THE COLORS OF NATURAL WATERS.

Mr. W. SPRING, of the University of Liege, has greatly advanced our knowledge of this subject in a paper in the *Revue scientifique* for Feb. 10, 1883, a translation of which also appeared in the *Popular science monthly* for May. He begins with a careful and critical summary of the views of previous observers, and from these and his own experiments reaches the following important conclusions: 1. Water, in the purest state in which it can be obtained, has a distinct and beautiful blue color, which must be regarded as its essential or proper color, as the color of absolutely pure water; 2. The green, yellow, and brown colors observed in water are due to the reflection of light by matter held in suspension. This suspended foreign matter is very finely divided, and probably is usually in the state of nascent precipitation. It may be liquid or solid, transparent or opaque.

"The important point is, that it be competent to reflect light. Then the light-rays of feebler intensity (violet, blue, green, etc.) suffer extinction, one after another, according to the thickness of the medium, till the yellow rays, the brightest to our eyes, are the last to survive the struggle.

"The obstruction of the light, inducing the yellowish tint, which may be produced by any salt, depends less on the quantity of the salt present than on its being near the stage of precipitation. Small quantities of a feebly soluble salt produce the same effect as large quantities of a more soluble salt. The variety in the colors of natural waters, then, may be thus explained: absolutely pure water, viewed in masses of sufficient thickness, has a beautiful blue color. If it holds in complete solution colorless salts, its color is not changed; but, in proportion as it may contain matter on the verge of precipitation, the light traversing it will be of a yellow or darker color, until a stage is reached when the liquid will let no light through, and becomes opaque or black. The yellow light will combine with the blue light of the water; and thus will be produced greenish-blue, bluish-green, and green tints, according to the strength of the yellow. If the latter is very strong, the dark blue will be wholly smothered, and the water will appear yellow, brown, or of a still darker color."

The less soluble bodies in natural waters — those which may be regarded as frequently in the state of nascent precipitation, and to which the colors are chiefly due — are the carbonates of calcium, and silica, and also, probably, the finest mechanical sediment or clay, which, although not properly soluble, forms an emulsion with water, and affects the light in the same way as an incipient precipitate.

This theory appears to me to be the only one yet advanced affording a consistent explanation of all the phenomena; and my present purpose is to call attention to a general and important fact concerning the color of natural waters (which appears to have been but little noticed or appreciated by scientific observers, and of which I have never seen any explanation), and to show that it harmonizes beautifully with Mr. Spring's theory. Briefly stated, this general fact is as follows: tropical and warm seas are blue, and polar and cold seas are green; i.e., other things being equal, the color of the water is determined by the temperature.

All voyagers in tropical seas must have noticed the magnificent blue color of the water; the color seeming to be purest and most intense under the equator, or where the water is warmest. On passing to higher latitudes and lower temperatures, the color changes to greenish blue, bluish green; and green, although the Gulf Stream and other warm currents carry the tropical color and temperature well up toward the frigid zones, and into the midst of seas whose prevailing tint is deep green. Probably nothing makes the Gulf Stream seem more real, especially to the unscientific observer, than the great contrast in color that is presented within a very short distance, when we cross its northern wall. On one side is the cold, green water of the polar current, and on the other the warm, blue water of the Stream. The difference in color between the Gulf Stream and the surrounding parts of the ocean is noticeable even in the North Atlantic, on the track of the transatlantic steamers; and I have found that this part of the sea is perceptibly greener in winter than in summer.

As already stated, this general difference in color between warm and cold seas, although not explained by Mr. Spring, is a necessary corollary of his theory: for warm water is, for most substances, a more powerful solvent than cold water; and if cold seas are green in consequence of some of the contained salts being imperfectly dissolved, i.e., in a state of nascent precipitation, then an increase of temperature in the water, by augmenting its solvent power, will tend to obliterate the green color, and restore the blue. Again: warm water possesses less adhesion than cold water, which would cause a more rapid deposition of fine clayey matter in warm water than in cold. Hence, if the green color of cold seas is due, not to imperfectly dissolved salts, but to the suspension of fine insoluble clays, forming an emulsion, an increase of the temperature of the water, by causing a more complete deposition of the suspended clayey matter, will also tend to change the color of the water from green to blue.

In short, it follows from this theory, that, other things being equal, the color of natural waters must be a function of the temperature; and this conclusion is sustained by observation. One general exception, however, should be noted; viz., that shallow water near shore is usually green, even in warm seas, on account of the large amount of foreign matter in suspension. This was very noticeable on the coast of Cuba; the sea being of a pure blue color to within a few rods of the beach, and then rapidly changing to green. When viewing the coast from an elevated promontory, these colors were quite distinct to the eye for a distance of one to two miles along the shore.

As affording additional confirmation of the theory, I offer the following notes on the colors of European waters, which were made during the summer of 1883, while travelling from Sicily to Throndhjem in Norway. I was not able to make corresponding observations of the temperature of the water; but this may be approximately inferred, in most cases, from the latitude and season.

April 14 to 16. — The Mediterranean, between Stromboli and Sicily, is a decided blue, but not so deep and brilliant as the blue of the Gulf Stream and West-Indian waters. In the harbors of Messina and Catania the water is a brilliant green, inclining to blue. The color of the sea along the entire east coast of Sicily, from Messina to Syracuse, as viewed from the land, is blue, inclining to green.

April 22 to 26. — The water about the Lipari Islands, and between them and Messina, is of a dark, intense blue.

April 27. — The Bay of Naples is dark green, with scarcely a trace of blue.

April 28. — The sea about Salerno, and between that and Amalfi, as seen from the shore, is a beautiful blue-green, but sometimes pure bright green, and again, when deep, inclining strongly to blue.

May 1. — The Bay of Naples, between Naples and Ischia, is a deep green, without a trace of blue.

May 4. — The sea all about Capri and Sorrento is a pure, deep, and beautiful blue. These shores are vertical walls of rock, which afford very little sediment to the water. Later in the summer, as many observers testify, the Bay of Naples is blue throughout.

June 1 to 4. — The waters of the Italian lakes — Como, Lugano, and Maggiore — are a beautiful and distinct green. John Ball, F.R.S., in his 'Alpine guide,' states that the southern end of Lake Maggiore is blue. I found it almost as green as the northern end: but it is probably blue in mid-summer; and, if so, it must be regarded as a striking confirmation of the theory.

June and July. — The Swiss lakes are generally bright green and somewhat opaque. Lake Geneva, however, as is well known, is a lovely blue, resembling the sea about Sicily; but toward the upper end it seemed to be slightly greenish. The other Swiss lakes derive their waters from regions that are largely composed of limestone, and hence these waters are saturated with carbonate of calcium. But the Rhone, which is the principal tributary of Lake Geneva, drains a region of metamorphic rocks containing but little limestone.

Aug. 2. — The Baltic, between Stralsund and Copenhagen, is dull green.

Aug. 3 to 4. — The color of the Cattegat is dull green, without a trace of blue.

Aug. 7 to 23. — Between Christiansand and Throndhjem the open sea and the lower parts of the fiords have a deep, dark green color, with scarcely ever a suspicion of blue. As we ascend the fiords, the color becomes a lighter green, and more vivid and opaque, in proportion as the water becomes fresher. The heads of the fiords and the adjacent lakes are usually indistinguishable in color from the Swiss lakes; but the beautiful Ringedalsvand, lying between the head of the Hardanger Fiord and the celebrated Ringedalsfos, at an altitude of fifteen hundred feet, is a notable exception. This lake is deep blue except near the shore, where it is greenish blue; and the streams flowing into it, as well as that flowing out, are nearly pure blue. The rule that cold water is green does not hold in this case, but the exception is readily explained as due to the unusual purity of the water. The lake is bounded on all sides by cliffs of granitoid gneiss, and where there is a talus at the bottom it is usually destitute of soil. Above the cliffs are immense fields of snow, whence the water of the lake is derived. None of the tributary streams flow from glaciers; but they are all limpid snow-water flowing down over hard rocks, which are alike destitute of soil or material which could be carried away in suspension in the water, and of limestone or other materials capable of being dissolved in the water. It would probably be difficult to find any considerable body of natural water which is more nearly a pure distilled water than this. And we may fairly say, that, on account of its remarkable purity, it is blue, in spite of its low temperature.

W. O. Crosby.