The normal human eye is a sensitive detector of radiant energy, and it has an extremely wide dynamic range (the ratio of maximum to minimum detectable signal). However, the precise work of hydrologic optics requires a more objective means of measuring the flow of radiant energy. Two main classes of light detectors have been developed to detect and measure radiant energy: thermal and quantum detectors. Thermal detectors measure the energy of the detected photons. In thermal detectors, radiant energy is absorbed and converted into heat energy, and the detector responds to the consequent change in temperature of the absorbing medium. Thermal detectors include ordinary thermometers, thermocouples, bolometers, and pyranometers. Quantum detectors respond to the number of incident photons, rather than to the cumulative energy carried by the photons, although the photon energy generally affects detector performance. Quantum detectors include photographic film and various photovoltaic, photoconductive, and photoemissive detectors. A brief description of the latter three detectors, collectively called photoelectric devices, is worthwhile.

A photovoltaic cell consists of two dissimilar substances in contact. Light incident on the photovoltaic element generates a difference of electric potential between the two dissimilar parts of the element, and as a consequence a current flows in the electrical circuit containing the cell. This current is measured by a current meter included in the circuit. When no light is incident on the element, no potential difference is generated and consequently no current flows. Generally, the greater the number of photons incident on the element of the cell, the greater is the resultant potential, and the greater is the ensuing current in the circuit. Becquerel first observed the photovoltaic effect in 1839 when a liquid electrolyte containing two immersed electrodes connected through a galvanometer was irradiated by sunlight.

It was found experimentally in 1873 that the electrical conductivity of the metal selenium increases when light falls upon it. This effect can be exploited for measuring radiant energy by constructing a series electrical circuit consisting of the selenium (or a similarly behaving substance), a seat of electromotive force (e.g. a battery), and a current meter. The greater the number of photons falling on the photoconductive cell containing the selenium, the greater is the cell's conductivity, hence the greater is the current flowing in the circuit. Some dark current flows even if no light is incident on the cell, since the photoconductive substance has a nonzero conductivity even in the absence of light.

The photoemissive effect (often called the photoelectric effect) was discovered in crude form in 1887 by Hertz in the very same experiment in which he verified the existence of electromagnetic waves. The basic photoemissive cell consists of an evacuated tube containing a negatively charged electrode (the photocathode, usually made of an alkali metal such as cesium, sodium, or potassium) and a positively charged electrode (the anode). When light is incident on the photocathode, the photons dislodge electrons from the surface of the electrode. These photoelectrons are drawn across a gap to the anode, thus generating a current in a series circuit containing the cell, a current meter, and a seat of electromotive force, which replenishes the supply of electrons on the photocathode and maintains the potential difference across the electrodes. In principle, no current would flow if no light were incident on the photocathode, but in practice a small dark current flows because of electrons spontaneously emitted by random thermal motions in the cathode.

A photomultiplier tube (PMT) is a specialized photoemissive cell. Rather than having only one photocathode and one anode, a PMT has a series of anodes (called dynodes), each of which is held at higher positive voltage that the previous one. The electrons liberated from the photocathode by the incident light are attracted to the first dynode. When these original electrons strike the first dynode, they knock loose additional electrons, which are then attracted to the second dynode. The electrons striking the second dynode liberate still more electrons, which are attracted to the third dynode, and so on. This electron cascade enables a PMT to greatly amplify (typically by a factor of one million) the current which would result from the photoelectrons alone. Commercially available PMT's have up to 15 dynodes and are extremely sensitive light detectors. However, PMT response is very sensitive to temperature, the response is not stable with time (owing to changes in the dynodes caused by electron bombardment), and stable high-voltage power supplies are required for operation. For these and other reasons, PMT's have been supplanted in many oceanographic instruments by solid-state detectors.

Semiconductor diodes can serve as light detectors, in which case they are called photodiodes. For example, in a typical pn-junction silicon photodiode, light incident on the junction frees electrons from the silicon atoms (but does not eject the electrons from the diode). The resulting positively charged silicon ions are held fixed in position by the crystal lattice, whereas the free electrons can move in response to an applied electromotive force. These electrons thus generate a current when the photodiode is included on a series circuit with a seat of electromotive force and a current meter. The diode thus functions as a photoconductive cell. Note that a photodiode does not amplify the photocurrent as does a PMT, and consequently photodiodes are much less sensitive detectors than are PMTs. However, photodiodes have good stability, are easy to calibrate, require little power, and are quite rugged and inexpensive.

When operated as light detectors, diode junctions have the external electromotive force applied so as to separate the photoelectrons and their parent ions, thus generating the measured current. However, if the electrons are allowed to recombine with the ions, then photons are emitted from the junction. These photons have the same energy as the photons required to liberate electrons from the semiconductor atoms. When operated in this fashion, the diode is called a light-emitting diode (LED). LED's have the same general characteristics (stability, low cost, etc.) as photodiodes, and are often employed as light sources in oceanographic instruments (such as beam transmissometers) that require an internal light source.

Another type of photoelectric detector is the charge-coupled device (CCD), which is the heart of modern electro-optic cameras (digital still cameras and camcorders). CCD's consist of linear or area arrays of small (of order $10\,\mu m$) spots of silicon. When light is incident on the array, electrons are released from each silicon spot in proportion to the radiant energy falling on the spot. The charge released by each spot is measured. Since the location of the silicon spots is accurately known, the pattern of released charge provides a map of the energy falling on the CCD array. When coupled with a standard camera lens, a CCD array (replacing the normal film) can record an image of the scene seen by the camera.

Theoretical understanding of the photoemissive effect came from Einstein in 1905 in a revolutionary paper (translated in Arons and Peppard (1969)) in which he introduced the concept of a photon along with its energy equation $q = h\nu$. This work was a major milestone in the history of physics, and it was primarily for his explanation of the photoemissive effect that Einstein received the Nobel Prize in 1921. Full understanding of the photovoltaic and photoconductive effects requires the quantum theory of the structure of matter. The photoconductive effect, for example, occurs when photons transfer electrons into the conduction band of the semiconductor, rather than completely ejecting the electrons from the material.

A thorough discussion of the physics and engineering of all types of radiation detectors can be found in various chapters of the Handbook of Optics (1995) and in the texts by Budde (1983) and Dereniak and Crowe (1984).