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ALCOHOL AND ALCOHOLIC INTOXICATION.*

BY EDWARD MELLANBY, M.A., M.D. (CANTAB.),
Professor of Physiology in the University of London, Household and Social Science Department.

THE investigation I am about to describe to-night has been directed more particularly to the acquisition of knowledge concerning the conditions affecting the development of symptoms which form the picture of acute alcoholic intoxication. The results obtained formed the answer to specific problems of alcoholic intoxication requiring elucidation by the Central Control Board. It is clear that in such an inquiry the actions of alcohol on the central nervous system demand most attention. This does not mean that the toxic effects of alcohol on other systems in the body—as, for instance, the alimentary canal, liver, and circulatory system—are not important, but rather that these latter assume greater comparative importance in investigations concerning the more chronic actions of alcohol. While it is true also that, even in the case of acute actions, the effects of small doses of alcohol present a large field of investigation, it was desirable in the experiments to be described to produce the fully developed symptoms of intoxication in most of the experiments. Many of the facts observed can, no doubt, be extended to the more mild symptoms resulting from small doses of alcohol.

In beginning an investigation of this type, the obvious and most direct method to employ would be to determine the effects of alcohol on the nervous system by measuring these actions and relating them to the amount of alcohol in the nervous system. Unfortunately this mode of attack is impossible, for any surgical

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interference with the nervous tissues would immediately make the experiment so artificial as to prevent its application to questions of alcoholic intoxication as usually understood. It appeared possible, however, that information of a fundamental nature might be obtained by determining the conditions which affected the entrance of alcohol into the blood, after being taken into the stomach. It is probable that the distribution of alcohol in the nervous system is directly related to the amount in the blood, and, if this is so, obviously some advance can be made in correlating intoxication and alcohol in nervous tissues. I wish, however, to make it clear that, although there is undeniably a general relation between blood and nerve alcoholic distribution, it has never been proved that the same relation always holds under all conditions. It is well to recognize the possible frailty of the methods employed at the outset.

Another great difficulty in working on a subject of this nature is that, whereas it is possible to determine exactly how much alcohol a man has drunk and to state exactly how much he has in unit volume of blood at any moment, it is not possible to say how many units of intoxication he exhibits. If we only had some means of describing the man A as ten units drunk and the man B fifty units drunk, a more satisfactory state would exist. As matters stand, it appears more probable that alcoholic intoxication will disappear altogether before we develop the standards and units of drunkenness. One other difficulty about intoxication is the impossibility of considering the condition only from a static point of view. One man might at a specific moment be more obviously intoxicated than a second man, yet half an hour later may be more sober than the latter—that is to say, he may make a more rapid recovery. We must, therefore, in all cases consider the *time factor* and its relation to intensity of intoxication.

After having emphasized some of the difficulties and limitations of this type of work, I now propose to describe briefly the experimental results obtained. In the first place, I shall describe some experiments made on dogs. Any physiologist knows by experience that the best way by which fundamental discoveries can be made in any research, whose ultimate object involves man, is by starting his investigations on animals. When the fundamental points have come to light, then it is often possible to control the results by extending the investigation to men. After describing, therefore, results obtained in animal experimentation, I shall show you a few similar results of experiments made on a man. Finally, I shall attempt to correlate these results with some rather crude indications of intoxication which were obtained in the human experiments, and you will be able to form your own judgment as to the points presented, for all the results will be shown to you by means of lantern slides.

In the experiments* now to be described, alcohol, in varying amounts and dilutions, according to the type of the experiment, was placed in the animal's stomach. This alcohol was absorbed

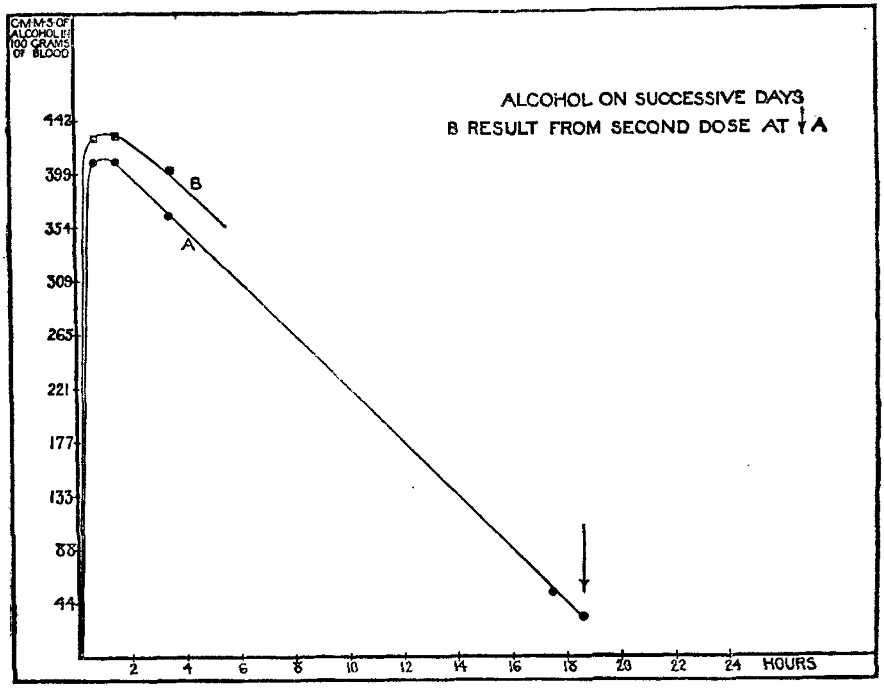

Fig. 1.

into the bloodstream from the alimentary canal. At different intervals, usually ½ hour, 1 hour, 1½ hours, 3 hours, and 5 to 6 hours after the beginning of the experiment, small samples of about 5 c.c. of blood were withdrawn, weighed, and the amount of alcoho l in the specimen estimated by a chemical method. Having obtained these results, it was possible to plot a curve

* For a full description of Technique and experimental results, *vide* Special Report Series, No. 31, Medical Research Committee.

showing at any given time the amount of alcohol present in unit volume of blood. The diagram (Fig. 1) shown on the screen illustrates a typical result. In this experiment the animal, of weight 13·5 kilograms, was given 50 c.c. of absolute alcohol to which water had been added to make the solution contain 20 per cent. by volume of alcohol. This curve illustrates the relative rapidity with which alcohol gains access to the blood as compared with the extreme slowness of getting out of it. You will see that the alcohol in the blood is at a maximum about one hour from the beginning of the experiment, whereas even nineteen hours later there is a trace of alcohol left in the blood. Probably in twenty-one hours the blood would be free from alcohol. This was made more evident by giving at this moment, indicated on the screen by an arrow, another 50 c.c. of absolute alcohol diluted as on the previous day. On the second day you will see

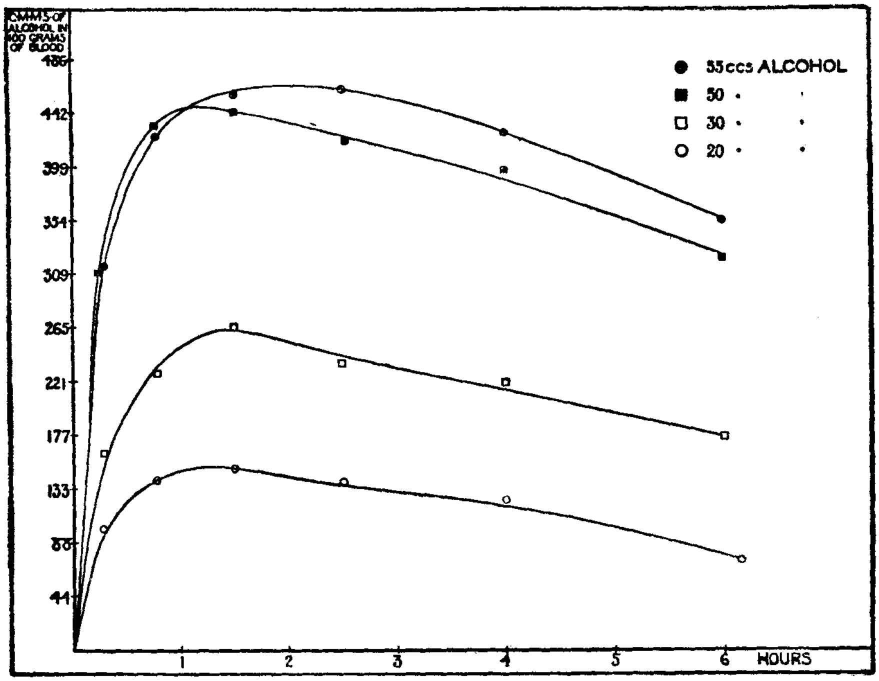

Fig. 2.

that a higher maximum of alcohol in the blood is attained—*i.e.*, an accumulative effect is produced. Now, the maximum point on the curve is also the point of maximum intoxication, and although there may appear to be but a small difference in the maxima on the screen, this small difference involves a very large increase or decrease in intensity of intoxication. In fact, it can be generally stated that any condition which depresses the point of maximum alcoholic concentration in the blood has a great effect in depressing the maximum intensity of intoxication.

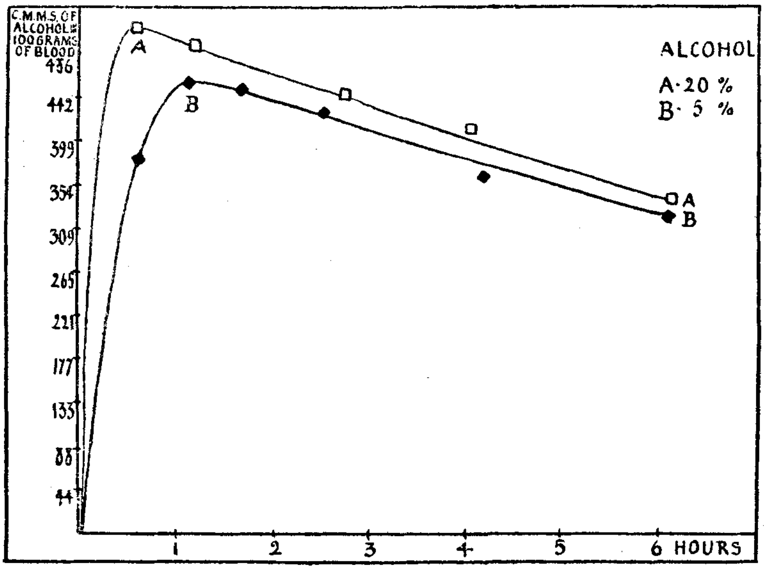

Fig. 3.

Fig. 2 shows the effect of drinking different quantities of alcohol when all other conditions are equal. On different occasions the same animal was given 20, 30, 50, and 55 c.c. respectively of alcohol in a 20 per cent. solution. Analysis of these curves shows several points of interest:

1. Except with small quantities of alcohol, the amount in the blood at the maximum points is roughly proportional to the amount drunk.

2. The decline of the curves represents the rate at which the blood gets rid of the alcohol. You will notice that the rate is practically constant in all cases. The interpretation of this point

is of some practical importance. The body gets rid of most of the alcohol imbibed by oxidation, and thereby is supplied with energy. Alcohol is, therefore, a source of energy to the body. Now, we see that in a given period—say, one hour—the body gets as much energy supplied to it by the alcohol, whether a large amount—*e.g.*, 50 c.c., or a small amount—*e.g.*, 20 c.c., is given it. That is to say, to get the maximum amount of energy over a given short period, a small quantity of alcohol, so long as it is not fully combusted in less than the given time, is as

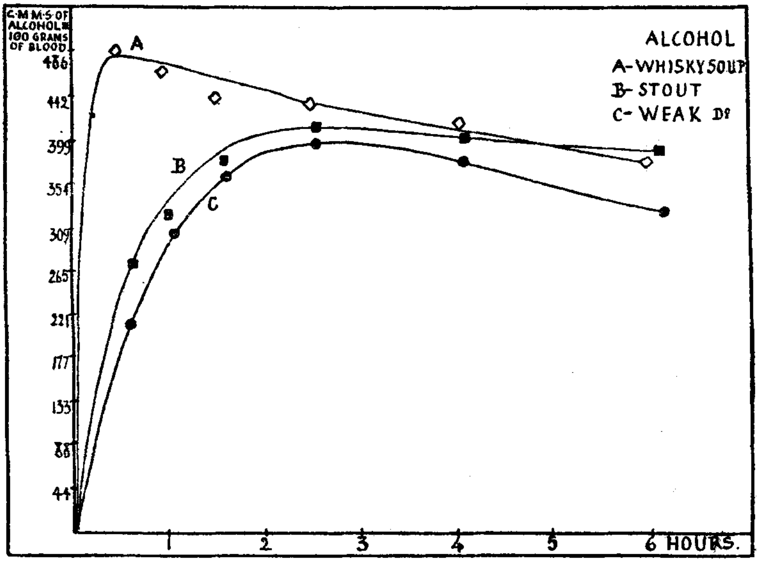

Fig. 4.

adequate, from this point of view, as an amount which will produce obvious symptoms of intoxication.

Let us now see the effect of varying the dilution of alcohol on the rate at which it enters the blood. Fig. 3 shows this point. In curve A the animal had been given 40 c.c. of absolute alcohol in a 20 per cent. solution. In B the same amount of alcohol in a 5 per cent. solution. In C and D, the amount of alcohol was reduced to 30 c.c., but in C it was given in a 20 per cent., and in D in a 5 per cent., solution. It will be seen that whereas there is a large difference between curves A and B, the difference between C and D is much less marked. The interpretation of this point is that with larger quantities of alcohol there is a greater difference produced in the alcohol of the blood by dilution than when smaller quantities are given—the rate of absorption and the point of maximum concentration are more influenced. In terms of intoxication in man, it ought to be relatively more difficult for a toper to get intoxicated by 5 per cent. beer, as compared with whisky, than a novice. Similar results to these were obtained when whisky and stout were compared. This can be seen in Fig. 4, where the same animal on different days was given equal quantities of alcohol, A in whisky

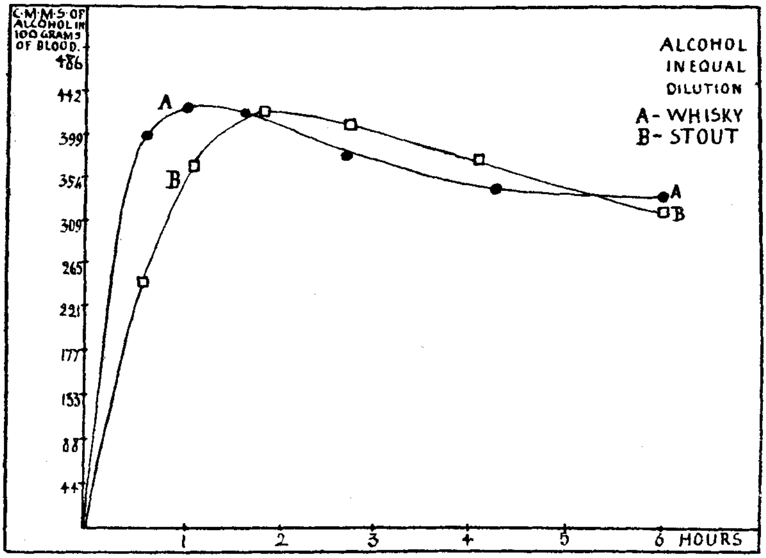

Fig. 5.

28·5 per cent. alcohol by volume, B in stout 5·5 per cent. alcohol by volume, C in stout 3·9 per cent. alcohol by volume. It is clear that the whisky alcohol was absorbed much more rapidly, and its point of maximum concentration in the blood is much higher than is the case of the stout alcohol. The stronger stout is also more rapidly absorbed than the weaker variety, and the alcohol attains a higher maximum. In keeping with these facts, the whisky produced a much more intense intoxication. Undoubtedly, dilution alone can explain much of the difference seen, but it seemed to me too great to be wholly explained in this way. To decide this point whisky was diluted with water until it contained the same percentage of alcohol as the stout—*i.e.*, 5 per cent. by volume—and the two solutions were then tested. It will be seen in Fig. 5 that, although the amount and strength of the alcohol in the diluted whisky and the stout are the same, yet the whisky alcohol was still absorbed more rapidly. The probable explanation of this result is that stout contains something which slightly inhibits the absorption of alcohol.

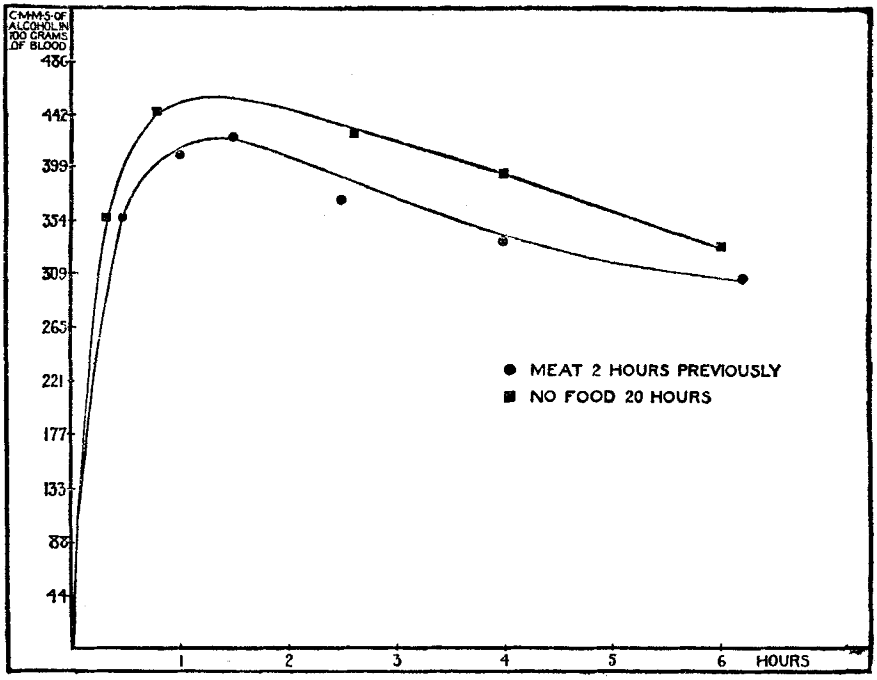

Fig. 6.

We can now pass on to consider the effect of taking alcoholic solutions with food, and on an empty stomach, for although any man in the street can tell you that alcohol on an empty stomach is more intoxicating than when taken with food, it is well to get as precise information on the subject as possible. Various foodstuffs were given to the dogs at different intervals before the experiment started, and the alcohol contents of the blood were compared with those obtained when the animals had had no food or drink overnight. The effect of giving a meal of meat is shown in Fig. 6. The influence of the meat is not striking. In Fig. 7, the effect of a meal of bread and milk is evident. In different experiments it was given 2½, 3½, and 6½ hours before the alcohol, and it will be noticed that the depressing effect was most obvious in the 2½ hours experiment, and became smaller and more nearly approaching the control (hungry) state with lapse of time, so that after 6½ hours the bread and milk had but little effect.

The question immediately arises as to whether there is any

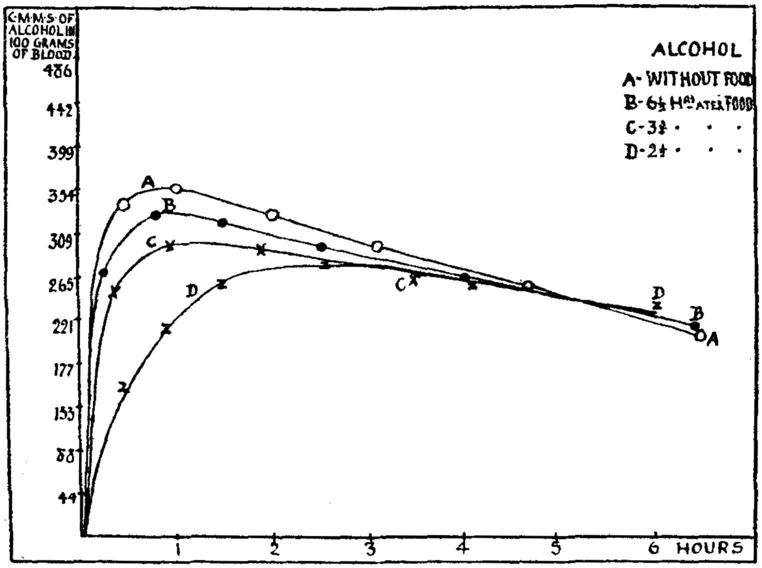

Fig. 7.

element in the bread and milk which has a specific action, or is it only a case of dilution? Against dilution of the alcohol by the bread and milk being the explanation are the facts:

1. That the effect is much greater than has been observed by diluting alcohol.

2. The effect on the alcohol contents of the blood is seen several hours after the meal, when it is almost certain that most of the fluid will have been absorbed.

On the positive side, Fig. 8 demonstrates that the inhibitory action can be obtained with milk alone; in this case the alcoholic solution was diluted with milk. When, however, the fat of the milk was removed by a separating process, adding the separated milk had but little inhibitory action on the absorption of alcohol from the intestine. These experiments tend to show that it is the fat of milk which is largely responsible for the above-described action of a meal of bread and milk. Fig. 9 rather con-

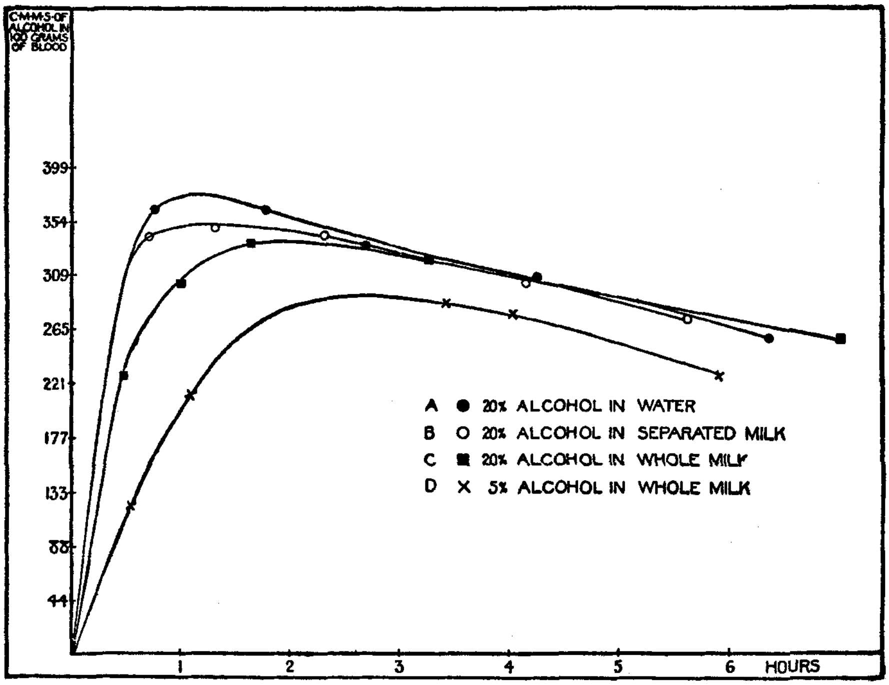

Fig. 8.

firms this result. In this last experiment, the animal was given 100 grams of suet four to five hours before the alcohol, and it will be seen that there is a depression in the rate of absorption of the alcohol and also in its point of maximum concentration in the blood. It will be further observed from Fig. 9 that the depressing effect of fat is best obtained with a strong solution of alcohol—*e.g.*, 20 per cent.—and not with a 5 per cent. solution. The probable explanation of this is that the stronger alcohol puts the fat into solution, and, in turn, the latter exerts its well-recognized inhibitory effect on the activity of the alimentary canal, so delaying the absorption of alcohol into the bloodstream. The effect of milk in preventing the worst symptoms of intoxication is very striking. This fact also has not escaped detection by the empiricist, for it is well known that the best real soak—the optimum state of alcoholic intoxication lasting over the maximum

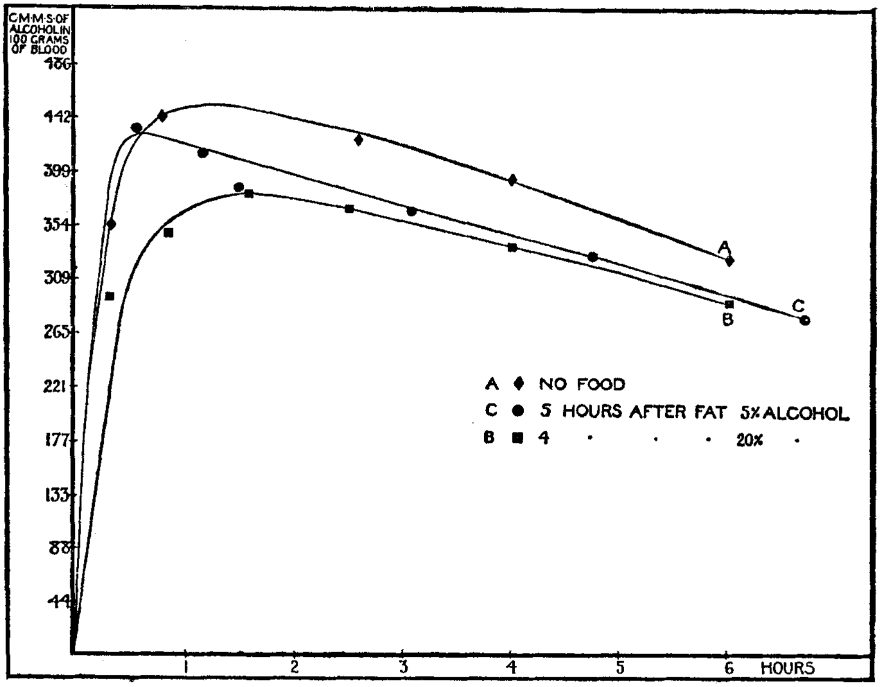

Fig. 9.

length of time with the elimination of the worst symptoms—has been discovered by the Scots as resulting from a drink of a mixture of rum and milk. Of all the foodstuffs investigated up to the present, milk has the strongest inhibitory effect on alcoholic intoxication.

In the case of animal experiments the influence of water on the absorption of alcohol from the alimentary tract is of some interest. If, of course, the alcohol is drunk immediately after water, then, as the result of mixing, the alcohol becomes more dilute and the ordinary effect of dilution, discussed above, results. Suppose, however, water is drunk by a thirsty and hungry animal and time given for it to absorb, then the effect of drinking alcohol is shown in Fig. 10. It will be seen that the alcohol is more rapidly absorbed into the bloodstream than is the case when the same animal has had nothing to eat or drink. Now,

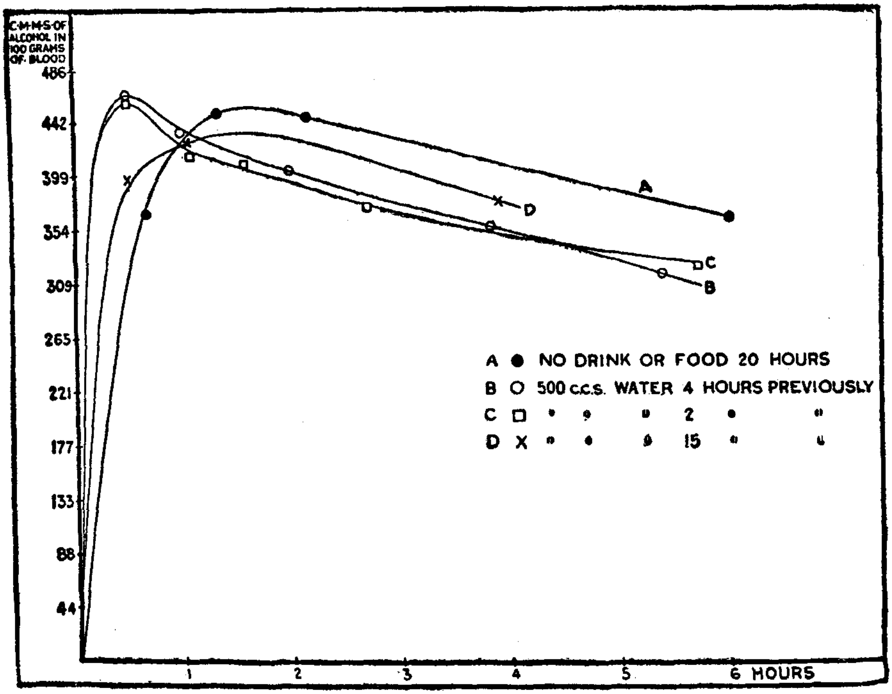

Fig. 10.

the effect of the drink of water must have been to eliminate the thirst of the dog, so that here we have an instance of the least thirsty animal getting intoxicated more rapidly. Physiologists have known for some years, as the result of Pawlow's experiments, that water has a stimulating effect on the secretion and activity of gastric and other digestive juices, but this is the first instance—so far as I know—where it is evident that water has a stimulating effect on pure absorption processes, independent of digestion. You will notice, therefore, that the effects of drinking water and milk respectively before taking alcohol are very different on the subsequent states of intoxication. In the case of water the intoxication may be more rapid and quite as intense, whereas after milk the intoxication will certainly be greatly diminished. These effects are seen in Fig. 11. You will notice the stimulating effect of drinking water, as compared with the

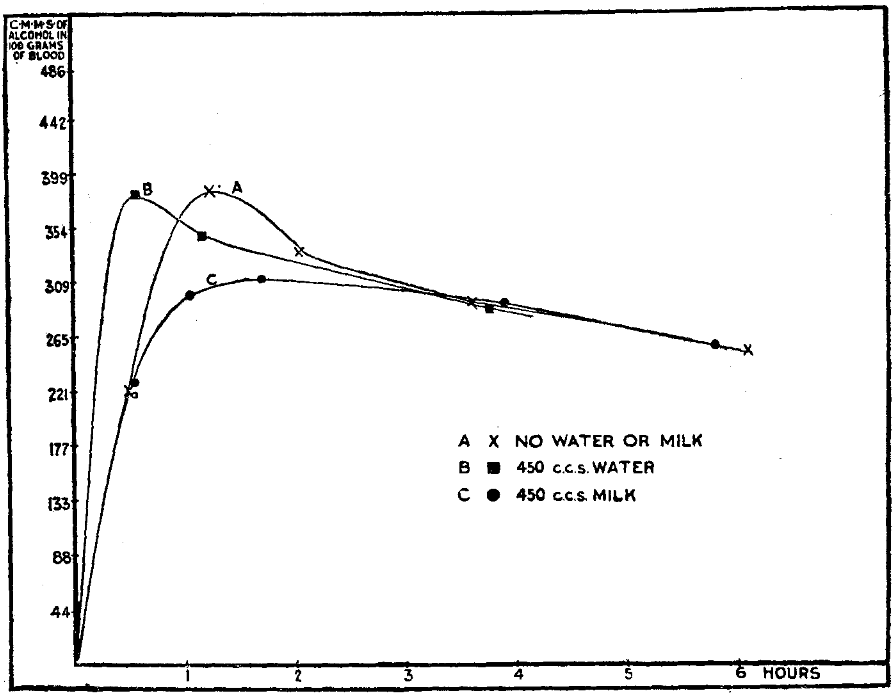

Fig. 11.

inhibitory action of milk, when taken two hours before the same amounts of alcohol.

So far I have dealt with experiments in which all the alcohol was placed in the stomach in the course of one or two minutes. I shall now consider the case where it was divided up into portions and given at varying intervals. Fig. 12 is the result of a series of experiments of this type all made on the same animal. In curve A all the alcohol was given at once. In curve C it was divided into three portions and given at intervals of one hour; in curve D the portions were given at two-hour intervals. You will see that, in spite of the intervals, the maximum point of concentration of alcohol in the blood is practically the same in each case. When the interval was three hours (curve B, two drinks only), then the maximum point was depressed. In keeping with these results, the intensity of intoxication at its maximum was practically the same in each case (except the three-hour interval, where it was less). No doubt if the interval was extended beyond three hours, the intoxication symptoms at

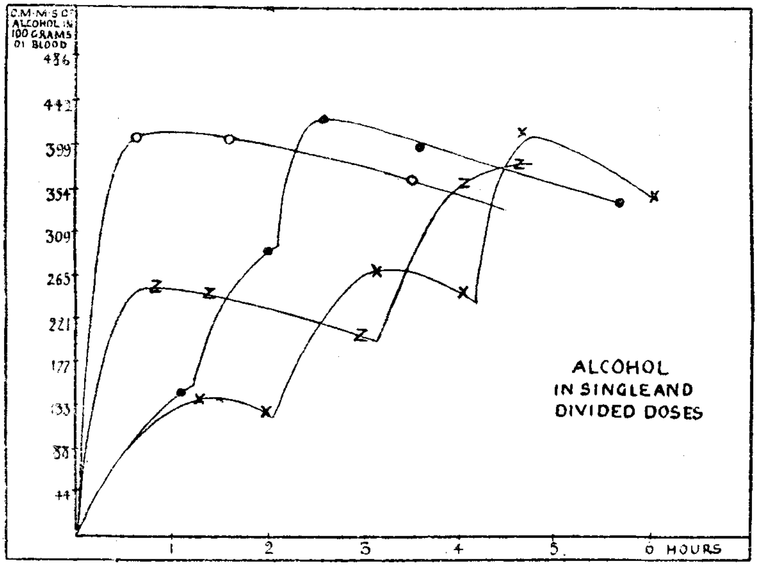

Fig. 12.

their worst would be further reduced. You will see also in these curves that there is evidence that the second drink is absorbed more rapidly into the blood than the first, and the third than the second. Here, no doubt, we have another example of the stimulating effect of water on the absorption capacity of the alimentary canal for alcohol, the first drink (after absorption) stimulating the rate of absorption of the second, and so on. Although it is probable that, under similar conditions, water after absorption would also have a stimulating effect on the absorption of alcohol in the case of man, a moment's consideration will show that the time intervals between drinks used in the above dog experiments (Fig. 12) would not give the same results in his case. His greater susceptibility to alcohol would undoubtedly mean that the two- and three-hour intervals would have to be reduced to get maximum intoxication symptoms. This point would have to be specifically determined in his case.

Having by means of these animal experiments brought to light several facts, it was necessary to see whether the same conditions held as regards man, and I shall now pass on to similar experiments performed on a man. On the whole you will see that there is fair agreement between the dog and man experiments. Probably the agreement would be better if I could be certain of getting as reliable results from human experiments. No doubt this is because of the impossibility of controlling all the conditions of the experiment in the case of man. Some things, like the type of food eaten on the day prior to the experiment, are probably responsible for the variations in results. The subject upon whom the experiments were made is a real toper —*i.e.*, drinks when he or his friends have any money. When an experiment is to be made, he takes no food or drink after his tea between four and five o'clock until the experiment starts at ten o'clock the following morning. After the first few experiments I found it necessary to extract a promise from him that he would not drink more than a pint of ale on the day before the experiment. The reason for this you will readily understand when you remember, from the first lantern slide shown, how long it takes alcohol to get out of the blood. On one occasion I found him slightly inebriated at three o'clock in the afternoon. I made an experiment on him the following day, and he got so intoxicated that I became alarmed. In addition, also, the experiment was no good for comparative purposes, although it again illustrates the above-mentioned fact—viz., the difficulty and slowness of completely oxidising alcohol when once in the body.

In these experiments the same technique was employed—that is to say, the man drank various alcoholic beverages according to the experiment, and then at different intervals samples of 5 to 7 c.c. of blood were taken from a vein in the arm, weighed, and the alcohol content estimated.

We will first consider the entrance of alcohol into his blood after drinking whisky and stout. In the whisky experiments he drank, in most cases, 300 c.c. of proof spirit diluted to 900 c.c. with water, the solution containing therefore 171 c.c. of alcohol and its strength 19 per cent. by volume. When he drank stout he imbibed the same quantity of alcohol—*i.e.*, 171 c.c.—and this required 3,100 c.c., or a little more than 6 imperial pints. The strength of the stout was 5·5 per cent. by volume. Fig. 13 shows the results obtained. (The whisky curve indicates rather more rapid absorption than is usually obtained.) You will see once more that, as in the dog experiments, there is a great difference in the alcohol of the blood in the two cases, the alcohol of whisky being much more rapidly absorbed and attaining a greater maximum. In keeping with these results, the intensity of intoxication after drinking whisky was much more profound than after drinking the same amount of alcohol in the form of stout. This is not all the story, however, as regards intoxication, and I shall return to the point again shortly. I wish to emphasize one great difference between the animal and man results in respect of this experiment: in the case of the dog it was possible to place all the whisky and all the stout in its stomach at the beginning of the experiment in the course of a minute or two. It is obviously impossible to do this with a man, especially in the case of stout—in fact, it took this particular man two hours to drink six bottles of stout. If he were pressed to drink more rapidly the "gates of his stomach" refused to open, with calamitous results. The whisky he could have drunk in five minutes with ease, but, to make the conditions more natural, I allowed him to drink it slowly over a period of half an hour. This question of time of drinking is obviously of great importance, and assumes an even greater importance when dealing with stouts and ales. If, for instance, this man had to drink 3 per cent. ale instead of 5·5 per cent., to imbibe the same amount of alcohol it would be necessary to drink not six bottles, but eleven bottles—that is to say, the time of drinking would be nearly doubled, and during this period he would be oxidizing about 10 c.c. of alcohol per hour. In addition, the dilution factor we saw in the case of the dog experiments would still hold, and would bring about a further lowering of the maximum point of concentration of alcohol in the blood. You can see, therefore, how difficult it would be to produce real intoxication with a 3 per cent. ale when only a limited time is allowed for drinking. Whereas it is possible for a man to get intoxicated almost to a moribund condition if allowed five minutes with a whisky bottle, the ordinary man could not approach this state if he were allowed complete freedom of action for four hours surrounded by unlimited 3 per cent. ale.

In some recent experiments made in America at the suggestion of the brewing interests there in a last endeavour to show that ale containing 2·75 per cent. alcohol by weight was not intoxicating, an experiment is described in which men during a period of four hours drank 5½ quarts (approximately) of ale of this strength. They were said to be able to speak distinctly, and to walk in a co-ordinate way, at the end of the period.

(Other figures were now shown demonstrating the effect of various conditions on the absorption of alcohol from the alimentary canal of man. More particularly the effect of previously

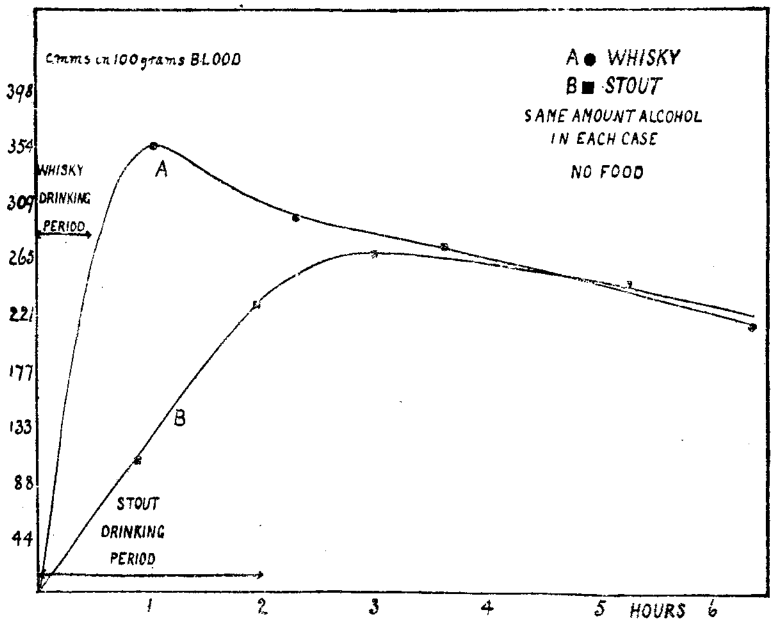

Fig. 13.—Alcohol in Blood after drinking: A, Whisky; B, Stout. (Same amount of alcohol in each case.)

drinking milk on the absorption of alcohol from whisky and stout was shown. The effects in man were strictly comparable to those obtained in the dog experiments.)

Up to the present I have spoken in rather a loose way about intoxication, and probably left you under the impression that the condition of intoxication can be directly interpreted by the alcohol in the blood curves. No doubt you think that if there is twice as much alcohol in the blood of a man he will probably be twice as intoxicated. I now wish to show you that this is really a complicated question, and is only true in a very limited sense. As I shall show you later, the symptoms of intoxication are only related to blood alcohol so long as the latter is increasing in concentration. In the experiments on the human subject I wished to have some objective indication of his state of intoxication simply for my personal guidance, but, on looking at the results, they turned out to be more interesting than I had expected, and I propose to show you some now. They are certainly only crude indications of intoxication, but lead, I think, to quite definite conclusions. During the experiments I asked the subject experimented on to copy at intervals a small drawing —a square, with diagonals, surrounded by a circle. These drawings have been inked over and photographed in series, and will now be shown on the lantern.

In the first place, let us consider the relative intoxication symptoms produced by the same amount of alcohol drunk respectively in the form of whisky and stout. We saw in Fig. 12 that, after drinking whisky, the maximum point of alcohol concentration in the blood was reached about one hour after drinking, whereas, in the case of stout, the maximum concentration was only reached about four hours from the commencement of drinking. Bearing these points in mind, consider Fig. 14, which represents a series of photographs of the subject's drawings at various intervals after imbibing whisky. You will notice that the drawings become rapidly worse, and then improve in their general character. Note, also, that the worst drawing is practically coincident with the point of maximum concentration of alcohol in the blood, and that as soon as the crest is reached and the curve begins to descend improvement sets in. Fig. 15 is a similar series of drawings after drinking stout, and here again you will see that the drawings, more gradually in this case, become worse. In this figure, however, even four hours twenty minutes from the beginning of the experiments there is not much indication of improvement, and this is, no doubt, explained by the fact that there is hardly any descent of the alcohol curve from its maximum to this point.

From a comparison of these drawings we see there is an obvious relationship between the alcohol in the blood and the symptoms of intoxication. As the alcohol increases symptoms become worse, and with the descent there is improvement.

It is possible, however, to carry the analysis a little farther. The difference between the third and fourth drawings of Fig. 14 —*i.e.*, in an interval of twenty minutes—is very great, and obviously indicates a big and rapid improvement in the man's condition of inebriety. This improvement increases progressively. No evidence of this improvement is seen in Fig. 14, and yet reference to Fig. 13 will show you that, taking the first four

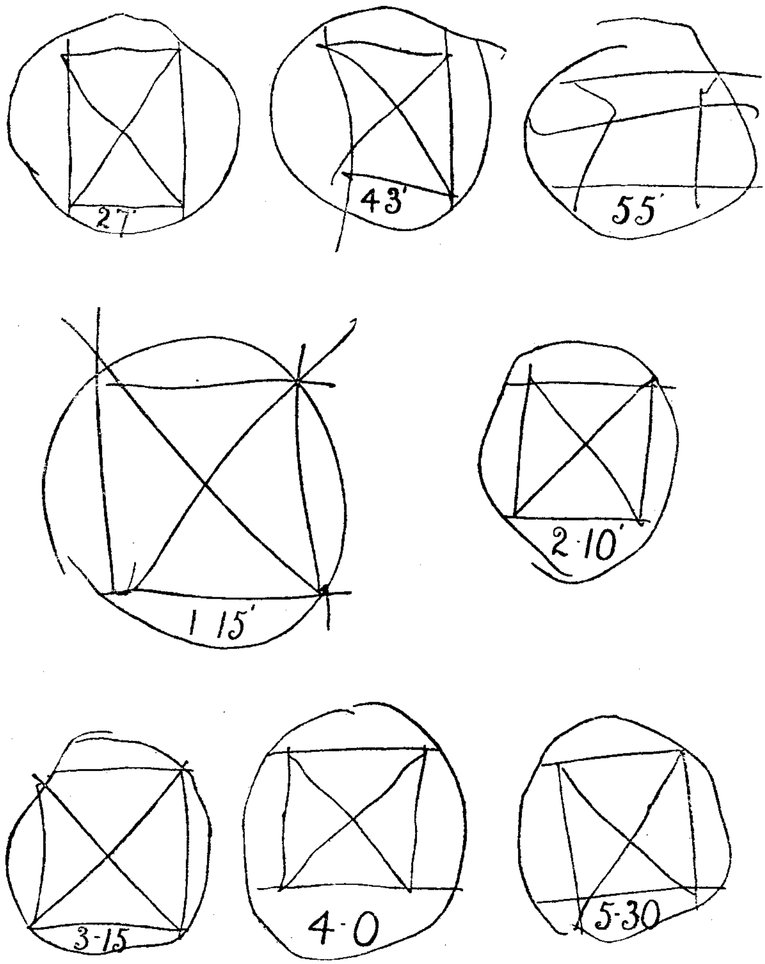

Fig. 14.—Drawings of Man at Different Intervals after imbibing Whisky.

hours of the two experiments, there is always more alcohol in the blood in the case of the whisky experiment. Here, then, is an instance of a man being more sober, so far as sobriety is indicated by drawing, at a time when there is more alcohol in the blood. It appears, then, that it is not possible to decide the condition of intoxication of the same man by simply estimating the amount of alcohol in the blood. It is true that the worst drawing in Fig. 14 is a much poorer effort than the worst in Fig. 15, so that, undoubtedly, the amount of alcohol is a deciding factor in the production of symptoms of intoxication, so

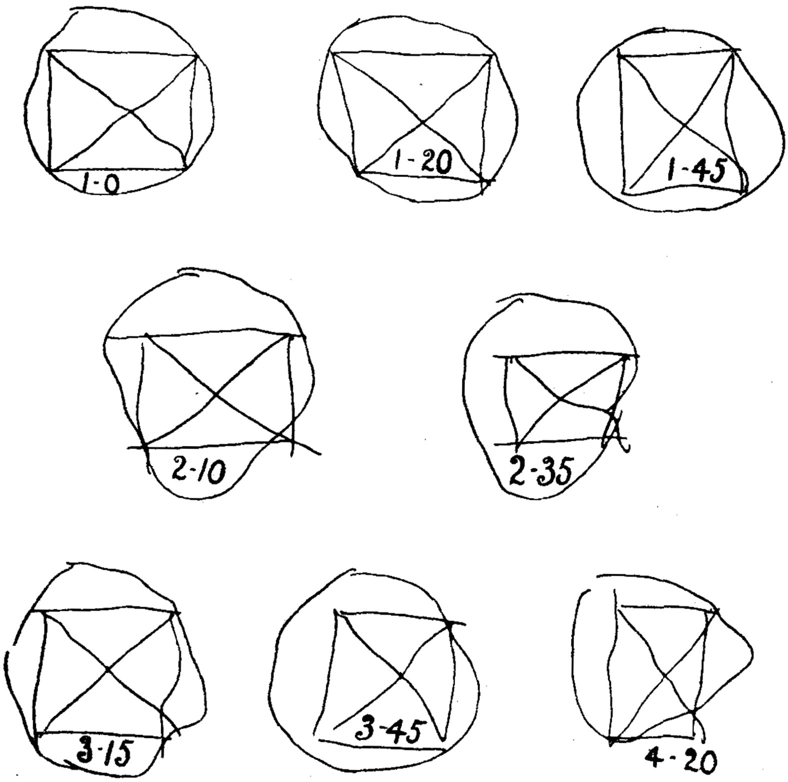

Fig. 15.—Drawings of Man at Different Intervals after drinking Stout. (Alcohol in blood seen in Fig. 13, B.)

long as this substance is increasing in amount in the blood and when it is at its maximum.

On the other hand—and this is a point I wish to emphasize—descent of alcohol in the blood means improvement, no matter what intoxicating symptoms have been developed. Further, the improvement may be so pronounced that a man may apparently be more sober than on the occasions when less alcohol is present in the blood.

It is quite probable, although this point I have not fully investigated, that the amount of improvement is dependent on the *rapidity* with which the curve of alcohol concentration can be brought down from its maximum, and that its rate of descent is at least as important a factor as the actual amount of alcohol present. That is to say, if a man has the same amount of alcohol in his blood on two occasions, on the first occasion the blood alcohol having suffered a rapid, and in the second a slow, descent, it is probable he would be more intoxicated on the second occasion at that particular point. In fact, it seems as if when a man gets drunk he tends to develop some immunity to an amount of alcohol less than the maximum attained on that particular occasion. However intoxicated a man may be, it is probable that alleviation in the symptoms of intoxication would result from some reduction in the concentration of the alcohol content of the blood. How this can best be brought about is still under investigation. It is clear from the experimental results that the problem is a difficult one, for the disappearance of alcohol from the blood is a slow process, and remarkably constant under many conditions. Under one condition, however, an increased reduction of alcohol certainly takes place. This condition is continuous muscular contraction. Fig. 16 shows the effect of running in the case of a dog while under the influence of alcohol. In curve C the dog was at rest, and in curve D running about in a more or less lethargic state. In each case the same amount of alcohol had been given. It will be seen that the effect of running is to bring about a more rapid reduction of alcohol in the blood. Exercise, therefore, means a quicker return to sobriety. Obviously this method of cure has its limitations, for at high concentrations of blood alcohol the man may be too intoxicated to walk, and, as a further fact, the dog experiments have shown that at high concentrations of alcohol exercise does not increase the rate of combustion of alcohol (see Fig. 16, curves A and B). The effect of muscular contraction on alcohol combustion has been previously demonstrated by Atwater and Benedict, Durig, and other workers. Here, however, I simply wish to point out how the analysis of the results of the foregoing experiments place upon an experimental basis what has long been known as an empirical fact—viz., that to keep a drunken man walking allows him "to work off" the effects more rapidly. Probably a part of this action is due to the better opportunity of the central nervous system to restore a perfect co-ordinating mechanism as the result of practice, and partly to the increased rate of combustion of alcohol in the body.

The differences in intoxication produced respectively by whisky and stout were striking. In the experiments with whisky, although the intoxication developed rapidly and was intense for a short period, relative improvement, as indicated by the drawings, was often rapid. With stout the process was long

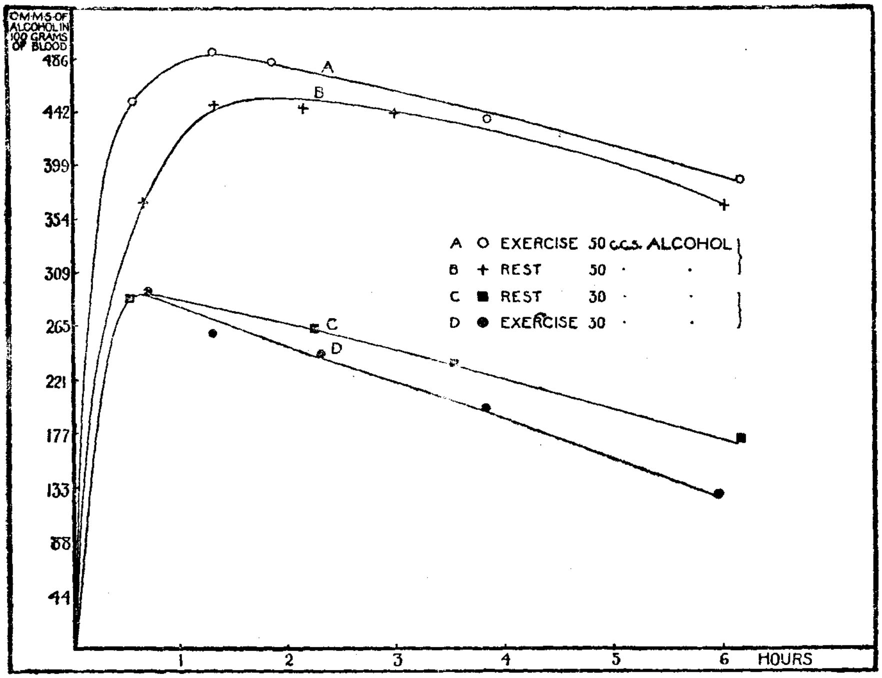

Fig. 16.

drawn out and the recovery slow. We see, therefore, that, although it is more difficult to produce profound intoxication by stout than by whisky, yet, in the former case, the inefficiency of the individual may last for a longer period and result in more serious disability.