

from the place where he settled was this same Mulhausen, famous then, as now, for its enterprise in arts and manufactures. Here was the *Société Industrielle*, which in 1826 offered large prizes for the best analytical investigations of madder. The existence of this enterprising *Société* in France was the natural outcome of the appointment by the French Government of a succession of eminent chemists, men of the first rank, like Macquer and Berthollet, to superintend the arts and manufactures, and particularly to improve the art of dyeing. The various competitions for the prizes offered by the Mulhausen *Société* led finally to the discovery by Robiquet in 1827 of alizarin, the most valuable of the coloring substances of madder. The same investigator showed that the carbonate of lime, which rendered the Avignon madder so much superior to that from other districts, acted by combining with the inferior dyeing principles so as to prevent their precipitation in the fibres of the fabric. Attempts were next made to prepare from the madder root as nearly pure alizarin as possible. After many failures, Robiquet and Persoz succeeded in making a material of such constant dyeing power that it came largely into use, and in 1864 it was used about equally with madder. In the preparation of this impure alizarin, a solution of sugar was obtained which yielded on fermentation enough alcohol (which, the writers of that time are careful to tell us, was not potable) to pay the cost of the whole process.

It was in the middle years of the century that the classical researches of Gerhardt, Laurent, Williamson, Frankland, Kolbe, Wurz and Kekule on the molecular constitution of carbon compounds led to a general activity in enquiries of this kind. One by one were solved problems about the probable arrangements of the atoms in the molecules of complicated compounds. Dalton's vivid conception of atoms as real things was expanded at this time into a theory which, in the hands of these masters and of those who succeeded them, guided research with a certainty hitherto unknown and truly marvellous in results. It was a happy combination of the spirit of research with practical knowledge of the industrial applications of chemistry which now led Bronner, Graebe and Liebermann to the discovery of the molecular constitution of alizarin and very soon after to a practicable method of synthesizing it from a substance present in coal tar.

In 1868 Graebe and Liebermann noticed that pure alizarin could easily be converted into anthracene, a substance then known to be present in coal tar to the extent of about one part in one thousand. In January, 1869, they succeeded in reversing the process, and anthracene was converted into alizarin, which was found to be identical with the natural compound, and to dye all the colors obtainable from it. The colors were also purer and the process of dyeing more certain than when madder or any of its preparations was used. This was the first instance of the artificial production of a vegetable coloring matter.

It will be interesting at this point to note the course of events in Great Britain in connection with madder dyeing. Presumably she was especially interested in the art, as, according to Dr. Ure, "Alumed wool takes, in the madder bath, a red color, which is not so bright as the cochineal, but is faster; and as it is far cheaper, it is much used in England to dye soldier's cloth." To which he adds, "The Turkey-red dye of Monteith & Co., of Glasgow, is celebrated all over the world." In 1662 the Royal Society asked Mr. Haak to translate *Plinio del Arte dei Tintori* by Giovanni Ventura Rosetti (1758), and on the same day (April 20th), Sir William Petty laid before the society "An Appendix to the History of the Common Practices of Dyeing" Boyle, Hooke and others, followed up with contributions, one in-

vestigator (Hooke) even showing the society specimens of cloth dyed in a new way by himself. But for a century and a half after this no important scientific investigation seems to have been made to improve the arts of dyeing and calico-printing in England, the men of science of that time being perhaps discouraged by the lack of connection between their work and that of the dyers. Early in the nineteenth century, Watt and Higgins investigated the coloring principles of madder, but the chemists of Great Britain seem to have contributed little, either to the improvement of the natural dyeing material, or to the researches which led immediately to the synthesis of alizarin. Immediately after the publication by Graebe and Liebermann of their remarkable and important discovery, they pushed on to devise a cheaper method, which might be applied commercially. W. H. Perkin, sr., the English pioneer in the production of coal tar colors, engaged in a similar research. The field reached the goal almost simultaneously. Perkin's application for a patent in England was one day behind that of Graebe, Liebermann and Caro. Curiously enough, according to the German patent laws the process could not be patented in Germany, as the discovery had been published. Thus, while the manufacture of alizarin was free in that country, in England where nearly all the raw material, anthracene, was produced, alizarin could be manufactured only under the patents.

The importance of this discovery can be estimated when it is known that before 1869 the yearly crop of madder roots was about 70,000 tons, worth about \$15,500,000. Of this, Great Britain consumed about one-third. In 1883 madder was no longer grown (*Journal of the Society of Chemical Industry*, Vol. II., p. 214). In 1882 Germany manufactured \$9,000,000 worth of alizarin, only \$1,000,000 worth being produced in other countries. The raw material, anthracene, still came almost altogether from England, but the production of anthracene in Germany was increasing, and manufactures of chemicals used in the alizarin process had been built up to the annual value of about \$2,500,000. At first the chromates required were imported altogether from Scotland, but in 1882 Germany was producing her own supply, of an annual value of about \$2,500,000. At first the chromates required were imported altogether from Scotland, but in 1882 Germany was producing her own supply, of an annual value of \$500,000. Thus the discovery of Graebe and Liebermann concentrated in Germany in a few years the lion's share of an industry from which France, Turkey, Italy, Holland and India had long been drawing large revenues.

Indigo is another dye the use of which goes back to the beginnings of civilization. As its name shows (the *indichon* (Greek) of Dioscorides and the *indicum** of Pliny) it comes from India, where the best indigo is still procured from various species of *Indigofera*. But the dye has also been long used in China; and in some districts (Chin Kiang, for example) the plant is cultivated by each farmer as part of his yearly crop, very much in the way in which the habitants of Quebec grow tobacco. The dye is manufactured and used for dyeing the family's cottons. Any surplus is put upon the market for sale. There is an odd superstition connected with the extraction of the dye in this Chinese province. The women constantly wear flowers in their hair, and while the

*Natural History, xxxiii., 1367 and xxxv., 636. The passages are as follows. "Indigo (*Indichon*) is a kind of sky-blue dyestuff not very long imported for the first time from India; the use of which in painting is for insertions, that is, to divide the shades from the light. There is another kind of indigo, older and better known to the Romans and more expensive, coming from the same place, in clay adhering to the pith of reeds. When it is rubbed, it is black, but on dissolving, strange to say it becomes a mixture of purple and sky blue. There is another kind in the purple factories, floating in the caldrons, and it is the foam of the purple. Those who adulterate it color the dung of doves or Selinusian chalk with the true indigo; or they steep in woad a white preparation made from chalk. It is tested on charcoal; for it affords, when it is genuine, a fine flame of purple, and, while it smokes, the smell of the sea."