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THE SCIENTIFIC AMERICAN SUPPLEMENT,
No. 74,
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THE HUMAN MACHINE AND ITS FUEL.

Dr. Joule has pointed out that not only does an animal much more nearly resemble in its functions an electromagnetic engine than it resembles a steam engine, but he also has stated that it is a much more efficient engine—"that is to say," says Professor Tait, "an animal, for the same amount of potential energy of food or fuel supplied to it, gives you a larger amount converted into work than any engine which we can construct physically." In other words, the duty—by which we mean the percentage of the energy of the fuel which it can convert into the useful or desired form—is greater in the case of animal mechanism than in that of any other engine in which fuel is employed. The work we obtain in the form of heat, constructive power, nervo-muscular action, mechanical motion, and the like: and here the analogy between the body and a machine ends, because the food in the animal is not merely a source of energy, but it enters into the development and maintenance of the body itself. It follows, therefore, that two classes of food are necessary; first, the organic, which alone is oxidizable or capable of generating potential energy, and secondly, the inorganic, which, though not oxidizable, is essential to the metamorphosis of organic matter which takes place in the animal economy. The organic constituents of food are generally divided into nitrogenous, fatty, and saccharine compounds, and the inorganic into water and saline matters.

Taking up these constituents in their order, Dr. George Wilson, in his recent admirable work, "A Handbook of Hygiene," states that the nitrogenous portions of food have for their main functions the construction and repair of tissues, besides possessing other functions of a regulative and dynamic nature not well defined. Fatty constituents play an important part in the maintenance of animal heat and in the conversion of food into tissue. The oxidation of fat in the blood generates to a great extent the energy which is rendered apparent in locomotion and manual labor. It, besides, renders the human machine elastic, and supplies lubricating material. The saccharine constituents of hydrocarbons (cellulose, starch, and sugar) are directly subservient to the maintenance of animal heat and the production of animal energy. Water in the animal economy dissolves and conveys food to different parts of the system, removes effete products, lubricates the tissues, equalizes the bodily temperature by evaporation, and regulates the chemical changes which take place in the processes of nutrition and decay. Saline matters, on the other hand, are the chief media for the transference of the organic constituents throughout the body. They are largely concerned in the consolidation of the tissues, and are supposed to convert unabsorbable colloids into highly diffusive crystalloids.

As we have already stated, the potential energy of food is the sole source of the active energy displayed in mechanical motion or work. And consequently, up to certain limits, the diet must be increased as the work increases. The question for the economist is then, first, on how much food can a man subsist and live: and second, how much more food must be added when certain work is to be performed. Dr. Edward Smith has determined that the Lancashire operatives during the cotton famine managed to live on 3,888 grains of carbon and 181 grains of nitrogen per day. This is equivalent to about 2 lbs. of baker's bread. On the other hand, a man, who could live on this amount during idleness, while at work requires (according to Dr. Letheby) 6,823 grains of carbon and 391 grains of nitrogen. This is equivalent to 2 lbs. of beef, with 1 lb. of potatoes, 1 lb. of beer, and about ¼ lb. of sugar.

Of course the quantity of the food required differs not merely with the amount of work done, but with its quality. Dr. Smith has prepared a table showing the weekly dietaries of low-fed operatives. Needlewomen, for example, in London average 124 ozs. breadstuffs, 40 ozs. potatoes, 7·3 ozs. fats, 16·3 ozs. meat, 7·0 ozs. milk, 0·5 oz. cheese, and 1·3 ozs. tea per week. This diet is richer in meat than that of the English farm laborer. The Macclesfield silk weavers are quoted at 3·2 ozs. meat per week. The Irish farm laborer gets but 4·5 ozs. meat weekly, but he has 326 ozs. breadstuffs and 135 ozs. milk. The Scotch farm worker eats over twice as much potatoes as the Irishman, despite the supposed fact that the tubers constitute the principal article of diet among the peasantry of the Emerald Isle. The table compiled by Dr. Smith includes silk weavers, shoemakers, farm laborers, and needlewomen, and the average diet per day for all is 4,881 grains of carbon and 214 grains of nitrogen. We can contrast with this, data obtained by Dr. Playfair covering the diets of English railway navvies, English and French sailors, soldiers in peace, prizefighters, hard-worked weavers, and blacksmiths. This shows that the average is 5,837 grains of carbon and 400 grains of nitrogen per individual per day. There are many suggestive comparisons to be made here. Take for example the figures relative to weavers. There is one class of these operatives who do light work on a daily average of 3,861 grains of carbon and 157 grains of nitrogen; when at hard work, this becomes 6,020 grains of carbon and 375 grains of nitrogen. As shown above, the first-mentioned quantities are no more than barely sufficient to sustain the body; and work here practically means a wearing away of the human machine. Now when the work becomes harder, 2,159 grains of carbon and 218 grains of nitrogen more are consumed; and these are the food equivalent for the extra work performed. In the case of the prizefighter in training, the daily average in point of carbonaceous matter is less than that of the low-fed operative, but the nitrogenous matter—flesh and muscle manufacturing material—the average is 690 grains, or over three times greater. The proportions of the training athlete's daily food are flesh formers 9·8 ozs., fats 3·1 ozs., starch and sugar 3·27 ozs.

It will be seen from the foregoing that it is quite possible to construct dietaries, especially suited to sustaining the animal mechanism, in accordance with the work to be accomplished. This subject we shall consider in another article.

WANTED—TORPEDO DEFENCES.

Mr. E. J. Reed, late Chief Naval Constructor of the British Navy, in a recent lecture before the Society of Arts, took occasion to express an opinion which, we think, every one who has given any thought to the method of waging future maritime wars has already more or less definitely reached. Coming from an engineer who has been so closely identified with the building of the ironclad navy of Great Britain, the views enunciated will assume greater force. They could not be more radical or more direct. Mr. Reed says, in substance, simply that, until a way of protecting vessels from the effects of torpedoes is invented, ironclad ships, notwithstanding their 24 inch armor and 100 ton guns, are anachronisms, and that their construction is waste of time and money. "Neither the suspension of chain nets, nor additional bulkhead divisions in ordinary forms of ships, will be a sufficient, nor anything like a sufficient, defence against this deadly submarine instrument of attack. The naval Whitehead torpedo delivers a most terrible blow; it moves for the space of some hundreds of yards with a speed double that of the fastest ironclads; its path is so sure and true that at that distance a second torpedo can be made to pass through the hole which the first has made; and whereas it has been assumed that, in ordinary conditions of weather and naval warfare under steam, a ship could not have more than a few feet of her depth below water attacked, the torpedo has the whole immersed bottom of the ship exposed to its assaults." Mr. Reed goes on to say that the days of war ships, more or less long and narrow, and with deep bottoms of thin iron containing the steam boilers and powder magazines, are numbered. He advises his government to reconsider its intention of beginning the building of a vessel of the Agamemnon class; and finally he concludes that modern naval necessities are "first, the construction of our large ships on principles which make them as little destructible by torpedoes as by guns, which I believe to be quite possible; and secondly, the building of all our other war ships of small and handy types." By the latter he means small vessels which can be manœuvred with sufficient rapidity to avoid torpedoes.

Mr. Reed unfortunately fails to mention the plan for protecting ships against torpedoes, the knowledge of which he implies that he possesses. It will be seen, however, that in his opinion a total reconstruction of the English navy is necessary, and that consequently the enormous sums of money which have been expended on its development are entirely thrown away. This is not cheering intelligence to the British taxpayer; and we doubt whether its purport will be acquiesced in until inventors, the world over, confess themselves vanquished by the problem of devising an efficient system of torpedo guard. So long as enormously heavy artillery is to be used, vessels must be built both capable of carrying the guns and likewise capable of resisting them. Already it is contemplated to build cannon which will dwarf the 100 ton gun; and the English iron founders, on the other hand, promise 40 inch rolled plates. If war ships must carry such loads of metal as these, it is difficult to see how they can be built light enough to dodge torpedoes. There is certainly little to be gained by building vessels possessing the latter advantage, if at the same time they are to be rendered easily vulnerable by heavy guns.

We agree with Mr. Reed in the belief that it is possible to protect large vessels against torpedoes, although we have no especial project to propose. The subject is one which we would particularly commend to the attention of inventors. It is obvious that the necessary protections can be obtained in two ways: first, by devices outside or extraneous to the vessel, and second, by modification of the construction of the ship itself. The simplest outside device is the torpedo netting constantly used by our vessels during the war. This is simply a network of chain or rope supported on booms at some distance around the ship and extending down into the water deep enough to guard the entire bottom. To prevent the access of torpedo launches, the ship may be surrounded by heavy spars also attached to the booms, and from these chain nets, as already described, may depend. These devices are obviously of little use or altogether impracticable when the vessel is in motion. To avoid stationary torpedoes anchored in channels, ships have used forked catchers protruding from the cutwater, to grasp and cause the explosion of the obstruction. Rafts pushed in front of ordinary vessels likewise serve a similar end. Under the second plan, war ships are built in watertight compartments. The Inflexible, for example, has 127 such sections. Or, as in the case of Admiral Porter's boat, the Alarm, there is a double hull with the space between divided up, while the entire hold of the ship may, through the watertight bulkheads which cross it, likewise be converted into separate sections. A torpedo, it is supposed, might injure a few compartments, while those still staunch would perhaps float the vessel. With iron ships there is not much surplus of buoyancy, however, and the racking effect of a blast might cause results much worse than the direct injury to the compartments immediately adjacent. Probably the means of defence, nearest to security, lie first in keeping the vessel constantly

under steam and under control, and second in the electric light which reveals the approach of an enemy by night. But the circumstances of weather or of locality may prevent the rapid manœuvring of the ship, and a fog may render the electric beam useless: while there is no safeguard against the unseen approach of the submarine torpedo of the Ericsson, Lay, or Whitehead type.

The conditions of the problem need no especial explanation. It is simply a question of how to render a ship's bot tom invulnerable, not merely to the explosion of the torpedo itself but to that shock *plus* the energy of the ramming blow delivered by the sharp bow of a heavy torpedo boat. An invention of this kind would be immensely valuable to every naval power, and would insure fame and fortune for its originator.

TORPEDOES.

BY G. GAKUMA.

The development of submarine warfare has been so rapid of late that it is hardly possible to foretell what potent influence it may have on the war now being waged in Eastern Europe. While England, France, Italy, and in fact nearly all the European naval powers, have been building huge engines of war, of a tonnage, armor, and artillery never heard of before, the torpedo has been gradually perfected, and threatens, at least under many circumstances, to neutralize them. A torpedo may be regarded as a gun which dispenses with a gun carriage, and which, without the vast and expensive agency of a great ship, inflicts as formidable a blow as that of the heaviest artillery.

The original inventor was David Bushnell, born at Westbrook, Connecticut, 1742. He not only devised a torpedo, but also a submarine rowing boat, intended to convey it to the bottom of the vessel to be attacked. His practical experiments, however, which he was enabled to carry out with the assistance of the private purse of George Washington, did not prove successful; and the invention sank into oblivion until the commencement of the present century, when Robert Fulton, an American sojourning in France, offered a similar one to the French Government. After considerable parleying, it was rejected, and Fulton sold his secret to the British Admiralty for $75,000. The so-called Catamaran Expedition, an attempt to destroy the French line-of-battle ships and transports off Boulogne, turning out a failure, Fulton returned to the United States, and, during the war of 1812, tried in vain to blow up several of the English blockaders. The rage of the British commanders knew no bounds and the proceedings were termed "unchristian," "the invention of a fiend," etc. Cousin John Bull has a frightfully short memory at times!

In 1829, Colonel Samuel Colt commenced experiments with a submarine torpedo exploded by a galvano-electric battery; and after many disappointments, he succeeded on October 18, 1842, in destroying the brig Volta in New York harbor, in the presence of 40,000 excited spectators. So far only vessels at anchor had been attacked; but on April 13, 1843, Colt blew up a brig of 500 tons under sail on the Potomac river, he himself being the operator, and at the time at Alexandria, five miles distant from the explosion.

The first European government to adopt the invention was Austria, who laid down a perfect electric torpedo net for the defence of Venice. Russia followed suit, and during the Crimean war protected the entrance of Cronstadt as well as that of Sebastopol harbor by an improved system of ground torpedoes, which kept the English fleet at a respectful distance. The American civil war for the first time clearly demonstrated the tremendous effect of the invention, and at the same time changed its character from a purely defensive to an offensive weapon. Galled by the soon-established superiority of the United States navy, which gradually sealed up all the important Southern ports, the Confederate Government organized a special torpedo service corps; and after sinking torpedoes in every available approach, they proceeded to build small steamers constructed to carry spar torpedoes. These torpedo boats, with an easily comprehensible Biblical allusion, were called "Davids," and were in several instances used with as much pluck and perseverance as terrible effect. The United States soon imitated the David, and in 1864 the late Commander Cushing, U.S.N., succeeded in destroying the Confederate ram Albemarle, lying at anchor in the James river. Since then the electric apparatus for torpedoes and the torpedo itself have been vastly improved; and numerous new inventions have been introduced, all of which, however, may be classed under the following five heads: Ground torpedoes, spar torpedoes, Harvey (towing) torpedoes, Whitehead (fish) torpedoes, and the Lay torpedo.

GROUND TORPEDOES.

The ground torpedo is a sort of sunken mine, exploding either by contact or by electricity. If these are judiciously laid down around a harbor or anchorage, the approach of hostile ships may be rendered impracticable, provided always they are protected by shore batteries or armed ships to prevent removal. Every channel may be barred by these hidden mines; and they may be made so powerful that any ship under which they explode is sure to become hopelessly disabled. They are fastened to and held in their positions either by anchors or by stockades. The bursting charge consists of gunpowder, gun cotton, or dynamite; and the case or shell is either made of iron or wood; in Charleston harbor, old steam boilers were frequently used.

SPAR TORPEDOES.

The spar torpedo is fastened to the end of a spar from 15 to 38 feet long, carried in a boat, no matter how small, and explodes also either by electricity or contact. A most remarkable experiment was recently made at Cherbourg, France, with spar torpedoes, carried by a little vessel called the Thorneycroft, which was almost submarine. We illustrated this invention on pp. 239 and 246 of our current volume. A very small part of it was above water, but it was of sufficient strength to carry engines and two lateen sails, and it was worked by a lieutenant, two engineers, and a pilot. The French Admiral had two disabled ships in succession towed out to sea at a speed of 14 knots an hour. The Thorneycroft, however, was able to go at the rate of 19 knots an hour, a rate not attained by any vessel in the squadron. She very soon caught up with her prey, delivered her blow with a spar torpedo, which projected from her bow, and rebounded. A rent as big as a house was made in the side of the ship attacked, and she sank at once. The Thorneycroft only spun round and round for a few moments, and then returned uninjured to the squadron, from which she had started. A vessel of this kind is scarcely discernible in the water; even if she were detected, she is so small that it would be difficult to hit her; and half a dozen Thorneycrofts attacking a large vessel would be a most dangerous foe. Their expense is quite trifling compared with that of great ships of war; they can be multiplied indefinitely, and they can be carried on board other ships and be launched from them as occasion may require. The Italian Government has already carried out this idea in the construction of her formidable new ironclads Dandolo and Duilio. These vessels are fitted in their sterns with a sort of armored dry dock, harboring a small torpedo steamer. As soon as the services of the latter are required, the dry dock is filled with water and opened, and the little craft rushes out at the enemy, returning to her safe berth after her mission has been fulfilled. Admiral Porter's torpedo vessel Alarm, also recently illustrated by us, is fitted with spar torpedoes, both for bow and beam; but the torpedo generally supplied to all the cruisers of the United States is the

HARVEY (TOWING) TORPEDO.

Invented by an English officer in 1862, it was soon adopted by nearly all the other navies, and probably will be exclusively used in general actions at sea as least liable to injure a friendly vessel in the *mêlée*. The Harvey torpedo is towed upon the surface of the water by a wire rope towline from a derrick end of the yard arm over or against the enemy; and just before reaching the ship to be destroyed this towline is slackened, and the torpedo, being heavier than water, dives under it. When in this position the explosion is effected by means of a mechanical firing bolt striking down upon a pin as soon as certain levers of the torpedo come into contact with the bottom of the target. This torpedo can also be made to explode by electricity. Two different forms are used for starboard and port.

WHITEHEAD (FISH) TORPEDOES.

This invention is the secret and the property of the British Admiralty, but the following details have leaked out: These torpedoes resemble in shape a cigar, pointed at both ends, and are 18 feet long by two feet in diameter. The inside is divided in three different compartments: First, the head, which contains a charge of 350 lbs. of gun cotton and the pistol or detonator to explode it; secondly, the balance chamber, which contains a contrivance for setting it so as to remain at any depth at which it is wished to travel under the water line; and lastly, the air chamber, which contains the engines and the compressed air to drive them. The after end supports the screws—a right and a left handed—which propel the torpedo and are made of the finest steel. The air chamber is tested to the pressure of 1,200 lbs. on the square inch, although for service it is only loaded to 800 lbs. The Whitehead torpedo can be made to go at the rate of 20 knots for 1,000 yards, and at any depth that is desired from 1 foot to 30 feet. It can be set to explode either on striking an object or at any particular distance under 1,000 yards—in artillery language, either by a percussion or a time fuse. It can also be set so that, if it misses the object aimed at, it will go to the bottom and explode at half cock or come to the top on half cock so as to be recovered, as it has buoyancy enough just to float on the surface of the water when not in motion. It is fired from what is called an impulse tube, which, out of a frame fitted to a port, discharges the torpedo into the water. It can be fired above the water, but will at once go to the depth it is set for, and then go straight to the object, no matter how fast the ship from which it is discharged is going, or how fast the object aimed at may be sailing or steaming. It fact, it seems that it can do anything but speak. It is calculated to make a hole on bursting of 70 feet area, and there is no doubt that, if one of them hits a ship of any sort or description at present on the water, she must at once proceed to the bottom. It is evident that by this means a comparatively feeble ship, if only able to approach within 1,000 yards of a large one, can discharge a deadly flight of unseen projectiles at her, and at night such an attack will probably be wholly unsuspected and scarcely open to resistance, as the vessel fired against will be positively unaware of the attack until she is blown up. The newly invented electric light from the tops is a great help to the party attacked; but if three or four boats of great speed attack a vessel from different points of the compass, and if they are commanded by smart officers, nothing that she can do will save her from being hit by one or more of them. There is no doubt whatever that this torpedo is the most formidable weapon of modern naval warfare.

THE LAY TORPEDO.

Properly speaking, the invention of Mr. Lay, purchased by the United States Government, is not a torpedo, but a very ingeniously devised submarine torpedo boat fitted with a spar torpedo. This boat has the advantage of not requiring any crew on board, but in other particulars is capable of great improvements. The motive power consists of an engine driven by carbonic acid gas and a screw propeller. The boat is entirely submerged, and is steered and in all other respects controlled by means of an electric battery on shore, connected with her by a cable which is coiled up in her hold and pays out as she moves away. Her location is indicated above the surface of the water by a flag, so as to enable the operator to direct her course. The greatest defect of the Lay torpedo is want of speed. The United States Government stipulated for a speed of 9 statute miles per hour, but the maximum speed actually attained at the late trial trip, when it was steered by Lieutenant R. B. Bradford, U.S.N., showed only an average of 6·60 miles per hour, so that a ship attacked would only have to lower her boats and let them row between the approaching torpedo and the shore, and cut the cable, which would leave the torpedo at their mercy. The defence of ships against torpedo attacks of all kinds is at present very imperfectly developed, principally owing to the fact that the offensive qualities of any weapon must first be learned before effectual means of defence can be devised; and as actual warfare only can give a correct idea of the former, we are, no doubt, on the eve of very startling events, which may entirely revolutionize and change every recognized principle of naval tactics.

The great anxiety felt in England for the future safety and efficiency of the British navy, on account of torpedoes, is shown by the attempted formation of an International Torpedo Association, which Lieutenant Colonel Martin, of Boxgrove, Guildford, late commanding 4th (the King's own) Royals, is about to set on foot. He says in his programme: "When explosive bullets and chain shot were invented and actually used in war, nations unanimously agreed to discontinue their use and prohibit their manufacture; yet explosive bullets and chain shot, it must be admitted, are harmless as compared with torpedoes. Poisoning is prohibited in war. Why not prohibit torpedoes, which are actually more subtle and deadly than poison, there being no antidote to escape from them? For instance, were I allowed to fire (from a mortar) gutta percha bags filled with strychnine and charged with a burster and time fuse to cause the bag to burst and scatter its diabolical contents over some obstinate city or fort which would not capitulate, this visitation would be far more merciful in its way towards the people of that city or fort than torpedoes would be against crews of ships, because the strychnine could be seen and avoided by flight; whereas, on the other hand, torpedoes secretly moored, or even fish torpedoes, insure complete, sudden, unexpected, and unavoidable destruction. Several clever artisans have already been killed by merely pumping compressed air into the tails of unloaded fish torpedoes. Had these torpedoes been loaded with gun cotton for service on board ship, and even if one of them exploded from careless handling during action while compressed air was being supplied to start it, or if by chance a shot or shell struck the ship at the time of starting a fish torpedo on its death track, the fearful consequences may be easily imagined. As a proof that governments appreciate the danger they incur by the use of torpedoes, I may here state that it is well known that, after the Austro-Italian war, all the picked-up torpedoes proved to be dummies. It is our bounden duty to keep pace with other countries, but every one will admit that the sooner the "International Anti-Torpedo Association has accomplished its task, the better for the cause of humanity!"

It is much to be feared that other nations will prefer to take a different view of the case, and continue to consider torpedoes a cheap and effective counterpoise to the costly and powerful English ironclads.

American Silk Manufacture.

A recent report of Mr. F. Allen, Secretary of the Silk Association of America, states that the total manufactures of silk in this country for 1876 were valued at $26,593,103. The business of last year is not considered satisfactory, although the raw silk consumed was within 150,000 lbs. of the largest amount used in any previous year. This unsatisfactory condition is ascribed to the use in the price of raw material, amounting on the average to 100 per cent; to the pressure brought to bear on our markets for goods by foreign manufacturers who had injured their markets abroad by excessive adulteration, in some cases reaching more than threefold the weight of the silk; and to the great extent of frauds by undervaluation at the Custom House. The estimate of loss to the revenue from the last named cause alone is placed at $4,000,000.

Titanic Iron from the Ural.

J. Popov has recently published analyses made by him of two titanium minerals from the Ural. The first is an ordinary titanic iron ore, containing magnesia; the other a perimorphose of the same in which the iron seems to be replaced by lime, only half a per cent of protoxide of iron remaining. The iron ore contained: Titanic oxide 56·81 per cent., sesquioxide of iron 4·02, protoxide of iron 19·65, protoxide of manganese 1·73, protoxide of magnesia 17·18; total 99·39. The perimorph contained: Titanic oxide 58·85, lime 40·83, protoxide of iron 0·58; total, 100·26.