to those described above as the result of the hypertrophy of the gland in response to iodine deficiency; the colloid disappears, the glandular epithelium undergoes hyperplasia, and coincidentally with these changes the iodine content of the gland diminishes. It is clear, therefore, that the thyrotropic hormone stimulates both the growth and activity of the glandular epithelium of the thyroid and the release of the active secretion into the blood stream.

Nothing is known of the way in which the pituitary controls thyroid activity in normal life. From what has been said, however, it will be clear that the possibility, and indeed the likelihood, of the existence of such control is now beyond dispute. The possible pathological implications of the work which has been done on the thyrotropic hormone are obvious. They cannot be discussed in detail here, but it may be pointed out that administration of the hormone affords the only known means of producing experimentally a syndrome indistinguishable from Graves's disease, and, further, that the histological and chemical changes which occur in the thyroid in Graves's disease are precisely similar to those elicited by thyrotropic hormone.

A stumbling-block in the way of understanding the normal mode of action of the thyrotropic hormone is that the effect of its administration is only temporary. After about six weeks the condition of an animal under treatment with it becomes again apparently normal, and, moreover, the blood serum at this time acquires the property of neutralizing the effect of thyrotropic hormone given to another animal, suggesting that an antibody against the hormone has been developed. The meaning of these observations remains quite obscure, but the phenomenon which appears to extend to other hormones of the anterior pituitary is one of great interest, and is being intensively studied by several groups of workers. If its explanation can be attained much light may be thrown on the whole question of hormone action.

Summary and Conclusions

The conclusions of this and the preceding article may be summarized as follows:

1. The thyroid has a specific affinity for iodine which enables it to utilize practically all of this element which normally gains access to the body.
2. The iodine taken up by the thyroid is introduced into the molecule of tyrosine to form 3:5-diiodotyrosine; part of this is further converted into thyroxine, which is the only naturally occurring pure compound to exhibit the qualitative physiological properties of the thyroid gland.
3. The thyroxine and diiodotyrosine so formed are then linked, either directly or, more probably, through other amino-acids, and are finally built up into the molecule of thyroglobulin or colloid, which constitutes the storage form of the thyroid secretion.
4. The true thyroid secretion is in all likelihood a peptide containing both thyroxine and diiodotyrosine, and is liberated from thyroglobulin and released into the blood stream in response to the demands of the body.
5. The general effect of the thyroid secretion is to control the rate of metabolic processes, and to this can be referred almost all if not all of the individual effects of the secretion on different organs or tissues which have been observed.
6. The normal function and structure of the thyroid are intimately dependent on an adequate exogenous supply of iodine; deficiency of this essential component of the active secretion leads to a work-hypertrophy of the gland with profound structural changes.
7. The functional activity of the thyroid is possibly subject to an inhibitory control by the suprarenal cortex;

it is undoubtedly influenced by the activity of the anterior pituitary, the thyrotropic hormone of which is able to induce in the thyroid of a normal animal a high degree of glandular hypertrophy and secretory hyperactivity.

BIBLIOGRAPHY

- Marine, D.: *Physiol. Rev.*, 1922, ii, 521.
Harington, C. R.: *The Thyroid Gland*, Oxford University Press, 1933.
Idem: *Lancet*, 1935, i, 1199, 1261.

THE RECOGNITION OF FATIGUE, WITH SPECIAL REFERENCE TO THE CLINICAL DIAGNOSIS OF MORBID FATIGUE IN INDUSTRY*

BY

HOWARD E. COLLIER, M.B., CH.B.

In his book *The Economics of Fatigue and Unrest*,¹ Sargent Florence rightly remarks, "as is usual with words that have come into popular use, 'fatigue' symbolizes several related things, just as 'unrest' was found to do. Particularly we must distinguish the *feeling* of fatigue or tiredness, the outward *manifestation* of fatigue in reduced efficiency, and a probable inward physiological *state* of fatigue. How far these three things are concomitant is still under investigation." Much of the confusion and vagueness which at present surround the whole subject of fatigue has arisen, as it seems to me, from the fact that the physiologist, the psychologist, and the industrial engineer have each concentrated attention upon a single aspect of fatigue. The isolated studies of these specialists have not been drawn together, nor have they been related to the underlying unity of which each is a part. We have, therefore, a physiology of fatigue, a psychology of fatigue, and a "science" of human efficiency, but we have no clear view of fatigue as a clinical entity—that is to say, of fatigue as a disorder of health from which actual people are suffering. This present discussion represents an attempt to approach the subject of fatigue, and especially the subject of morbid fatigue as it occurs in industry, from the wider angle of its human or clinical manifestations.

Human fatigue is not an abstract entity: it has no existence except as a state of living persons. If, then, we are to bring order into the confusion which surrounds the study of fatigue we must make a fresh start; we must approach it from the clinical angle and must endeavour to relate the discoveries and researches of the specialists to one unifying conception.

The absence of such a unifying conception may have results which are practically dangerous. Thus, by a study of "production rates" the industrial engineer may conclude that the "highest industrial efficiency" can be attained by increasing the rate of production in a certain manufacturing process by a given figure. Yet the engineer, being a specialist, may fail to realize that his added production is only to be won at the hidden cost of ill-health, of premature invalidity of the workers, of serious increases in accident rates, or of a larger amount of spoilt work. That this danger is a real one is obvious to clinical observers. The danger is still further increased by the fact that there exist certain strong emotional and psychological "drives" that are capable of raising human productivity to a level which is "unphysiological." A worker may unconsciously do harm to his health when he is in the grip of these powerful motives. (It is here that we touch upon the field of the expert psychologist.) These hidden costs of unphysiological production are observed by the clinician who is called upon to diagnose unexplained illness, or they can be recognized by the industrial manager when he is confronted by unexplained variations in his production statistics. Finally they may be noted by the observant workman when he himself or his fellow workers fall ill.

* A paper read at the British Association for the Advancement of Science, Blackpool, September, 1936.

The most important of these potentially dangerous emotional urges are the lure of high wages, the fear of unemployment, self-regard, and hyper-conscientiousness. Any of these motives may drive individuals and groups of men through the stage of fatigue into that of actual illness, yet neither the worker nor the manager may be aware of what is actually happening. I have seen cases in my practice of men who have ruined their health as a direct result of the passion for "big money," and others who, fearing dismissal, have persisted at overtime or on night work until a serious illness has supervened. It is unnecessary to elaborate this point, but it is important to emphasize that studies of isolated aspects of fatigue may lead to very erroneous conclusions.

Fatigue as a Clinical Entity

The tired worker not unreasonably blames his real fatigue upon the most recent innovation in industrial methods, yet all the while his fatigue may really be due to causes which operate outside the factory. The manager, on the other hand, lacks any recognized method by which he may know whether any alterations in production methods are increasing or diminishing real industrial efficiency. If increased production has to be offset against many intangible and hidden industrial or social losses, increased production may be won at too great a cost. The human organism is so flexible that it is able to respond to extra calls upon its strength for a time, only to collapse, it may be months or years afterwards, in an apparently inexplicable manner. Those who served in the war remember the slow, insidious onset of "war fatigue," with its final sudden, inexplicable collapse of "morale" or its unexpected explosions of "sickness." The worker, for his part, needs to know whether he is really overworking himself; the manager needs to know whether any alterations in his methods of production still keep the pace of production within the limits of the psychophysiological powers of his staff. If those limits are exceeded inefficiency, ill-health, and accident will soon rob him and rob society of most, if not all, of his apparent production gains. From a clinical or a medical standpoint only a narrow margin separates fatigue from disease. It has been observed that artificially fatigued animals succumb with excessive rapidity to infection with the pneumococcus, and every clinician knows how often manifest ill-health is preceded by a period of more or less prolonged "overwork."

I hold, therefore, that sufficient attention has not been paid to the study of fatigue in human beings as a clinical entity, as a precursor of disease, and as an important factor in the rising tide of sickness and invalidity among the industrial population. I do not say, of course, that fatigue is the sole cause of this increase in sickness; but that fatigue of one kind and another (industrial and non-industrial) is an important factor my experience of the health conditions of the industrial worker leaves me no room to doubt. If, then, by drawing attention to what is already known about the clinical symptoms and signs of human fatigue in industry we can succeed in encouraging a closer study both of this important health problem and of the scientific measures which we have already at our disposal for the successful control of it, my purpose will be amply fulfilled. To that study must be brought the contributions of clinician, physiologist, psychologist, and engineer, while to the prevention of fatigue in industry must be brought the teamwork of a whole army of practical specialists.

Any systematic discussion of fatigue must proceed from the general to the particular. Industrial fatigue is a particular kind of fatigue due to industrial factors. Any scheme of diagnosis which aims at the recognition of industrial fatigue must be designed to assist us to isolate the industrial from all non-industrial factors. In practice we need to be able (1) to determine the limits of safety under given industrial conditions up to which methods and speeds of work may be operated without causing fatigue; and (2) to be able to recognize the actual existence of industrial fatigue either in a worker or in a group of workers.

What is Fatigue?

Human fatigue may be defined provisionally as a state of the human organism in which there is a significant lack of balance between intake and output of biological energy. This absence of harmony may exist between the organism and its environment or between the various subordinate parts within the organism itself. Fatigue is due to this "lack of balance," and it manifests itself as a deterioration of efficiency, as feelings of tiredness, as physiological changes in the bodily organism (pulse rates, pulse pressures, etc.), or as combinations of all of these. It is not a disease, but it may be prodromal to disease. Health depends upon the constant maintenance of a balanced living economy. The passage from health to disease is, as a rule, a gradual process of transition, one stage of which may be fatigue. This state of "healthy balance" between intake and output is a phenomenon of life itself. Now there are many kinds of absorption or intake and many kinds of biological expenditure or output, all of which bear complicated relations to each other. Thus in health, our food and our oxygen requirements are balanced to the energy needs of all parts of the whole body. In health the recuperation of our nervous emotional energies is equal to our nervous-emotional output or expenditure; in fatigue, output exceeds intake; katabolism is greater than anabolism. Rest, change, and sleep as well as food and air are important factors, therefore, both in the maintenance of health and in the production of fatigue. It is important to recognize that "unbalance" may be qualitative or quantitative, and that it may be due only to the time factor—that is, to a lag in recuperation after work has been done.

Normal Tiredness and Temporary Exhaustion

The human organism begins to suffer from fatigue whenever the available reserves required for any particular kind of activity have become dangerously depleted. Like pain, fatigue is a defence mechanism. This depletion may be quite transient, and the individual may rapidly recover from it; on the other hand, recovery may take a long time. If the depletion is transient the resulting fatigue is merely a temporary exhaustion or a normal tiredness. Every day of hard work should leave us tired, but tiredness of this kind is not morbid fatigue. Normal physical or mental tiredness is distinguished from morbid fatigue by the fact that a brief rest (say for a night) abolishes the tiredness. Therefore the first step in the diagnosis of fatigue is to discriminate normal tiredness or temporary exhaustion from morbid fatigue. The exhaustion of the athlete at the end of a race is an example of temporary exhaustion. Many physiological researches and some of the "tests of fatigue" about which a good deal has been written have been studies of these exhaustion phenomena rather than of the kind of morbid fatigue which we meet in modern life and industry. Normal tiredness and temporary exhaustion need concern us no further in the present discussion. It is enough to recognize their existence.

Subacute Fatigue

The degree of the exhaustion of the energy reserves of a part or the whole of the organism may be so profound that a brief rest serves only partially to restore those reserves. In that case, if the activity which caused the fatigue is continued at the same degree of intensity upon the next day, a progressive depletion of the reserves begins and a cumulative morbid fatigue develops. Each morning finds the tired worker less prepared for his work; a vicious circle is set in operation, and a chronic, progressive, cumulative fatigue of the overworked or under-rested function is established. It often happens, however, that a more prolonged rest at the end of the week is sufficient to break the vicious circle. In modern life cases of mild subacute fatigue from which the individual recovers at the week-end are familiar enough. Nor is it uncommon to observe the ill effects that follow inadequate rest at the week-end. If the week-end rest is not sufficient to restore the depleted reserves, or if, for any

reason, that rest is interfered with by work or by unwise recreation, the progress of the fatigue is rapidly accelerated and chronic morbid fatigue develops.

Kinds of Chronic Morbid Fatigue

Enough has been said to make it clear that chronic morbid fatigue, even when it occurs among industrial workers, is not always due to industry. Experience teaches us that neither illness nor fatigue is ever due to single, isolated causes: both are the outcome of a number of causes acting together. It is useful and customary to classify fatigue, therefore, according to the most important factor in the causation of the particular case under discussion. If the fatigue can be shown to be due predominantly to our lack of skill or practice we term it "learning fatigue"; if it is due, predominantly, to the nature, intensity, or conditions of our occupation we speak of "industrial fatigue"; while if it is due chiefly to poverty, to neglect of the laws of health, to bad feeding, to lack of rest, or to hectic recreations (all of which operate chiefly outside a man's occupation), we should term it "personal or non-industrial fatigue."

Learning fatigue commonly occurs during the acquisition of a new skill or upon the resumption of a task at which we lack practice. This kind of fatigue is well recognized. Its presence is revealed, for example, by the high accident rate observed among "learners" and among men who have been long unemployed when first they return to work. It has great industrial importance, but it can largely be obviated by intelligent oversight. Learning fatigue, however, is not what we mean by morbid industrial fatigue. One important practical point concerning learning fatigue is that we are not justified in concluding that any new process or method will produce "fatigue" until the workers engaged upon it have had sufficient time to become proficient at the new process and adapted to the new conditions.

If the views expressed above are sound it should be possible to set out a scheme or method for the practical diagnosis of morbid fatigue in industry. This diagnosis should include not only the recognition of fatigue as it occurs among individuals and groups of workers, but also the diagnosis of the *actual factors* in the industrial situation from which that morbid fatigue arises. When once a complete diagnosis has been made we shall be able to approach the problem of prevention in a coherent and scientific manner also.

Diagnosis of Morbid Industrial Fatigue

The experienced medical practitioner always suspects fatigue when he is confronted with a patient who shows the following general characteristics. The patient looks tired, his eyes are heavy, he yawns, his shoulders droop, he moves slowly, and his complexion is pallid. He complains of tiredness in the morning, sleeps heavily but is unrefreshed, frequently suffers from headache, and complains of vague pains in some part of his body. He is "out of condition," is readily exhausted and may be short of breath, his urine is, as a rule, thick and turbid. But in spite of looking ill, his temperature is normal, or perhaps subnormal, and the most exacting physical examination fails to reveal any clear indication of recognized disease. Such patients are clumsy, are liable to accident through inattention, their minds wander during a conversation, they are irritable, bad-tempered, and very apt to be offended. Especially they resent loud noises. "Debility" is the usual diagnostic label which the medical practitioner attaches to this condition. No one familiar with modern life can fail to recognize this common symptom-complex. Confronted with a patient with this symptom-complex the doctor's first step in diagnosis is to exclude gross physical disease. Having eliminated intercurrent illness, the next step is to endeavour to discriminate between the non-industrial and the industrial factors in the particular case under consideration. It often happens, for example, that of a group of workers engaged in moderately strenuous or monotonous occupations only one or two of them will show signs of fatigue. Careful inquiry will reveal that those who have broken

down are malnourished, worried, are suffering from illness, or are of subnormal physique. Measures directed to correct these errors may be all that is needed to abolish the morbid fatigue.

Proceeding with the diagnosis, the next step is to eliminate learning fatigue as an important factor in the special case. If the condition is due to the fatigue of learning, a short rest, followed by persevering efforts to master the new technique, will result in a cure, provided the patient's physique is adequate to do the prescribed work once skill has been acquired. My experience suggests that many young persons who are selected haphazard for their employment, and are chosen according to their age rather than according to their physical development, suffer from a form of real morbid industrial fatigue which may be easily confused with learning fatigue. This is especially the case among young persons employed at such tasks as tile or brick carrying, and as messenger boys and parcel carriers. No young person should be allowed continuously to carry weights which are more than one-third of his body weight; for short distances and for brief spells of carrying slightly larger weights may be permitted (up to 60 lb. for a boy of 10 st. in weight).³

Personal Fatigue

Illness, normal tiredness, and learning fatigue having been excluded the next step in diagnosis is to inquire into the personal factors which might be the cause of the fatigue. The personal factors may be briefly summarized thus: (1) Defective intake—for example, malnourishment, faulty dieting, disease, alcoholic excess, irregular meals, etc. (2) Excessive output, such as over-strenuous hobbies and recreations, late nights, etc., domestic anxiety, worry, etc. (3) Defective reserves—for example, subnormal physique, subnormal emotional stability. Most of the personal causes of fatigue fall within one of these three categories, and can be fairly easily recognized. I shall not discuss them here, but their importance is obviously very great.

Industrial Fatigue

If careful inquiry has failed to reveal any reasonable explanation of the fatigue from which the patient is suffering in any of these personal factors a tentative diagnosis of industrial fatigue may be made. Before, however, a definite diagnosis of industrial fatigue can be reached one further step is essential. If the fatigue is really industrial in origin we should expect to discover similar evidences of fatigue among the other people who are working at the same tasks and under similar circumstances. The final and conclusive diagnosis of industrial fatigue is to be made, therefore, by a study of the collective or group manifestations of fatigue in industry.

The main points in the collective diagnosis of morbid industrial fatigue may be stated thus: In a group of skilled workers industrial fatigue ought to be suspected whenever two or more of the following rates are observed to be changing concurrently with alterations in production methods, or to be comparatively high in any group of workers. Comparison may be made either with other groups in the same factory or with standard rates in other similar factories.⁴

1. Labour turnover rates. (Workers are seeking new jobs.)
2. Absence rates. (Workers are tired.)
3. Spoilt or imperfect work rates. (Workers are careless.)
4. Accident rates. (Involuntary inattention.)
5. Frequency or severity rates of illness. (Fatigue sickness.)
6. Debility and nervous disorder rates. (Strongly suggest psychogenic fatigue, which may be non-industrial.)
7. Output rate. (A falling output rate suggests that the worker's task or pace of work may be excessive.)

In some modern industrial organizations some or all of these statistical rates are calculated as a routine measure and for other purposes. It is possible to gain clear indications of the presence of group fatigue from a careful observation of marked alterations in them. It must be emphasized, however, that group fatigue cannot be diagnosed with certainty merely because changes are observed in any one of these rates. But if significant changes in several of the rates can be correlated in a positive fashion with alterations in methods, or with speeds or conditions

of production, then a strong presumption exists that true industrial fatigue is occurring among the workers in the group concerned. By means of a combination of statistical and clinical observation the original and tentative diagnosis which has been made from the examination of an individual worker is either confirmed or revised. Finally, the diagnosis may be put beyond dispute by the discovery of other workers belonging to the same group who show similar symptoms and signs. Experience suggests that in the diagnosis of collective or group fatigue special significance should be attached to the corrected sickness rates (and especially to the number of workers suffering from debility), to the accident rates, and to the amounts of spoilt work. In this way the industrial practitioner is able to recognize industrial fatigue when he meets it in industry with a fair degree of assurance.

Industrial Causes of Morbid Fatigue

As soon as a diagnosis of industrial fatigue has been made it is necessary to be able to discover the actual (industrial) cause or causes of the fatigue in the particular group of workers. This is the final step in the diagnosis, and it may be a problem of the greatest complexity, the solution of which demands a wide knowledge of all of the relevant facts. It is not possible to discuss this matter in detail, but the recognized industrial causes of morbid fatigue may be roughly classified as follows:

Conditions within the factory :

(a) Physical.

1. Heat, cold, humidity, lighting, noise, fresh air ; speed of work, rhythm of work ; seating, etc.
2. Hours of work and rest pauses, etc. ; wage rates and overtime ; bonus for "weight moved."
3. Exposure to low degrees of toxic materials—for example, solvents, carbon monoxide, petrol, etc.

(b) Emotional.

Monotony or variety of work.
Correct supervision and discipline.
Social or group harmony.
Correct incentives (wages, etc.).
Psychological fitness.

Industrial conditions which operate largely outside the factory :

Regular and adequate meals (canteen).
Selection of personnel.
Night work, shift work, and "broken time" or "spread-over."
Travelling to and from work.

In many instances the probable cause of the fatigue immediately suggests itself. Thus much nervous debility among high-speed repetition workers suggests that the speed of work may be too high to be consistent with health. Rheumatic disorders among metal casters or foundry workers suggest excessive chronic muscular strains in overheated shops. Headache among solvent users suggests a solvent toxæmia, and so on. Furthermore, it is a sound rule to look for, and to correct, errors in industrial physical environmental conditions, and to endeavour to correct dietary defects before more refined investigations are undertaken. Most of the major causes of industrial fatigue lie very close to the surface and are easily open to intelligent observation.

In conclusion, I will touch upon one or two matters the practical importance of which, my experience teaches me, is often overlooked. I am convinced that much more attention needs to be paid to those causes of industrial fatigue which I have classified as "industrial conditions which operate outside the factory." I shall briefly refer to night work, shift work, "spread-over time" or "broken time," and travelling to work. To work at night is not natural. If and when night work is inevitable careful consideration should be paid to all of the conditions of work ; even increased rates of pay cannot purchase adequate nourishment if the canteen is not open. Again, certain classes of individuals (especially those who do not sleep well at night) are psychologically unfitted for night work ; therefore careful and expert personnel selection is essential. Again, overtime is a prolific cause of fatigue. A few hours' extra work

may upset an otherwise satisfactory health balance. This is especially the case with heavy manual labour, with high-speed repetitive work, and in processes which expose the workers to toxic fumes or dust.

A recent and extensive unpublished inquiry into the incidence of fatigue among workers in various trades showed that, from the worker's point of view, nothing is felt to be more fatiguing than the hours spent in overcrowded trains, buses, and trams when travelling to and from work. My own medical experience has convinced me that the "spread-out" of towns and the removal of workers from the near vicinity of their work is of itself the most fertile single cause of fatigue in modern industry. When the added cost of travelling is subtracted from the worker's earnings this tendency to fatigue is aggravated by inadequate nourishment. Many workers leave home at 6 a.m. and do not get home until 8 or 9 o'clock at night.

In the great transport industry the prevention of fatigue presents special difficulties. The "spread-over" of hours, the irregular and inadequate meals, added to the always exacting and sometimes arduous nature of the occupation, create a problem the solution of which ought to demand our careful thought. It is not a chance that gastric disorders are rife among transport workers, nor is it an accident that increasing numbers of them are being found to suffer from high blood pressure. There is a wide field of investigation here calling for further research.

The problem of industrial fatigue is as important, therefore, as it is complex. Nothing less than an impartial scientific study of it in all its aspects, and by a team of trained specialists, will enable us to abolish morbid fatigue from industry.

REFERENCES

- ¹ Florence, Sargent: *Economics of Fatigue and Unrest*, 1924. Footnote (p. 99).
- ² Bailey, G. H.: *Amer. Journ. Hyg.*, 1929, ix, 192.
- ³ Cathcart, et al.: *Physique of Women in Industry*, Medical Research Council, Special Report Series, No. 44, 1927.
- ⁴ Florence, Sargent: *Loc. cit.*, pp. 113 and 135.

THE STATE OF THE PUBLIC HEALTH

ANNUAL REPORT OF CHIEF MEDICAL OFFICER*

SECOND NOTICE

The deaths from cancer in England and Wales in 1935 numbered 64,507 (30,780 males and 33,727 females), an increase of 1,244 on the figure for 1934. The increase in cancer mortality is affected by the increased longevity of the population, so many more people reaching the "cancer age," and by more accurate diagnosis. When these two factors are taken into account the efforts so far made to gain a measure of control of the disease appear less discouraging than the crude figures of mortality suggest. Sir Arthur MacNalty writes:

"The increasingly prominent position which cancer (malignant disease) assumes in our mortality rates has led, particularly within the last ten or fifteen years or so, to what may be called a 'movement,' a consciousness exhibited by lay and medical minds alike that we are brought face to face with a problem demanding the exercise of our best resources, both investigatory and administrative. Nor do we stand alone in this respect; all the civilized nations of the world share the same disquietude."

In treatment notable advances have been made by the wide substitution of radiation for operative methods. Generally stated, it appears that in so far as those varieties of the disease which are amenable to operative treatment are concerned, and judging by the usual standard of survival, the results of radiation are not very different from those of operation ; on the other hand, radiation treatment possesses other important advantages,

* *On the State of the Public Health*. Annual Report of the Chief Medical Officer of the Ministry of Health for 1935. H.M. Stationery Office. (3s. 6d. net.)