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WHAT HAPPENS TO ALCOHOL IN THE BODY

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WHAT HAPPENS TO ALCOHOL IN THE BODY

THE changes that occur in behavior after drinking immoderate amounts of alcoholic beverages and the diseases that develop in those who, after many years of excessive drinking, become chronic alcoholics, often raise the questions: How does alcohol bring about these changes? What happens to the body? Rarely, except by scientists, however, is the question raised: What happens to alcohol in the body? To this question scientists have given much attention, for they realize that in order to understand how alcohol affects the body they must first find out how the body deals with alcohol.

It is important to know whether alcohol reaches the various organs of the body in its original form or whether it is transformed into some other substance before it enters the blood. Likewise, the action on various parts and functions of the body depends upon whether or not alcohol reaches all or only certain parts of the organism. The possible effects of any substance on the body depend, also, upon whether the substance leaves the body only through the kidneys and the breath, or whether it is largely "burned" in the body.

In the following pages, what happens to alcohol in the body is described in order to give a foundation for the understanding of the effects of alcohol on bodily and mental functions, which will be dealt with in another Supplement.

When an alcoholic beverage is drunk the alcohol is absorbed from the stomach and intestines. Alcohol requires no digestion. It passes directly into the blood and is carried to all parts of the body. A small portion of the absorbed alcohol is eliminated in the breath, sweat and urine, but the far greater portion is destroyed in the body by a process of oxidation in which the energy of the alcohol is liberated as heat. The products formed in the oxidation of alcohol are water and carbon dioxide. Both are harmless.

The intoxicating action of alcohol is exercised only by that portion of the alcohol which has been absorbed into the blood stream but not yet oxidized or eliminated.

The loss of alcohol by oxidation is slow but continuous. In contrast, the rate at which alcohol is absorbed, that is, the amount absorbed in a minute or any unit of time, and the length of time it continues to be absorbed, are highly variable. They depend upon the amount and nature of the alcoholic beverage drunk, the time over which it is drunk and the state of digestion. When the absorption of alcohol is more rapid than the loss by oxidation and elimination the amount in the body increases and the concentration in the blood rises; when all the alcohol has been absorbed the amount in the body diminishes and the concentration in the blood falls until finally none is present.

OXIDATION OF ALCOHOL

THE amounts of alcohol which diffuse—"evaporate"—from the blood into the air of the lungs and are breathed out and the amounts which pass into the urine are small as compared to those which are lost by oxidation. The total amount of alcohol eliminated may vary from less than 1 per cent of the amount drunk to as much as 5 or 10 per cent. The remainder is oxidized.

One of the recent discoveries concerning the oxidation of alcohol is that at least the first stage of the process occurs only in the liver. The rate at which the liver oxidizes alcohol is apparently governed by the size of the liver, and the size of the liver is, in turn, related to the weight of the body. The rate at which the liver oxidizes alcohol is not greatly affected by muscular exercise. It is in this respect particularly that the oxidation of alcohol differs from that of ordinary foods such as carbohydrate. Carbohydrate is oxidized in all tissues of the body and the rate varies with the needs for energy. Thus when a man runs he oxidizes 4 to 10 times as much carbohydrate an hour as he does when he is sitting still and needs energy from the foods only to maintain the heat and normal resting activities of his body. If he has drunk an alcoholic beverage the energy from the oxidation of alcohol will replace as much as 70 to 80 per cent of the energy (and correspondingly of the ordinary foods) needed during rest. But if he exercises, the extra energy is not supplied from the alcohol but from carbohydrate and other foods.

A man of average size, 154 pounds, sitting at rest, expends

energy to the extent of about 75 calories an hour. If he had drunk alcohol, as much as 50 or 60 of these calories (that is 70 to 80 per cent) might come from the alcohol. One fluid ounce of alcohol (0.79 ounces by weight) yields 166 calories.* Therefore, some 2½ to 3 hours would be required to oxidize this amount of alcohol. One fluid ounce of alcohol is the amount in 2 to 2¼ ounces of whisky or 1½ pints (2 bottles) of beer.

The rate at which energy is expended during rest varies approximately with the weight of the body (more accurately with the area). The weight of the liver and hence its capacity to burn alcohol also varies approximately with the weight. Consequently a large man can oxidize alcohol more rapidly than a small one. Table 1 gives the approximate amounts of alcohol which can be oxidized in 1 hour and in 24 hours by men of different weights. It must be borne in mind that these figures are averages only and are subject to considerable variation and also that the alcohol from different beverages may be oxidized at somewhat different rates.

TABLE 1

Approximate Rate at Which Alcohol Is Oxidized by Men of Different Weights

Weight, lb.	*Approximate amount of alcohol oxidized in* 1 *hr. fluid oz.*	*24 hr. fluid oz.*	*Corresponding amount of 90° proof whisky in 24 hr. fluid oz.*
120	0.25—0.30	6—7	14—16
140	0.30—0.33	7—8	16—18
154	0.33—0.36	8—9	18—20
160	0.34—0.37	8—9	18—20
180	0.40—0.44	9—10	21—23
200	0.44—0.47	10—11	23—25
220	0.47—0.52	11—12	25—28

Many people believe that very heavy drinkers may drink a quart or even 2 quarts of whisky a day for many years. We do not argue against the fact that occasionally, when on a spree, an

*Alcohol is a rich food. The same weight (0.79 ounces) of carbohydrate would liberate 98 calories and of fat, 215 calories.

abnormal drinker, especially one of large size, may drink these amounts of whisky in a day. It is, however, out of the question to continue these prodigious rates of consumption beyond a short time. Alcohol cannot be oxidized at these rates and it would accumulate in the body day by day. A part of that drunk on one day would remain the next and be added to that drunk on the second day. In a short time the man would first be continuously drunk and then unconscious so that he could drink no more.

The man of average size can get rid of 8 to 9 ounces, or possibly in exceptional circumstances as much as 12 ounces, of alcohol in 24 hours by oxidation and elimination. These amounts of alcohol correspond to that in from 1 to 1½ pints of whisky or, if the man were capable of coping with the extremely large amount of fluid, 1½ to 2¼ gallons of beer. For a man of exceptional size, 220 pounds, the figures might become 11 to 12 or even 16 ounces of alcohol and 1½ to 2 pints of whisky, or again, if he were able to drink the bulk of fluid, 2¼ to 3¾ gallons of beer.

ABSORPTION OF ALCOHOL

ALCOHOL is one of the few food substances which is absorbed rapidly from the stomach. As stated previously, it requires no digestion and is passed into the blood unchanged. The effects of alcohol would be greatly modified if, as is true for fats and proteins, both digestion and passage into the intestine were required before absorption. An interval of an hour, and probably much longer, would intervene between the drinking of the alcohol and the appearance of any appreciable amounts in the blood and consequently any effects experienced. Because of its initial rapid absorption, alcohol appears in the blood within a minute or two after it is drunk, although for larger amounts the maximum concentration may not be reached for an hour or more.

When alcohol is taken into the stomach, it is for a short time absorbed rapidly; absorption then decreases to a slow rate, even though considerable amounts remain in the stomach. Beyond the slow rate, further absorption depends upon the passage of the contents of the stomach into the intestine where absorption is rapid and complete.

The presence of food in the stomach slows both the absorption

of alcohol there and also the rate of passage into the intestine. Contrary to popular belief, fats do not slow absorption as much as do bread and meat and milk. When taken on an empty stomach the alcohol of brewed beverages, such as beer, is absorbed much more slowly than that from distilled spirits. The carbohydrates and other materials in beer exert a food action in slowing absorption of the alcohol.

CONCENTRATION OF ALCOHOL IN THE BLOOD

THE absorption and distribution of alcohol throughout the body are essentially a process of dilution. When a strong alcoholic beverage is taken into the stomach, the digestive juices of the stomach dilute it until the concentration of alcohol is only 3 or 4 per cent. When the alcohol is absorbed it passes into the blood flowing about the digestive organs and is diluted by that fluid. It is then carried throughout the body by the circulating blood. It spreads from the blood to dissolve in the fluid in and about the cells of the tissues of the body and is still further diluted by the fluid.

The extent of the dilution is expressed in terms of concentration.* The alcoholic beverage drunk may contain as much as 40 per cent (by weight) of alcohol if it is taken as distilled spirits and as little as 2.5 per cent if it is taken as beer. Concentrations of these magnitudes never appear in the blood. As between no intoxication and severe intoxication the percentage in the blood might range between 0.05 or 0.1 per cent on the one hand and 0.3 or 0.4 per cent on the other. At the very low concentrations which occur in the body alcohol does not have the direct damaging and irritating effect which we are accustomed to associate with undiluted alcohol. Such undiluted alcohol is painful if it enters a cut or the

*Concentration of alcohol in the blood is variously expressed as milligrams of alcohol per cubic centimeter of blood, as milligrams per cent and as per cent by weight. Per cent is now the most commonly accepted form and it expresses the weight of alcohol in 100 units of blood. Thus if 100 g. (or cc.) of blood contained 0.1 g. of alcohol, the concentration would be 0.1 per cent. If the concentration is expressed in milligrams per cubic centimeter it is converted to per cent by dividing by 10 and if it is expressed as milligrams per cent it is converted to per cent by dividing by 1,000. Thus 1 mg. per cc. corresponds to 0.1 per cent and 100 mg. per cent also corresponds to 0.1 per cent.

eye; alcohol diluted to even 1 per cent—a much higher concentration than ever occurs in the body—is entirely nonirritating and will not damage the structure of the most delicate tissues. These facts are often overlooked by those who erroneously attribute the effects from alcohol to direct damage of brain or other tissues. Any disturbances caused by alcohol after it is absorbed are due to its effects on the function, the action, of living tissues.

Alcohol leaving the digestive tract in the blood is distributed to every part of the body. It dissolves in the water of the blood and tissues. The amount of water in the body varies somewhat as between individuals but is approximately 70 per cent of the weight of the body. Thus a man weighing 154 pounds would have 109 pounds of water in his body in which the alcohol would eventually be diluted. Now if he had in his body—absorbed but unoxidized—1 fluid ounce of alcohol what would be the concentration in his blood? A little calculation gives the answer. Concentration is estimated on the basis of weight of alcohol and therefore we must first convert the fluid ounce to weight. Alcohol weighs only about 0.79 as much as water; therefore 1 fluid ounce weighs 0.79 ounces. Seventy-nine hundredths of an ounce of alcohol is therefore diluted in 109 pounds, or 1,744 ounces of water. If we multiply the weight of the alcohol by 100 and divide by the weight of the water, we obtain the percentage of alcohol in the water—which is 0.046. There is just one further step in the calculation. The various tissues of the body contain various amounts of water—some little and some large; the blood contains about 85 per cent. The concentration of alcohol in the blood would therefore not be 0.046 per cent as in the water of the blood but 85 per cent of this: 0.039 per cent or, in round numbers, 0.04 per cent of alcohol.

The amount of water in the body varies somewhat as between different individuals of the same weight and in the same individual at different times, but the percentage used here is a fair average. It therefore follows that the larger the man the lower the concentration of alcohol in the blood for any given amount of alcohol in the body. Table 2 shows the approximate concentration of alcohol in the blood for each ounce of alcohol in the body for men of different weights.

TABLE 2

Approximate Concentration of Alcohol in Blood for 1 Fluid Ounce of Alcohol in the Body (Absorbed but Unoxidized)

Weight, lb.	*Concentration of alcohol in blood, per cent*
100	0.060
120	0.050
140	0.043
154	0.040
160	0.038
180	0.033
200	0.030
220	0.028

It must be borne in mind that the amounts and concentrations given here apply, as we have said, only to alcohol that has been absorbed and not yet oxidized and eliminated. These figures cannot be taken directly to calculate the concentration that would be developed in the blood from drinking these amounts of alcohol. Time would be required for absorption and during this time part of the alcohol would be oxidized. Consequently all of the alcohol would not be in the body at any one time and the concentration would be lower than that shown in Table 2. This point is emphasized here because in tables and charts intended to show the relation between amount of alcohol drunk and the concentration in the blood the calculation is often made as if all the alcohol were absorbed as fast as it was drunk. In reality from ½ to several hours are required for the absorption, depending upon the amount, the kind of beverage and whether or not there is food in the stomach. Thus 1 ounce of alcohol as whisky taken on an empty stomach would be absorbed within a half hour and only about 1/6 of an ounce would be oxidized in that time. At the end of this half hour there would be 5/6 of an ounce of alcohol in the body and the concentration in the blood would be approximately 5/6 as high as that given in Table 2, i.e., for an average-sized man 0.033 per cent. If the same amount of whisky were taken after a meal, absorption might not be complete for 1½ to

2 hours; during this time ½ to ⅔ of the ounce of alcohol absorbed would be oxidized so that at the end of the time, the concentration developed in the blood would be only ½ or ⅓ as high as that given in Table 2, i.e., for an average-sized man 0.02 to 0.013 per cent. The same effect would be obtained even on an empty stomach if the fluid ounce of alcohol were taken as 1½ pints of beer, since the material in the beer would slow absorption the same way as does food taken before the alcoholic beverage is drunk. Before drawing conclusions as to the concentration of alcohol developed in the blood after drinking various amounts of alcohol, it is essential to know what sort of beverage was used and whether or not the stomach was empty or full.

An even greater complicating factor from slow absorption and continuous oxidation is encountered when, as often happens, the alcoholic beverage is not drunk at one time but is drunk slowly over an hour or even several hours.

Thus if a man of average size were to drink only ⅔ of an ounce, or a little less, of whisky (⅓ ounce of alcohol) or an 8 ounce glass of beer an hour, each hour in the 24, his blood at the end of each hour would show practically no alcohol, for he could burn this much. He would at no time be drunk, or indeed show any appreciable effects from the alcohol, and yet in this time he would have drunk a total of a pint or more of whisky or 1½ gallons of beer. If he drank the same amount of whisky in 1 hour he would be drunk. The fact that he would not become intoxicated on drinking this amount of whisky slowly over 24 hours does not signify that if he repeated this performance day in and day out for many years he would escape entirely the ill health of "chronic alcoholism." The occurence of drunkenness itself has little or nothing to do with the development of diseases of chronic alcoholism; these diseases are, as we point out in other supplements, due mainly to vitamin deficiency. From the pint of whisky a day he would, unless it were fortified with vitamins, obtain some 1,325 vitamin free calories a day, which would replace from his diet a corresponding amount of other foods which might contain vitamins.

In medicolegal standards applied to motorists, a concentration of no more than 0.05 per cent of alcohol in the blood is usually

taken as prima facie evidence of sobriety. For the man of average size, as shown in Table 3, the level will not be exceeded on drinking on an empty stomach 1 highball, 1 cocktail or approximately 3 bottles of beer. Approximately double these quantities could be taken with the same results soon after a full meal.

For the man who occasionally drinks beyond the bounds of medicolegal moderation, it is important, either as a driver or pedestrian, that, to avoid any suspicion of any influence from alcohol, he wait until the concentration has fallen to 0.05 per cent. Table 3 shows the approximate length of time in which the concentration will fall to this level after different amounts of alcoholic beverages. These calculations apply to a man of average size—154 pounds—who drinks all of the alcoholic beverage on an empty stomach and within a period of less than ½ hour. For one who is smaller or larger the concentration in the blood should be multiplied by: $\frac{\text{his weight}}{154}$ and for the length of time the concentration stays above 0.05 per cent by: $\frac{154}{\text{his weight}}$.

TABLE 3

Time after drinking certain amounts of alcoholic beverages that the concentration of alcohol in the blood is at 0.05 per cent.

Figures apply to a man of average weight—154 pounds—who drinks the beverage within a short time and on an empty stomach. A highball and a cocktail are taken to contain ¾ fluid ounce of alcohol (i.e., corresponding to about 1½ ounces of whisky). A bottle of beer contains 12 ounces of beverage.

1 highball* or 1 cocktail* or 3 bottles of beer* (about 4 glasses)	The concentration of alcohol in the blood will reach its maximum in ½ to 1 hour at or below a level of 0.05 per cent.
2 highballs or 2 cocktails	The concentration in the blood will reach a maximum slightly above 0.05 per cent but will fall to this level within 1 hour.

*If taken within 2 hours after a full meal approximately double these amounts.

3 highballs or 3 cocktails	The concentration will fall to 0.05 per cent in 2 to 3 hours.
4 highballs or 4 cocktails	The concentration will fall to 0.05 per cent in 5 to 6 hours.
5 highballs or 5 cocktails	The concentration will fall to 0.05 per cent in 8 hours.

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