DISTRIBUTION OF CURRENT AT THE SURFACE OF CATHODES IN VACUUM TUBES.*

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If a vacuum tube with metallic internal electrodes is exhausted, the cathode shows the well-known phenomena in the usual succession. The small spot of glow light which first appears on the cathode expands more and more as the pressure decreases, until finally the whole cathode is covered with glow light. On further exhaustion the cathode space, at first narrow and dark, expands more and more. At the same time cathodes, consisting of plane metallic plates at right angles to the axis, and nearly filling the sectional area of a cylindrical vacuum tube, show a crowding together of the canal rays and cathode rays into a sheaf which becomes thinner and thinner. This unequal covering of the cathode surface with visible structures led me to investigate whether the current through the surface of the cathode shows inequalities, or whether independently of the visible structures the current flows evenly through the whole surface of the cathode.

I.—DISTRIBUTION OF CURRENT IN CATHODES NOT COMPLETELY COVERED WITH GLOW LIGHT.

If a tube with a wire cathode is exhausted, the glow

FIG. 1.

light either forms a small luminous gap at the end of the wire, or surrounds the wire cathode at any other place, as shown in Fig. 1. To decide the question whether the current only passes through the portion covered with glow light or through the whole surface, I used the arrangement shown in Fig. 2.

The cathode consists of a thin tube of brass, K_2 , 0.5 centimeter in diameter, through which a well-insulated brass wire D is led. At the end of the thin brass wire D is attached a piece of thicker brass wire of the same diameter as the tube, and rounded in front. The whole cathode then behaves like a single-wire electrode, except that the front and back portions can be connected separately to earth through a galvanometer. A_1 serves as the anode if the glow light is to appear at K_1 , and A_2 if it is to appear at K_2 . The experiments carried out with a high-tension battery of accumulators showed that the current only flowed through that part of the cathode to which the glow light was attached. When A_1 was the anode, and the glow light, therefore, only sat upon K_1 , then the current only passed through K_1 when the glow light owing to increase in the current strength extended further over the cathode and began also to cover K_2 . Whether the glow light is attached to the end of the wire or to any other part of it, it is not sharply defined at the edges, but the dark cathode space clearly becomes larger at the margin, as shown in Fig. 1. The same phenomena as G. Wiedemann has shown also occurs in circular plane cathodes. The middle portion of the glow light lies much closer against the cathode than the marginal portions, as shown in Fig. 3. Modern experiments furnish a simple explanation for this phenomenon.

If in the case of the perfectly covered electrode the intensity of the current is reduced, the length of the Hittorf dark cathode space increases, as shown by detailed experiments made by Hehl at Erlangen, the results of which are shortly to be published. Now, it is very unlikely that the current density at the limit, g (Figs. 1 and 3) of the glow light is suddenly reduced to zero. It is more probable that it gradually approaches zero. Accordingly, the thickness of the dark cathode space at the limit of the glow light must be greater than in the middle.

To decide the question whether, in the case of plane circular cathodes nearly filling up the section of a cylindrical vacuum tube the total current in the vacuum

FIG. 2.

tube flows through the portions covered with glow light, or whether, also, the uncovered portions take part in conducting the current, I used a cathode, K , consisting of a central round disk, S (Fig. 4), and an insulated concentric ring, R , which closely surrounded it. Both the disk and the ring had separate leads and were attached to a plate of mica, which protected the portions lying behind the cathode from discharges (Fig. 5). The surface of the disk S was 1.96 square centimeters, that of the ring 6.33 square centimeters, and therefore the ratio of the surface $R/S=3.3$.

With the aid of a mercury commutator, C , a galvanometer, G , could be introduced into the earth connection of one or of the other electrode. The sensitivity of the galvanometer used was in most cases 1.98×10^{-6} amperes per scale division. In the other

branch there was a coil W , of exactly the same size and number of turns as the galvanometer coil. This arrangement was used so that in the case of oscillations, as they occurred later on, in some cases either by themselves or through the introduction of spark-gaps, the condition of inductance and resistance should be the same. That with a continuous-current, differences in the resistances of the current branches played no part, was shown by the complete absence of a change in the current conditions on the introduction of 100,000 ohms in one of the branches. These oscillations, which are only strongly marked in the case of aluminium electrodes, owe their origin to slight impurities of the surface. Cleaning with fine emery paper is of no avail. The surface assumes a dirty, gray color, and the cathode so treated produces strong oscillations. Filing down the aluminium with a clean smooth file is rather more effective. But the most advantageous process was always that of scraping the aluminium with a sharp knife, as used for erasures. After such treatment I have never obtained oscillations except at pressures where the high discharge potential alone would account for them. The source of current was sometimes a 20-plate influence machine and some-

FIG. 3.

FIG. 4.

times a high-tension battery of 1,800 accumulators with a tension of 3,600 volts.

If the tube is so far exhausted that only a small patch of glow light is attached to the cathode, the patch shifts hither and thither in the well-known manner. The deflections of the galvanometer show that the current always flows through that portion of the cathode (R or S) on which the glow light happens to be, and that the portion free of glow light shows no perceptible current. If the pressure is reduced to such an extent that the glow light occupies a larger surface, and partly covers the ring and the disk, there is always more current through that portion of the cathode which is more covered with glow light. When the cathode is just completely covered, the ratio of the ring current to the disk current is 3.4, while that of the ring surface to the disk surface is 3.3. The current density on the cathode is, therefore, everywhere the same when it is completely covered with glow light.

II.—DISTRIBUTION OF THE CURRENT AT THE SURFACE OF COMPLETELY COVERED PLANE CATHODES.

While the experiments just discussed have reference to cathodes which are not yet completely, or only just completely, covered, i. e., which are in the normal condition, in what follows I give particulars of the distribution of the current at lower pressures, i. e., under normal conditions. In exhausting cylindrical discharge tubes provided with circular cathodes which are normal to the axis and nearly fill the whole section, it is found that the sheaf of canal rays and cathode rays, which fills the whole tube at high pressures, contracts more and more as the pressure decreases, so that at very low pressures the sheaf only touches the cathode in one point. To decide whether it is only those parts of the cathode which are touched by the rays that conduct the current, or whether any part of the current is conducted by the non-luminous portions, I used the tube shown in Fig. 4 with the plane cathode consisting of ring and disk (Fig. 3).

FIG. 5.

At various pressures the galvanometer was inserted either in the lead of the ring R , or in the lead of the disk S , by changing the commutator. The following table contains the current intensities observed at decreasing pressure in scale divisions of the galvanometer. One scale division corresponded to 1.98×10^{-6} amperes. The sum of the disk current and the ring current is always nearly the same, since the influence machine yields a current nearly independent of the external resistance.

It follows from the table: (1) As already shown, the ratio of the current strengths passing through the ring and the disk respectively is 3.4 when the cathode is completely covered, and the ratio of their surfaces is 3.3, i. e., the current density is the same at every point of the cathode. (2) As the visible bundle of rays at the cathode contracts toward the middle, the ring current becomes feeble, until at last at very low

pressures, when the canal rays and the cathode rays are reduced to a thin pencil, the inner part of the ca-

Current through		Sum.	Remarks.
Disc.	Ring.		
28	95	125	Whole cathode covered.
43	88	131	Less than half the ring covered.
101	21	122	Narrow zone of the ring covered.
(140)	(Current reversed)	...	Ring quite free. Strong disturbed discharge.
127	0	127	Thin sheaf in the centre of the disc.

thode alone conveys the current, i. e., the current only passes through those parts of the cathode which are covered by the visible rays.

At a certain pressure, which varies according to the circumstances, strong oscillations suddenly appear in the tube owing to the causes above mentioned. The disk current is in this case stronger than the total current furnished by the influence machine, while a feeble current flows in the opposite direction through the ring, so that the external portions of the cathode behave as an anode with respect to the central portions. To investigate the distribution of the current during these oscillations, the condenser was inserted, or a spark-gap with or without a condenser. Fig. 5 shows the connections. By forming the connections shown in dotted lines in Fig. 4 at the commutator, the total current of the influence machine could be conducted through the galvanometer. Then the tube was exhausted so far that at first a continuous current passed through it. Thereupon the pressure was so regu-

FIG. 6.

lated as to make the oscillations as strong as possible. In both cases the distribution of current was first measured without a condenser and then with a condenser.

The following table contains the results:

I.—CONTINUOUS CURRENT.	
A.—Without a condenser at the tube:	
Total current $J=67$ divs.	
Disc current $i_d=67$ "	
Ring current $i_r=0$ "	
$i_d+i_r=67$ "	
B.—With a condenser:	
Total current $J=79$ divs.	
Disc current $i_d=75$ "	
Ring current $i_r=2$ "	
$i_d+i_r=77$ "	
II.—CONTINUOUS CURRENT.	
A.—Without a condenser:	
Total current $J=76$ divs.	
Disc current $i_d=110$ "	
Ring current $i_r=-33$ "	
$i_d+i_r=77$ "	
B.—With a condenser:	
Total current $J=74$ divs.	
Disc current $i_d=191$ "	
Ring current $i_r=-119$ "	
$i_d+i_r=72$ "	

Similar phenomena were observed on introducing a spark-gap.

The tables show that in the case of a non-continuous current the distribution of the current is very different from what it is in the case of a continuous current. While in the latter case the current distributes itself accurately in the ratio of the luminous surfaces of the ring and disk, in the former case not only do the ring and the disk convey currents in opposite directions, but of these currents one or both may have a higher numerical value than the undivided current. But if the current in the opposite direction be regarded as negative, the sum of the two currents has the same value as the main current. That really a current passes in a direction contrary to the normal current is clearly seen by the positive light which appears on the ring. Not only in the ordinary alternating current, but also in the continuous current, cases occur in which the current is stronger in each branch of the divided circuit than the main current. But the algebraic sum of both currents is, of course, equal to the main cur-

FIG. 7.

rent. The above experiments have determined the distribution of current in cathodes in the case of an undisturbed discharge. To test the conclusion that the current always flows through those parts of the cathode which are touched by the luminous rays, the point of contact was shifted to other parts of the cathode either by a magnet from without or by deflection from within. If a strong magnetic field is made to act upon the cathode rays, it is found, as shown by E. Wiedemann and H. Ebert, that the point of contact of the canal rays and the cathode rays on the cathode is displaced, and is converted into an elongated oval. According to the above results this implies a change in distribution of the current. As a matter of fact, when two insulated semi-circular plates of aluminium were employed as an electrode, it was found that under the influence of a strong magnetic field by far the greatest part of the current passed through that portion which lay

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in the direction of the deflection of the point of contact of the canal and the cathode rays. If insulators or conductors are introduced into the dark cathode space it is well known that an enlarged shadow of the body appears on the cathode in the layer of canal rays, i. e., the canal rays and cathode rays and their points of contact with the cathode are pushed asunder on the cathode. If, for instance, in the tube shown above (Figs. 4 and 5) a glass rod, *b*, attached to a small piece of sheet iron, *a*, is pushed along the axis toward the middle of the ca-

FIG. 8.

thode, the point of contact on the cathode forms a ring between the glass rod and the wall of the tube. The thickness of the glass rod *b* (Fig. 6) was so chosen that at the pressure at which the whole current passed through the disk *S* the point of contact of the rays was crowded from the disk on to the ring *R*. Under these circumstances the galvanometer showed that the current then no longer passed through the disk but through the ring.

The result of the above experiments led me further to test whether the cathode rays also only proceed from the luminous part of the cathode, or whether they have their origin on the whole surface of the cathode. For this purpose a cylindrical tube with a circular cathode, *K*, was exhausted so far that only a thin bundle of canal rays and cathode rays was visible. Into the path of the rays were brought three wires *D*₁, *D*₂, *D*₃, parallel to each other, and indicated in Fig. 7 by black points, together with a screen, *S*, placed at a small distance behind and covered with Balmain's luminous paint. The wires and the screen were rigidly connected and attached to a small piece of sheet iron. With the aid of a magnet this arrangement could be displaced in the tube from outside. Two measurements were made at a distance, *d* equal to 7 centimeters and 5.2 centimeters, respectively from the cathode. The distance *a* between the wires *D*₁ and *D*₂ was 0.72 centimeter, and the distance *b* between *D*₂ and *D*₃ was 0.6 centimeter. The distance *c* of the wires from the screen *S* was 5 centimeters.

<i>d</i> .	<i>c</i> .	<i>f</i> .
I. 7cm.	1.22cm.	1.33cm.
II. 5cm.	1.07cm.	1.16cm.

The distances between the shadows on the screen are given in *e* and *f*. Now, if *x* denotes the distance at which the point of intersection of the cathode rays, as calculated from the position of the shadows, lies in front or behind the cathode surface, the following four values are obtained for *x*: 0 centimeter—0.6 centimeter, 0.7 meter and 0.1 centimeter. The experiment shows clearly that the luminous point of the cathode is also the origin of the cathode rays, for the small value of *x*, which also changes in sign, must be attributed to

FIG. 9.

small errors of measurement. Therefore, the place at which the current passes through the cathode is also the origin of the cathode rays.

III. DISTRIBUTION OF THE CURRENT AT THE SURFACE OF CURVED CATHODES.

In curved cathodes, the cathode rays emerging from the interior appear distinctly brighter than those proceeding from the outer portions. This gives an impression as if more cathode rays proceeded from the hollow space than from its walls. In what follows, the question is investigated as to whether this is due to a greater current density from the interior, or whether secondary causes (deflection) produce a crowding together of the cathode rays into a small space and thus an increased visibility of the rays. Hollow electrodes of

various forms were used in which the interior and exterior portions were carefully insulated from each other and provided with separate earth connections. A galvanometer could be inserted as before into either of the two earth connections. To avoid the influence of the walls, the cathodes were always in the center of a large spherical vessel about 15 centimeters in diameter (Fig. 8a). The cathodes used had the shapes shown in Figs. 8, a, b, c.

In the electrodes *a*, *b*, *c*, the interior current, i. e., the current flowing through the internal portion, was always equal to the exterior current, i. e., the current flowing through the external portion, as soon as the glow light completely covered the electrode. This rule was not broken, except when the dark space became large. But if the pressure was reduced so much that a vivid fluorescence appeared on the glass walls, the discharge was in all these electrodes crowded out of the inner space, so that eventually the interior became less than the exterior current. An electrode of the form Fig. 8d, consisting of a solid cylinder with a conical boring at one end and an insulated thin plate of the same diameter on the other end, arranged so that both the cylinder and the plate had separate leads, was used to determine how much the current flowing through the hollow space decreases at very low pressures. Every portion, like the leads and the mantle of the cylinder, was insulated with sealing wax. The following table gives the current flowing through the funnel and the surface in scale divisions of the galvanometer at decreasing pressures:

Funnel.	Plane.	Funnel.	Plane.
42 divs.	26 divs.	36 divs.	33 divs.
42 "	26 "	36 "	33 "
40 "	28 "	34 "	34 "
38 "	32 "		

The ratio of the currents at the higher pressures, but with the hollow electrode completely covered, was 1.6, and that of the surfaces was 1.68. The former is therefore equal to the latter. At lower pressures the ratio of the current densities approaches more and more to unity, so that eventually only the aperture of the hollow cathode determines the current. The hollow electrode at low pressures behaves toward the current as if there were no hollow, but only a plate of the same sectional area as the aperture. The greater brightness of the cathode rays coming from the hollow electrodes is therefore not caused by a stronger current in that region, but only by a stronger crowding together of the cathode rays by deflection.

The explanation of this fact, which at first sight ap-

FIG. 10.

FIG. 11.

pears somewhat surprising, is very simple if one assumes that the same quantity of electricity flows through the unit of surface at the limit between the glow light and the dark cathode space. For if the limit of the dark cathode space is examined at somewhat lower pressures (Fig. 9), it is seen that this limit is almost entirely plane for the funnel-shaped opening of the cathode—that is to say, the separating surface between glow light and dark cathode space is similarly shaped and of the same size in the case of a plane and the hollow cathode. But from this it follows, according to the above assumption, that the amount of electricity flowing through the flame and through the funnel must be equal, and this is fully corroborated by the experiment.

IV. INFLUENCE OF THE MATERIAL AND THE SURFACE CONDITION UPON THE DISTRIBUTION OF THE CURRENT BETWEEN TWO PARALLEL CATHODES.

(a) Influence of the cathode fall of potential at various metallic surfaces upon the distribution of the current.—I investigated whether the differences observed in different metals in the cathode fall of potential, as described by E. Warburg, has an influence upon the distribution of current in discharged tubes, whose cathodes consist of two different metals. In a discharge tube, Fig. 10, was mounted a cathode, *K*, consisting of two semicircular plates. Their diameter was considerably smaller than that of the discharge tube, so as to avoid the influence of the walls. The two plates consisted of different metals, such as platinum and aluminium, and were carefully insulated from each other by a thin strip of mica and had separate leads. Immediately behind the cathode was a large plate of mica filling the whole section of the discharge tube, so as to protect the leads lying behind the cathode from the current. About 8 millimeters in front of the cathode was a platinum probe, *S*, which passed through the center of the tube, and remained parallel to the line of division of the two plates (in the upper figure, the cathode is turned through 90 deg. in order to show the arrangement of the plates). One of the cathode halves always consisted of a polished platinum plate, while the other consisted in turn of aluminium, iron, zinc, copper, and silver. As already mentioned each earth connection of the two cathode halves could be put through a galvanometer.

I only give those results in full which I obtained with a cathode consisting of platinum and aluminium in an atmosphere of hydrogen. I chose aluminium since, according to Warburg, its cathode fall of potential in hydrogen strongly differs from that of platinum, thus

giving the most decided difference. Magnesium, which possesses a still lesser cathode fall than aluminium, was not at my disposal. With a gradually decreasing pressure the cathode falls of the walls were measured separately, then together, and from the moment at which the discharge passed through both plates the current passing through each half of the cathode was measured.

The following table contains, for the experiments in hydrogen, in the first column the pressure in millimeters of mercury, and in the three following columns the cathode fall of potential of aluminium and platinum alone, and of both together. The fifth and sixth columns contain the current intensities flowing through aluminium and platinum. For the measurements of potential I used a Warburg electrometer as modified by E. Wiedemann and G. C. Schmidt.

Cathode Gradient and Current Distribution at Al and Pt at different Pressures.					
Pressure.	Cathode fall.		Al + Pt	Current through	
	Al	Pt		Al	Pt
0.15	(652)	> (700)	647	81	51
0.4	475	557	458	84	43
0.6	395	510	380	89	36
0.78	348	480	342	93	33
1.1	302	416	302	105	0
1.8	282	353	266	...	...
2.1	277	342	258	...	...
3.5	269	329	255	...	...

The following results are taken from the above table: (1) If a cathode consists of two metals having different cathode potentials, the whole cathode fall of potential is equal to that of the metal having the lowest cathode fall. (2) The current distributes itself in such a manner that at least at the higher pressures by far the largest portion flows through the metal with a smaller cathode fall of potential. At lower pressures and greater dark spaces the difference disappears more and more. This is due to the fact that with large dark spaces the influence of the material of the electrodes is less prominent—that is to say, the percentage influence of the fall of potential at the cathode itself disappears beside the great abnormal fall.

The potentials given for a pressure of 0.15 millimeter do not represent the total fall at the cathode, since at that low pressure the dark cathode space had extended far beyond the probe.

The other metals tested showed qualitatively the same behavior, but quantitatively they had smaller differences, since their cathode falls of potential do not differ so much from that of platinum as in the case of aluminium. I give as examples the measurements made with platinum and iron and platinum and lead in hydrogen and in air:

Pt and Fe in H.				
Pressure.	0.6	0.34	0.2	
Current through { Pt.....	51	59	62	
Fe.....	74	64	62	
Pt and Fe in Air.				
Pressure.	0.2	0.1	0.06	
Current through { Pt.....	27	33	31	
Fe.....	35	35	32	
Pt and Pb in H.				
Pressure.	0.7	0.37	0.2	0.1
Current through { Pt.....	34	35	38	38
Pb.....	44	42	40	38
Pt and Pb in Air.				
Pressure.	0.26	0.14	0.1	0.013
Current through { Pt.....	38	38	36	35
Pb.....	32	35	35	35

The metals were tested, as I said, in hydrogen obtained by electrolysis, since, according to Warburg, the differences in this gas are specially marked. But measurements in pure nitrogen show the same phenomena, except that, in accordance with the small differences in discharge potential, the differences in the current were also smaller. The distribution of current between platinum and lead in hydrogen corresponds to their cathode falls of potential, but in air the reverse is the case. But then the differences are so slight that they may also be due to accident. That the potentials are higher than those given by Warburg is due to slight impurities in the gases. It was of great importance to keep the electrodes clean and polished, since otherwise the results show great variations. Such variations were especially strong in the case of aluminium, but they influenced the current more than the cathode fall of potential.

With small dark spaces, the smaller one was always attached to the wall possessing the lesser cathode fall, and which, therefore, conveyed the chief part of the current. This corresponds to the fact that an increase in the current reduces the dark cathode space.

The first, probably, to observe such differences in the thickness of the dark cathode space was W. Crookes. He saw that when a disk-shaped cathode was half covered with lamp black, the dark space at that portion was considerably larger than at the polished portion, probably owing to the distribution of the current.

(b) Influence of the surface condition upon the distribution of current in the cathode.—The aluminium electrode, consisting of two semicircular pieces insulated from each other was studied in the same tube as before. One half of it was polished with fine emery paper so that its surface was a dirty gray, while the surface of the other was scraped with a knife. The surfaces of both electrodes were nearly equal in size. It was found that the potential gradient in both halves was equal, but the current through the scraped electrode was much stronger than through the gray one. The following table shows the distribution of current at different pressures. The current intensities are given

in scale divisions of the galvanometer (1.98×10^{-6} amperes):

Pressure in mm.	1.66	1.32	1.03	0.81	0.63	0.41	0.13	0.053	0.027
Current (Al rough ... through Al pure.....)	6	10	19	45	46	49	55	53	58
	113	110	98	76	74	70	64	57	58

Here also the differences in the conduction of the current disappear at low pressures. Of two equally large and equally thick semicircular aluminium electrodes the one *a* was provided with grooves as shown in Fig. 11. Since the surface was larger than that of the plane electrode *b*, the stronger current passed through *a* at pressures at which the cathode was just completely covered with glow light. With greater dark spaces the currents flowing through both halves were exactly equal which again shows that at lower pressures only the projection of such surfaces upon the plane determines the current.

Results.—1. When the cathode is not completely covered with glow light, the current only flows through those portions which are covered with glow light.

2. In cylindrical discharge tubes with circular cathodes normal to the axis at low pressures, the current only passes through those portions to which the rays are visibly attached.

3. The visible point of attachment of the rays at the cathode must be regarded as the origin of the cathode rays.

4. In current electrodes (funnels, spherical cathodes, etc.) the current densities at the inner and outer surfaces are equal when the cathode is completely covered with glow light. At low pressures, in spite of the greater brightness of the visible cathode rays emerging from the interior, the current density at the interior surface is smaller than on the exterior. With decreasing pressures and increasing dark spaces the current distribution at the cathode is more and more regulated by the rule:—"The current density is the same at all parts of the limiting surface between the glow light and the dark cathode space." The current density at the different parts of the cathode itself is determined by the portion of the limiting surface which corresponds to it. Since, in the hollow cathode, nearly equal portions of this limiting surface correspond to the exterior and interior surfaces, it follows that the current intensity in both is equal.

If a discharged tube contains two cathodes of equal surfaces but different metals in parallel, the current flows through the metal having the lower potential gradient as soon as it is completely covered with glow light. At low pressures this difference disappears more and more, since in the dark spaces the high gradient in the gas exceeds the gradient at the metal.

WHAT THE UNITED STATES OF AMERICA IS DOING FOR ANTHROPOLOGY.*

HAVING recently had the good fortune to pay a somewhat extended visit to the United States of America, I have thought it might not be uninteresting to you to hear what our kinsmen and colleagues across the Atlantic are doing for the furtherance of anthropology.

The means for the advancement of the science of anthropology fall under the following heads: (1) The collection of information in the field; (2) the publication of such information; (3) the collection of specimens; (4) the preservation of specimens; (5) the publication of museum specimens; (6) the instruction of students; (7) independent investigation of collected material.

As no hard and fast line can be drawn between some of these activities, I shall deal first with the museums and with the field work undertaken by the more important institutions in the United States of America, and then very briefly with the teaching of anthropology in the United States.

I. FIELD WORK AND MUSEUMS.

It is a glory to the nation of the United States that it has recognized the duty of collecting information about the aboriginal Americans. The twenty or more annual reports published by the Bureau of Ethnology constitute a monument to the intelligence of the government and of its departmental officials of which their country may well feel proud. Nor does the Bureau of Ethnology neglect the collection of specimens, as is evidenced by the very extensive collections transferred to the National Museum. I cannot, however, refrain from remarking that it seems very strange that the anthropography, or physical anthropology, of the native tribes is entirely neglected by the Bureau, and I know that others share with me the hope that this state of affairs will be remedied.

The head curator of the department of anthropology in the National Museum, Dr. W. H. Holmes, is gradually working out his conception of what his museum should be. His object is twofold: (1) to illustrate the cultural history of mankind; (2) to demonstrate the distinctive characteristics of the various races and people.

(1) Numerous series of objects have been installed to illustrate the progress of culture, such, for example, as the various stages of evolution from stone implements, on the one hand, to the most modern steel tools and engineering appliances on the other. In this work the curator has been ably helped by the veteran Dr. Otis T. Mason, whose writings on technology are so well appreciated by students. An admirable land transport series has been got together, and one hall is devoted to a wonderful collection illustrating transport by water. There is also an interesting section devoted to comparative religions, of which Dr. Cyrus Adler is the custodian. No government in the world does so much for ethnology as does that of the United States.

The Free Museum of Science and Art in Philadelphia contains some very valuable and pleasingly arranged collections of Babylonian, Egyptian and Etruscan antiquities. Good representative collections of American ethnology and archaeology are being got together, owing to the exertions of Mr. Culin, the director. Of the

special collections given to the university, mention need be made only of the collection of gems, of musical instruments and the Furness-Hose collection from Sarawak. In the museum is also to be found Mr. Culin's very instructive and almost exhaustive collection of games, but unfortunately it is stored away in drawers. If this collection was adequately exhibited it would give to the museum a unique position among anthropological museums.

It is instructive to note that although this is a university museum, no support is received from the university, all the scientific work being prosecuted by funds raised from private sources, a result largely due to the enthusiasm of Dr. Sara Y. Stevenson, the energetic secretary of the department.

In 1869 a little band of public-spirited men was created by the Legislature "a body corporate by the name of 'the American Museum of Natural History,' to be located in the city of New York, for the purpose of establishing and maintaining in said city, a Museum and Library of Natural History; of encouraging and developing the study of natural science; of advancing the general knowledge of kindred subjects, and to that end of furnishing popular instruction and recreation."

A partnership, under sanction of the law, was entered into by the citizens of New York in their corporate capacity with the president and trustees of the museum, it being mutually agreed that the city should pay for the erection of the buildings, their maintenance and protection, while the trustees took upon themselves the responsibility of providing the exhibits, the library, the lectures and other means of instruction and mental recreation. This arrangement is perpetual and irrevocably binding on both parties.

The anthropological department of the museum has accomplished an unprecedented amount of research during the past year, a large sum of money having been received from private sources for the purchase of several important collections of American archaeology and ethnology and for the expenses of many expeditions in the field.

The greater part of the anthropological collections in the Yale University Museum are archaeological in character. The Peabody Museum of Harvard University is already overcrowded and fresh collections are constantly arriving, which the curator, Prof. F. W. Putnam, is forced to keep in boxes in the storerooms. The main collections are the results of the digging of mounds in the Eastern and Central States; thus the archaeology of that portion of America can be very well studied in the museum. During the years 1887 to 1893 the late Mrs. Mary Hemenway provided funds for archaeological and ethnological expeditions to the Pueblo Indians of Arizona and New Mexico.

The history of the progress of anthropology in Chicago is eminently characteristic of that typical American city.

There is no need to give a detailed history of the anthropological department of this museum, as Dr. Dorsey has already done so in the *American Anthropologist*, n.s., ii. 1890, p. 247; but I will briefly indicate the main collections and their origin.

The anthropological collections which formed the foundation of the department were obtained through special expeditions sent out under the direction of Prof. F. W. Putnam, or by collectors resident in the field, who were commissioned by the department of ethnology to undertake the work. A mass of interesting and valuable material from Alaska to Peru was thus accumulated. A few collections from other quarters of the globe were also obtained. The history of the museum since then has been one of almost unparalleled activity. Expedition after expedition has been sent out to collect ethnological and archaeological material in North and Central America; some of these have been paid for out of the museum funds, while others have been rendered possible by special donations from benefactors, most of whom are Chicago merchants.

The more technical aspect of the museum has been so well described by Dr. A. B. Meyer that I need not dwell upon it.

The most recent inauguration of anthropological activity is that displayed by the University of California. A department of anthropology was established by the Regents of the University in September, 1901.

As an encouragement to others and as an expression of her great interest in the new department, Mrs. Phoebe A. Hearst, who is one of the Regents and a most generous benefactor to the University, has promised 10,000l. (50,000 dollars) a year for five years for anthropological research. In this manner is struck the key-note of the new department. Research first and foremost. We may look forward in the immediate future to the establishment of a really important museum on the Pacific coast which, being under the jurisdiction of the University of California, will be the center of considerable anthropological research and instruction.

Now that the financial position of the Stanford University at Palo Alto is permanently secured, it is to be hoped that the claims of anthropology will not be overlooked.

This is not the place to describe the points of interest in the various museum buildings, the installation of the collections and the details relating to museum administration and technique. It is the less necessary as Dr. A. B. Meyer, of Dresden, who is a recognized authority on all matters pertaining to museums, traveled in the United States in 1899, and he is publishing a series of well-illustrated reports on the institutions he visited. These reports are invaluable to all those who are interested in the promotion or maintenance of museums and libraries, and it is to be hoped that no architect in the future will attempt to draw up plans for a new museum or library until he has consulted this work.*

II. THE TEACHING OF ANTHROPOLOGY IN THE UNITED STATES OF AMERICA.

In America courses of anthropology were established about fifteen years ago at Harvard University and at the University of Pennsylvania. It was one of the first subjects introduced into the curriculum of the University of Chicago. Seven or eight years ago anthropology was recognized in Columbia University in the city of

New York. At the present time some thirty-three universities and colleges offer instruction in anthropology. Limit of space precludes my giving details concerning the instruction in anthropology in these numerous institutions, so I confine myself to a consideration of two of the universities where the teaching is most firmly established. Further information on this subject will be found in Prof. G. G. MacCurdy's report on "The Teaching of Anthropology in the United States" in *Science*, n.s., vol. xv. 1902, p. 211.

It would be impossible to include within the limits of a brief address an account of all the work that is being done in anthropology by the government, by public and private institutions, or by individual effort in the United States of America. Much as I should have liked to have emphasized the interest exhibited in the subject and the wonderful activity that is being displayed, the bare enumeration of all this activity would make a very weary chronicle.

I must confess that I felt a not inconsiderable amount of envy when on every hand I witnessed this energy and then recalled the apathy which pervades our own country.

The American public is more intelligently alive to the interest and importance of anthropology than is our public. The exponents of the science are energetic, enthusiastic and competent, and they succeed in gaining the practical sympathy of wealthy merchants, who are not averse to spending money freely when they see that the money will be wisely spent for the good of the State or of the city. One cannot say that the wealthy Americans are more intelligent than are our rich men, but they do seem to appreciate the value of learning to a much greater extent than do ours. At all events, they respond more readily to the very pressing need there is for the endowment of research and of those institutions which bring the knowledge of the expert down to the comprehension of the masses.

I am quite willing to admit that the fault in this country may lie as much with the specialist as with the capitalist. In any case we have an inspiring demonstration in the United States of America of what can and should be done in Great and Greater Britain, and I venture to thank our American colleagues in the name of anthropological science for this good example of strenuous effort and praiseworthy accomplishment.

SOUTH AFRICAN COAL FIELDS.

"It is, perhaps, natural that in the race for wealth in South Africa attention should be largely concentrated upon gold and diamonds, not only because of the handsome profits to be derived from such products of the soil, but also on account of the opportunities for 'making money' afforded by dealings in the shares of companies connected with those branches of mining," says the *London Financial News*. "Still, it is rather surprising that a comparatively limited interest only is taken in the potentialities of the Transvaal as a coal field. If it were realized that the coal measures of that country are practically inexhaustible; that only enterprise and capital are now needed to convert a relatively small trade into one of world-wide proportions, and that the profits would be very substantial, British investors would provide the funds necessary for the proper exploitation of coal mining as a South African industry. Up to now it can hardly be said to have had the attention its importance deserves. There are, of course, several collieries already at work, but their annual output, considerable as it is, is inadequate to the needs of South Africa itself, while an export trade hardly exists at all. This was, no doubt, due in the past very largely, if not exclusively, to high railway rates, the want of facilities for transport to the coast, and the primitive simplicity of the arrangements at the ports for loading and unloading; but the extensive railway policy which Lord Milner is said to be about to inaugurate will remove all difficulties in the way of bringing down the coal to East London, Durban and Lourenço Marques quickly and cheaply, and the local authorities of those places may be relied upon to provide ample accommodation for storing and proper appliances for transferring it to the ships. There is thus a great opportunity quietly unfolding itself—a lucrative and remunerative industry waiting to be seized by the British investor, who will only have himself to blame if he allows it to be snapped up by the Americans or Germans already on the spot."

Continuing, our contemporary says: "The whole of the East Rand district is literally honeycombed with coal; the seams being of considerable thickness and easily reached from the surface, while the quality is excellent and commands good prices at the gold mines. Of the quantities raised by the existing collieries, complete or detailed records are not available; but the total production of the Transvaal rose from 1,035,121 tons in 1895 to 1,640,486 tons in 1899—not a great increase, it is true, if measured by the developments shown at gold mines in the same period, but one which proves that, with energy, enterprise and capital, the coal industry could be built up to enormous dimensions. The proportion of the output contributed by the East Rand had reached to well over 1,000,000 tons per annum before the outbreak of hostilities in 1899, and yet this coal-bearing area was barely tapped, and the supply was always unequal to the demand. If, therefore, as is anticipated, over 17,000 stamps are to be at work on the Rand within the next five years, and the country is to be overrun by a vast network of new railways, the coal production must advance correspondingly, with substantial benefits to the owners of collieries. But these last will also have to be greatly increased in numbers, and plants of the most up-to-date type will be needed. There is no reason why the whole East Rand should not be dotted with pits. The seams are fairly uniform in thickness, and every description of coal is found—gas, steam and household. The railway freight before the war was, on all lines alike, ½ pence per ton per mile on consignments to the ports, but this rate will probably now be reduced, and what is even more important, an ample supply of trucks and engines will be provided. Before the war as much as £2 per ton was paid by steamships for the best steam coal delivered at Delagoa bay, and ships were often turned empty away. It would, of course, be too much to expect that this level of prices will be maintained in the future; nevertheless, the requirements of the vastly

* Abridged from the presidential address delivered by Dr. A. C. Hadson, F.R.S., before the Anthropological Institute on January 28. The address is published in full in the current number of the *Journal of the Institute*.

* The two parts already issued are entitled "Ueber Museen des Ostens der Vereinigten Staaten von Nordamerika." *Reisenstudien von A. B. Meyer.* (Berlin: R. Friedländer und Sohn.)