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The new physiology of vision—Chapter XXXVII. The spectrum of the night-sky

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The major result which emerges from the investigations described in the two preceding chapters is that we are concerned with only one kind of vision and its variations in the entire range of illumination in which our eyes can perceive light. The differentiation made in the past between three distinct types of vision named as "photopic vision", "mesopic vision" and "scotopic vision", and functioning at different levels of illumination is shown by the factual results of the study to possess no valid basis or justification. In what follows, it will be shown that the characteristic features of human vision at low levels of brightness ascertained by spectroscopic methods and described in the two preceding chapters can be demonstrated in a very simple and striking fashion with the aid of appropriate colour filters.

On any clear moonless night, the light which reaches ground-level is principally that received from the stars overhead. Some of it comes from the very bright stars which are the most conspicuous objects in the night-sky. A substantial contribution is also made by the fainter stars of various magnitudes which can individually be perceived by an observer. Far more numerous are the faintest stars which cannot be perceived individually but which in the aggregate make a notable contribution to the observed luminosity of the sky. When these faint stars are present in great numbers in any particular area, e.g., in the Milky Way, the resulting diffuse luminosity of the sky is quite conspicuous. Nevertheless, except in the case of the very brightest stars, the luminous flux which reaches the eye of an observer from an individual star or from any limited area in the sky is extremely small.

That our visual perceptions are very different at low levels of illumination from what they are in bright light is made strikingly evident when the night-sky is viewed through a plate of glass which freely transmits light of wavelengths greater than 600 mμ and is opaque to shorter wavelengths. Such a plate exhibits a bright red hue by transmitted light in day-time. Held against the night-sky, it resembles a sheet of black glass, completely obscuring both the individual stars and the general luminous background of the sky. Only the very brightest stars, viz., Sirius and a few others can be glimpsed through the filter as dim red spots of light. Quite different, however, is the appearance in like circumstances of a disk of yellow glass which acts as a colour filter excluding light in the spectral range from 400 to 500 mμ and freely transmitting greater wavelengths. Held against the night-sky, the disk appears quite transparent and colourless. Neither the individual stars (except Sirius and a few others) nor the general background of the luminosity appears diminished in brightness when seen through the filter.

From the foregoing observations, it can be inferred that the part of the spectrum which makes a sensible contribution to the perceived luminosity of objects at low levels of brightness is limited to and falls within the range of wavelengths between 500 and 600 mμ. We can go further towards fixing the part of the spectrum which functions in dim light by making use of colour filters which exclude both the red and yellow sectors of the spectrum and freely transmit the green and blue sectors. Such filters are readily prepared by staining gelatine films with an appropriate dye-stuff, e.g., cyanin, or disulphine blue. They exhibit a bright greenish-blue colour by transmitted light in day-time. But when held against the night-sky, the filters appear quite colourless and completely transparent. No noticeable reduction of brightness either of the individual stars (other than the most highly luminous) or of the background luminosity of the sky results from viewing them through the blue-green filters. Comparative study of the night-sky through the three different types of colour filter thus enables us to conclude that only the green sector of the spectrum, in other words, the wavelength region between 500 and 560 mμ is effective in the perception of light at the low levels of illumination with which we are concerned here.

The stated conclusion is confirmed by observations of the night-sky through colour filters of other kinds. Of particular significance is the fact that a filter of glass which transmits light only within the wavelength range between 400 and 500 mμ, and accordingly exhibits a blue colour by transmission in daylight appears perfectly opaque when held up against the night-sky. Neither the individual stars—except a few of the highest luminosity—nor the general background of sky-illumination can be perceived through such a filter. A solution of cuprammonium in a flat-sided glass cell with its concentration adjusted to transmit the blue sector of the spectrum and absorb the rest exhibits the same behaviour. These observations establish that the blue region of the spectrum makes no sensible contribution to our perception of very feeble light-sources.

Colour filters of several sorts can be prepared with the aid of appropriately chosen dye-stuffs which completely eliminate the green sector, in other words, the wavelength range between 500 and 560 mμ, while the other parts of the spectrum are transmitted more or less freely. For example, a gelatin film heavily dyed with methyl violet transmits light of a purplish-blue colour in which both the green and the yellow sectors are absent. Likewise, a filter dyed heavily with magenta cuts out the green and the yellow and allows the red and the blue to come through. Rhodamine also absorbs the green and the yellow sectors of the spectrum. The exclusion of the green sector by these filters results in their appearing opaque when held up against the night-sky, neither the individual stars—except those which are very highly luminous—nor the background illumination being visible through them.

Several dye-stuffs can be used to prepare colour filters which appear green in colour by transmitted light in day-time. Spectroscopic examination shows this colour to be the result of a nearly complete absorption of the yellow and red sectors of the spectrum, while the blue sector is also much weakened and the green sector comes through freely. As examples of such filters may be mentioned those prepared with the dye-stuffs "fast-green", "brilliant green" and "lissamine green". As is to be expected, filters of this description transmit the light of the night-sky very freely, both the background illumination and the feeblest stars being seen clearly through them.

Filters exhibiting diverse colours by transmitted light in day-time may exhibit a partial absorption of the green sector of the spectrum. As examples, we may mention filters which appear of an orange hue in daylight. Such filters exhibit an extinction of the blue as also of the green up to about 545 mμ and a practically free transmission of greater wavelengths. When viewed through such a filter, the night-sky exhibits a weakening both of the general luminosity and of the brightness of the individual stars. But they continue to be visible. Filters which appear of a blue colour by daylight but are only partially transparent to the green of the spectrum exhibit a similar behaviour when the night-sky is viewed through them.

The spectra of individual stars: An observer with a replica diffraction grating held before his eye and viewing the sky on a clear moonless night will notice that the stars of exceptionally high luminosity, e.g., Sirius, α-Centauri, Arcturus, Vega, Capella and Rigel are accompanied by brilliantly-coloured streaks of light which are their diffraction spectra of the first and higher orders. Less brilliant stars also exhibit a similar phenomenon but with much diminished intensity. Indeed, in such cases, only the spectra of the first order can be seen and the colours are barely perceptible. The spectra also appear much shortened, the blue and red terminations being hardly noticeable. Fainter stars do not show the phenomenon at all, for the reason that the general luminous background of sky-illumination overpowers the faint diffraction spectra.

It is obviously a matter of interest to ascertain how the spectra of the less luminous stars present themselves to the unaided vision. The observations with colour filters described above demonstrate that the spectral region which is effective in our perceiving most of the stars in the sky is limited to the wavelength range between 500 and 560 mμ. To observe their spectra directly, it is necessary to exclude the general luminosity of the sky. This requirement may be met by viewing the night-sky through a long narrow slit, the observer and his diffraction grating being located inside a completely darkened room. The spectra of the individual stars are then seen as bright streaks crossing the elongated spectrum of the diffuse general illumination of the sky. Except in the case of the highly luminous stars, the streaks do not extend outside the spectrum of the diffuse illumination.

The question naturally arises whether the spectrum of the so-called "diffuse illumination" of the sky is itself not the result of the superposition of a great number of streaks representing the spectra of the individual stars. Any attempt to answer this question by observational study should evidently be made in specially favourable circumstances, viz., in an observatory situated at a high level and not troubled with the illumination of the sky by the light of neighbouring cities.