incomplete new facets on the humerus. The development of two new crests, which serve as guides to rotating margins. Second, the partial filling by exostosis of two unused facets, one on the ulna, and one on the radius; third, the filling by exostosis of an epicondylar fossa which serves to build out a new facet; and, fourth, the building out by exostosis of the head of the radius, which if continued would have extended the head of the radius for adaptation to the inwardly luxated humerus.

Etiology.—That the new structures described are due to the abnormal mechanical relations of the bones, will be questioned by no one. We observe three distinct processes of osseous metabolism due to these conditions. These are : *First*, the removal of tissue from its original locality, and the substitution of dense tissue for spongy tissue at the point of removal. This has been accomplished at three points. A. Where the inferior extremity of the external posterior rib of the shaft of the humerus has been largely cut away, in adaptation to the movement of the olecranar crest of the ulna, and a dense layer developed over the new surface thus produced. B. Where the internal border of the head of the radius has been beveled off. C. Where the internal face of the humeral facet of the olecranar process of the ulna has been planed down without exposing the spongy bone. That this process was not completed at some points is shown by the two new facets of the humeral condyles, where the dense layer is penetrated and no corresponding dense layer established on the spongy layer thus exposed (Figs. *1d* and *1e*).

Second. The deposit of osseous bodies beneath the synovial walls where the bursa was kept expanded by the failure of the articular ends of the bones to maintain contact, as in the case of the trochlear groove of the head of the radius, and the external side of the humeral facet of the olecranar process of the ulna.

Third. The development of exostoses at the insertions of articular ligaments and tendons at the following three points : A. At the insertion of the *flexor metacarpi externus* ligament, at the exterior border of the posterior face of the inferior end of the shaft of the humerus, which crest overhangs the new facet above described. B. Where the osseous crest is developed on the ulna, concentric with the interior humeral facet of the olecranar process. C. Where extensive exostosis appears on the internal side of the head of the radius. D. Where the external epicondylar fossa is filled with exostoses (other ligamentous exostoses at *3e*, *f* and *g*, Figs. 1, 2, 4, 5).

From the above analysis we may derive the following conclusions as to the nature of the metabolism in the several cases :

Class First Continued excessive friction removes osseous tissue from the points of contact until complete adaptation is accomplished and the friction is reduced to a normal minimum.

Class Second. Where the normal friction is wanting, and an inflammatory condition is maintained by a pulling stress on the investing synovial membrane, excess of osseous deposit is produced.

Class Third. Stress on the articular ligaments and tendons stimulates osseous deposit at their insertions, which deposit may be continued into their substance. This is a pulling stress.

Conclusions.—We find illustrated in these specimens three kinds of osseous structures which are observed in normal vertebrate skeletons.

These are, articular facets, osseous deposit at presumed points of irritation from various stimuli, and the development of bone at ligamentous and tendinous insertions. To the combination of the causes which produce the first and second effects we owe most of the secondary peculiarities of the vertebrate skeleton; and to the third we owe the fundamental construction of the skeleton on which the secondary modifications have been superposed. It is not important to our contention if the histological structure of some of the abnormal osseous deposits in our specimen may differ slightly from the normal tissues sought to be explained by it. This may be accounted for by the different circumstances to which the two sets of phenomena are due. In the dislocation the change from the antecedent state of the parts is violent and abrupt. In the evolution of the vertebrate skeleton the process was slow and gradual. In the cases of the luxations nature had to meet the changed conditions by correspondingly abnormal measures. In orderly evolution "*saltus non fecit.*" It may, however, be justly inferred, that if such characteristic structures can be produced in the space of months, how much more easy has it been for stimuli of allied character to develop the features of normal articulations during the ages of geologic time.

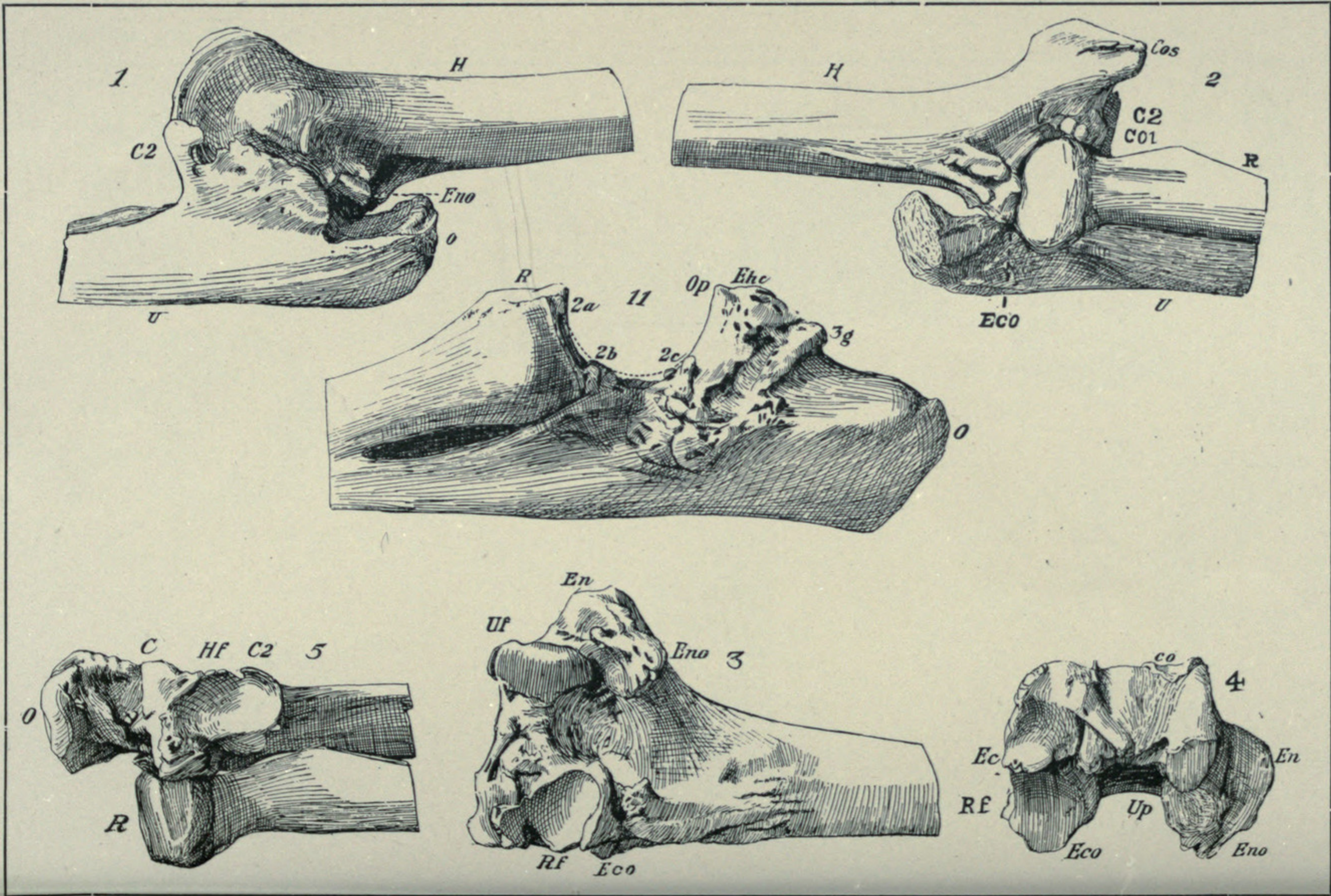
We have here, also, an instructive lesson as to the matter of inheritance. Every one knows that mutilations, luxations, etc., are not usually inherited. This is because they are not "acquired" in the proper sense of the word. Since characters truly acquired are inherited, it is evident that a long continuance of the stimulating cause is necessary to produce a true acquisition. The difference between a character produced by causes apart from the normal life of an animal and not repeated, and those produced by causes operating daily and hourly for geologic ages, is necessarily very great. And, as Prof. Scott* remarks, the latter have not been acquired during the lifetime of each generation, since they are found in the young before birth, before external stimuli have had the opportunity to exert their influence.

Explanation of Plates.

Figs. 1–5. *Homo sapiens,* luxated elbow joint; one half natural size.
1. Luxated elbow joint, from within.
2. Luxated elbow joint, from outer side.
3. Humerus, posterior view of distal region.
4. Humerus, distal view.
5. Ulna and radius, anterior (superior) view.

Lettering.—*H,* humerus; *U,* ulna; *R,* radius; *C,* coronoid process; *C2,* second (abnormal) coronoid process; *O,* olecranon; *En,* entepicondyle; *Ec,* ectepicondyle; *Eno,* entepicondylar exostosis; *Eco,* ectepicondylar exostosis; *Co,* condylar exostosis; *Cos,* superior condylar exostosis; *Coi,*

* "On the Osteology of Mesohippus and Leptomeryx," *American Journal of Morphology,* 1891, p. 385.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