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SURGICAL AND ANATOMIC EVIDENCE OF EVOLUTION¹

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I PROPOSE in this address to approach evolution, not from the controversial side or from general arguments, but from a plain statement of a series of *facts*, many of them drawn from my personal experience as a surgeon and anatomist—facts which, to my mind, absolutely demonstrate the solidarity of animal life, more especially in the case of the vertebrates, such as fish, birds, other mammals and man, the highest mammal.

Many opponents of evolution admit the gradual development of animal life from its lowest form up to and including the anthropoid apes, but they draw the line there, basing this belief on the account in Genesis. Man, they insist, stands as a separate direct creation by the Almighty, "out of the dust of the ground." Such an argument is like declaring that the laws of mathematics reign in numbers up to, say, 100,000 or 1,000,000, but beyond that limit are no longer valid.

* * * * *

Let me now point to *facts*—not theories but facts—which demonstrate this unity of the animal kingdom, including man.

1. Let me relate some operations I have done on the human brain. The brain in animals, including man, consists in a general way of (a) the cerebrum; (b) the cerebellum; (c) the spinal cord; and (d) certain structures which bind these three together. Extend the fingers straight forward. The fingers then resemble the "convolutions" on the surface of the brain; the furrows between them resemble the "fissures" between the convolutions of the brain. The principal fissures between the convolutions are similar in man and animals.

¹ Part of the Commencement Address at Crozer Theological Seminary, Chester, Pennsylvania, on June 6, 1922.

In the convolutions on the surface of the brain are certain small aggregations of motor nerve cells in the gray matter called "motor centers." On being stimulated by an electric current, these cells produce motion, each center in one definite portion of the body, and never in any other part. These motor centers are all grouped around the fissure of Rolando, which runs obliquely downward and forward above the ear. This, and another deep furrow called the fissure of Sylvius, are always readily identified in the lower animals. The motor centers for movements of the leg, arm, face, fingers, etc., in the brains of the lower animals, up to the anthropoid ape, have been exactly mapped out by experiments on animals. In the human brain the location of the corresponding motor centers is a duplicate of those in the brains of animals. Let me relate some striking cases to confirm this statement.

A young woman with epilepsy, in whom the attacks were constantly increasing in frequency and violence, insisted that her attacks always began in her left thumb, then spread to the hand, then to the arm, followed by unconsciousness and violent convulsions all over the body. Careful observation for two weeks in hospital confirmed her statements that the fits always did begin in this left thumb. If, then, I could prevent the fit from beginning in this thumb, so I reasoned, it might be that I could prevent the entire attack. Just as, in a row of bricks standing on end, if I can prevent the first one from falling, none of the others will fall.

The possibility of the exact localization of the little cube of gray matter on the surface of the brain, dominating all the muscles of the thumb, was the key to the whole operation. This localization of the thumb center had been made absolutely by experiments on the brains of animals. Accordingly, I opened her skull, identified the spot corresponding to the thumb center (*i. e.*, the great toe of the fore foot) in animals, and cut out a small cube less than an inch on each side.

Next, note the fact that there are nine muscles moving the thumb, some in the ball of the thumb, some between the thumb and the forefinger, some extending up the front of the forearm, and some up the back of the forearm,

both of the latter reaching nearly to the elbow. Some flex and some extend the thumb, some separate it from the other fingers, and by one we can make the thumb touch each of the other four fingers. This is the motion which differentiates the human "hand" from the animal fore foot.

When this patient awoke from the ether, *every one* of these nine muscles was paralyzed and in *not a single additional muscle* was motion affected. The human brain center and the animal brain center for the thumb were proved to be *precisely identical*. My hopes were justified. Her epileptic attacks, which had occurred almost daily, recurred only about once in a year. In a few months she even regained full control over this thumb.

Two other later similar cases still further confirmed this wonderfully exact localization.

A fourth brain case: In 1888, I reported my first three cases of modern surgery of the brain. Attending the meeting of the American Surgical Association in Washington, when I read this paper, was Sir David Ferrier of London. He had contributed very largely to this then wholly new mapping of the brain centers which control motion. In one case, I described how I had stimulated a certain small, definite motor area in the brain of my patient by the battery,² and described the resulting movements of the arm at the shoulder. Ferrier afterwards said to me, "I could hardly restrain myself from leaping to my feet, for this was the very first demonstration on the human brain of the exact identity of my own localization of this very center in animals."

A fifth brain case: A midshipman in the United States Naval Academy at Annapolis, in 1902. I saw him three days after his accident. All the history I obtained was that he had been injured in a foot-ball game, had been unconscious for half an hour, and since then had complained bitterly of headache, which he located in his forehead. He was almost comatose, his pulse was only 52. There was no fracture of the skull. Soon after the accident, he developed local convulsions—note this care-

² The brain tissue itself is wholly devoid of sensation and can feel no pain.

fully—first in the right leg and later and chiefly in the right arm, but never involving the face. In six and a half hours he had had twenty-four of these convulsions, all in the right arm. The only evidence of a local injury was a slight bruise at the outer end of the left eyebrow. Had I seen this case prior to 1885—when I first made a careful study of the motor centers in the brain—I should have followed, of course, the only visible indication of the location of the injury to the brain, namely, the bruise. Had I opened his skull near the bruise, I should have been confronted with a perfectly normal brain. I should then have been compelled to close the wound and have perforce done nothing more. He would have died within two or three days.

But experiments on animals, after 1885, had shown that above the ear and a little in front of it lay the centers controlling the muscles of the face, the arm, and the leg, from below upwards, the leg center being near the top of the head.

As there was no fracture of the skull, and as the convulsions began first in the leg and then concentrated chiefly in the arm, but never extended to the face, my diagnosis was a rupture of the large artery on the surface of the brain over these motor centers; that the escaping blood had formed a clot, the edge of which first overlapped the leg center, but that the chief mass of the clot lay over the arm center. Moreover, I felt sure that it had not yet reached downwards over the motor center controlling the muscles of the face. Evidently, this clot must be immediately removed or he would quickly die. I opened his skull directly over the center for the arm muscles, and *far away from the bruise*. The opening in the skull at once disclosed the clot, the thickest part of which did lie exactly over the arm center, as I had foretold. I removed nine tablespoons (three-quarters of a tumblerful) of blood, which had caused the headache, the somnolence, the slow pulse and the convulsions; then tied the artery and closed the wound. He made an uninterrupted recovery. He entered the navy but some years later lost his noble life in saving his ship and the crew from destruction by a fire near the powder magazine.

Do not such exact localizations of the brain centers in animals, as directly applied to man, in hundreds, if not thousands of operations by now, most closely ally man to animals?

II. Go with me next into the Museum of the Academy of Natural Sciences in Philadelphia, and compare the skeleton of man with those of the lower animals. Practically, these animal skeletons all closely resemble the human skeleton, though when clothed with flesh and skin they look very unlike.

All of the ape and monkey skeletons are practically replicas of the human skeleton.

Look at the many skeletons with five toes—the prevalent or typical number—such as those of the cat, tiger, bear, elephant, etc.³ Take, for instance, the front and hind legs that correspond to the arm and leg in man. Bone for bone, they are counterparts of the human skeleton—shoulderblade, humerus, radius and ulna (the two bones of the forearm), and those of the hand; with a similar correspondence in the bones of the hind leg and foot.

Nothing could be more unlike externally than the flipper of a whale and the arm and hand of a man. Yet you find in the flipper the shoulderblade, humerus, radius, ulna, and a hand with the bones of four fingers masked in a mitten of skin.

Observe the bones of the next chicken you eat. The breast bone of all birds has a great ridge developed to give a large surface for attachment of the large and powerful breast muscles for flight. You will find in the wing the counterpart of the shoulderblade, the humerus and the radius and ulna. The bones of the bird's wing, *i. e.*, the hand, are three in number, the bones corresponding to the little finger and the ring finger being absent. They are thus modified to support the feathers. It is a hand altered to suit the medium in which birds move so gracefully.

While undoubted evidence shows that man has existed for only about 500,000 years, the horse has a consecutive geological history of over 3,000,000 years. The skeleton of the earliest horse, which was scarcely larger than a cat, had four toes in front and three behind.

³ Sometimes there are only four toes in the hind leg, or the fifth, if it exists, is rudimentary.

Gradually, all the toe bones except one—the middle toe—have been lost. But the second and fourth digits, though they do not show externally, are represented by two rudimentary bones, the two “splint bones.” The horse of to-day walks literally on tip toe, for the hoof is the toe- or finger-nail.

III. The internal organs of the body have the same story to tell of likeness or identity. Let us first look at the *heart*. You all know there is a right side of the heart which sends the blood through the lungs to be oxygenated, and a left side, which sends the blood to all the rest of the body. Each of these sides has two cavities—the auricle to collect the blood, the other, the ventricle, with strong, muscular walls, to drive the blood on its long journey. These four cavities are all united into one heart, with an important *groove* on the surface, marking a partition between the two auricles above and the two ventricles below.

A steady, rhythmical action of the four cavities is essential for the proper propulsion of the blood, and, therefore, for health and life. The four cavities act, not all at once, but in succession, like the feet of a walking horse—1, 2, 3, 4; 1, 2, 3, 4, each foot having its own number. Until 1892 we did not know exactly what regulated this orderly sequence. In that year, the younger Professor His discovered that in the groove between the auricles and the ventricles there was a small bundle of muscular fibers which existed as one bundle until it reached a certain point. There it divided into two smaller bundles, one going to the muscles of the right side of the heart, and the other to those of the left side.

But the great importance of this “bundle of His” was not fully appreciated until twelve years later (1904). If, under an anesthetic, an animal’s chest is opened, the heart laid bare, and this “bundle of His” is injured, the rhythm of the heart is at once disturbed. Instead of 1, 2, 3, 4, the order in which the hoofs struck the ground might be 1, 4, 2, 3, or 1, 3, 2, 4, etc. This fluttering of the heart threatens life. If the bundle is destroyed, death quickly follows.

In man, such physiological experiments, of course, are forbidden, but occasionally disease maims or destroys this bundle of His in the

human heart itself. A small tumor named a *gumma*, in a few cases, has formed directly in or near the bundle of His, and in some cases has destroyed it. This has deranged the action of the heart of the human patient, just as the physiologist did in the experimental animal. Severe flutterings of the human heart, with difficulty of breathing, a pulse slowed down from 72 to 20, 10 or even 5 in the minute were observed. Not seldom sudden death occurred. The post-mortem in these cases disclosed the tumor, or other cause, which had injured or destroyed this bundle of His, and was the immediate cause of death.

Now, this bundle of His is found in all vertebrates, in man and other mammals, in birds, and even in frogs and fishes. Does not this show a solidarity of the entire animal kingdom? Do not so many such exact parallels between the human and the animal body strongly suggest a close inter-relation of the two?

Even plants convey the same message. I have seen Professor Bose, of Calcutta, put plants to sleep with ether and chloroform. If enough is given, they are killed just as a man is killed. If only a moderate dose is given, the plant passes into a state of greatly lessened activity, which may be well called sleep. When the anesthetic is withdrawn, it gradually awakens and returns to its normal activity, just as a man does.

One can even descend still further down in the scale to the bacteria, that is, germs visible only by the microscope. As Welch, of the Johns Hopkins, points out, “The gentle killing of certain bacteria by chloroform enables us to detect in their bodies toxic [poisonous] substances which are destroyed by more violent modes of death.”

IV. The Liver and the Ductless Glands. Everybody knows that the liver secretes bile, or gall. The bile, which is necessary for proper digestion, is discharged into the intestine through a tube called the bile duct. The gall bladder is simply a reservoir for extra bile, and a sturdy means of support for us surgeons, especially in the late hard times—by reason of the dangerous gall stones which form in it and require removal by a surgical operation.

Now, in 1848, Claude Bernard, of Paris, one

of my own teachers in the middle sixties, discovered that the liver had a second function totally unsuspected until then. Practically all the blood from the intestines goes through the liver on its way back to the heart. Bernard opened the abdomen of a fasting animal, drew some of the blood *before* it entered the liver, and also some of the blood *after* it had gone through the liver. He found that the blood, before it entered the liver, was sugar free, but after it emerged from the liver, it always contained *sugar*. This was the first step in the scientific study of diabetes, in which there is an excess of sugar which is excreted through the kidneys:

But the liver has no second duct or tube for the discharge of this sugar into the blood current. Being in solution, it soaks through the thin walls of the blood vessels into the blood current as it passes through the liver.

Following this, came later the discovery of the now numerous "ductless glands" of which we have learned so much chiefly by animal experimentation in the last few years. Some of them, though only as large as a pea, are essential to life itself.

V. Let me now say a few words about one of the most important of these ductless glands—the thyroid gland in the neck. When it becomes enlarged it is familiar to us as a "goiter."

From this gland, as in the case of the liver, there soaks into the blood stream a secretion of great importance to life. If the gland is rudimentary, either in substance or in function, it results in that form of idiocy known as cretinism. As a remedy we have learned to administer an extract from the thyroid glands of animals. The remedy is usually remarkably successful.

In certain conditions, goiter is very prevalent in the thyroid gland of brook trout. It has even threatened to destroy the culture of these food fishes.⁴ By the administration of iodine, this disease has been prevented in the trout. As a result of this success, the same method has been found efficient in preventing goiter in human beings.

Here, again, you perceive the solidarity of

the animal kingdom in such identity of function that the thyroid gland of animals, when given as a remedy to man, performs precisely the same function as the human thyroid. Moreover, it is not the thyroid gland from the anthropoid apes that is used as a remedy, but that from the more lowly sheep.

VI. The Sympathetic Nerve and its wonderful phenomena. When I was a student of medicine, one of our text books was Dalton's Physiology. In connection with the sympathetic nerve, there was a picture of a cat, of which the Chessy cat of *Alice in Wonderland* reminded me, for in both only the face was pictured.

The sympathetic nerve is a slender cord about as thick as a fairly stout needle. It runs vertically in the neck, alongside of the carotid artery and the jugular vein, and so close to them that a dagger, a knife or a bayonet thrust, or a bullet which would cut the nerve, would almost surely cut the great artery and the vein. The patient then would bleed to death in a few minutes and never reach a hospital. Hence, no one had ever had a chance to observe the effects following division of this nerve in man. Before Brown-Séquard's experiment in animals, in 1852, its function, therefore, was entirely unknown. By a small incision he exposed the nerve in the neck of a cat, rabbit and other animals, divided the nerve, and observed what happened. The small wound healed quickly.

These results were as follows: 1. The pupil of the eye on the same side as the cut nerve diminished from the normal large sized pupil in the cat to almost the size of a pin hole. 2. The corresponding ear became very red from a greatly increased flow of blood, *i. e.*, the blood vessels were greatly dilated. 3. On that side there was increased sweating, that is, the sweat glands became very active as a result of the increase in the blood supply. 4. The temperature increased to a marked degree; in rabbits, by seven to over eleven degrees Fahrenheit.

Dalton's picture of the cat could not be forgotten because the two pupils differed so greatly in size.

In 1863, during the Civil War, when I was assistant executive officer of a military hospi-

⁴ Kimball: *American Journal of the Medical Sciences*, May, 1922, p. 634.

tal, one day a new patient approached my desk just as I was about to sign a letter. The moment I looked up at him I was struck with his appearance and instantly said to myself, "Surely you are Dalton's cat." "Where were you wounded?" I quickly asked. He pointed to his neck and I said to myself, "His sympathetic nerve must have been cut." Further careful observation showed the reddened ear, the increased temperature, the sweating and the greater flow of saliva, thus confirming in every particular the results of Brown-Séquard's experiments on animals. It is interesting to know that this was the very first case in surgical history in which division of the sympathetic nerve had ever been observed in man.

Further experiments on this little nerve in animals revealed a wholly new world of most important phenomena. It was discovered that the sympathetic nerve sent branches to every artery in the body, from head to foot. Now the arteries are tubes, like the water pipes in a house, not, however, of rigid metal but soft and flexible, for they consist largely of muscular fibers which contract or relax automatically, making the arterial tubes of a larger or a smaller diameter according to the need for more or less blood.

For instance, just before a meal, the stomach is of a yellowish color. Not a single blood vessel is to be seen. An hour later the stomach has become so red that it seems almost as if the wall of the stomach is made up of nothing but blood vessels. This greatly increased supply of blood is needed to secrete gastric juice for the digestion of our food. As the food is digested, less and less blood is needed, the caliber of the arteries is gradually diminished by the contraction of the muscular wall of the arteries until the stomach looks as bloodless as before breakfast.

How fortunate that all this is automatic! Were it not, and after breakfast you forgot to order an increasing supply of blood for digestion, or if after digestion was accomplished, you forgot to shut off the blood, what would become of you?

The iris, the colored circular curtain inside the eye, with a round, black hole in the center called the pupil, is under similar automatic

control of this sympathetic nerve. The iris is like a wheel. Around the pupil there are circular fibers which one may call the hub, while the rest of the iris consists of radiating fibers corresponding to the spokes. When you go out of doors, the bright light at first almost blinds you, but very quickly the circular fibers around the pupil contract so that the pupil becomes as small as a pin hole and protects the retina. On going into a dark room, at first you stumble over the furniture, but in a few moments the radiating fibers pull the pupil wide open and you see clearly everything in the room.

When you blush from emotion, the arteries of your skin have dilated. When you turn pale with fright, the caliber of your arteries is lessened, and if the arteries going to your brain supply too little blood, you fall in a faint. When you cut your hand, you know how all around the cut the redness shows that the arteries have dilated to furnish extra blood for the repair of the injury, and when the wound is healed, your blood vessels again contract and the redness at last disappears.

All these processes also are automatic. You do not have to remember to order blood to or from a cut hand, or to contract or widen the pupil, etc. It is all done for you; in fact, it is done in spite of you, for you have not the least control over these varying conditions. The automatic action of this nerve is of the utmost importance for many functions involving life itself.

I could go on almost indefinitely with a multitude of similar illustrations. All of our knowledge of these facts started from Brown-Séquard's little experiment of cutting the slender sympathetic nerve in the neck of an animal.

VII. Another evidence of our animal origin is found in organs which are well developed and actively functioning in some of the lower animals, but which in man are only rudimentary. The best known example of this is the appendix, which, in some of the lower animals, is well developed and functions actively. Its frequent inflammation is also a good example of the fact that such imperfect vestigial organs are very prone to disease and often require the

surgeon's skill to avert disaster. The only really safe place for the appendix is in the surgeon's collection of trophies.

VIII. Let us now turn to the very significant evidence of our animal origin in the embryonic development of man. I have time to note but a single, though very enlightening instance.

During pre-natal development in man, between the two upper jaw bones is a triangular bone which carries the four upper incisor or "front teeth." At birth, and afterwards, there is normally no such bone because it has become fused on each side with the upper jaw bone. In sheep and some other animals, this always persists as a separate bone called the pre-maxillary bone. Now note a curious defective development in human fetal life. Sometimes this pre-maxillary bone, in the human embryo, fails to unite with the upper jaw bone on the right or the left side, and then we have what you all know as "cleft palate." If not only the bones fail to fuse together, but this failure extends also to the lips, we have a "hare lip." We see in some cases only a cleft palate, in others only a hare lip, in still others, both hare lip and cleft palate.

When there is such a deformity, it *never* occurs in the middle line, or any indifferent place, here or there, but invariably to the right or the left side and corresponding exactly to the site of the failure of this pre-maxillary bone to unite with the upper jaw.

Is not such an exact correspondence between the anatomy and development of the sheep and of the child most significant of the ancestry of the human body?

IX. Lastly, there have been discovered several grades of actual prehistoric men. Their skeletons or skulls, their flint instruments, and the remains of their fires are evidences of the grade of their several civilizations. This chain of human ancestors was unknown to Darwin, for they have been discovered since his death.

I have myself seen in the caverns of southern France the extraordinary and convincing evidences of the assured existence of our immediate ancestor, the Cro-Magnan man, who lived about 25,000 years ago. There are to be seen the work of the first painter and the earliest

sculptor, prehistoric Sargents and Rodins of remarkable skill.

Before the Cro-Magnan man was the Neanderthal man, "whom we know all about, his frame, his head-form, his industries, his ceremonial burial of the dead," as Dr. Henry Fairfield Osborn has pointed out. Before him was the Piltdown man; before him the Heidelberg man; still earlier, in Java, the Trinil man; and still further back in geologic time was the Foxhall man—all named for the localities in which their remains were found. This earliest Foxhall man lived in England before the Great Ice Age, about 500,000 years ago.

The differences between the highest anthropoid apes and the lowest man gradually grow less and less the further we trace them backwards. We must clearly understand that no existing species of anthropoid apes could have been our ancestors. They and we are collateral descendants from ape-like species living far, far back in geologic time; before, and probably long before the Great Ice Age. The earth is very big, the various excavations have covered only a very minute part of its surface during only half a century. Every discovery has but confirmed the wonderful story of the ascent of man. Bateson, himself, who has been misquoted as an opponent of evolution, says: "Let us proclaim in precise and unmistakable language that our faith in evolution is unshaken. Every available line of argument converges on this inevitable conclusion."

Man's ascent from an animal of low intelligence seems to me to be absolutely proved by the many phenomena which reveal identical organs and physiological processes in the animal and the human body, a few of which, chosen out of a very great number, I have described. It is confirmed by the discovery of the remains of a number of prehistoric men, as is now definitely proved. This ascent of man, in perfectly orderly sequence, is far more probable than that evolution progressed up to the anthropoid apes and stopped there, and that God then made man by a separate, special, creative act, yet—*mirabile dictu*—with all these minute and exact correspondences of similar structures and functions in animals. Microscopically, the various structures in man and

animals are practically identical. Even the tiny muscles moving the wings of insects, such as the fly and the mosquito, resemble microscopically the muscles of man.

If man was a special creation, the Almighty was not limited to the lowliest form of matter—the “dust of the ground”—as material for the human body. He could have created a nobler, a more subtle, a more puissant and exalted stuff out of which to fashion man. The plan and structure and function of man's body would then supposedly have differed *toto coelo* from man's present body. Probably it would have been free from the defects and deformities inherent to the animal body, and free from the diseases which it shares with animals.

But, no! God deliberately made man out of the same stuff as the animals, and, as I have shown, on the same plan as animals. Body-wise, man is an animal, but, thanks be to God, his *destiny* is *not* the same as that of the beasts that perish. To develop great men, such as Shakespeare, Milton, Washington and Lincoln, and then by death to quench them in utter oblivion, would be unworthy of Omnipotence. To *my* mind, it is simply an impossible conclusion. Man's soul *must* be immortal.⁵

* * * * *

W. W. KEEN

CULTIVATION AND SOIL MOISTURE

THE question of cultivation in relation to soil moisture is one on which there has been difference of opinion among agricultural workers. The work of Professor Call of Kansas has tended to show that (under his conditions) cultivation, as cultivation, does not conserve soil moisture.

Since 1913 the writer has been engaged in agricultural work where the question of cultivation in relation to the conservation of soil moisture has been important. In the early years of this work the surface mulch idea, which is quite generally accepted by agriculturalists, was believed and used to explain the presence of ample moisture under cultivation when there was a deficiency without cultiva-

tion. When other features of plant growth were investigated some effects of cultivation, other than moisture, were brought out.

The recent controversy between Dr. Jerome Alexander and Mr. L. S. Frierson in the September 2, 1921, the February 10 and March 24, 1922, issues of SCIENCE has been interesting. One of these writers accepts the general view that cultivation of the surface of the soil conserves soil moisture by preventing surface evaporation, while the other does not believe that this is in accord with engineering experience. If our work had shown that, in cultivation, we were dealing with a moisture factor alone, the writer might agree with one of these two men without going into the specific conditions under which the data were obtained. Our work has shown that cultivation changes the composition of the soil solution and has an effect on the water requirements of the plants grown.

The Journal of Industrial and Engineering Chemistry for March, 1922, Vol. 14, No. 3, has the following in an article by the writer in discussing a composition basis for the water requirements of plants: “There is a common saying, cultivate to conserve soil moisture and you will have larger crops. The author believes that cultivation lets air down into the soil, thereby increasing bacterial activities which in turn cause the plants to get more food and grow larger on less moisture, would be nearer the truth. Experiments are reported where fertilization has decreased the water requirements of plants over one half, when expressed as the amount of water necessary to produce one unit weight of plant.

In the field experiments we had plants growing well, *with* cultivation, when on the same soil *without* cultivation, lack of water in the soil was hindering plant growth. It was easy to say that these were the results of cultivation in conserving soil moisture but to find out how the mulch conserved the soil moisture was a problem for intensive study. The evident facts were that the well cultivated crops were not suffering from lack of water in the period of dry weather.

It was found that the soil having the water reserve had a higher concentration of plant food and the plants growing in this soil con-

⁵ The full address will appear in the *Philadelphia Public Ledger* for Sunday, June 11.