Stellar Distribution and Movements*

What Determines the Arrangement of Stars in Space, and Their Motion?

By A. S. Eddington

THE last few years have brought to light many new facts in the field of astronomy, and it is opportune to look back and take stock.

It is believed that the great mass of the stars (excluding the Milky Way) is arranged in the form of a lens or bun-shaped system, in which our sun occupies a nearly central position, at least midway between the two flattened surfaces. The thickness of the lens, though enormous, is not so great as to prevent the telescope from detecting the absence, or, at any rate, a gradual thinning, of stars beyond when looking toward the poles of the Milky Way. When looking along the plane of the Milky Way, in the direction of the perimeter of the lens, the thinning out is much less marked, though probably not beyond the power of the telescope. Near the sun the stars appear to be distributed in a fairly uniform manner; in the remoter parts series of clusters forming the Milky Way are observed. As regards the galactic plane, two distinct phenomena (sometimes confused) have to be distinguished; firstly, the plane in which the clusters of the Milky Way are coiled, and, secondly, the median plane of the lens-like arrangement of the nearer stars.

The study of the movements of the stars has to be confined to the central system, and perhaps to the inner parts of it. The remarkable result is that the stars seem to move with a strong preference in two opposite directions in the galactic plane, as Kapteyn showed in 1905. The two streams seem to be more or less independent, but intermixed for the time being, and to move to and fro along a particular line; and it is a significant fact that this line lies in the galactic plane, suggesting a connection between the phenomena of stellar distribution and stellar motion, though it remains to be explained why there is a plane of symmetry in the one case and a line of symmetry in the other. The next noteworthy features are the moving clusters—groups of stars which, though widely separated in space, move with equal velocities in parallel paths. There is the Taurus cluster of forty members; the Ursa Major cluster, now known not to be confined to the one constellation, of thirteen known members; the Perseus cluster of seventeen helium stars; a very large ill-defined cluster in Scorpio, etc. In each case the members move with apparently identical velocities, ignoring, as it were, other stars interspersed between them. The peculiar movements have in many cases afforded means of detecting distances and absolute luminosity of stars far too remote for ordinary methods of measurement.

The stars of the Orion or helium type of spectrum stand out exceptionally. They do not share in the stream motion, have in fact little individual or systematic movement; many of them are of enormous intrinsic brilliancy and probably lie beyond that part of the universe generally considered; others tend to

* Report, adapted from *Engineering*, of a paper read before the British Association.

form moving clusters, which give out diffused nebulae of enormous extent (Orion and Pleiades clusters). The strangest result is connected with the study of their spectral types. Stars had been arranged by their spectra in what astrophysicists believed to be successive ages of evolution, and stars of early types of evolution have much slower motion than those of later stages. It seems as if a star were born with no motion at all and gradually acquired a motion in the progress of time.

Proceeding to details, according to parallax measurements, a sphere of a radius of 95 billion miles (one million times the radius of the earth's orbit roughly) seems to contain seventeen stars, including our sun; a few members may be missing, but they can only be small. Those stars are rather tightly packed; seven of the seventeen are double stars, possibly a high proportion; in intrinsic luminosity they range from forty-eight times the luminosity of our sun down to one one-hundredth that value. Five of the seventeen are more luminous than the sun. Stars as bright as 10,000 suns exist in space, but are probably very rare. Comparing the stars of this sphere with others, it would appear that stars of the *M* type are abundant, but faint, and stars of the Orion *B* type very rare, but prominent because brilliant; the frequency figures deduced from star catalogues are misleading. Parallax measurements do not carry the astronomer far out into the universe; there are 300 stars of more or less trustworthy parallax, but that number contains many cases of parallaxes of 0.1 second and less. In order to go beyond the limits of parallax measurements, the astronomer had to examine statistics of magnitude and motion. This brings out the crowding of stars near the Milky Way, partly accounted for by the lens shape of the Universe. A peculiar distribution rule has long been known. In an unlimited Universe the number of stars of one magnitude, e. g., the eighth, should be four times as great as that of stars of the next magnitude above, i. e., the seventh (the brighter the stars, the lower is the figure denoting magnitude). The star ratio falls short of the theoretical value, however, at greater distance, especially in the polar direction of the galactic plane.

Probably at least half a million stars belong to the two star streams. When plotted on a globe the two streams converge to two points, not diametrically opposite one another, but 110 degrees apart. On the globe we may also mark the solar antapex, the direction in which all the stars appear to move in consequence of the solar motion through space. It is owing to this motion of the solar system that the favored directions did not appear exactly opposite, as they would from an absolute standpoint.

Streaming in two directions has now been detected in the radial motions by Hough and Halm and by Campbell. It is curious that the helium stars do not share in the stream motion, while those of the *A* spectral type, next to the helium stars in the order of

evolution, show the streaming in its purest form. The anomaly might be explained by the great distance of these stars. As to clusters, Boss has pointed out that the Taurus cluster would appear globular in the distant future, while the stars of the Ursa Major and of the Perseus stream are according to Turner, nearly in the same plane. According to Hinks all the globular clusters are found in one hemisphere.

The most startling result of the most recent observations (long foreshadowed, however) is that stars of the later spectral type have larger motions than those of earlier types. In the Orion type the individual movement is only a third of what it will ultimately become. How is the individual motion to be accounted for? The assumption that stars are developed from a primordial matter not subject to gravity is unwelcome and also unnecessary. Suppose a star were formed by lumping together the meteors or gases of some portion of space. If a thousand stars were lumped together, their individual motions might cancel, and the resultant superstar might be at rest; similarly, the motions might cancel in a single star. It is more difficult to explain how the star acquires motion, and how clusters moving through space filled with stars not belonging to their system retain their equal and parallel motion. It is a necessary conclusion, that the forces which produce the individual velocities are nearly constant over large volumes of space, i. e., large with regard to the distances from their neighbors. That means that the central gravitational attraction of the Universe, and not the casual interference of neighbors, has been effective, and this agrees with calculations. The nearest neighbor of our sun is α Centauri, on which the sun acts with a force which would take 400 million years to produce a velocity of one kilometer per second. In close approach the velocity would temporarily be much greater; but there would be a subsequent loss on receding, and the effect of such an encounter would only be a slight change in the direction of motion.

On the other hand, a resultant force of all the matter of the Universe seems adequate to produce stellar motion. The Universe, of course, does not act as if it had a center of gravity. A rough idea of the force can be gained from a comparison of light and gravitation. Both vary as the inverse square of the distance, and roughly the attraction toward any part of the sky may be measured by the total light of the sky at that part. That total light is estimated at 2,400 stars of the first magnitude, and the total gravitation would probably bear the same ratio to that of a star of the first magnitude. Owing to the central position of the sun the pull is pretty uniform in all directions, and there is little resultant force, which would, however, be considerable on an eccentrically placed star. According to another suggestion, due to Halm, the Orion stars are slow, not because young, but because they are heavy. A third possibility is that the great distance of the Orion stars was the cause.

The Iron-Ore Supplies of the World*

How Shall We Meet Future Demand?—An Inventory

By J. W. Gregory, D.Sc., F.R.S., Professor of Geology at the University, Glasgow

IRON may be said to be the material in which modern civilization chiefly finds its expression. Substitutes could be found for any other of the metals in use or the world could go on without it; even if our coal supply failed, other sources of heat and power would still be available: but modern civilization would inevitably wither in a serious iron famine, as cheap iron is required for the construction of the appliances used in the cultivation and preparation of our chief foods and in the manufacture of our clothing; it is also indispensable as a building material in our modern cities and in providing the means of rapid transport which render their existence possible.

The exhaustion of the world's supply of iron ores has been repeatedly predicted and one essential difference between the lode in which ores of iron and those of most other metals occur seems at first to give some plausibility to such forecasts. The lodes of gold, copper and tin met with at or near the surface of the earth continue to great depths beneath it. Thus gold is being worked in Bendigo at a depth of 4,700 feet, copper in

the Lake Superior region at over 5,000 feet and tin in Cornwall at 3,000 feet; no doubt such ores occur at even far greater depths. The best ores of iron, on the other hand, occur only at comparatively shallow depth: instead of being derived from solutions rising from the deep interior of the earth, they have been deposited on the surface or by water percolating downward from the surface; on this account, oxide ores in sufficient bulk and purity to be of present commercial importance are practically confined to the layer accessible to water containing oxygen; as that depth is limited, it appears most probable that the high-grade ores of iron will not continue downward to depths below the earth's surface in any way comparable with those reached by mines of copper, gold and tin.

It is true that the vast barysphere within the earth is composed chiefly or largely of oxide of iron; that mass, however, is separated from the surface by so thick a layer of rock that the material is quite beyond our reach; while the accessible igneous rocks rich in iron contain constituents which render the material either useless as ore or so refractory, that if it had to be utilized

the exhaustion of the world's coal supply would be seriously hastened.

Mr. Andrew Carnegie, in his Rectorial Address to the University of St. Andrews, in 1902, declared that the British iron ores were nearly exhausted, as the Cumberland supply was almost finished and the mines at Cleveland, except two, would last only for another twenty to twenty-five years. The British ironmaster has been warned repeatedly that the rich Spanish oxides which are used so largely in our blast furnaces will soon give place, as they are followed downward, to poor carbonates; and the American steel-magnate has been assured that the Lake Superior ore, on which the great iron and steel industry of the United States was founded, will be exhausted a few years hence. In answer to various jeremiads, numerous estimates have been made in recent years of the quantities of ore actually available. Much information was collected by the British consular authorities in a report edited by Sir Llewellyn Smith and published by the Board of Trade in 1905; but as these accounts came from men who had no special knowledge of the subject, they were irregular and incom-

* Reprinted from "Science Progress."

plete. Recognizing that the supplies of Scandinavian ore were becoming of increasing importance to the British iron industry, I invited Prof. Sjögren to read a paper at the Leicester meeting of the British Association upon the iron-ore reserves of Scandinavia. He kindly undertook this task and visited several of the more important areas to bring the information up to date; his valuable report was published in full by the Association.¹ Tornebohm had previously prepared an estimate of the iron-ore supplies throughout the world but the information available was so limited and unsatisfactory that his optimistic estimates were unconvincing. Prof. Sjögren, realizing the importance of more reliable and comprehensive data, proposed that the International Geological Congress should arrange for an authoritative estimate to be made by an international body of experts. The work was undertaken by the Congress and thanks to Prof. Sjögren and the secretary, Dr. Gunnar Andersson, a series of fifty-five reports has been collected, dealing with all the iron-producing countries of the world. These have been issued by the Geological Congress in connection with its recent session at Stockholm in two large volumes and a folio atlas.² They form the most comprehensive attempt yet made to estimate the total available resources of any mineral, as they include the whole world in their range; they deal with an industry conducted on so large a scale that the unit adopted is a million tons and of such antiquity that some of the contributors refer back to the time of Alexander the Great or the still earlier dawn of the iron age.

The reports on the different countries vary greatly according to the local condition of the industry. The most important reports deal with Great Britain, Scandinavia, Germany, France, the United States of America and Russia, the long report by Prof. Bogdanowitsch on this last country, owing to the comparative inaccessibility of some of the literature, being of special value. Some of the reports deal with countries which, like Belgium, once had important iron mines, the relics of these, M. Lespineux remarks, remaining as monuments of former folly. There are short notes on countries such as Holland, which contain only insignificant deposits of bog-iron ores far too small to be of commercial value; and there are general statements from some countries in which it has not yet been worth while to make an accurate survey of the ore, though the amount is known to be considerable.

The only continent of which the iron-ore supplies are adequately known is Europe. Prof. Sjögren considers it improbable that any new deposits of the first rank will be discovered in this continent but even the European estimates vary greatly in value and it is probable that they may be considerably increased. In the case of the British Isles, as the iron ores belong to private land-owners and not to the State, it is no one's business to estimate the available supplies. Prof. Louis's report on the British iron field is, therefore, of special interest, particularly as he takes a very pleasing view of the extent of our reserves. The British output of pig-iron is now over fifteen million tons per annum and there is still, on the whole, a slight annual increase in the amount produced. Prof. Louis concludes that the British Isles have in reserve 39,500 million tons, containing an average of from 30 to 35 per cent of iron. If all this ore could be used, it would supply all our blast furnaces for nearly 3,000 years. Prof. Louis, of course, recognizes that a very large proportion of the ores cannot be smelted profitably under any conditions that may be reasonably expected, though it may be added that he has formed a much more favorable view of the extent of the Wealden ores than I formed after some inquiry into their quantity in 1907.

Dr. Sjögren has divided the world into sections A—D, according to the extent to which available estimates can be trusted. In division A, which includes 13.3 per cent of the land of the world, the calculations are fairly trustworthy. In division B, including 10.3 per cent of the land, only very approximate estimates can be made. In division C, including 51.6 per cent of the land, no numerical estimates are possible. Division D includes the unknown countries and the Polar regions, covering 24.8 per cent of the land area. Hence even general estimates of the iron-ore supplies are possible for less than a quarter of the land of the world. Prof. Sjögren has recently proposed a formula which appears to yield the most probable approximation to the ore in the less-known countries. He takes the average iron-ore content per square mile of the lands in division A and multiplies this factor by the remaining land area; according to this method, the iron-ore supply in it is some 425,000 million tons. This cheering estimate may be exaggerated if Europe and the Eastern States of America, by some fortunate circumstance, have been endowed with more than the average share of iron;

and as the iron-ores were only discovered after the settlement of those countries, it seems probable that the extent of the ore supplies is due to the thoroughness with which search has been made for them.

No doubt in some cases fuller knowledge may involve a reduction in the estimated quantities. Vague reports and traditions of mountains of iron-ore may prove to be exaggerated; stories of this sort in reference to China and India are discredited in this monograph. But there seems no reason to doubt that as countries now sparsely occupied become better known increased quantities of ore will be found in them.

As the monograph deals essentially with the quantity of ore, it does not often refer to the manner in which the ores have been formed. In some cases the genesis of an ore must be determined before the amount can be estimated. Iron ores can be classified according to their mode of origin into six main groups. The first, igneous ores due to magmatic segregations in molten rocks, are represented by the titaniferous magnetites such as occur at Taberg in southern Sweden and at Routivaara in Lapland; but few ores unquestionably of igneous formation are at present of practical value. It is true that this origin is accepted by some leading authorities for the great masses of magnetite in Lapland; but this view is not yet established and Mr. Lundbohm, the manager of the Kiruna mines, both in his report in this monograph and in another submitted at the recent meeting of the Geological Congress, represents this question as still unsettled.

The second group includes ores formed as contact-deposits beside eruptive rocks; the present tendency is to transfer some ores, such as those of Gora Blagodat in the Urals, from the magmatic to this group. There is also a somewhat uncertain boundary between contact ores and those of the third group, the lodes and masses due to the replacement of other rock by ironstone. They are represented, for example, by the masses of rich kidney iron ore in the Carboniferous limestones of the north of England, which provide the only British supply of Bessemer ore. This group also includes the famous iron mines of southern and central Sweden.

The ores of sedimentary origin which form the fourth group include the most widely distributed ores, now of much economic importance. Among them are the Carboniferous and Mesozoic ironstones of the British Isles and of Spain, the Clinton ores of the United States and the vast beds of minette in France and Germany.

The fifth group comprises the banded ironstones and their associated ore bodies, which are ores of great importance in the United States and in all the existing fragments of the ancient continent of Gondwanaland. They occur in Brazil, South Africa, India and Australia. Hitherto it has only been in the Lake Superior region of North America that these ores have been of great importance; they have there furnished the main supply of material to the iron and steel industry of the United States. The iron has been concentrated into huge bodies of ore by water, which has dissolved the metal from the rocks above and deposited it where the descent of the solution has been stopped by some impermeable layer.

The last group includes the laterites which are so widely spread as superficial deposits in the tropics and sub-tropics. They extend occasionally farther into the temperate regions, occurring, for example, in workable quantities in the north of Ireland. Hitherto these ores have only been mined to supply local demands or for use as iron-bearing fluxes. Many primitive races still obtain their iron from laterite; the prehistoric smiths of the early iron age were probably mainly dependent on such ore and in the event of a serious rise in the price of iron ore laterite deposits would once again become of great industrial importance.

The estimates of the iron ore supplies throughout the world included in the various reports have been collected in tables compiled by Mr. Tegengren; the chief results are shown in the list in the next column.

The total reserves of ore are shown by the following list to be enormous and ample for all probable requirements. The estimates are the best hitherto made but they are inevitably indefinite. More precise estimates would hardly be worth the time and trouble it would cost to procure them. A final determination of the iron ore available is impracticable because there is no fixed test of what is ore, the availability of a material as ore varying with political and commercial changes. The percentage of iron in a material affords no absolute separation between iron-bearing rock and iron ore. Thus 60 per cent of iron in a material may be useless when associated with much titanium, while another containing only 20 per cent of iron may be a valuable ore. Commercial conditions also control the profitable working of ore and therefore affect the estimates hitherto made.

Material that in one place or time may be quite valueless may become a useful ore through some change

¹ H. Sjögren, "The Iron-Ore of the Scandinavian Peninsula," Rep. Brit. Assoc. 1907, pp. 332-45.
² The Iron-Ore Resources of the World. An Inquiry made upon the Initiative of the Executive Committee of the Eleventh International Geological Congress, Stockholm, 1910. Vol. I., pp. lxxix + 552; Vol. II., pp. 553-1068, 22 pls., 142 figs.; Atlas, 43 maps.

Country.	Actual Ore Supplies.	Equivalent in Metallic Iron.	Potential Ore Supplies.
	Million tons.	Million tons.	Million tons.
France.....	3,300	1,140	—
Luxemburg.....	270	90	—
Spain.....	711	349	considerable
Portugal.....	—	—	75
Italy.....	6	3.3	about 2
Switzerland.....	1.6	0.8	2
Austria.....	250.9	90.4	323.2
Hungary.....	33.1	13.1	78.9
Bosnia and Herzegovina.....	—	—	21.9
Servia.....	—	—	probably 78.9
Hungary.....	33.1	13.1	probably moderate
Servia.....	—	—	1.4
Bulgaria.....	—	—	probably moderate
Greece.....	100	45	considerable
Turkey.....	—	—	1055.3
Russia.....	864.6	387.2	about 45
Finland.....	—	—	178
Sweden.....	1,158	740	1,545
Norway.....	367	124	37,700
Great Britain.....	1,300	455	moderate
Holland.....	insignificant	insignificant	—
Belgium.....	62	25	enormous
Germany.....	3,607.7	1,270	probably enormous
Canada.....	considerable	considerable	enormous
Newfoundland.....	3,635	1,961	enormous
United States.....	4,257.8	2,304.6	75,105.3
Mexico.....	55	30	probably considerable
Central America.....	—	—	exist
West Indies.....	1,903	856.8	1,007
Columbia, Venezuela, Bolivia, Peru and Chile.....	4.2	2	considerable
British Guiana.....	—	—	exist
Dutch Colonies.....	—	—	exist
Brazil.....	—	—	5,710 +
Argentina.....	—	—	exist
Western Australia.....	—	—	26 +
South Australia.....	—	—	21.6
Queensland.....	—	—	13.7
New South Wales.....	48.9	26.8	5.1
Victoria.....	—	—	moderate
Tasmania.....	23	15	2
New Zealand.....	64	32	0.2 +
Asiatic Russia.....	—	—	considerable
British India.....	100	65	400 +
China.....	100	60	considerable
Japan.....	55.6	28	probably enormous
Rest of Asia.....	4.8	2.5	moderate
Algeria and Tunis*.....	about 125	about 75	—

* The supplies in the rest of Africa are at present incalculable and are reported from the various States as considerable, moderate and enormous.

in political or commercial conditions. For example, there are said to be large supplies of high-grade ore available in Honduras but it has not yet been worth any one's while to test these reports: no doubt, if Honduras were a great importing country the ore would be investigated at once, as it could then be exported owing to the cheapness of return freights. The working of British ores, on the other hand, is retarded because the ships that export our coal bring back ore at an abnormally low rate.

The conditions controlling the development of an iron ore are so complex that no simple rules can be stated and so some of the reports include ores containing as little as 20 per cent of iron; others restrict the limit to a minimum of 30 or 40 per cent or even 60 per cent. The lower-grade ores can be used if they form a good smelting mixture with richer ores or after the others are exhausted. Twenty years ago the ores used in the United States contained an average of 62½ per cent of iron; at the present time cargoes containing over 60 per cent are exceptional, the average being about 50 per cent; even cargoes of 40 per cent iron are used and in Alabama ores are mined and included in the reserves having on an average as little as 36 per cent of iron.

Though the data collected by Dr. Sjögren show that the fear of an iron famine is idle, the supply of ores containing 60 per cent of iron is acknowledged to be comparatively limited. The total supplies of such ore are estimated at 1,300 million tons of known ore and some 687 million tons of potential reserves. Of the known supplies, about 1,100 million tons or more than four-fifth of the total known amounts are in Sweden. In America, excluding ores too rich in titanium to be of present value, the reserves amount to only 58 million tons and are limited to Mexico and the West Indies; Australia reports 49 million tons in Westralia and Tasmania and an additional 34 million tons of potential reserves in South Australia and Queensland. In Asia there are 530 million tons, all belonging, however, only to the potential reserves.

At the present time about 60 million tons of pig-iron are produced every year; the production has on the whole more than doubled in every twenty years, so that if we were dependent on ores containing 60 per cent or more of iron, the known supplies would only last another fourteen years, though the potential supplies, which have been crudely estimated, including 250 million tons in India, would last another six or seven years. But when the lower-grade ores are included, the total actual reserves of iron are estimated at over 10,000 million tons, and the potential at 50,000 million tons, exclusive of enormous supplies which are still unmeasured and may amount even to ten times that great amount. The known supplies, at the present rate of production, would last two hundred years. Including the potential reserves, they would last over a thousand years; by lowering the grade of ore that iron-masters

are willing to smelt, ample ore supplies would be available for further millenniums.

These estimates fully confirm the opinion expressed to the Geological Section of the British Association in 1907, when I remarked that—

"The geologist who knows the amount of iron in most basic rocks finds it difficult to realize the possibility of an iron famine; he can hardly picture to himself some future iron-master complaining of 'iron, iron everywhere and not a ton to smelt.' There are reserves of low-grade and refractory materials which the fastidious iron-master cannot now use, since competition restricts him to ores of exceptional richness and purity. When the latter fail, an unlimited quantity could be made available by concentration processes. The vast quantities of iron ores⁴ suitable for present methods of smelt-

⁴ Presidential Address to Section C, Rep. Brit. Assoc. 1907, p. 501.

ing in Australia, Africa and India show that the practical question is that of supplies to existing iron-working localities and not of the universal failure of iron ores."

The future demands on the world's supplies of iron ore will be affected by industrial changes and on those of separate countries by their financial policies. Thus the introduction of reinforced concrete must materially diminish the demand on the iron ores. The adoption of a protectionist policy by a country may lead to the development of its own iron mines and perhaps the closing of those of some of its neighbors. Thus the imposition by the United Kingdom of a tariff on imported iron ores would no doubt lead to the working of British ores that now lie unutilized and might close some Mediterranean iron fields which can only mine iron ore for export, having neither fuel supplies nor water power.

Alarmists tell us that we are using an unfair share of minerals and that there will be none left for future

generations. On the other hand, the well-known commercial principle, use an asset while you can, is applicable to many iron ores. For when South America, Asia, Africa and Australia smelt their own high-grade ores, iron produced from our poorer ores will not compete in their markets. Hence European ores which can be worked profitably at present may become valueless if not used before the newer countries establish iron industries of their own. If the present opportunity of working such ores be lost there may never be another.

The real danger to the future in regard to the iron-ore resources of the world is not the limited quantity of ore but the limited supply of coking coal necessary for its reduction. Even if the heat required for smelting iron be supplied electrically, one ton of coking coal is required for the reduction of two tons of iron ore. The supply of iron ore is unquestionably adequate; indeed, it is certain that there will be plenty remaining when there is no more coking coal left for its reduction.

Document Photography—Its Use in the Courts

The Camera is Mightier Than the Eye

So VERY few people realize just how far scientific methods are employed in the detection and conviction of criminals that the following exposition by William J. Kinsley, examiner and photographer of questioned documents, will be found of interest. The original article appeared in the *American Annual of Photography* and is here reprinted with some editorial matter furnished by the author.

The first step in a contested questioned document case should be to photograph the entire document natural size. The next step to enlarge all of it, or any disputed or questioned parts. These natural size photographs should be made, if for no other purpose, merely as a permanent record, to forestall loss or theft.

A witness to a forged will in her anxiety to account for all of the unusual features of the document testified with emphasis and particularity about just how all of the blots on the instrument were made at the time of signing—including several blots which were made in the Surrogate's office some months after the document had been photographed! The witness did not know that the document had been photographed.

In another case where typewriting was in question and the disputed document was in French, it was found that the accent marks over the letters were put on by pen and pencil—thus showing that a typewriting

and the ordinary photographic plate being very sensitive to yellow, the faintest of stains, scarcely discernible to the naked eye, are reproduced much stronger on the negative—in some cases plain enough to read

Fig. 12.—Enlargement of questioned signature showing name "James Connelly" twice. Faint writing reproduced because of yellow stains left by erasing with chemicals.

what appears only as a faint yellow smudge in the original.

The "James Connelly" illustration (Fig. 12) shows a case of this kind. The defendant was indicted for giving as security for a bond, a house and lot he did not own. The bail bond book was a public record. After he was indicted the defendant said that the name signed to the book was not his signature. And when the prosecutor looked again, he found that the original signature had been erased by chemicals, the same name written over it—but in another handwriting, and a big blot put over part of the signature. Photographs were made and the faint yellow stain read "James Connelly." The expert for the prosecution testified at the trial that the faint writing was in the handwriting of the defendant. An expert for the defendant, who was in court, prepared to testify that the second or overwriting was not in the hand of the defendant, immediately after examining the photographs took his hat and left the court room.

Writing faded toward yellow will photograph quite black and thus makes it plainer in the photograph than in the original.

Color screens or ray filters are useful in many cases in catching any bit of color; and of course orthochromatic plates are often a necessity.

For enlargements over three diameters it is better to place the filter over the object, as it gives sharper definition.

By the use of contrast ray filters any color in the writing or document may be emphasized. Sometimes it is necessary to use a filter to correct the background in the paper—manila for example—or to exclude some extraneous thing—for example, a red blot on black writing, etc.

A transmitted light photograph will nearly always show differences in inks, thickness of strokes, quality

Fig. 13.—Transmitted light photograph of altered book account showing use of different inks and pens, and an erasure by abrasion.

of line, writing over fold in paper, retouching, patching and overwriting—if these things are actually present. Two ink strokes that look practically alike to the unaided eye, when photographed by transmitted light, will show that two different inks were used (Figs. 8, 13).

Transmitted light photographs are also useful in showing watermarks, and wire mesh marks in paper; also the fiber of the paper. Sometimes erasures are shown up best by transmitted light (Figs. 6, 13).

Photographs are essential in many cases, because it is necessary to make a juxtaposition comparison. After photographing and printing the disputed and standard documents natural size, the parts necessary for comparison can be clipped from the prints and be arranged and pasted on thin cardboard or heavy paper. These clippings thus arranged can then be further enlarged up to any desired diameter. This makes a fair and effectual way of making the comparison and of showing the facts. If the writings are actually unlike, it will be easier to see their unlikeness when enlarged in this way. On the other hand, if the writings are alike, this fact will be demonstrated by such an enlarged comparison.

Comparisons cannot be properly made unless the writings to be compared are brought side by side; and for persons unaccustomed to making such comparisons (jurymen for example) it is absolutely necessary

Fig. 14.—Signatures in Hewitt Will Case, showing differences in pens and inks; and showing writing over fold in paper.

to have the things to be compared arranged in this way.

Occasionally an enlarged photograph or photo-micrograph will bring out a point that may be the determining one in a case.

In a recent criminal court case an enlarged photograph was being criticised for the defense by an "expert" photographer, who admitted that he had never made such an enlargement. He found fault with a break in the line in the photograph of the disputed signature (which was a forgery by tracing), claiming that the enlarged photograph showed a condition which did not exist in the original. The trial judge looked at the original through a simple microscope and then handed the glass and original to the fault-finding witness, asked the witness to examine the original with the glass and see if the line was not broken just as shown in the enlargement. The witness admitted that it was and retired from the witness stand in considerable confusion. This witness afterward admitted that he did not know that writings could be enlarged to such a degree; that he did not know of any lenses as small as two-inch focus; or that the United States Bureau of Standards certified lenses.

There can be no reasonable objection to the use of photomicrographs. It would be as reasonable to object to the use of a microscope, or for that matter, to the use of eyeglasses by the jury or witnesses. Some few judges have ruled that only photographs of entire documents may be used. When an enlargement to twelve diameters (one hundred and forty-four times

machine other than one made to write the French language was used.

When the document was again produced by the suspect at a second investigation, it was found that some of the most prominent and palpably-added accent marks had been covered by ink blots. The producer of the document had not learned that the document had been photographed!

It is a great saving of wear and tear on the original papers to have photographs of them.

For court use, photographs are very helpful. All parties interested, court, jury, lawyers and witness, have the same thing before them at the same time. The witness's explanation can be followed much more easily, and the peculiarities pointed out can be observed then and there—and not forgotten, as they would be oftentimes, when the jury retired for deliberation.

Photographs frequently disclose things unobserved by the naked eye. Patched and overwritten lines (Figs. 11, 9), erasures by chemicals or abrasion, differences in ink tints (Figs. 8, 13), differences in pens used, breaks in continuity of writing, underlying pencil lines, writing over folds in paper (Figs. 8, 14), tearing paper before or after writing, etc. Differences in printing, engraving, size and ruling of paper, etc., can be readily shown by photographs.

Chemical erasing stains being in most cases yellow,