CH begin to appear. $T_{eff} \sim 5\ 500$ K and examples are Rigel Kent (α Centauri) at G2, the Sun at G2 and Capella (α Aurigae) at G8.

K Mettallic lines of neutral metals (especially iron) continue to dominate and increase in intensity. Appearance of molecular bands of TiO and K5. $T_{eff} \sim 4\ 000$ K and examples are Arcturus (α Boötis) at K2 and Aldebaran (α Tauri) at K5.

M 'Titanium oxide stars'. Numerous bands of TiO and other molecular species and neutral metals are prominent, especially Ca and Fe. $T_{eff} \sim 3\ 000$ K and examples are Antares (α Scorpii) at MI, Betelgeuse (α Orionis) at M2 and Barnard's Star at M5.

The continuous radiation from stars has a wavelength distribution very similar to that of a black body emitting at the effective temperature of the star. As we have seen for spherical black bodies the power output is given by

$$L \propto R^2\ T^4.$$

Thus, hotter bodies always emit more radiation than do cooler bodies of the same size. (A black body twice as hot emits sixteen times more power.)

This shows that as the black body temperature increases, the maximum of the radiated power appears at shorter wavelengths. A black body of temperature 300 K (a dark room) has a spectrum which has maximum intensity at a wavelength of 10 μm (infrared). A star of temperature 3 000 K has peak emission at 1 μm = 1 000nm (far red) and for a very hot star of 30 000 K this peaks well into the ultraviolet at 100nm.

We can now see that this range of temperature can explain the colours of the stars in the sky: very hot stars appear bluish; hot stars emit nearly equal amounts of radiation at the wavelengths at which the human eye responds and we see this mixture as colourless or white; cool stars, on the other hand, have a very red appearance. The image of the Hyades taken with an objective prism spectrograph is shown on page 47. The spectrum of each star may be examined and its spectral type determined. This technique is very useful as a single picture simultaneously records the spectra of many stars. Also, by making colour photometric measurements of stars it is found that the colour indices (B-V) and (U-B) are well correlated with temperature and spectral class for normal (dwarf type) stars.

Stellar luminosity varies with temperature but it is also proportional to the surface area of the star (that is, to the radius squared). For a fixed temperature, if the star is doubled in radius the luminosity increases by a factor of four. So we are still unable to deduce the size of stars. However, for a few hundred stars which are sufficiently close for their distances to be well determined we can, using the distance modulus (and correcting for any interstellar absorption effects), calculate the absolute magnitude, M, to an accuracy of at least 0·5 magnitudes. We can, therefore, construct graphs of absolute magnitude versus temperature. Absolute magnitude is synonymous with luminosity and so the radii of these stars may be determined. A plot of this type was first published by Ejnar Hertzsprung and Henry Norris Russell in 1913 and the diagram now bears their name, abbreviated to **H–R diagram**.

An H-R diagram is shown in Fig 3·3. It is immediately apparent that stars are not scattered at random across the diagram but fall into well defined zones. The most prominent of these in called the **main sequence**. Here the increase in luminosity is a steadily increasing value or **function** of both temperature and size. From our knowledge of luminosity it is obvious that stars which are intrinsically faint but have high temperatures must be very small in size. These are referred to as **white dwarfs**. On the other hand, stars which are cool but very luminous must therefore be very large and are known as **red giants**.

It was suggested in an earlier section that if the absolute magnitude of a star could be deduced then its distance could be determined. We now see such a method exists because if we can accurately determine the spectral class, then the H-R diagram will reveal the absolute magnitude. The distance is then found. It sounds simple but there is a snag. If one refers to Fig. 3·3 for, say, a KO star, what value of the absolute magnitude do we choose, +6, 0 or −6? It is not sufficient just to determine the spectral class – we need to know the type of star. It is big or small? Spectroscopy once again comes to the rescue because the densities in the atmospheres of giant and dwarf stars vary enormously. This density difference causes subtle but noticeable changes in the spectra. An experienced observer can not only tell the spectral class of a star but also if it is a giant or dwarf. The inclusion of the sizes of stars into a classification scheme fell to the Yerkes observers Morgan and Keenan. They developed what is referred to as the

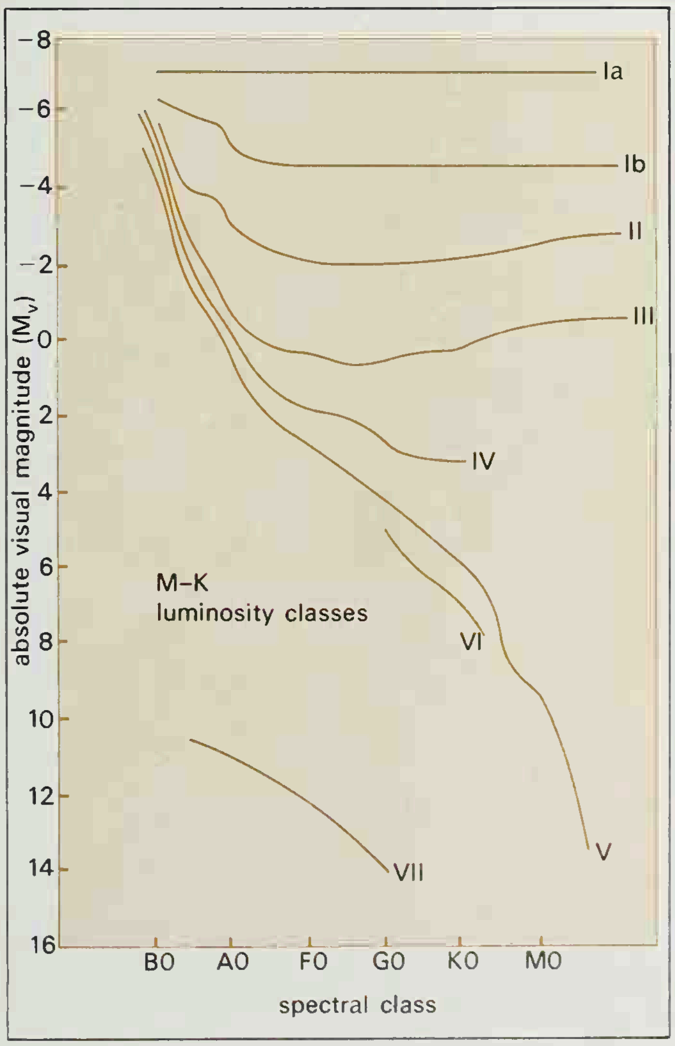

Fig. 3·4
The Morgan-Keenan (Yerkes) scheme whereby stars are classified according to their luminosities and temperatures.