REMARKS UPON TEMPERATURE.

By M. S. PEMBREY, M.A., M.D.,
Lecturer on Physiology, Guy's Hospital.

MANY a so-called fact in physiology is but a statement of the balance of evidence. This must vary from time to time, for new evidence may be obtained or old discarded evidence may be restated and confirmed. It is useful, therefore, at times to attempt to sum up the evidence and to draw conclusions which can be tested by further investigations. The personal equation may bias the verdict, but this is a necessary condition in the examination of evidence upon all debated questions.

The temperature of man and of other warm-blooded animals is a subject in which such a review may be useful. The general opinion has been that the temperature is remarkably constant, and under physiological conditions shows but a narrow range of variation. Since the thermometer is one of the physician's guides, it is most important that the conditions which affect the range of the temperature in a healthy man should be carefully determined. The practical side of this physiological question will therefore be kept in view in the present article.

THE TEMPERATURE OF THE NEWLY-BORN.

The Darwinian theory leads to the conclusion that the warm-blooded have been evolved from the cold-blooded animals. Physiological facts support this conclusion. The temperature of newly-born pups, kittens, and rabbits falls when they are removed from the warm surroundings afforded by their dam, and continues to fall until it reaches a point a few degrees above the temperature of the air. Newly-born guinea-pigs, however, are able to maintain their temperature if the exposure to cold be not excessive; they are at birth in a condition of great development, they are well covered with fur, their eyes are open, and they are quickly able to run about. Young warm-blooded animals can, therefore, be divided into two classes—those which at birth are blind, helpless, in some cases naked, and unable to regulate their temperature; and those which are born in a condition of greater development and capable of maintaining the temperature of their bodies at a fairly constant level. Young birds can be classified in a similar manner. These important observations were published by W. F. Edwards¹ in 1824. Within recent years they have been confirmed and extended, and it has been shown that the difference lies in the development of the power of regulating temperature; the first class respond to changes of external temperature in a manner similar to that of cold-blooded animals; their combustion, as measured by the output of carbon dioxide, varies with and in the same direction as the temperature of their surroundings; the second class, however, increase their combustion when they are exposed to cold; they resemble warm-blooded animals.² The development of this power of regulating the temperature of the body can be traced in the developing chick.³

The practical interest of the question is centred in infants. Raudnitz⁴ has investigated the variations in the temperature of infants at birth and during the first few days after birth. The effects of affusions of cold water were observed; the rectal temperature rose in the case of strong infants, but remained stationary or fell in the case of the weak. The influence of the large cutaneous surface in relation to the mass of the body and the loss of heat from the skin were shown to be only secondary causes of the irregular temperature. The chief cause was the imperfect development of the power of regulating temperature. Shivering and other muscular movements were more marked in the strong than in the weak infants. Quite recently Babák⁵ has made an important series of observations upon the respiratory exchange and the production of heat in infants. Their temperature is low, even when they are fully clothed and in a room at 15° C. (59° F.); in infants an hour or two old the temperature may be as low as 34.0° (93.2° F.) or 33° (91.4° F.); it rises gradually during the first day or two, but shows considerable variations; thus on the fifth day after birth the rectal temperature varied from 36.2° (97.16° F.) to 33.5° (92.3° F.) in an infant weighing 2,550 grams (approximately 5½ lb.), and kept in a room at 12.0° C. (53.6° F.). The conclusion drawn from numerous observations made at different times of the year and upon infants of different ages is that the power of regulating temperature is incompletely developed in the newly-born. The regulation of the loss of heat is imperfect, and this is markedly shown if

the infant be insufficiently clothed when it is exposed to even moderate cold. The regulation of the production of heat by variations in combustion is also incomplete, and only within narrow limits can the newly-born respond to changes of external temperature in a similar manner to the response of the adult. The further development of these powers of regulation can be traced during the first week after birth.

The results, therefore, of observations upon infants and other warm-blooded animals agree. The evolution of the warm-blooded animal can be traced not only in the animal series, as shown by the important observations of Sutherland⁶ and C. J. Martin⁷ upon marsupials and monotremes, but also in the same individual at different stages of its existence.

The practical importance of the knowledge of this imperfect regulation in the newly-born is obvious; maternal instinct, however, has for long ages anticipated physiological knowledge. The mother by means of the heat of her own body fosters the helpless young. That this care is primarily for the benefit of the young, and not for the satisfaction of maternal yearnings or weakness, is shown by the fact that in many cases both the cock bird and the hen bird brood over the newly-hatched young, and that parturition does not incapacitate animals and uncivilized women from the daily routine of life. Many premature infants have been reared by proper attention to the temperature of their surroundings; the more premature and weak the more nearly do they resemble cold-blooded animals in their inability to regulate their temperature. The heat of their bodies and the combustion of their food vary with and in the same direction as the temperature of their surroundings. Cold—even moderate cold—to such premature infants is not a stimulant but a depressant, for they can regulate neither the loss nor the production of heat.

THE PHYSIOLOGICAL LIMITS OF THE TEMPERATURE OF THE ADULT.

The range of temperature in healthy men and animals has not been adequately determined. This is chiefly due to errors in the methods and the times of observation. In the case of man reasons of convenience and delicacy have led to the observation of the temperature in the mouth. Such a determination is not an exact measure of the internal heat of the body. The balance of evidence shows that Lorain⁸ rightly maintained that the temperature of the rectum alone represents the internal heat of the body. It would occupy too much space to refer to the numerous observations which have been made upon the comparative values of determinations of the temperature in the mouth, axilla, groin, rectum and urine. These data have been given elsewhere.⁹ It is only necessary to insist that a so-called "half-minute" clinical thermometer will not give true or even comparable values for the temperature of the body under different conditions, even if it be retained for five or ten minutes under the tongue of a firmly-closed mouth. Such a determination is unreliable owing to the cooling of the tissues which surround the buccal cavity; this is especially the case after exercise or in cold weather, but even in warm weather there is a loss of heat from the boundaries of the mouth by the evaporation of sweat. These sources of error are obviously not so marked in the case of many patients, for when the subject is lying in bed the clothes around the neck and the protection from draughts maintain the temperature of the mouth at a value more comparable to that of the rectum.

The method used by Stephen Hales,¹⁰ the observation of the temperature in the stream of urine, gives results¹¹ which in point of accuracy come next to rectal determinations. Although this method is obviously limited in its application, yet it is very rapid, convenient and free from the danger of carrying infection. Haldane and Pembrey easily determined in this way the temperature of eighty-three soldiers in one hour and a-quarter.

It would be unnecessary to insist so much upon the errors of the method, were it not for the fact that some observers¹² have maintained that the temperature of the mouth is equal to that of the rectum, and many have insisted that, even if the buccal determinations be lower than the rectal, the results are comparable. Further, the observation of the temperature in the mouth has led to wrong conclusions regarding the influence of muscular work upon the temperature of man.

The internal temperature of a healthy man shows a range from 36.0° C. (96.8° F.) to 37.8° C. (100.0° F.); these are average figures for the temperature of the rectum or urine (Jaeger, Jürgensen, Mantegazza, Neuhaus, Nicol, Pembrey, and Richet), and do not include the absolute physiological

Animal.	Average Rectal Temperature.	Extremes of Observations.	Number of Observations.	Observer. ¹³
	° °	° °		
Horse	37.9 (100.2)	37.2—38.6	On 150 horses	Strecker
	37.9 (100.2)	36.1—38.6	On 212 "	Hobday
Cow	38.6 (101.5)	37.5—39.4	On 87 cows	Hobday
	38.6 (101.5)	37.7—39.6	On 100 "	Singleton
Sheep	40.0 (104.0)	39.7—40.2	On more than 100 sheep	Hobday
	40.1 (104.2)	39.6—41.0	On 100 sheep	Singleton
Pig	39.6 (103.3)	38.3—40.8	169 on 4 young pigs	Siedamgrotzky
	38.7 (101.7)	38.7—39.3	On more than 100 pigs	Hobday
Dog	38.6 (101.5)	38.1—39.2	On more than 200 dogs	Hobday
	38.8 (101.8)	38.0—39.8	On 100 dogs	Singleton
Cat	38.7 (101.7)	37.9—39.7	On 41 cats	Hobday
Monkey (rhesus) ...	38.4 (101.1)	36.9—39.7	22 on 2 monkeys	Hale White and Washbourn
	37.7 (99.8)	35.9—38.9	1,000 on 26 "	Sutherland Simpson ¹⁴
Rabbit	39.2 (102.5)	37.3—39.9	72 on 27 rabbits	Hale White
	38.7 (101.7)	37.0—40.8	31 on 10 "	Pembrey
	39.8 (103.6)	38.6—41.0	77 on 13 "	Pembrey
Guinea-pig	38.6 (101.5)	36.0—39.2	140 on 10 guinea-pigs	Eyre ¹⁵
	37.9 (100.2)	37.0—39.2	19 on 5 "	Pembrey
Rat	37.5 (99.5)	37.0—38.5	16 on 4 rats	Pembrey
	37.9 (100.3)	37.4—38.9	60 on 2 "	Pitts
Mouse	37.4 (99.3)	36.1—38.6	27 on 8 mice	Pembrey
Fowl (common) ...	42.8 (109.0)	41.7—43.9	On 14 fowls	Davy
	41.6 (106.9)	40.6—43.0	On 111 "	Hobday

These figures clearly show that the average temperature is, in all the cases, considerably above that of man. The range of variation is also greater, but it is uncertain, even with these numerous determinations, whether the true range has been ascertained. The lowest temperatures occur during the hours of rest and sleep; under such conditions very few observations have been made except in the case of man.

range. It will be shown later that muscular exercise will raise the internal temperature of healthy men to 38.5° C. (101.3° F.) without causing distress or any pathological effects.

The range of temperature in healthy animals is also of practical importance. Their temperature must be determined in many physiological and pathological experiments, after the injection of tuberculin and mallein and in veterinary practice. The data are gradually becoming more numerous and complete; they show that domesticated animals also have during health a range of temperature which is wider than that generally accepted. In fact, temperatures which are within the healthy range have been recorded, the high ones as fever, the low ones as subnormal. Here may be given the average temperature and range found in the case of some of the animals in which the temperature is frequently observed. As far as possible the effects of exercise or of struggling have been excluded, but it is obvious that this precaution is not so easy as in the case of man.

THE INFLUENCE OF MUSCULAR WORK UPON THE TEMPERATURE OF THE BODY.

Upon this subject numerous observations have been made by different investigators, but the results have been conflicting. The general opinion has been, both among physiologists and physicians, that muscular work does not raise the temperature of the body; more heat is, indeed, produced, but it is maintained that the body compensates, or even over-compensates, by an increase in the loss of heat. This conclusion is based in nearly all cases upon the results obtained from observation of the buccal temperature. The determination of the temperature in the mouth, especially after exercise, is not an exact or comparable measure of the heat of the body. The data, therefore, only justify the conclusion that the temperature of the mouth does not rise, and may even fall during muscular work. Even this conclusion is not the whole truth, for if the cooling of the face be prevented by a high external temperature or by other means, the temperature of the mouth rises.

This question is of practical importance in relation not only to the general effects of muscular exercise, but also to the causation of "heatstroke" and to the modern treatment of tuberculosis.

Muscular exercise causes a marked rise in the temperature of the rectum and urine of healthy men. Thus the temperature may rise to 38.5° (101.3° F.) or to 38.9° (102° F.) without causing distress or any pathological effects. The experimental data and a critical examination of previous work upon this subject have been given elsewhere,¹⁶ and need not be reproduced here. The question is one which must be decided by experiment, and any healthy man who knows how to properly use an accurate clinical thermometer can make such experiments. There is no evidence to show that the rise in the internal temperature is injurious; evidence is gradually forthcoming to show that it may be beneficial. It should be noted that the average temperature of most of the domestic-

ated mammals is, apart from the influence of exercise, as high as 38.5° (101.3° F.).

There is little room for doubt that heat-stroke and heat-exhaustion are due, not to a hypothetical germ, but to a disturbance of the nervous control of temperature, brought about in most cases by muscular exercise in unsuitable clothes and in hot surroundings laden with moisture.¹⁷ This view is strongly supported by the nature of the best preventive measures and of the most successful methods of treatment.

In the case of phthisical patients¹⁸ the rise of temperature after exercise would not appear to be of such diagnostic value as the reaction after exercise and the temperature during rest. It is to be feared that many patients with a temperature somewhat above the so-called normal have been still further enfeebled by enforced rest in bed.

THE INFLUENCE OF CHANGES IN EXTERNAL TEMPERATURE.¹⁹

In the healthy man the nervous control of temperature is so well developed that his internal temperature is practically the same whether he be living in the Arctic regions or in the tropics. Even apart from alterations in clothing a man can compensate for large differences in external temperature. To the higher warm-blooded animals, man included, cold is a stimulant more powerful in its effect upon metabolism than any drug. Exposure to cold will often increase the output of carbon dioxide by 50 or 60 per cent. This in turn will cause an increased absorption of oxygen, a greater demand for food, a greater exchange of material in all respects. In European children this effect is often seen; languishing in hot surroundings in the tropics, they rapidly improve in the cooler hill-country or in England.

It is probable that the exposure of phthisical patients under the modern treatment of consumption is an important factor in success; it must be useless physiologically to largely increase the food unless the metabolism be augmented. The two natural methods of increasing combustion are cold and exercise. On the other hand, it must be remembered that if the natural response to a change of temperature be defective, as it is in many debilitated subjects, cold will be injurious.

The prevalent idea that adults and children should be shielded from changes of temperature, that living rooms and bedrooms should all be maintained at an equitable temperature and thus the danger of "colds" be warded off, must lead to deterioration. Colds are no doubt infectious diseases; the arctic explorers, it is said, do not thus suffer until they return to temperate and populous countries, where they are exposed to infection. Physiological resistance can only be maintained by training; the healthy man, who takes a cold bath or is exposed to cold in the winter, trains his body to react to changes of temperature and is less liable to "colds" than the man who is constantly protected, as he vainly imagines, by excessive clothing and warm surroundings. The value of outdoor sports in maintaining this resistance, this power of accommodation, is obvious; as a therapeutic agent sport is recognized but not to the extent which it deserves.

THE INFLUENCE OF ALCOHOL AND OF ANAESTHETICS.¹⁹

Alcohol acts upon the vasomotor system and also upon the nervous control of the production of heat. The dilatation of the cutaneous vessels, the increased perspiration and the cooling thereby produced are well known. The temperature of the subject may be lowered although he himself feels warmer; this is due to the warm blood which flushes the cutaneous nerves where the sensations of temperature arise. In large doses alcohol paralyses the nervous control of temperature. The man who is "dead drunk" resembles a cold-blooded animal; exposure to cold produces not an increase but a decrease in combustion and his temperature steadily falls. The lowest temperatures recorded in men, who have recovered, appear in drunkards who have been exposed to cold.

Anaesthetics rapidly paralyse the nervous regulation of temperature. The disturbance in temperature, be it a fall or a rise, which is seen after many surgical operations, appears to be largely due to this cause. The convenient explanation of "shock" needs further definition. The anaesthetized patient cannot regulate his temperature. The importance of warm surroundings to a patient who is deeply under an anaesthetic during a long operation is generally recognized. Such patients require warmth; an anaesthetic in the case of warm-blooded animals quickly reduces the combustion of the body to one-half its normal value; the vital resistance and the power of accommodation are concomitantly reduced. Warmth will increase, cold, even moderate cold, will diminish the combustion.

From a physiological point of view anaesthesia would appear to be often too deep and prolonged. Pain is beneficial in numerous cases; it is a natural safeguard, and brings about appropriate responses to sensations which are too often quenched by an anaesthetic. A drug which will so profoundly disturb the nervous control of combustion can never be considered harmless. The rapid recovery of animals and savages from serious wounds is generally attributed to a greater resistance; but the question can be fairly asked whether the smaller resistance of the civilized man is not further diminished, and often seriously diminished, by deep and prolonged anaesthesia? The patient dies—not, it is said, from the anaesthetic, not from the operation, which was quite successful, but from "shock"—he does not rally. May not this absence of a rally largely depend upon the fact that the combustion of the body, one of the most characteristic signs of life, has been so greatly diminished and for a time, at least, has been removed from the control of the nervous system? It is impossible by means of an anaesthetic to influence the nervous system alone; the body works as a unit, and as such is affected by abnormal conditions.

THE LIMITS OF BODILY TEMPERATURE COMPATIBLE WITH LIFE.¹⁹

Under pathological conditions the temperature of man shows a range of about 22° C. (approximately 39° F.), from 24° (75.2° F.) to 46° (114.8° F.). Higher and lower temperatures have been observed in moribund patients; here, however, only well-authenticated cases, in which recovery took place, need be considered. Several observers have recorded rectal temperatures as low as 24° (75.2° F.) in drunkards who have been exposed to cold for several hours; the patients were unconscious, but under careful treatment recovered in two or three days. Low temperatures have also been observed in chronic cases of insanity, and have persisted for several weeks.

The cases of hyperpyrexia scattered throughout medical literature are exceedingly numerous. Some of the observations appear to be unreliable, owing to defects in the thermometer or to fraud on the part of the patient. The range above the normal temperature is less extensive than that below, and a very high temperature is rapidly followed by death, whereas a very low temperature is compatible with life for a relatively long period. This would be expected on general physiological grounds, for some mammals have, under the natural conditions of hibernation, a temperature only five or six degrees above the freezing point.

The highest records in patients who have recovered appear to be 45° to 46° (113° to 114.8° F.), but in these cases the high temperature appears to have been maintained for a very short time.

REFERENCES.

- ¹ Edwards, *De l'Influence des Agents Physiques sur la Vie*, Paris, 1824.
² Pembrey, *Journ. Physiol.*, Cambridge and London, 1895, vol. xviii, p. 363.
³ Pembrey, Gordon, and Warren, *ibid.*, 1894-5, vol. xvii, p. 337.
⁴ Raubnitz, *Zett. f. Biol.*, München, 1888, Bd. xxiv, s. 423.
⁵ Babák, *Arch. f. d. ges.*

Physiol., Bonn, 1902, Bd. 89, s. 154.
⁶ Sutherland, *Proc. Roy. Soc.*, Victoria, 1897, vol. ix, p. 57.
⁷ Martin, *Phil. Trans.*, London, 1902, vol. cxv B, p. 1.
⁸ Lorain, *De la Température du Corps Humain*, Paris, 1877, Tome 1, p. 434.
⁹ Pembrey, article Animal Heat, *Textbook of Physiology*, edited by Schäfer, Edinburgh and London, 1898, vol. 1, p. 824.
¹⁰ Pembrey and Nicol, *Journ. Physiol.*, Cambridge and London, 1898, vol. xiii, p. 386, see also references 16 and 18.
¹¹ Stephen Hales, *Statistical Essays*, London, 1731, second edition, vol. 1, p. 59.
¹² Pembrey and Nicol, *loc. cit.*; see also 16.
¹³ Ringer and Stuart, *Proc. Roy. Soc.*, London, 1877, vol. xxvi, p. 186.
¹⁴ The references to these authorities are given in Animal Heat, *loc. cit.*
¹⁵ Sutherland Simpson, *Proc. Phys. Soc.*, *Journ. Physiol.*, Cambridge and London, 1902, vol. xxviii, p. xxi.
¹⁶ Eyre, *ibid.*, 1900, vol. xxv, p. xxiv.
¹⁷ Pembrey, Arkie, Boius, and Lecky, *Guy's Hospital Reports*, London, 1902, vol. lvii, p. 283.
¹⁸ Pembrey, *ibid.*, p. 261.
¹⁹ Burton-Fanning and Gurney Champion, *Lancet*, London, March 28th, 1902.
²⁰ Numerous references are given in Animal Heat, *loc. cit.*

THE CAUSES AND TREATMENT OF CHRONIC RHEUMATISM.

By RALPH STOCKMAN, M.D.,

Professor of Materia Medica and Therapeutics, Glasgow University;
 Physician, Western Infirmary of Glasgow.

ACUTE rheumatism is an acute microbic infection, running a course of variable duration when untreated, and usually presenting certain well-defined symptoms which render its diagnosis an easy matter. One attack predisposes to others. Those cases which we are accustomed to call "subacute rheumatism" are really milder cases of the same disease, and no hard and fast line of distinction can be drawn. A case of acute rheumatism may be unusually prolonged, but never becomes chronic in the true sense of the term. That is to say, it never becomes chronic any more than enteric fever or diphtheria, becomes chronic. These diseases may leave sequelae in the form of bowel lesions or peripheral neuritis, respectively, but such sequelae are not designated chronic enteric fever, or chronic diphtheria. In the same way acute rheumatism may cause fibrous thickening of the valves of the heart, or fibrous indurations of the aponeuroses, fasciae, ligaments, and nerve sheaths, but these are results of the original disease and not an indefinite continuation of it.

Such indurations of the fibrous tissue give rise to pains referred to the muscles, joints, and nerves; but these symptoms, and the lesions causing them, cannot properly be regarded as the chronic stage of acute rheumatism, more especially as acute rheumatism is not the only condition which precedes them and is responsible for their presence. Nevertheless, the name chronic rheumatism has been so long applied to chronic painful conditions of the muscles and joints that its retention is now a matter of convenience. In the popular mind, and, to some extent, in the medical mind, the name has been long associated, specially and almost exclusively, with affections of the joints; and formerly, when so many separate and quite distinct articular lesions were classed together as "rheumatic" this idea was, to a large extent, justified. Gradually, however, the meaning of the term has become much narrowed by more accurate diagnosis, and we now distinguish rheumatoid arthritis, morbus coxae senilis, coxa vara, pulmonary osteoarthropathy, Haygarth's nodosities, septic and gonorrhoeal arthritis, and other diseases and affections implicating the joints, as things quite distinct from each other and from chronic rheumatism. It is also now recognized that the articular structures proper—cartilage, synovial membrane, bone—are not primarily affected in chronic rheumatism, but that the parts implicated are the fibrous ligaments of the joints, and more especially all the fibrous tissues of the muscles and bones. In our textbooks the condition is described as chronic rheumatism, muscular rheumatism, mascular and tendinous rheumatism, myalgia, rheumatic myositis, pain being assigned the most prominent place as a symptom and damp cold as an exciting cause. Its original causation is variously stated as a rheumatic affection, as a special infection, as a diathesis, as a neuralgia, as a manifestation of gout, and as a muscle pain from imperfect nutrition. The same indefiniteness characterizes the accounts given of its pathology. Some authors hold that there are no morbid anatomical changes, others consider it a neuralgia, or an active hyperaemia of the muscles, or of their fibrous sheaths, while only a few describe definite fibrous changes and thickenings in the connective tissues. Speaking in general terms, the treatment recommended is regarded as palliative rather than curative, and no great hope of complete and ultimate relief is held out. A consideration of its pathology and experience of the results of properly-directed and persevering treatment have led me, how-