

# HUMAN ENVIRONMENT

NP5

bil-326

1585

## 2. The Optimum Human Environment

*Harold Hillman*

MAN exists in countries where the temperature varies from  $-20^{\circ}\text{C}$ . to  $+45^{\circ}\text{C}$ , where the humidities can be zero to 95 per cent, and in atmospheric pressures of 40–120 cm. Hg.; he can live with illuminations of 2–2,000 lux,<sup>1</sup> and noise intensities of zero to 120 decibels<sup>2</sup>. His air may be dust and bacteria-free or thick and foggy, and he may have days lasting 24–72 hours.

### Clothes

Of course, since the dawn of civilisation, a microclimate has been created, firstly in respect of clothes, and secondly, in respect of housing. Although clothing is not normally considered as part of the microclimate, a few remarks might be apposite here.

The general tendency for people in Western countries to wear fewer and lighter clothes is a healthy one from the point of view of hygiene. The vagaries of female fashion are probably sufficiently rapid as not to be very significant, although the mini-skirt has been said to be responsible for

increased incidence of urinary infections; the longer skirts have also caused many accidents on lifts and buses. However, tighter underwear must result in less evaporation of sweat, and probably predisposes to an increasing incidence of minor skin diseases; they may act as a mechanical irritant themselves, and should probably also be recognised as such.

The introduction of detergents in washing clothes caused a considerable increase in skin reactions, usually from contact with the housewives' skin during washing, but also probably from failure to rinse away all the detergent. The same is true of cosmetics, deodorants and toilet preparations. The presence of allergens in the newer enzyme detergents has been widely recognised; these may not necessarily originate from the pure enzyme, but may be extracted in its preparation. While ladies' preferences in regard to make-up, fashions and washing, are unlikely to be influenced, the awareness of these sources of irritation in the microclimate is spreading among the public as it has been among general practitioners and dermatologists for some time. ▶

<sup>1</sup> A lux is a measurement of light intensity and is equal to a value of one lumen per square metre.

<sup>2</sup> A decibel is one tenth of a bel, and is a unit of sound intensity.

*H. Hillman, MB, B.Sc, P.HD, is Reader in Human Biology at the University of Surrey at Guildford in Surrey.*

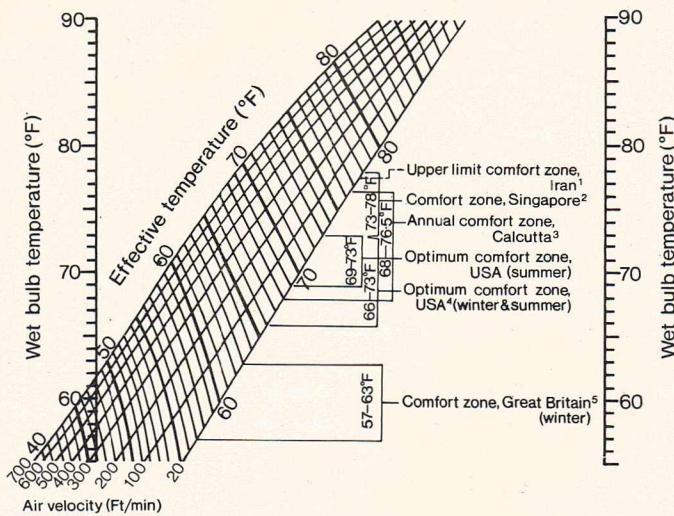


Figure 1. Comfort zones for different parts of the world.

From F. P. Ellis, 1953, Ann. Roy. Coll. Surg., 13, Fig. 6.

### Personal Hygiene

It might be appropriate here to put in a plea for wider education of schoolchildren in personal hygiene. Although the Education Act of 1944 required this to be done, and health visitors advise teachers in the matter, it is ignored far too often. Simple explanations are needed of the biological principles underlying the necessity to wash the perineum and axilla, to wash the hands after visiting the toilet, to remove make-up at night, to change underwear frequently, etc. There is a cogent case for including the study of the biology of personal hygiene in the curricula of all secondary schools.

### Temperature

In thinking of the microclimate it is the temperature of a room which first comes to mind. In many mammals, the 'zone of thermal neutrality',—the temperature at which the body is in equilibrium with its environment—has been measured (Figure 1). It is the region at which temperature regulation is least active. For unclothed man at rest, it is from 25–27°C. In the USA thermostats are usually held at 23–25°C to take account of the body heating due to muscular activity and the wearing of clothes. However, in the UK the schools have their central heating kept at 5–10°C less than this; this illustrates the fact that the optimum temperature is partly determined culturally.

Within the zone of thermal neutrality, the person feels comfortable, and minor variations in ambient temperature are compensated for by reflex changes in vasomotor tone and slight muscular activity. Outside the zone of thermal neutrality, there are metabolic, circulatory, respiratory, endocrine and psychological reactions, which may be acute or chronic. For example, in acute cold, hyperpnoea and shivering occurs; the basal metabolic rate goes up; pilo-erection and vaso-constriction occurs; adrenaline and nor-adrenaline are liberated, and the sympathetic nervous

system is activated. Most of these acute changes die away, or acclimatisation supervenes.

Chronic effects of cold include increased thyroid and adrenocortical activity. More gastric juice is secreted. Excretion of 17-ketosteroids is increased. There is increased leucocytosis and thrombocytosis. There are less calcium, magnesium and phosphate ions in the blood in the winter, and secretion of growth hormone and gonadotrophins also fall at this time; these changes may be complicated by alterations in dietary habits. Although direct evidence of cold decreasing the resistance to infection is difficult to obtain in human beings, rabbits are immune to myxomatosis at 26–39°C, but it is fatal at -3 to +15°C.

### Hypothermia

People, of course, normally protect themselves from cold by heating their houses, but the combination of senility, poverty, isolation and lack of sufficient heating, may result in clinical hypothermia, a condition only recognised clearly in the last decade. Although old people are the usual sufferers, babies who also have poor temperature regulation may also be affected in temperate climates. In tropical, humid or desert climates, the condition is also common because the excessive heat of the daytime dictating open-plan houses turns to severe cold at night. Many people in underdeveloped countries sleep out all night in intense cold.

The hypothermic patient is usually an old, poor, somewhat thin person living by him- or herself. He is often undernourished. One of the earlier signs is confusion, a confusion which often prevents the person taking elementary measures, like lighting a fire or calling for help. The patient is usually huddled up, has not eaten recently, and is often cyanosed. If temperature is below the minimum reading of a clinical thermometer, diagnosis is made; if the heart is slow and irregular, or if coma has supervened, prognosis is poor.

Colds, influenza, bronchitis, rheumatic disease, arthritis and angina, occur more commonly in the winter, and individual attacks are often triggered off by exposure to cold. Their high incidence in the UK is usually attributed to the combination of dampness and cold, and the relative rarity of central heating.

The physiological effects of cold act on sensory receptors in the skin, and temperature receptors in the hypothalamus. Through this temperature regulating system, and its connection with the sympathetic nervous system, the vasomotor, circulatory and endocrine systems, normally respond, but hypothermia is a direct effect of cold on the tissues, largely bypassing these systems.

### Warmth

The effects of too warm a climate are much less serious, and acclimatisation occurs in about a fortnight to a month. Sweating becomes gradually more profuse; initially a healthy young man will produce 10–12 ml. per minute, but this goes up to 40–50 ml. per minute as a result of acclimatisation. In early stages the individual has vasodilatation, tachycardia, tachypnoea and postural hypotension, and diuresis is inhibited. All of these signs gradually disappear,

and he then adapts. He sweats much more, at progressively lower temperatures; his sweat becomes more dilute, and normal diuresis returns. His core temperature falls and so does his skin temperature. A number of carefully controlled studies of Indian soldiers in India and the UK, Negroes in the Northern and Southern States of the USA, British soldiers in the UK and Aden, and Nigerian students in London and Nigeria seem to have arrived at a general consensus that reported ethnic differences in heat tolerance can generally be explained by differences in acclimatisation, nutrition and training of the peoples studied.

The small minority of people in subtropical climates like the USA, who have air-conditioning, are relatively immune to the high temperatures and humidity; regulation of the air-conditioning may be slow or ineffective, and draughts, dryness of the air, and noise of the air-conditioning plant are common complaints. However, except in the historical past of Somerset Maugham's imagination, heat *per se*—as distinct from the poverty, infestation and malnutrition often found in tropical countries—is not a common cause of disease.

On the other hand, high temperatures are not conducive to efficient work. Whether measured as tolerance to continuous performance of hard manual work or output of factories, or ability to carry out intelligence tests, there is, in general, an exponential fall starting above the zone of thermal neutrality. For example, absence from work due to illness among 809 female factory workers went up by 32 per cent when the temperature was raised by seven per cent. In one study, the tolerance time for manual work at 50 per cent was one sixth of the time at 0°C. Mental tasks were much less efficiently carried out by typists at 38°C than at 23°C. These instances can be multiplied many times. Running through all these

studies is the implication that an optimum temperature, say for working on an assembly line, may be quite different from that for sitting watching television.

### Effective Temperature

An index called 'effective temperature' has been defined to take into account the humidity and the air speed as well. In one study 2,000 factory workers found an effective temperature of 64°F (17.5°C) most comfortable; this consisted of a dry bulb temperature of 69°F (20°C), a relative humidity of 58 per cent and an air speed of 50 ft. per min. Effective temperatures above 71°F (22°C) were intolerable. Generally, 60-68°F (15-20°C) is considered most comfortable subjectively by British people. Air speeds less than 5 metres per minute feel stuffy, but over 8 metres per minute, complaints are made of draught.

In the UK, Section 3 of the Factories Act, 1961, provides that: 'effective provision shall be made for securing and maintaining a reasonable temperature in each workroom.... In every workroom in which a substantial portion of the work is done sitting and does not involve serious physical effort, a temperature of 60°F (17.5°C) shall not be deemed, after the first hour, to be a reasonable temperature while work is going on'. In another part of the regulation there is provision for 'reasonable temperatures' for all factories or for any class of work. These are gradually being defined by the Institute of Heating and Ventilation Engineers.

There are also older regulations for flax spinning and weaving specifying from 50-55°F (11-14°C) for particular jobs. The decision about optimal temperatures for work in the past have been largely empirically derived, but nowadays, they are being examined experimentally.

### Humidity

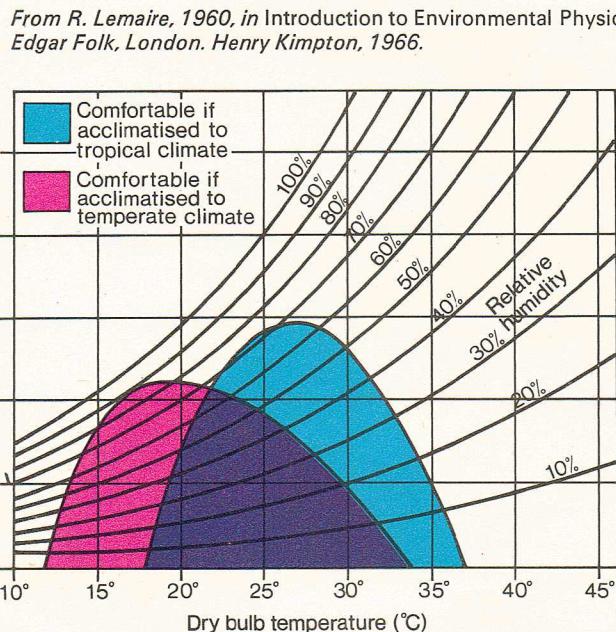
The main reasons for concern about humidity are its effects in relation to low and high temperatures. At low temperatures, where the body resistance to infection is probably higher, bacteria can travel in the moisture droplets. If the humidity is high enough to moisten the clothes, this will increase the patient's heat loss considerably as water conducts heat much more rapidly than even saturated air (Figure 2). The very high incidence of bronchitis and rheumatism in the UK is often attributed to the combination of low temperature and high humidity, which is thought of as being characteristic of non-centrally heated houses in winter.

The other dangerous combination is high humidity combined with high temperature. Bacteria multiply more quickly than in temperate climates and infections travel in water droplets.

Even in temperate climates, high humidity becomes a problem in conditions of hard physical work, as in laundries, factories and mines. The body normally loses 500 calories for every millilitre of perspiration evaporated from the surface of the body. Perspiration cannot occur into an atmosphere saturated with water vapour.

Section 4 of the Factories Act requires 'effective and suitable' ventilation. This is not defined for normal factories, but in those factories where humidity is produced artificially

**Figure 2. Comfort at different humidities.** These data represent estimates for comfort of lightly clothed individuals at rest at various dry-bulb and wet-bulb temperatures. This nomogram takes acclimatisation into account.



From R. Lemaire, 1960, in Introduction to Environmental Physiology, Edgar Folk, London. Henry Kimpton, 1966.

ally by steaming or other textile process, further humidification of rooms is not permitted.

Too dry or rapidly moving air from air-conditioning may result in loss of excessive moisture in the expired air, and a subjective feeling of dryness of the mouth, which can be counteracted by drinking water. Inhalation of excessive cold air in arctic climates gives a very unpleasant sensation in the throat, partly due to the lower vapour pressure of water in the air.

In the UK, a humidity of 40-45 per cent saturation for offices and light manual work appears to be the most comfortable, though operating theatres are kept at a much higher humidity than this (see below).

### Light

The importance of the light intensity in the microclimate has been much exaggerated. This has arisen from the popular belief in 'eye-strain' due to working in poor illumination. It is an image deriving from Victorian novels. There are probably only three evident effects of poor lighting. The first one is excessive use of the ciliary, pupillary and oculomotor muscles in order to gain the maximum contrast in conditions of poor illumination; this may result in headaches.

Secondly, lack of sunlight may result in Vitamin D deficiency, and rickets may occur if the condition is permitted during the growth of children. However, the most important element is the psychological effect of poor illumination. It makes fine manipulations difficult to carry out accurately and may increase the incidence of industrial accidents. Certainly the Standards of Lighting Regulations of 1941 dictate that the level of illumination: 'be not less than six foot candles at three feet above the floor where persons are regularly employed, and not less than 0.5 foot candles in passageways. Sources less than 16 foot above floor level must not exceed ten candles per square inch, if visible from 100 foot, unless at an angle of elevation from the eye exceeding 20 degrees'.

The Illuminating Engineering Society has drawn up a code of practice indicating the optimal light intensity for manipulations requiring various degrees of visual attention. The eye is so effective at visual discrimination in the presence of illumination of several orders of intensity that it is difficult to appreciate that the light intensity in the back of a room due to sunlight is only about one half to two per cent of the intensity near the window.

It might be appropriate to mention here that sometimes the complaints of 'eye-strain' are due to failure to correct refractive errors with suitable spectacles.

### Photoperiodicity

Among animals, breeding activity, body weight, hair density, mating and bearing of young, have clearly been related to the relative duration of light and dark (the photoperiod). These correlations become more convincing the lower one goes in the evolutionary tree, and their importance for modern man must be minimised by the control of the light intensity in his immediate environment. There are no doubt periods of increased sexual activity, body growth,

etc., in human beings, but social factors, eating habits, climate, circadian rhythms and personality, can probably account for all the seasonal variations observed.

From a climatic viewpoint, a high intensity of sunlight is generally considered desirable in cold climates, but undesirable in warmer countries. The lighting engineer tries to provide adequate sunlight in the winter, protection against excessive radiation in the summer (the greenhouse effect), and regulation of brightness to avoid glare. The modern practice is to attempt to provide the illumination relevant to each task performed in a particular part of the room. For example, fine drawing might require 300-400 lux, while a cocktail party is probably more agreeably held in a room in which the illumination of the guests is only 100 lux.

### Noise

Noise has in recent years begun to be considered a pollutant; 0 decibels is the minimum sound intensity which can be detected, 50 decibels is the intensity of a conversation at 12 feet distance, 80 decibels is the noise of a drill 30 feet away. In discotheques, the noise level is often 100 decibels, and 120 decibels produces pain in the ears. Besides pop fans, many industrial workers are subjected to intensities of sound which may produce permanent deafness to particular frequencies and their overtones. 'Boiler-makers disease' and deafness of men who use pneumatic road drills are recognised industrial hazards.

Much more common are the psychological troubles induced in people trying to listen to sounds not much louder than the continuous background noise. This phenomenon of masking of sounds is easy to demonstrate experimentally. Obviously, the closer the intensity and frequency of the background to the sound which the listener is attempting to hear, the more difficulty and conflict is produced.

On the other hand, continuous background music is popular among factory workers, lorry drivers, and supermarket shoppers, as well as laying battery hens. We may, therefore, re-define sound pollution in terms of high intensities of sound, which are unpleasant to the people who are subjected to them. By the same token, it may be appreciated that much of the objection to aircraft noise and pop music (though probably not traffic noise) is psychological, and should be treated as such.

At the other extreme, lack of sound—as experienced by people living by themselves, or prisoners in solitary confinement—is a form of sensory deprivation, which is also undesirable.

Changes in threshold to noise can be demonstrated experimentally in animals, and they are probably a variety of auditory fatigue, resulting from over exposure. They should not be confused with the condition common among old people who have lost their ability to hear high frequencies. In the latter case, it is difficult to know how much industrial and traffic noise contributes to this loss, and how much it is a manifestation of ageing itself.

The levels of dust and bacteria in the microclimate are important determinants of health, particularly in operating theatres, factories and mines. The subject of operating

theatres will be considered below, and factories and mines will be dealt with in an article on pollution.

### Psychological Aspects

The physical characteristics of the microclimate have been given much attention, but the psychological aspects are probably even more important. No one knows what percentage of the phenomenal absence from work for periods less than three days, i.e. not requiring a certificate under the National Health Service, is due to work dissatisfaction, or bad interpersonal relationships at work. Besides the three-day absentees, there are those whom every general practitioner knows who spin out an illness as long as possible. When the doctor recognises this type, he would probably be wise to give supportive psychotherapy in mild cases, or recommend full psychiatric help in the more severe and persistent ones. There is often a serious difficulty in knowing how much simple idleness contributes to the condition.

Often, young people go out to parties at the week-end, and the effects last until the Monday morning. An interested worker will attend as usual, despite his or her hangover. An ill-adapted or idle person will telephone to say that he or she 'has a cold'. In the Scandinavian countries, social workers visit the houses of allegedly ill people, who draw health insurance, to see that their illness is sufficiently serious to merit the absence for which the certificate was issued.

Psychological problems at work may be classified into three varieties. There are those reflecting domestic tensions, like conflicts within the family, fears about the attention of young children, etc. Secondly, there are personal conflicts within factories and offices. These probably arise from hierarchical systems, in which, for example, the boss can arrive late, take a long lunch hour, or misuse the petty cash in the presence of junior staff, who are not permitted the same privileges. The gradual democratisation of industrial countries will, in time, make this rarer, but it is inevitable in an hierarchical system. Attempts to enforce factory or office rules are a frequent cause of friction.

The third variety of psychological condition is job dissatisfaction, where a worker does not feel committed to the work. This may be because it is unpleasant or hard—as in mining, where, for example, the absenteeism is 20 per cent in South Wales. Another main cause is people feeling that their intelligence would merit much 'better' jobs, but their economic background, education, paper qualifications, or the job availability, do not permit them to have such jobs as use their full talents. This is sometimes seen among graduates who have become secretaries, technicians, teachers, or nurses. It is also common among young women whose social or financial situation forces them to go out to work, until they become housewives.

### Houses Versus Flats

Many new towns and housing estates have been built since World War II. The earlier ones like Crawley and Basildon paid tribute to the dream of every Englishman to have his own house and garden. However, this means either that people must travel long distances to work or shopping,

or own a car. Additionally, land has been expensive in towns, so that gradually the single house has been giving way to the tall concrete block of flats. There have been many complaints from users, and several studies have been done by sociologists and doctors to compare illness among flat and house dwellers. One study showed a much higher rate of attendance of doctors, and a lower threshold of calling them in new housing estates. Another found a 77 per cent higher incidence of neurosis than the national average. Flat dwellers had twice as much respiratory disease in the under ten age group, and twice the incidence of consultations of predominantly emotional origin.

One particularly interesting study by Fanning compared two groups of servicemen's families stationed in Germany. The morbidity of the flat dwellers was 57 per cent higher, and their referral to specialists was 63 per cent higher, but their admissions to hospital occurred at about the same incidence as the house dwellers. The women had a greater incidence of psychoneurosis, and they and the children had more frequent respiratory infections. Fanning attributed the differences mainly to smaller space and less social contacts enjoyed by the flat dwellers relative to the house dwellers. It is difficult to know what more doctors can do than recognise the problem, but clearly a lot more research is needed in this area, which may also be of interest to town planners. Shortage of urban land, and therefore, high blocks of flats and offices, are liable to be the normal environment of an increasing proportion of the population in the future.

### Operating Theatres (Figure 3)

One particular environment of special interest to us is the operating theatre. Its design is governed by the following considerations. The patient is anaesthetised, and, therefore, his temperature regulation is impaired. He may have had drugs like phenothiazines which have an important hypothermic effect, but, even if he has not, all general anaesthetics make the patient less resistant to cold.

Secondly, the open wounds, high temperature, elevated humidity and sweating operators, all combine to make the situation hazardous microbiologically.

Thirdly, volatile anaesthetics and source of electrostatic charge make explosions a considerable hazard. Fourthly, space has to be provided for operating staff, monitoring instruments and access to the operating table.

Fifthly, there has to be enough illumination for the surgeon's manipulations, and for the instrument dials to be read. Finally, the operating theatre must be reasonably quiet.

In the UK, the Ministry of Health recommended a temperature of 65-70°F (18-21°C), though some go as high as 70-75°F (21-24°C). The temperature is controlled automatically, but is mainly determined by the external temperature. The humidity—comfortable at 45 per cent—is normally kept over 55 per cent in order to reduce electrostatic charges and to prevent excessive heat losses from the patient. In the UK, ventilation of at least 12 changes of air per hour is recommended, although higher rates are used in the USA. This rapid turnover of air would increase the heat loss from the patients if the humidity were not kept so high.

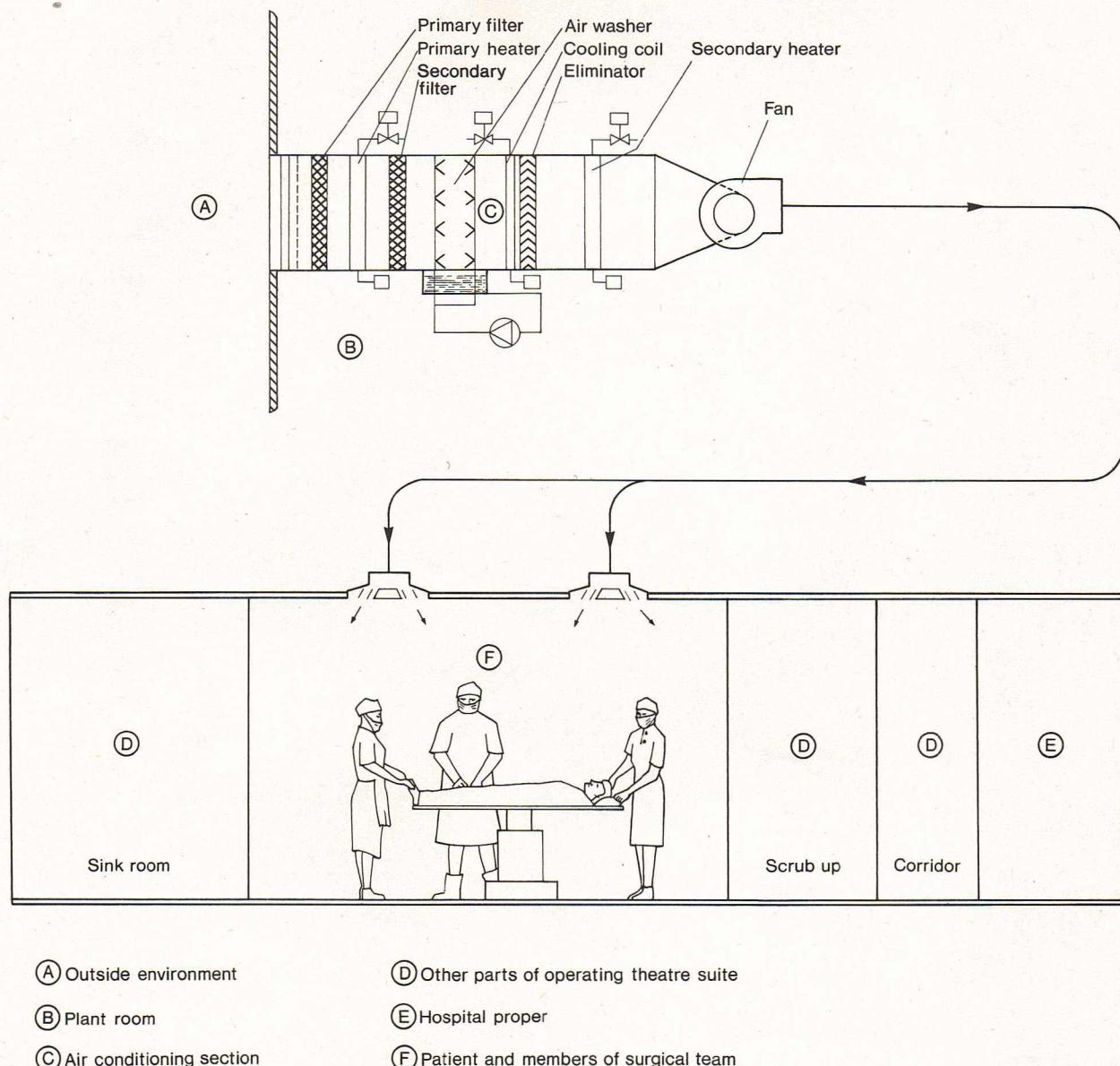
There is much discussion about how much 'fresh' air should be drawn in from outside, as distinct from recirculation. Recirculated air has the same bacteria, anaesthetic and smell, and may be reinfected from the filters. 'Fresh' air from some industrial towns contains much dust, bacteria, fungi and other contaminants.

The air must be circulated at such a rate that sufficient changes are induced, but it must not produce draughts (more than about 25 ft. per min.). It must also not 'blow off' too many bacteria from the theatre personnel; it must not pick up bacteria from the floor, and it must be at a slightly increased pressure to ensure that the relatively cleaner

theatre air always pushes out into the less purified auxiliary rooms—even when the doors are open. The Medical Research Council recommended that air be supplied at not less than 1,000 ft.<sup>3</sup> per min. with a positive pressure of 0.04 in. w.g.

The high risk of explosion is dealt with by the following measures: high humidity over 55 per cent diminishes the build-up of electrostatic charges; nylon and plastic materials which charge up easily are avoided where possible; volatile anaesthetics like cyclopropane, divinyl ether, and ethyl ether, which form explosive mixtures with oxygen and nitrous oxides, are being replaced with non-explosive ones like

Figure 3. The sources of air-borne contamination in an operating theatre suite with air-conditioning.



fluothane, and diluents like helium, in which sparks do not occur easily.

In one study, it was found that 30 per cent of anaesthetic explosions were due to static electricity. Anaesthetic explosions—if involving the patient—may blow the lungs to pieces, and are a nightmare of every anaesthetist.

### Infections in Wards and Operating Theatres

In England and Wales from 5-20 per cent of operations in the last decade became infected to a greater or lesser degree. In a ten-year study in New York, half the infections came from the alimentary tracts. Some could be traced to the patients, and some to the operators. *Staphylococcus aureus* is a common pathogen. Besides human beings, operating theatre infection comes from outside, from air conditioners, from humidifiers, from the theatre suite, from the wards in the hospital, and from the visitors. Hospital bacteria may, of course, be resistant to antibiotics.

Most infections travel on dust particles of about 10-20 microns, though the bacteria themselves are less than 2 microns. A ward that has 10-20 colonies per square foot of air, may increase to 2,000 colonies per square foot from dust released during bed-making. The aim of ventilation and air purification is to decrease the bacterial content to less than two per square foot of air, in neurosurgery, and less than 20 in a dressing casualty department. The travelling habits of bacteria on particles means that if one can filter out all particles less than 5 microns (a 99.9 per cent efficiency) aerial contamination is reduced to a minimum. In North America filtration is often intended to remove all particles down to 1 micron.

The space required for major surgery has been gradually going up in the last decade, and 400 square foot seems to be the figure towards which architects are gravitating. The control of the environment becomes astronomically expensive as the volume of space rises.

The lighting of the operating theatre should be uniform, not produce too much glare, not induce eyestrain, be easily cleaned, be capable of dimming, and not be too hot for the operators. The Ministry of Health recommended an average background of 30 lumens per ft.<sup>2</sup>, and 1,000 lumens on the working plane. However, it pointed out that some surgeons use 2,000-5,000 lumens. Green towels and dressings are fairly standard to reduce glare. It is also advisable to have an outside window so that the surgeon can rest his ciliary muscles at intervals to diminish 'eye-strain'.

Surgeons usually insist on fairly quiet operating theatres. Besides the staff, the main source of noise is the air conditioning equipment. The Americans have defined 'noise criteria'—of which they have an index (the NC). They prefer having a level less than 30 units on their scale, or 40 at a maximum. Ventilators and air conditioning equipment, like jet aircraft, must produce noise, and considerable engineering ingenuity has been expended to minimise it.

### Summary

In summary, we may characterise the operating theatre as a very specialised human environment. It is also a good

example of a 'tailored' environment. Its design illustrates the main theme of this article that in the future we will be able to define the optimum temperature, humidity, ventilation, light-intensity, bacterial level, and noise intensity, appropriate for a factory, an office, or even a dining-room. One perhaps can be permitted the luxury of a reservation. It is quite possible that the physical solution of the environment problem will uncover many psychological difficulties more fundamental to our souls. □

### Further Reading

- Introduction to Environmental Physiology*, G. Edgar Folk, Jnr., London, Henry Kimpton, 1966.
- The Physiology of Human Survival*, O. G. Edholm and A. L. Bacharach (Eds.), London, Academic Press, 1965.
- Handbook of Physiology*, Section 4, 'Adaptation to the Environment', D. B. Dill, E. F. Adolph and C. G. Wilber (Eds.), Washington, American Physiological Society, 1964.
- 'Air Conditioning Design for Hospital Operating Rooms', *J. Inst. Heating Ventilation Engs.*, Sept., 1965.
- 'Hospital Building Note Operating Department', HMSO, 26th Jan., 1967.
- Symposium, 'Design and Function of the Operating Suite and Special Areas', 1969, *Anaesthesiology*, 31, 1.