Edinburgh, taking at once a good rank in his profession, and showing considerable versatility in subject-matter. Portrait-painting for some years occupied much of his time; and he was particularly prized for likenesses of ladies and children. In February 1837 he was appointed master of the school of design of the Board of Manufactures, Edinburgh. In the same year he published a pamphlet on the management of schools of this description, which led to his transfer from Edinburgh, after eighteen months' service there, to London, as superintendent and secretary of the then recently established school of design at Somerset House. Mr J. R. Herbert was head-master about the same time. Dyce was sent by the Board of Trade to the Continent to examine the organization of foreign schools; and a report which he eventually printed, 1840, led to a remodelling of the London establishment. In 1842 he was made a member of the council and inspector of provincial schools, a post which he resigned in 1844. In this latter year, being appointed professor of fine art in King's College, London, he delivered a noticeable lecture, *The Theory of the Fine Arts*. In 1835 he had been elected an associate of the Royal Scottish Academy; this honour he relinquished upon settling in London, and he was then made an honorary R.S.A. In 1844 he became an associate, in 1848 a full member, of the London Royal Academy; he also was elected a member of the Academy of Arts in Philadelphia. He was active in the deliberations of the Royal Academy, and it is said that his tongue was the dread of the urbane President, Sir Charles Eastlake, for Dyce was keen in speech as in visage; it was on his proposal that the class of retired Academicians was established. In January 1850 Dyce married Jane, daughter of Mr James Brand, of Bedford Hill, Surrey. He died of a cancerous disease in his house at Streatham on 14th February 1864, leaving two sons and two daughters.

Such is a brief outline of the honourable and prosperous career of one of the most learned and accomplished of British painters—one of the highest in aim, and most consistently self-respecting in workmanship. His finest productions, the frescoes in the Queen's Robing-room in the Houses of Parliament, may rightly be called great, and an honour to the country and time which produced them; these frescoes, and the water-glass paintings of Maclise in the same building, would find few rivals in contemporary Continental labours. Generally, however, there is in Dyce's work more of earnestness, right conception, and grave, sensitive, but rather restricted powers of realization, than of authentic greatness. He has elevation, draughtsmanship, expression, and on occasion fine colour; along with all these, a certain leaning on precedent, and castigated semi-conventionalized type of form and treatment, which bespeak rather the scholarly than the originating mind in art. The following are among his principal or most interesting works (oil pictures, unless otherwise stated). 1829: The Daughters of Jethro defended by Moses; Puck. 1830: The Golden Age; the Infant Hercules strangling the Serpents (now in the National Gallery, Edinburgh); Christ crowned with Thorns. 1835: A Dead Christ (large lunette altar-piece). 1836: The Descent of Venus, from Ben Jonson's "Triumph of Love;" The Judgment of Solomon, prize cartoon in tempera for tapestry (National Gallery, Edinburgh). 1837: Francesca da Rimini (National Gallery, Edinburgh). 1838, and again 1846: The Madonna and Child. 1839: Dunstan separating Edwy and Elgiva. 1844: Joash shooting the Arrow of Deliverance (the finest perhaps of the oil-paintings). 1850: The Meeting of Jacob and Rachel. 1851: King Lear and the Fool in the Storm. 1855: Christabel. 1857: Titian's first Essay in Colouring. 1859: The Good Shepherd. 1860: St John bringing Home his Adopted Mother; Pegwell Bay (a coast scene of remarkably minute detail, showing the painter's partial adhesion to the so-called "pre-Raphaelite" movement of that time). 1861: George Herbert at Bemerton. Dyce executed some excellent cartoons for stained glass:—that for the choristers' window, Ely Cathedral, and that for a vast window at Alnwick in memory of a duke of Northumberland; the design of Paul rejected by the Jews, now at South Keningston, belongs to the latter. In fresco-painting his first work appears to have been the Consecration of Archbishop Parker, painted in Lambeth Palace. In one of the Westminster Hall competitions for the decoration of the Houses of Parliament, he displayed two heads from this composition; and it is related that the great German fresco-painter Cornelius, who had come over to England to give advice, with a prospect of himself taking the chief direction of the pictorial scheme, told the Prince Consort frankly that the English ought not to be asking for him, when they had such a painter of their own as Mr Dyce. The cartoon by Dyce of the Baptism of Ethelbert was approved and commissioned for the House of Lords, and is the first of the works done there, 1846, in fresco. In 1848 he began his great frescos in the Robing-room—subjects from the legend of King Arthur, exhibiting chivalric virtue. The whole room was to have been finished in eight years; but ill-health and other vexations trammelled the artist, and the series remains uncompleted. The largest picture figures Hospitality, the admission of Sir Tristram into the fellowship of the Round Table. Then follow—Religion, the Vision of Sir Galahad and his Companions; Generosity, Arthur unhorsed, and spared by the Victor; Courtesy, Sir Tristram harping to la Belle Yseult; Mercy, Sir Gawaine's Vow. The frescos of sacred subjects in All Saints' Church, Margaret Street, London; of Comus, in the summer-house of Buckingham Palace; and of Neptune and Britannia, at Osborne House, are also by this painter.

Dyce was an elegant scholar in more ways than one. In 1828 he obtained the Blackwell prize at Aberdeen for an essay on animal magnetism. In 1843–4 he published an edition of the Book of Common Prayer, with a dissertation on Gregorian music, and its adaptation to English words. He founded the Motett Society, for revival of ancient church-music, was a fine organist, and composed a "non nobis" which has appropriately been sung at Royal Academy banquets. His last considerable writing relating to his own art was published in 1853, *The National Gallery: its Formation and Management*. (W. M. R.)

DYEING is the art of colouring in a permanent manner porous or absorbent substances by impregnating them with colouring bodies. Most vegetable and animal bodies are porous or absorbent, and can be dyed; some minerals also, such as marble, can absorb liquid colouring matters; but the term dyeing is usually confined to the colouring of textile fibrous materials by penetration. The superficial application of pigments to tissues by means of adhesive vehicles, such as oil or albumen, as in painting or in some kinds of calico-printing, is not considered as a case of dyeing, because the colouring bodies so applied do not penetrate the fibre, and are not intimately incorporated with it. The mere saturation of textile fibre with a solution of some coloured body and subsequent drying do not constitute a case of dyeing, unless the colour becomes in so far permanently attached to the fibre that it cannot be washed out again by the solvent employed or by common water. In the present article dyeing will be considered only with relation to the vegetable and animal fibrous substances which are commonly used in clothing or furniture,—the less important arts of dyeing feathers, skins, ivory, wood, marble, &c., being left over for treatment under other headings.

Historical Sketch.

That dyeing was practised in the most ancient times is abundantly proved by the frequent mention of dyed colours in the oldest extant writings; that it was not a common art seems apparent from the uses to which coloured garments were devoted, and the distinction which they conferred upon the wearers. It is probable that such definite and bright colours as the "blue, and purple, and scarlet" mentioned several times in the book of Exodus, as well as the Tyrian purple so often referred to by Roman writers of the Augustan age, were so costly as not to be available for general and common use. Pliny is the only one of the older writers from whom we might have expected some account of the processes of dyeing employed at his time; but, except a reference to two or three tinctorial substances, and a description of a process of obtaining several colours by one dyeing operation, which he saw practised in Egypt (see Calico-Printing, vol. iv. p. 684), there is nothing detailed in his writings;—he in fact formally excuses himself from entering upon the subject as one not worthy of his attention. The Tyrian purple is the only dye treated of at some length in Pliny and contemporary authors; its discovery and employment gave wealth and prosperity to Tyre and Sidon more than 1000 years B.C. In the days of the Roman conquests in the East it was reserved under penal statutes for imperial use; its p oduction then declined, and eventually both the material and the art of using it were lost. From Pliny's description, modern investigators were enabled to rediscover the shell-fish which yielded the dye; but the colours furnished by it were neither so bright nor so permanent as those obtainable from much less costly dyeing materials; and there is reason to conclude that the most brilliantly tinted garments of an Egyptian priest of Isis or Osiris, or the mantle of a Roman emperor, were poor and dull in hue compared with those within reach of a domestic servant of the present time.

From many independent sources—Homer, Strabo, Herodotus, &c.,—it is clearly shown that the manufacture of coloured tissues was carried on by the Oriental nations. A knowledge of the art spread slowly westward, but there are few records of its existence to be found from the time of Pliny to about the 13th century. It would appear that the Jews held the secret or the monopoly of the dyeing art during this long period. According to Mrs Merrifield, Benjamin of Tudela relates that when he visited Jerusalem between 1160 and 1173 he found only 200 Jews resident in that city, and these were all engaged in wool-dyeing, which trade was entirely in their hands. Beckmann shows that at the same epoch the art of dyeing in Italy was principally carried on by Israelites. It is in Sicily that we can first distinctly discern the practice of dyeing in Europe; afterwards the Italians generally practised it; and in the 13th century dyers formed important guilds in Florence, Venice, and other cities. It is not to be supposed that the art of dyeing was ever completely lost; the records of particular seats of the art only indicate that at such places some special excellence had been acquired which gave them a higher reputation than was enjoyed by others. The domestic records of all modern nations speak of dyers and dyed cloths. Among the ancient laws of Ireland are some which lay down the number of colours that may be employed in the dress of various classes of society, the monarch alone being permitted to wear seven colours; from which it may be inferred that if the Irish at a very early period were not dyers, they at least had variously dyed garments. Similar facts can be adduced of all countries that possess an early literature.

From the perishable nature of textile substances and their comparatively small intrinsic value, very few ancient examples of the dyer's art have been preserved. We have, however, one account of a cloth containing dyed yarn which may have been in the dyer's hands in Egypt 1000 years before the Christian era; and we have still in good preservation ecclesiastical vestments containing dyed silks which are certainly 600 to 700 years old. The late Mr Thomson of Clitheroe examined numerous mummy cloths, some of which had a border of blue and fawn-colour made by coloured threads introduced into the loom. The blue, upon examination, was proved to have been dyed with indigo; other specimens of mummy cloth of a reddish colour appeared to have been dyed with safflower, though this colouring matter could not be recognized with the same certainty as indigo. Dr Rock, in his catalogue of the textile fabrics in the South Kensington Museum, attributes many of the church vestments there preserved to the 12th and 13th centuries, and in these can be seen silks of all the colours known to dyers up to the middle of the present century, which, though in most cases changed and faded, still present sufficient evidence that dyeing, upon this material at least, was successfully practised in the Middle Ages. It is interesting further to note that in inventories of vestments of the 13th century the silks in the vestments are often designated by their colours, as in a chasuble at St Paul's, London, 1295, which is set down as "purpureo aliquantulum sanguineo," of a purple inclining to blood red. This, as Dr Rock says, is intelligible; but other definitions are not, as "pannus Tarsici coloris," a Tarsus-coloured cloth; it can only be conjectured that it was a purple dyed at Tarsus, and something like the Tyrian purple; sky-blue silk is named "indicus," probably because it was dyed with indigo.

The earliest account of the processes and materials used by dyers is to be found in a collection of manuscripts in the French National Library, No 6741, known as the manuscripts of Jehan le Begue. These mostly refer to the art of painting and the making of artists' colours and the modes of applying them, but some describe the preparation and use of dyes. The most interesting of these manuscripts is by Jehan Alcherius (Le Begue was only the copier or compiler), which from internal evidence cannot be dated later than the year 1410, and some parts of which refer to a period at least thirty years earlier. Among the colouring matters and mordants there mentioned we find iron (the dust or mud from grindstones on which knives are ground) dissolved in vinegar and mixed with alum, green copperas, and gall nuts prescribed as a black colour; and methods are given for the use of Brazil wood, litmus, indigo, in conjunction with lime and honey, verdigris, alkalies, oxide of tin, kermes, &c., much in the same way as those employed four centuries later by dyers and calico-printers. There are also eleven receipts for preparing colours, for painting on cloth to imitate tapestry,—examples of which (*toiles peintes*) of the 15th century were exhibited in Paris in 1876. Curiously enough, a certain Fleming named Theodore in 1410 brought these receipts to Alcherius from London, where they were in regular use. They are all chemical dyes, and seem to be the prototypes of the same class of colours employed long subsequently by calico-printers in England and other countries.

The first printed account of dyeing processes was an Italian work. It is referred to under the title *Mariegola dell' arte dei Tintori*, published at Venice in 1429. The writer has never seen a copy of this work, nor does it appear that any exists in the chief libraries of Europe; an enlarged edition was published in 1510. In 1548 Rosetti wrote an account of dyeing, which was also published at Venice. Copies of this are not very scarce; it is the only one of these early books which is actually known. The so-called Bolognese manuscript translated in Merrifield's

Ancient Practice of Painting, is preserved in the convent of St Salvatore at Bologna, and is said not to be of later date than the middle of the 15th century—that is, about 100 years anterior to the date of Rosetti's work. In this manuscript, in addition to the materials enumerated by Alcherius, mention is made of woad and methods of making indigo from it; of indigo imported from India, called *bagadon* and *bagadel*; of sumach, gall nuts, and lac; of the berries of buckthorn, similar to the Avignon or Persian berries, to be used for yellow; and of Brazil wood or *verzino*, sandal wood, and madder for red; and archil for purple. The use of nitric acid to give a yellow colour to silk, and of alum for preparing and mordanting that material, and the subsequent dyeing of it by Brazil wood, are also clearly pointed out. The receipt No. 362 of this manuscript is of interest as showing that the Italian dyers early possessed the method of dissolving indigo by means of the action of honey and quick lime upon it, and used the solution for the blue required in dyeing silk green.

It is very clear, then, from these accounts, and from numerous existing samples of coloured stuffs, that dyeing was well understood in Europe in the 15th century, and that the materials at the command of the dyer were sufficiently numerous and varied to enable him to produce all desired shades of colour. The improvements which took place in the dyeing art from this time until the commencement of the present era of artificial colouring matters were no doubt important in detail, but not very striking in principle.

The discovery of America was soon followed by the introduction of cochineal (see vol. vi. p. 97), but this did not enable the dyer to produce any new colours, since it differed from the ancient kermes, frequently called *grana* or grains, only in being ten or twelve times as rich in colouring matter. Logwood or Campeachy was also an introduction from the New World, and greatly enlarged the power of the dyer, though, from the looseness of the colours it yielded, it brought his art into some disrepute; it was in many respects a new colouring matter, but eventually settled down as the principal ingredient in the common black dye. In mordants, the discovery in Holland in the 17th century of the use of solutions of tin in acid, especially for the scarlet dye with cochineal, was one of the greatest utility. The gradual introduction of the acetates of aluminium and iron to replace the respective sulphates was of more importance calico-printing than dyeing proper. At the close of the last century Dr Bancroft discovered and introduced quercitron bark from America for dyeing yellows, and this, from its superior richness and less cost, displaced other materials used for that purpose. Of the natural dyes introduced in the present century probably the most important is catechu. The discovery of the use of bichromate of potash as a mordant for woollen goods belongs to the latter half of this century, and has been of the highest benefit to the dyer. We shall not speak in detail of a number of dye-stuffs used by dyers of the present day, which were probably unknown to their predecessors, because most of them are only varieties of what have been long employed. Such, for example, are valonia, divi-divi, and myrobalans, which have no properties different from galls or sumach, and the different red woods, which are merely varieties of the anciently known Brazil woods.

Artificial Colouring Matters.—In the year 1858 commenced the discovery and application of a series of artificial colouring matters, which have created a distinct era in the history of dyeing. Up to that date the colouring matters used in dyeing were either the spontaneous productions of nature or simple preparations of the same. An exception, however, must be made to this statement in respect of Prussian blue and the so-called sulphate of indigo, which have been largely used as colours in dyeing since the middle of the last century, and are as truly products of art as any of the modern creations of chemistry. The purple of murexide had only a brief existence as a dye. Mr Perkin was the first to practically produce a dyeing material from aniline, the well-known mauve or purple shade so much in vogue for several years, for a history of which see vol. ii. p. 48 of the present work. Other discoveries rapidly followed, and in the course of a few years it may be said that a hundred patents were taken out for methods of making artificial colouring matters from aniline and its homologues; these alkaloid bases, under the transforming hands of chemists, supplied the dyer with every shade and hue which could be desired. Up to 1869 the artificial colours were of one general family, and had many characters in common; they were very brilliant, very easily applied on fibre of animal origin (silk and wool), required no mordant, and for the most part were very loose and unstable. Imitating more or less closely the colours obtained on tissues from natural colouring matters, they had no similarity of chemical composition, and were in every other respect fundamentally different from them. In 1868 two German chemists, Graebe and Liebermann, by means of a severe synthetical investigation, succeeded in transforming anthracene into alizarin, the latter being identical in chemical composition as well as tinctorial properties with the colouring matter of madder, one of the most anciently known and most valuable of all natural dye-stuffs (see vol. i. p. 577). This was the first instance in which chemistry had produced one of the old and well-known colours of the dyer; in a short time after its discovery it was made practically available for the trade, and has at this date (1877) almost entirely driven from the market the native product,—accomplishing a revolution which has no parallel in the history of colouring matters, and which is one of the most signal triumphs of modern chemistry. Other natural colouring matters have since then been produced by art, such as indigo and archil, but from some difficulties in their manufacture they have not yet become commercially available.

Mechanical Improvements.—In the art of dyeing, steam power has proved no less serviceable than in other important industries. Its applications are not further alluded to in this article, but in the article upon CALICO PRINTING (vol. iv. p. 684) some illustrations of modern machinery may be seen.

GENERAL PRINCIPLES OF DYEING.

Although many eminent chemists have worked and written upon the subject, there still remains much difference of opinion as to what actually takes place in dyeing operations. The following general account of the chief cases of dyeing will illustrate the principal methods in use, and serve as an introduction to a description of actual processes practised in dye-houses. Afterwards, the attempts made to construct a general theory will be briefly considered. The simplest cases of dyeing are those in which only two substances are employed—the fibre to be dyed and the colouring matter—and where the process of dyeing consists in nothing more than leaving the two materials in contact for a certain time at a convenient temperature. Of natural colouring matters few can be practically used in this simple way without some previous chemical treatment. The artificial colouring matters from aniline, however, illustrate this kind of dyeing very well. To obtain the finest shades of mauve, magenta, purple, and numerous other colours upon wool and silk fibre the whole process consists in placing the material in a solution of the requisite colour and of sufficient quantity to give the desired shade; it absorbs the

colour, becoming dyed, while the solution is rendered nearly colourless. During the process the fibrous material is kept in a constant state of movement, so that the dye solution shall have equal access to all portions, the temperature employed and time allowed being regulated according to the necessities of the case. The colour absorbed by the fibre has entered into an intimate state of combination with it, since it cannot be washed out again; a true dyeing has taken place. Besides the aniline colours, the older artificial dyes—sulphindigotic acid, picric acid, and one or two others—have the same property of combining directly with wool and silk.

There are other cases of dyeing closely resembling the foregoing, in which the resulting dyed stuff may be considered as being a binary compound of fibre and colouring matter, but in which the methods of application are less simple. These may be taken generally as consisting in the use of materials or processes which bring a previously insoluble colouring matter into a soluble state; thus the pink colours of safflower are obtained by the action of an alkali; and the dyes yielded by archil, arnotto, and indigo are also the result of the action of solvents. It is possible that during the process of solution important internal changes may take place in the composition of the above dyes, but if so, they are only of a temporary nature, for there is no reason to suppose that the colouring matter attached to the fibre differs in chemical composition from that which is free.

With regard to nearly all other colouring matters, the above simple processes are quite powerless to induce a permanent combination with the fibre. Let wool or silk be immersed at boiling temperature in decoctions of any of the best known natural dye-stuffs, such as cochineal, logwood, madder, quercitron bark, &c., and then washed in water, it will be found that the fibres are simply discoloured, or stained of no definite shade; they have taken up but a small portion of colour from the decoction. and no real dyeing has taken place.

Use of Mordants.—To obtain permanent dyes from the great majority of native colouring materials the intervention of another class of bodies entirely different from either fibrous or colouring matter is found necessary; these bodies are called *mordants*. The term mordant is found in Latin and Italian manuscripts of the 12th and 13th century, as the name of an adhesive composition by means of which gold leaf could be attached to wood, marble, or metal; early dyers appropriated the word to designate a substance by means of which colouring matters could be made to adhere to fibre, and it has been retained in that sense in all modern treatises upon dyeing.

The chief mordants used in dyeing are salts of aluminium, iron, tin, chromium, copper, and a few other metals. When a decoction of a colouring matter, say logwood or cochineal, is heated with a small quantity of a properly chosen salt of one of these metals, it is found that the colouring principle loses its solubility, forms a combination with the metallic salt or its bases, and precipitates to the bottom of the solution, leaving the supernatant liquid nearly or quite colourless. The precipitate is usually called the "lake" of the particular metal and colouring matter, which are probably in a state of chemical combination; the lakes are insoluble in water, and are only split up again into their constituents by the action of somewhat powerful chemical agents.

Fibre cannot usually be dyed by means of ready formed lakes, for the reason that they are insoluble in water and not easily soluble in any menstruum which can be safely applied to such material; they are themselves of too coarse and gross a nature to penetrate the fibre, and when applied to it rest for the most part on the surface, and are therefore easily removable by washing or mechanical friction. It is known, however, that for some colours in calico-printing lakes can be applied, but that is only in conjunction with acid salts and at a high temperature, by means of which a sort of solution is obtained while in contact with the fibre itself. The art of the dyer consists in so arranging these three elements—fibre, metallic salts, and colouring matter—that he may obtain the formation of the insoluble coloured lake in the body of the fibre itself, whereby either by the lake being mechanically retained or chemically combined the fibre is permanently coloured.

Application of Mordants.—There are three principal ways in which the mordant and colouring matter can be put into contact with the fibre, the developments and modifications of which constitute the whole art of dyeing.

1. By the first method, which is by far the most common, the fibrous matter is separately impregnated with the mordant, which is by various means decomposed, so as to deposit its base in an insoluble state upon or within the fibre, and afterwards the colouring matter is applied. Take, for example, the case of dyeing a common black from logwood upon calico, which has no affinity for the colouring matter of the logwood. The first process is to pass the calico through a hot aqueous solution of sulphate of iron, sometimes mixed with acetate of iron, and to remove the excess by passing the cloth through rollers; the cloth, either previously dried or not, is then passed through a mixture of lime and water which has the effect of decomposing the iron salts and liberating oxide of iron. A washing in water to remove the excess of lime or any loosely attached oxide of iron prepares the calico for coming into contact with the logwood. The calico, which has now a buff colour, owing to the attached mordant of oxide of iron, when placed in a hot decoction of logwood speedily acquires a dark hue and in about half an hour has become dyed of a dense black colour, and, when smoothed and finished, forms the common black calico of the shops. A variety of other cases might be adduced; woollen cloth boiled for some time in bichromate of potash solution acquires a certain amount of a salt of chromium, which enables it to take a black colour from logwood, and other colours from other dye-stuffs. Woollen, boiled with salts of tin, is enabled to dye up a brillant scarlet in decoction of cochineal; boiled with alum, it will take a great variety of colours in various dye-stuffs. The practice of calico-printing illustrates in a very forcible manner the action of mordants; by the aid of apparatus described in the article upon that subject, portions of a piece of calico are impregnated with mordants, and these portions alone acquire colour from the dyeing solution, and thus designs or patterns are produced upon a white ground. The most usual method of impregnating the fibrous matter with mordant, consists in heating it with the required metallic salts, and it will be seen hereafter that easily decomposed salts are those preferably used; or substances such as chalk, alkalies, or tartar are added to some more stable salt, such as alum, to induce the formation of comparatively unstable compounds, which, under the influence of a high temperature and contact with fibrous matter undergo decomposition,—the metallic oxide or some basic insoluble compound of it becoming intimately combined with the fibre, which is then said to be mordanted.

2. A second method, less general than that above described, is to apply the colouring matter before the mordant. It is resorted to only with heavy goods which absorb a large quantity of liquid, or with light colours upon other fabrics; dyes produced in this way are superficial in their character, and not so permanent as those produced by the first method. In dyeing by that method it is in many cases customary to add a small quantity of mordant to the dye-bath when the process is quite or nearly finished, or to pass the dyed goods, as a final operation, through a diluted mordant.

3. A third method is to apply the mordant and the colouring matter together to the fibrous substance. In common piece-dyeing in weak liquids this plan is seldom followed, on account of the tendency to form insoluble lakes in the solution, which, depositing only on the external part of the fibres, give inferior results, alike as to stability of colour, depth of shade, and evenness or regularity of the dye. In calico printing or in padding, this method is of extended application and the inconveniences experienced in common dyeing are not perceptible, owing to the greater concentration of the mordanting salts and the use of thickening matter. Lakes are very probably formed to some extent during the preparation of the mixtures, but, the combination taking place in the presence of a fluid made viscous with gum or starch, the insoluble lake is in an extremely fine state of division; in such a mixture there is always present an acid or an acid salt, such as acetic acid, oxalic acid, tartaric acid, or alum, chloride of tin, cream of tartar, or binoxalate of potash. These tend, in the first instance, to restrain the formation of a lake, and afterwards, when the fibre and the mixture of mordant and colouring matter are submitted to heat, as in the process of steaming or stoving, facilitate the solution of any lake formed, which thus finds entrance into the fibrous matter, and there undergoes combination with it,

owing to decomposition of the mordanting salts, a true dyeing taking place.

Practical Dyeing Processes.

By the foregoing preliminary observations the reader will have been prepared to comprehend the *rationale* of the practical processes of dyeing. In order to give a fairly comprehensive account of these, it has been found convenient to take the colours in the old arrangement of simple and compound colours. Red, blue, and yellow are supposed to be simple or primitive colours; the methods of obtaining these being given, then follow the colours from mixtures of two of the elementary colours, as green from yellow and blue, orange from red and yellow, and purple from red and blue. The colours not included in the above, and in the dyer's philosophy made by mixing the three elementary colours, red, blue, and yellow, in different proportions—namely, the browns, greys, and chocolates, and black—will be conveniently treated of after those supposed to result from the mixture of two of the primary colours.

This arrangement, though perfectly arbitrary, is both convenient and consistent as far as regards dyeing, for though modern discoveries in optics may show that pure blue and yellow do not make green, and may in other respects disturb the older ideas concerning primitive and secondary colours, yet the dyer has sufficient justification for retaining the old system, because he can show that his blue and yellow always make green, and that the proper mixture of the so-called simple colours produces a compound shade which can be calculated beforehand from the proportion of the respective colours employed.

Red Colours.

The most important of the red colours produced by dyeing are obtained from cochineal and from madder, the former being used for woollen and the latter for cotton goods. They are both old colours, and have arrived at their present excellence by slow degrees; they are deep and brilliant, and, as far as regards permanency, hold the highest position among all dyed colours. The processes employed are instructive as illustrating the diversity of treatment required by different fibres and colouring matters.

Red upon wool from cochineal.—Let it be assumed that the shade of red required is fine scarlet, such as is worn by officers of the British army, and that the woollen cloth is of finest quality. The cloth first requires purifying from all the adventitious substances which it has acquired in the process of manufacture, in order to prevent irregularity and unevenness in the shade of colour; this is done by methods described in the article Bleaching. The only materials required to produce a fast scarlet upon wool are oxide of tin and the colouring matter of cochineal, but it requires much practical skill to bring them into contact properly. After the cloth is cleaned, and while it is still wet from its last washing, it is mordanted by boiling it in a solution of a salt of tin with or without cream of tartar. The parts of the boilers not in actual contact with the fire are frequently constructed of pure block tin, or at least all parts out of water should be of this metal, or else protected by wood, or the dyeing vessel should be made entirely of wood and heated by steam pipes; for if the cloth containing the acid solution of tin comes in contact with a copper or brass surface it acquires a stain which afterwards dyes up an impure colour. What takes place in the course of boiling is that eventually a certain portion of tin, probably in the state of stannic oxide, becomes fixed upon or within the fibres of the wool, and this in a perfectly uniform manner. The tin not in intimate combination with the wool, or held merely by capillary attraction, is washed off by water before the cloth is brought into contact with the colouring matter.

The mordanted cloth is now brought into a boiler containing finely ground cochineal diffused through a sufficient quantity of water, to which it is usual to add some more tin mordant and tartar; the cloth is turned continually to prevent folds or creases from interfering with the free access of the dye to all parts of it. The contents of the boiler are heated to the boiling point, and in half an hour or so the liquid becomes nearly colourless, and the cloth is found dyed of a bright red.

The above may suffice to furnish a general view of the procedure usually followed, and to illustrate the principles involved with regard to numerous other dyes besides cochineal. To give the general reader a further idea of certain operations practised in the use of that colour (and the description applies more or less to others), the following particulars may be noted.

The tin mordant used for scarlet on wool.—It is now 200 years since the discovery was made of the use of tin with cochineal for dyeing scarlet; it might be thought that by this time the exact kind and quantity of tin solution to be used would have been settled; there exists, however, the greatest diversity upon this point among practical dyers. The two salts of tin met with in commerce, designated by chemists stannous and stannic chlorides, have received various names from dyers. Crystallized stannous chloride is generally known as "tin crystal;" the solution of the same as muriate of tin. A single muriate and a double muriate of tin are also distinguished, the difference being in the degree of concentration; but in some parts of the country double muriate of tin is the name given to a solution of stannic chloride, elsewhere called bichloride of tin, and a good deal of confusion is sometimes caused by the various uses of the trivial names of the solution of tin. Experience teaches the dyer that there are scarcely two dye-works in the world in exactly the same condition with regard to either water and air, or apparatus, or quality of materials, and that the nature and quantities of drugs, mordants, and dye-stuffs used, and the duration and temperatures of the operations which secure admirable results in one place are altogether unsuitable in another. It is, however, clear that by far the greater part of the variations introduced by practical dyers are not really founded upon necessity. Thus although the best colours can be obtained by the use of simple tin solutions manufactured on the large scale, in nine cases out of ten the operative dyer of scarlet insists upon preparing his own solution, and pretends that he employs special methods and preparations without which it would never be fit to use; and hence a countless number of tin solutions are in use.

Tin spirits.—The solution of tin used by dyers for the scarlet and for many other colours upon wool, silks, and cotton, are commonly called spirits, or "tin spirits," a name which is very old, and appears to have originated in the use of nitric and hydrochloric acids to dissolve the tin, which acids were formerly, and are even at present, called spirits of nitre and spirits of salts. One solution which is a favourite, from the ease with which its metal goes to the wool, is the so-called nitrate of tin (sometimes called "bowl spirits," from being prepared in an earthenware bowl) made by dissolving thin metallic tin in moderately strong nitric acid. This is an operation requiring great care and some experience to prevent the formation of insoluble metastannic acid; the tin is added by small portions and gradually, so that the acid does not become hot; the solution takes place quietly, inodorous nitrous oxide is evolved, and ammonia is formed. If the tin be added too rapidly to the acid, red fumes of nitric oxide are evolved, the liquid boils up, becomes thick from separation of metastannic acid, and is utterly useless as a mordant. This so-called nitrate of tin is a very unstable compound, decomposing spontaneously in a few days, so that it has to be prepared just as it is wanted; it is therefore not an article of commerce. The other very numerous "tin spirits" may be said to be solutions of tin in a mixture of nitric and hydrochloric acids; but the latter acid is sometimes replaced by the chlorides of sodium and ammonium, the resulting mordant being essentially a stannic chloride mixed with stannous chloride. Closely woven and loose woollen fabrics, such as yarn and flannel, require different tin mordants, as some mordants are more quickly decomposed than others. The result of using an easily decomposable mordant such as the nitrate of tin upon closely woven cloth would be the formation of a deposit upon the external fibres of the wool, the interior of the cloth being unaffected. For such cloth, therefore, a tin spirit which is only slowly decomposed, such as the muriate alone or mixed with tartar, must be chosen, so as to allow of a tolerably thorough saturation of the cloth before the breaking up of the mordant during the boiling. Here it may be observed that good, thick, and finely woven cloth which is dyed in the piece, that is, after weaving, is hardly ever completely dyed through; this can easily be shown by cutting through the cloth with a sharp knife, when the interior will be seen sometimes nearly white and generally much paler than the exterior; hence the preference which is given to cloth made from yarn dyed before weaving, the colours of which do not fade so readily as those of piece-dyed goods. Imperfection in the dyeing of the latter can by care, however, be reduced to a minimum, and in dark goods is hardly discernible.

Use of tartar along with tin mordant.—The "tartar" of the dyer is a more or less impure form of the cream of tartar of the shops, or the acid potassium tartrate of chemists. It is in very general use for wool dyeing, and when employed with dye-stuffs plays the part of an acid, and could in fact be replaced by an acid; in other cases, when used in mordanting, it no doubt acts as a salt, contributing to neutralize the strong mineral acids of the mordant, and rendering them more ready to decompose in the presence of the cloth. In a particular receipt for dyeing scarlet the proportions of materials are as follows:—20 lb of tin solution, containing about 20 ounces of metallic tin dissolved in nitric acid, with the addition of a little common salt, are used to 100 lb of woollen cloth. Of the 20 lb of mordant, 13 lb are taken and mixed with a solution in water of 8 lb of crude tartar, and about 8 ounces of cochineal are added to enable the dyer to form a judgment of the progress of the mordanting. The ingredients having been boiled for a couple of hours, the cloth is rinsed in clean water and placed in another boiler, containing the residual 7 lb of mordant and 6 lb of ground cochineal, which are sufficient to dye up a full scarlet colour; but if the scarlet is required to be very bright, or what is called "fiery" coloured, a further quantity of tartar is added; this has the effect of somewhat reducing the depth of colour, and at the same time giving it a yellowish or orange hue, which for certain purposes is much desired.

Use of yellow in scarlet.—It appears that Bancroft, who wrote about the end of the last century, was the first to suggest that the bright fiery scarlet, which the dyers found they could best obtain by using a large quantity of tartar, might be produced more cheaply by adding some yellow colouring matter to the cochineal, or by first dyeing the cloth a light yellow; he tried the yellow from quercitron bark, and succeeded as far perhaps as was possible with that material. At any rate from his time it has been customary for dyers who do not aim at the highest degree of excellence in the scarlet colour to use a purified preparation of quercitron bark, commercially known as flavine, in conjunction with cochineal; other yellow colouring matters, such as fustic and turmeric, are also used. An admixture of these substances cheapens the cost of the colour, which can be made nearly equal in appearance to that obtained with cochineal alone, but it does not stand wear so well, and is more readily stained by various influences. The best scarlets are still dyed exclusively with cochineal.

Scarlets on wool from lac-dye.—The colouring matter of lac-dye is in its chemical properties and composition very similar to, if not quite identical with that of cochineal. As it is imported into this country from India, it is, however, less pure than average qualities of cochineal; and it is probably on account of its impurities that the dyer cannot obtain quite so good results as the best cochineal colours, although if skilful he may approach them very closely. Having been submitted to a preliminary treatment with acid to free it from alumina and other earthy matters used in its preparation, it is then applied exactly in the same way as cochineal. It is extensively used for a second class scarlet, and is believed to be somewhat more durable and stable even than cochineal. The red cloth so much used for military dress is reputed to be prepared mainly with lac-dye.

Crimson red on wool.—This colour is also dyed with cochineal, but with a mordant of alum instead of tin. It is a far less important colour than the scarlet, and compared with it is dull and flat; it is, however, rich and durable, and combines excellently with other colours.

The mordanting of cloth by means of alum, an operation of capital importance for a large series of colours derived from all varieties of dye-stuffs, must now be noticed.

Aluming of wool.—The method of mordanting with alum, generally called aluming, is practically a simple process, but the chemical principles involved have given rise to much debate amongst experimenters. The aluming is usually performed by boiling the wool for one or two hours in a solution of common alum mixed with tartar; a certain portion of alumina, or, it may be, of some compound of aluminium, becomes thus intimately combined with the wool, and forms a basis upon which a coloured lake may be produced with solutions of colouring matters. The chemical conditions are somewhat different here from those which obtain in the case of mordanting with tin; for the disposition of tin salts in dilute solutions to decompose even spontaneously is so manifest that it may readily be supposed that some action on the part of the wool takes place which induces the formation of oxide of tin. The great apparent stability of alum caused the explanation of its action given by Thenard and Roard to be for a long time accepted. They held that it was absorbed whole or unchanged by wool, which retained it by some undefined power, so that it could not be removed by cold water, and required to be heated twenty times with boiling water to dissolve it out. In the light of modern researches this explanation may be safely rejected as erroneous. What appears to be the true state of the case was mainly brought out by experiments of Havrez, suggested by the celebrated Belgian chemist Stas, and supported by further knowledge of the properties of alum discovered by Tichbourne and Naumann. In fact, alum, contrary to what was formerly thought, is particularly liable to decomposition, even when not in contact with fibrous matters which might possibly have an influence upon it. Naumann has shown that by simply heating a solution of alum, saturated in the cold to its boiling point, an insoluble basic compound is soon produced, so that, after prolonged heating, as much as 25 per cent. of the alumina is precipitated, and the liquid is found to have become acid. Beyond this fact it is proved that wool when placed in a solution of alum, containing pure sulphuric acid, has the property of absorbing more acid than alum; this unequal absorption is attributed by Havrez to a kind of dialysis, which, together with the tendency of the alum to decompose, sufficiently explains the deposition of alumina upon the wool. The action of tartar in aluming, according to the same authority, is that of an acid salt, and its addition influences the nature of the mordant deposited in the same way as if an excess of alum were present, or as if other acid bodies, such as sulphuric acid, oxalic acid, &c., were added. The insoluble aluminous compound which separates from solution of alum on prolonged boiling in a glass flask could not act as a mordant, being indifferent or passive to colouring matters; when deposited on fibrous matter it does not adhere, but can be washed off, or when dry may be shaken off like dust; this, therefore, is not the alumina mordant, nor do the researches of Havrez really point out what the alumina mordant is, though they are valuable and suggestive as showing under what conditions either a basic or an acid aluminous deposit is formed. With the former, which is unfavourable for dyeing, a blue colour is given with logwood, and a purplish red with Brazil wood; with the latter, the wool dyes up a violet with logwood, and a purer red with Brazil wood. The basic state of the aluming results, it is supposed, from the deposition of hydrate of aluminium upon the wool, and is caused by having too little alum or too much water, by boiling for too long a time, or by the use of salts which have a neutralizing action upon the alum. It is easily induced, when the weight of wool is more than 15 times greater than that of the alum. In other circumstances the acid state results, in which the wool is said to fix first hydrate of alumina, and also hydrated sulphuric acid from the sulphate of alumina. These conclusions of Havrez cannot, however, be accepted as final or satisfactory; and there is still much to learn upon the principles of aluming and mordanting generally.

The wool being successfully alumed acquires a crimson colour by dyeing in cochineal, but, as before stated, this shade is not of much value.

The shades of red between scarlet and crimson reds proper, or cherry reds, are also dyed with tin mordant and cochineal in nearly the same way as the scarlet; but in order to avoid a yellowish tone, the natural cochineal may be mixed with the manufactured or modified material known as ammoniacal cochineal.

Ammoniacal cochineal.—This is made by treating ground cochineal with concentrated aqueous ammonia for several days; the colouring matter undergoes important changes by this process, an amide is formed, and the effect upon the colouring matter is that tin mordants give with it no longer a scarlet, but rather a violet tone. Ammoniacal cochineal is much used in fine dyeing for pinks; and according to the proportion in which it is added to ordinary cochineal, the normal scarlet shade is gradually brought over to the red and even to the crimson.

Pink or rose colour upon wool.—This shade is obtained from ammoniacal cochineal, mordanting previously in a mixture of tin solution, alum, and tartar; the quantity of tin mordant used is small, the alum being the essential basis.

Other red colours upon wool.—The colours mentioned above are from cochineal or its congener lac-dye, there are several reds obtainable from other colouring matters, which, though less important, are still worthy of mention.

Madder red upon wool.—This colour is wanting in brightness, but it is valuable for its stability, and has at times been largely used for common red military cloth. As a basis for browns, chocolates, and other dark colours, it is very suitable when its comparatively high cost is not an objection. To obtain madder red, the wool is boiled for two hours with a mixture of alum, tartar, and tin salt,—3 lb alum, 1 lb tartar, and 4 ounces of the tin solution being taken for 10 lb of cloth; after boiling, the cloth is rinsed in water to remove uncombined mordant, and then dyed with madder, or preferably its derivative garancin, with addition of a portion of tartar; the dyeing may be accomplished in an hour, the depth of colour varying with the amount of colouring matter used.

Artificial alizarin on wool.—By employing artificial alizarin somewhat better shades of colour can be obtained, and even pink colours of much solidity produced. A process for obtaining a fast red on woollen yarn, from alizarin, is as follows:—boil 10 lb wool for an hour and a half with $1\frac{1}{2}$ lb sulphate of alumina and $\frac{1}{2}$ lb tartar; rinse in water, and then dye with 6 to 7 ounces of artificial alizarin paste containing 10 per cent. of dry matter; commence the dyeing cold, and gradually heat to boiling. Alizarin can be used as a basis for producing fast brown shades, by adding fustic and extract of indigo after the red has been developed, and if necessary, a further quantity of sulphate of alumina and tartar.

Red colours can also be obtained by using Brazil wood or other red woods instead of madder; they are, however, of a low class and seldom employed. Archil alone, without mordant, can yield a full crimson upon wool, but it is not very stable, and is, moreover, expensive.

Aniline reds upon wool.—There are several artificial red dye-stuffs, which may be used for wool, but none possesses great excellence. The only one which resembles cochineal in its qualities is the recently discovered eosine; this, with an alumina mordant, gives upon wool a very good imitation of cochineal scarlet, but an imita-