of the eight hours. Many of those who immediately survived died afterward of putrid fever ("Annual Register," 1758). The incident of the "Black Hole of Calcutta" has frequently been repeated on emigrant and slave ships, by confining great numbers in the hold of the vessel, where they were entirely shut out from the fresh air.

The condition of the system has a marked and important influence on the rapidity with which the effects of vitiated atmosphere are manifested. As a rule, the immediate effects of confined air are not developed so soon in weak and debilitated persons as in those who are active and powerful. It has sometimes been observed, in cases where a male and female have attempted suicide together by the fumes of charcoal, that the female has been restored some time after life had become extinct in the male. This is probably owing to the greater demand for oxygen on the part of the male.

When poisoning by confined air is gradual, the system becomes accustomed to the toxic influence, the temperature of the body is lowered, and an animal will live in an atmosphere which will produce instantaneous death in one that is fresh and vigorous. Bernard has made a number of experiments on this point. In one of them, a sparrow was confined under a bell-glass for an hour and a half, at the end of which time another was introduced, the first being still quite vigorous. The second became instantly much distressed and died in five minutes; but ten minutes after, the sparrow which had been confined for more than an hour and a half was released and flew away.

CHAPTER VI.

ALIMENTATION.

General considerations—Hunger—Seat of the sense of hunger—Thirst—Seat of the sense of thirst—Duration of life in inanition—Classification of alimentary substances—Nitrogenized alimentary substances—Non-nitrogenized alimentary substances—Inorganic alimentary substances—Alcohol—Coffee—Tea—Chocolate—Condiments and flavoring articles—Quantity and variety of food necessary to nutrition—Necessity of a varied diet.

In the organism of animals, every part is continually undergoing what may be called physiological wear; the nitrogenized constituents of the body are being constantly transformed into effete matter; and as these constituents never exist without inorganic matters, with which they are closely and inseparably united, it is found that the products of their disassimilation are always discharged from the body in combination with inorganic substances. This process of molecular change is a necessary condition of life. Its activity may be increased or retarded by various means, but it can not be arrested. The excrementitious matters which are thus formed are produced constantly by the tissues and must be continually removed from the organism.

It is evident, from the amount of matter that is daily discharged from the body, that the process of disassimilation must be very active. Its constant operation necessitates a constant appropriation of new matter by the parts, in order that they may maintain their integrity of composition and be always ready to perform their offices in the economy. The blood contains all the materials necessary for the regeneration of the organism. Its inorganic constituents are found generally in the form in which they exist in the substance of the tissues; but the organic constituents of the parts are formed in the substance of the tissues themselves, by a transformation of matters furnished by the blood. The physiological wear of the organism is, therefore, being constantly repaired by the blood; but in order to keep the great nutritive fluid from becoming impoverished, the matters which it is constantly losing must be supplied from some source out of the body, and this necessitates the ingestion of articles which are known as food. Food is taken into the body in obedience to a want on the part of the system, which is expressed by the sensation of hunger, when it relates to solid or semi-solid matters, and of thirst, when it relates to water.

Hunger and Thirst.

The term hunger may be applied to all degrees of that peculiar want felt by the system, which leads to the ingestion of nutritive substances. Its first manifestations are, perhaps, best expressed by the term appetite; a sensation by no means disagreeable, and one which may be excited by the sight, smell, or even the recollection of savory articles, at times when it does not absolutely depend on a want in the system. In the ordinary and moderate development of the appetite, it is impossible to say that the sensation is referable to any distinct part or organ. It is influenced in some degree by habit; in many persons, the feeling being experienced at or near the hours when food is ordinarily taken. If not soon gratified, the appetite is rapidly intensified until it becomes actual hunger. Except when the quantity of food taken is unnecessarily large, the appetite simply disappears on the introduction of food into the stomach and gives place to the sense of satisfaction which accompanies the undisturbed and normal action of the digestive organs; or in those who are in the habit of engaging in absorbing occupations at that time, the only change experienced is the absence of desire for food.

It has been observed that children and old persons do not endure deprivation of food so well as adults. This was noted in the case of the wreck of the frigate Medusa. After the wreck, one hundred and fifty persons, of all ages, were exposed on a raft for thirteen days, with hardly any food. Out of this number only fifteen survived; and the children, the young persons and the aged, were the first to succumb.

Important modifications in the appetite are due to temperature. In cold climates and during the winter season in all climates, the desire for food is notably increased, and the tastes are somewhat modified. Animal food, and particularly fats, are more agreeable at that time, and the quantity of nutriment which is demanded by the system is then considerably increased. In

many persons the difference in the appetite in warm and cold seasons is very marked.

Exercise and occupation, both mental and physical, when not pushed to the point of exhaustion, increase the desire for food and undoubtedly facilitate digestion. Certain articles, especially the vegetable bitters, taken into the stomach immediately before the time when food is habitually taken, frequently have the same effect; while other articles which do not satisfy the requirements of the system have a tendency to diminish the desire for food. Many articles of the materia medica, especially preparations of opium, have, in some persons, a marked influence in diminishing the appetite. The abuse of alcoholic stimulants will sometimes take away all desire for food. When hunger is pressing, it has been observed that tobacco, in those who are accustomed to its use, will frequently allay the sensation for a time.

If food be not taken in obedience to the demands of the system as expressed by the appetite, the sensation of hunger becomes most distressing. It is then manifested by a peculiar and indescribable sensation in the stomach, which soon becomes developed into actual pain. This is generally accompanied with intense pain in the head and a feeling of general distress, which soon render the satisfaction of this imperative demand on the part of the system the absorbing idea of existence. Furious delirium frequently supervenes after a few days of complete abstinence; and this is generally the immediate precursor of death. It is unnecessary to cite the many instances in which murder and cannibalism have been resorted to when starvation is imminent; suffice it to say, that the extremity of hunger or of thirst, like the sense of impending suffocation, is a demand on the part of the system so imperative, that it must be satisfied if within the range of possibility.

The question of the seat of the sense of hunger is one of considerable physiological interest. Saying that it is instinctively referred to the stomach, is simply expressing the fact that the sensation is of a nature to demand the introduction of food in the usual way. When the system is suffering from defective nutrition, as after prolonged abstinence or during recovery from diseases which have been accompanied by a lack of assimilation, the mere filling of the stomach produces a sensation of repletion of this organ, but the sense of hunger is not relieved; but if, on the other hand, the nutrition be active and sufficient, the stomach is frequently entirely empty for a considerable time without the development of the sense of hunger. The appetite is preserved and hunger is felt by persons who suffer from extensive organic disease of the stomach, and the sensation has been occasionally relieved by nutritious enemata or by injections into the veins. It is certain that the appetite and the sense of hunger are expressions of a want on the part of the organism, referred by the sensations to the stomach, but really existing in the general system. This can be completely satisfied only by the absorption of digested alimentary matters by the blood and their assimilation by the tissues.

The sense of hunger is undoubtedly appreciated by the cerebrum, and it has been a question whether there be any special nerves which convey this

impression to the encephalon. The nerve which would naturally be supposed to have this office is the pneumogastric; but notwithstanding certain observations to the contrary, it has been shown that section of both of these nerves by no means abolishes the desire for food. Longet has observed that dogs eat, apparently with satisfaction, after section of the glosso-pharyngeal and lingual nerves. This observer is of the opinion that the sensation of hunger is conveyed to the brain through the sympathetic system. Although there are various considerations which render this somewhat probable, it is not apparent how it could be demonstrated experimentally. It is undoubtedly the sympathetic system of nerves which presides specially over nutrition; and hunger, which depends upon deficiency of nutrition, is certainly not conveyed to the brain by any of the cerebro-spinal nerves.

Thirst is the peculiar sensation which leads to the ingestion of water. In its moderate development, this is usually an indefinite feeling, accompanied by more or less sense of dryness and heat of the throat and fauces, and sometimes, after the ingestion of a quantity of very dry food, by a sensation referred to the stomach. When the sensation of thirst has become intense, the immediate satisfaction which follows the ingestion of a liquid, particularly water, is very great. Thirst is very much under the influence of habit; some persons experiencing a desire to take liquids only two or three times daily, while others do so much more frequently. The sensation is also sensibly influenced by the condition of the atmosphere as regards moisture, by exercise and by other conditions which influence the discharge of water from the body, particularly by the skin. A copious loss of blood is always followed by great thirst. This is frequently noticed in the inferior animals. After an operation involving hæmorrhage, they nearly always drink with avidity as soon as released. In diseases which are characterized by increased discharge of liquids, thirst is generally excessive.

The demand on the part of the system for water is much more imperative than for solids; in this respect being second only to the demand for oxygen. Animals will live much longer when deprived of solid food but allowed to drink freely than if deprived of both food and drink. A man, supplied with dry food but deprived of water, will not survive more than a few days. Water is necessary to the processes of nutrition, and acts, moreover, as a solvent in removing from the system the products of disassimilation.

After deprivation of water for a considerable time, the intense thirst becomes most distressing. The dryness and heat of the throat and fauces are increased and accompanied with a sense of constriction. A general febrile condition supervenes, the blood is diminished in quantity and becomes thickened, the urine is scanty and scalding, and there seems to be a condition of the principal viscera approaching inflammation. Death takes place in a few days, generally preceded by delirium.

The sensation of thirst is instinctively referred to the mouth, throat and fauces; but it is not necessarily appeased by the passage of water over these parts, and it may be effectually relieved by the introduction of water into the system by other channels, as by injecting it into the veins. Bernard has

demonstrated, by the following experiment, that water must be absorbed before the demands of the system can be satisfied: He made an opening into the œsophagus of a horse, tied the lower portion, and allowed the animal to drink after he had been deprived of water for a number of hours. The animal drank an immense quantity, but the water did not pass into the stomach and the thirst was not relieved. He modified this experiment by causing dogs to drink, with a fistulous opening into the stomach by which the water was immediately discharged. They continued to drink without being satisfied, until the fistula was closed and the water could be absorbed.

In a case reported by Gairdner (1820), in the human subject, all the liquids swallowed passed out at a wound in the neck, by which the œsophagus had been cut across. The thirst in this case was insatiable, although buckets of water were taken in the day; but on injecting water, mixed with a little spirit, into the stomach, the sensation was soon relieved.

Although the sensation of thirst is referred to special parts, it is an expression of the want of liquids in the system and is to be effectually relieved only by their absorption by the blood. There are no nerves belonging to the cerebro-spinal system which have the office of conveying this sensation to the brain, division of which will abolish the desire for liquids. Experiments show that no effectual relief of the sensation is afforded by simply moistening the parts to which the heat and dryness are referred. As a demand on the part of the system, it is entirely analogous to the sense of want of air and of hunger, differing only in the way in which it is manifested.

The length of time that life continues after complete deprivation of food and drink is very variable. The influences of age and obesity have already been referred to. Without citing the individual instances of starvation in the human subject which have been reported, it may be stated, in general terms, that death occurs within five to eight days after total deprivation of food. In the instance of the one hundred and fifty persons, wrecked on the frigate Medusa, in 1816, who were exposed on a raft in the open sea for thirteen days, only fifteen were found alive. Savigny, one of the survivors, gave, in an inaugural thesis, a very instructive and accurate account of this occurrence, which has been very generally quoted in works of physiology. Authentic instances are on record in which life has been prolonged much beyond the period above mentioned; but they generally occurred in persons who were so situated as not to suffer from cold, which the system, under this condition, has very little power to resist. In these cases, also, there was no muscular exertion, and water was generally taken in abundance.

Bérard quoted the example of a convict who died of starvation after sixty-three days, but in this case water was taken. An instance of eight miners who survived after five days and sixteen hours of almost complete deprivation of food is referred to in works upon physiology. Bérard has also quoted, from various authors, instances of deprivation of food for periods varying between four months and sixteen years; but these accounts are not properly authenticated and are discredited by physiologists. They generally occurred in hysterical females, and their consideration belongs to psychology rather than

to physiology. According to Chossat, death from starvation occurs after a loss of four-tenths of the weight of the body, the time of death being variable in different classes of animals.

Thirty to thirty-five days may be taken as the average duration of life in dogs deprived entirely of food and drink. It is important to bear in mind this fact in connection with observations on the nutritive value of different articles of food.

Alimentation.

Under the name of aliment, in its widest signification, it is proposed to include all articles composed of or containing substances in a form which enables them to be used for the nourishment of the body, either by being themselves appropriated by the organism, by influencing favorably the process of nutrition, or by retarding disassimilation. Those substances which are themselves appropriated may be called direct aliments; and those which simply assist nutrition without contributing reparative material, together with those which retard disassimilation, may be termed accessory aliments. In this definition of aliment, nothing is excluded which contributes to nutrition. The air must be considered in this light, as well as water and all articles which are commonly called drinks.

In the various articles used as food, nutritious substances are frequently combined with each other and with indigestible and innutritious matters. The constituents of the food which are directly used in nutrition are the true alimentary substances, embracing, thus, only those which are capable of absorption and assimilation. The ordinary food of the warm-blooded animals contains alimentary matters united with innutritious substances from which they are separated in digestion. This necessitates a complicated digestive apparatus. In some of the inferior animals, the quantity of nutritious matter forms so small a part of the ingesta that the digestive apparatus is even more complicated than in the human subject. This is specially marked in the herbivora, the flesh of which forms an important part of the diet of man. In addition to what are distinctly recognized as alimentary substances, food has many constituents which exert an important influence on nutrition, which have never been isolated and analyzed, but which render it agreeable. Many of these are developed in the process of cooking.

Alimentary substances belong to the inorganic, vegetable, and animal kingdoms. They are generally divided into the following classes:

1. Organic nitrogenized substances (albumin, fibrin, caseine, myosine etc.), belonging to the animal kingdom, and vegetable nitrogenized substances, such as gluten and legumine.
2. Organic non-nitrogenized substances (sugars, starch and fats).
3. Inorganic substances.

Nitrogenized Alimentary Substances.—In the nutrition of certain classes of animals, these substances are derived exclusively from the animal kingdom, and in others, exclusively from the vegetable kingdom; but in man,

both animals and vegetables contribute nitrogenized matters. In both animal and vegetable food, nitrogenized substances are always found combined with inorganic matters (water, sodium chloride, the phosphates, sulphates etc.), and frequently with non-nitrogenized matters, especially the carbohydrates.

The most important nitrogenized alimentary constituents of food are contained in the muscular substance, eggs, milk, the juices of vegetables, cereal grains etc. Many of these substances have been isolated and studied by chemists. Among the most important are myosine, the chief organic constituent of muscle, the various albumins found in eggs and in animal fluids, analogous substances existing in vegetables, caseine in milk, a substance sometimes called vegetable caseine, vitelline in yelk of egg, fibrin, gelatine, and gluten, an important alimentary substance found in the cereal grains, etc. A distinctive character of these substances is that they all contain nitrogen, being composed of carbon, oxygen, hydrogen and nitrogen, with probably a small quantity of sulphur. They are all either liquid or semi-solid in consistence, not crystallizable, and are coagulable by various reagents. The type of substances of this class is albumin, which has the provisional formula, $C_{72}H_{112}O_{22}N_{18}S$ (Lieberkühn); and they are sometimes called albuminoids. They are also called proteids, after a hypothetical substance described by Mulder, under the name of proteine.

The nitrogenized substances are found in animal bodies, as has already been stated. They originate in vegetables by a union of nitrogen, derived from saline matters, with the carbohydrates, the carbohydrates in vegetables being produced from carbonic acid and water. No part of the nitrogen used by vegetables in the formation of the albuminoids is derived from the atmosphere (Hoppe-Seyler).

A distinctive character of substances of this class is that under favorable conditions of heat and moisture they undergo a peculiar form of decomposition, called putrefaction. In the process of digestion, these substances are changed into peptones, and afterward, it is thought, into leucine, tyrosine and some other substances not well defined. An analogous decomposition is said to take place under the influence of dilute hydrochloric acid, at a temperature of 104° Fahr. (40° C.), and of dilute sulphuric acid, at a temperature of 212° Fahr. (100° C.). The chemical history of these substances would require for its comprehension an elaborate description such as properly belongs only to special works on physiological chemistry.

Non-Nitrogenized Alimentary Substances.—The important non-nitrogenized alimentary substances are sugars, starch and fats. They are all composed of carbon, hydrogen and oxygen. In sugars and starch, the hydrogen and oxygen exist in the proportion to form water, and these matters are therefore called carbohydrates. The non-nitrogenized constituents of food are of organic origin, definite chemical composition and crystallizable.

Sugars.—Many varieties of sugar occur in food, and this substance may be derived from both the animal and the vegetable kingdoms. The most common varieties derived from animals are sugar of milk, and honey, beside a small quantity of liver-sugar, which is taken whenever the liver is

used as food. The sugars derived from the vegetable kingdom are cane-sugar, under which head may be classed all varieties of sugar except that obtained from fruits, and grape-sugar, which comprises all the varieties existing in fruits. The following are the formulæ for the different varieties of sugar in a crystalline form:

Cane-Sugar (Saccharose), $C_{22}H_{12}O_{11}$
Milk-Sugar (Lactose), $C_{12}H_{24}O_{12}$
Grape-Sugar (Glucose, Dextrose), $C_6H_{12}O_6$

All varieties of sugar have a peculiar, sweet taste; they are all soluble in water, glucose being more soluble than cane-sugar or lactose; glucose is sparingly soluble in alcohol, which dissolves small quantities, only, of cane-sugar or lactose; glucose ferments readily and is changed into alcohol and carbon dioxide; cane-sugar and lactose are said to be incapable of fermentation, but cane-sugar may easily be converted into fermentable glucose, and lactose, into a fermentable sugar called galactose, by boiling with dilute mineral acids; they are capable of being converted into lactic acid in the presence of decomposing nitrogenized matters; they are inflammable, leaving an abundant carbonaceous residue and giving off a peculiar odor of caramel; they undergo other modifications when treated with the mineral acids or with alkalies, which are interesting more in a chemical than a physiological point of view. Of all the varieties of sugar, that made from the sugar-cane is the most soluble, the sweetest and the most agreeable. Beet-root sugar is identical with cane-sugar.

Much of the sugar used in the nutrition of the organism is formed in the body by the digestion of starch. This transformation of starch may be effected artificially. The sugar thus formed, called glucose, is identical in composition with grape-sugar. Except in the milk during lactation, this is the only form in which sugar exists in the organism, all the sugar of the food being converted into glucose before it is taken into the blood.

Starch.—A non-nitrogenized substance, closely resembling sugar in its ultimate composition ($C_6H_{10}O_5$), is contained in abundance in a great number of vegetables. It is found particularly in the cereals (wheat, rye, corn, barley, rice and oats), in the potato, chestnuts, and in the grains of leguminous plants (beans, peas, lentils and kidney-beans), in the tuberous roots of the yam, tapioca and sweet-potato, in the roots of the maranta arundinacea (arrowroot), in the sago-plant and in the bulbs of orchis. In the cereals, after desiccation, the proportion of starch is usually between sixty and seventy per cent. It is most abundant in rice, which contains, after desiccation, 88·65 per cent.

When extracted in a pure state, starch is in the form of granules, varying in size between $\frac{1}{10000}$ and $\frac{1}{400}$ of an inch (2·5 and 62·5 μ), and presenting, in most varieties, certain peculiarities of form. The granule frequently is marked by a little conical excavation called the hilum, and the starch-substance is arranged in the form of concentric laminæ, the outlines of which are often quite distinct. When starch is rubbed between the fingers, these little, hard bodies give it rather a gritty feel and produce a

crackling sound. The different varieties of starch may be recognized microscopically by the peculiar appearance of the granules.

Starch is insoluble in cold water; but when boiled with several times its volume of water, the granules swell up, become transparent, and finally fuse together, mingling with the water and giving it a mucilaginous consistence. The mixture on cooling forms a jelly-like mass of greater or less consistence. This change in starch is called hydration and is important as one of the transformations which take place in the process of digestion, when starch is taken uncooked. This change is generally effected more or less completely, however, in the process of cooking.

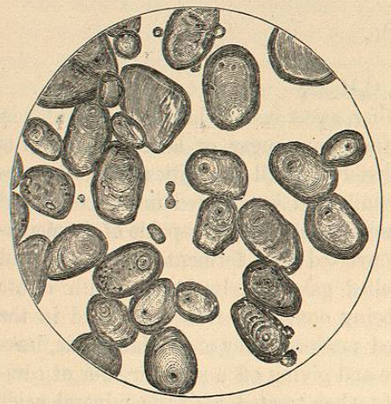

FIG. 49.—*Arrowroot starch-granules; magnified 370 diameters* (from a photograph taken at the United States Army Medical Museum).

The most important properties of starch are connected with its transformation, first into dextrine, and finally into glucose. This always takes place in digestion, before starch can be absorbed. In the digestive apparatus, the change into sugar is almost instantaneous, and the intermediate substance, dextrine, is not easily recognized. By boiling starch for a number of hours with dilute sulphuric acid, it is transformed, without any change in chemical composition, into dextrine, which is soluble. If the action be continued, it appropriates one atom of water and is converted into glucose. The change of starch into dextrine may be effected by a dry heat of about 400° Fahr. (204° C.), a process which is commonly employed in commerce.

Vegetable Substances resembling Starch.—In certain vegetables, substances isomeric with starch, but presenting slight differences as regards general properties and reactions, have been described, but they possess no great importance as alimentary matters and demand only a passing mention. These are inuline, lichenine, cellulose, pectose, mannite, mucilages and gums. Inuline is found in certain roots. It is convertible into sugar but does not pass through the intermediate stage of dextrine. It differs from starch in being very soluble in hot water. Lichenine is found in many kinds of edible mosses and lichens. It differs from starch only in its solubility. Mannite is a sweetish substance found in manna, mushrooms, celery, onions and asparagus. It is perhaps more analogous to sugar than to starch, but it is not fermentable and has no influence on polarized light.

Gums and mucilages may enter to a certain extent into the composition of food, but they can hardly be considered as alimentary matters. Gums are found exuding from certain trees, first in a fluid state, but becoming hard on exposure to the air. A viscid, stringy mucilage is found surrounding many grains, such as the flax-seed and quince-seeds, and exists in various roots

and leaves. Both gums and mucilages mix readily with water, giving it a consistence called mucilaginous. The composition of gum is $C_{20}H_{10}O_{10}$. Experiments have shown that gum passes unchanged through the alimentary canal and has no nutritive properties. Gum is mentioned in this connection from the fact that it is frequently used in the treatment of disease and is thought by many to be nutritious.

The carbohydrates, although important articles of food and especially useful in the processes involved in the production of animal heat, are not in themselves capable of sustaining life.

Fats.—Fatty matters, derived from both the animal and the vegetable kingdoms, are important articles of food. As a constituent of the organism, fat is found in all parts of the body, with the exception of the bones, teeth and fibrous tissues. It necessarily constitutes an important part of all animal food and is taken in the form of adipose tissue, infiltrated in the various tissues in the form of globules and granules of oil, and in suspension in the caseine and water in milk. Animal fat is a mixture of oleine, palmitine and stearine, in various proportions, and possesses a consistence which depends upon the relative quantities of these substances.

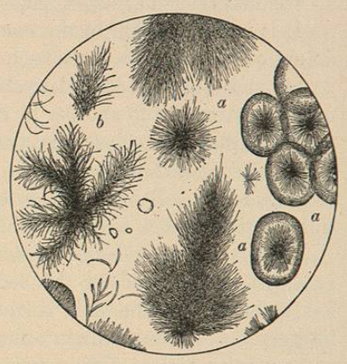

FIG. 50.—*Crystals of palmitine and palmitic acid* (Funke). *a*, *a*, *a*, palmitine; *b*, palmitic acid.

The different varieties of animal fats do not demand special consideration as articles of diet. Butter, an important article of food, is somewhat different from the fat extracted from adipose tissue, but most varieties of fat lose their individual peculiarities in the process of digestion and are apparently identical when they find their way into the lacteal vessels.

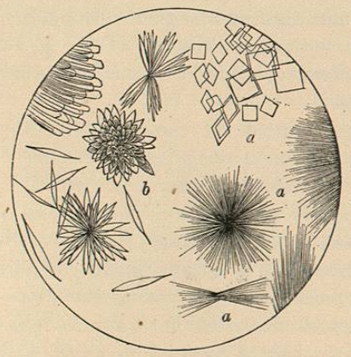

FIG. 51.—*Crystals of stearine and stearic acid* (Funke). *a*, *a*, *a*, stearine; *b*, stearic acid.

In the vegetable kingdom, fat is particularly abundant in seeds and grains, but it exists in quantity in some fruits, as in the olive. Here it is generally called oil. It exists in considerable proportion in nuts and in certain quantity in the cereals, particularly Indian corn.

Fat, both animal and vegetable, may be either liquid or solid. It has a peculiar oily feel, a neutral reaction, and is insoluble in water and soluble in alcohol—particularly hot alcohol—chloroform, ether, benzine and solutions of soaps. The solid varieties are exceed-