THE ANALOGY

OF

SOUND AND COLOUR.

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SOUND & COLOUR,

THEIR

Relations, Analogies & Harmonies,

BY

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TO

SIR DAVID DEAS, K.C.B., M.D.,

&c., &c., &c.,

INSPECTOR GENERAL OF HOSPITALS AND FLEETS,

THIS WORK IS DEDICATED,

WITH THE WARMEST ESTEEM

OF

THE AUTHOR.

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PREFACE.

It has long impressed the Author, that, if the undulatory theory were applicable to Light and Sound, in all their bearings, the seven colours of the rainbow and the seven notes in the musical scale might prove to be perfectly analogious in their relative properties and effects, either in single sequence, or in combination. Thus, the law of interference, which so fully explains the nature of consonance and dissonance in music, if it be alike applicable to colours, will enable us to make practical use of the principles of Musical Harmony in Painting, or the association of colours in matters of dress or decoration. It will be perceived however, that unless the particular number of vibrations producing the several notes of the musical scale can be shewn to hold an exact relation to the ratio of vibrations calculated in the intervals of the prismatic series, there would be no premiss from which an inference like the above could be drawn. To this desideratum special attention has been given in the first chapter, and it is presumed that the arguments there adduced, are sufficiently conclusive to warrant the further development of the subject in the succeeding chapters.

Painting, as an Art, may be at least on a par with Music; but Music as a Science, is certainly in advance of the fine Arts, its most essential principles admitting of mathematical expression. This last remark, however, has special reference to harmony, for we are still almost quite ignorant of the philosophy of the representative or allegorical power of music; and design and drawing in the arts, as regulated by precept and principle, are much more intelligible than the essential nature of subject and theme in music.

Coincidentally with the reception of Painting and Music, as sister arts, their votaries have intuitively felt the existence of a striking analogy between them, an analogy which is more particularly traceable in the phenomena of sound and colour. Since the time of Newton, various systems have been advanced in elucidation of this analogy, each assuming a colorific scale of its own, but, with the exception of the remarkable results obtained by Newton himself, with the prism and monochord, no purely scientific application of the principles of Musical Harmony to Painting appears to have been made. A reliable theory of harmonious colouring is therefore most desirable in the Arts, as there exists at present no rule to guide the Painter in his selection of colours, but a certain notion of a beau ideal, gained from the example of others, or originating in his own taste, fancy, or caprice.

SOUND AND COLOUR.

CHAPTER I.

AGREEMENT OF THE MUSICAL AND COLORIFIC RATIOS OF VIBRATION, THE BASIS OF THE ANALOGY OF SOUND AND COLOUR.

SECTION I.

Introductory Remarks, and exposition of the ratios of Musical Vibration.

The phenomena of Light and Sound mutually illustrate each other, and the more they are studied and compared, the more it becomes manifest that both are obedient to the same essential laws and governing principles, though the vibrations of the one may be represented as almost infinitely more minute and subtle than those of the other. A great interval, therefore, may be said to exist between the smallest sonorous and the largest colorific vibration. Moreover, the vibrations of the colorific scale are within very narrow limits, embracing but a single octave, whilst musical vibrations, extending over numerous octaves, take a much wider range. Nevertheless, the internal constitution of the eight intervals of a diatonic musical scale, founded upon any note, will be seen, on close investigation to be represented in striking analogy by the prismatic series.

Admitting the application of the undulatory theory to both Light and Sound, the broad principle has long been admitted, that the undulations of the colours of the iris increase in number and diminish in size, as they ascend from the base red to the violet, just as happens in the musical scale, in passing from the graver to the more acute sounds. But the precise relationships existing between the two scales have never been satisfactorily worked out, which, if it could be done, would elevate painting to the status of a science, based like Music, upon mathematical principles.

Pythagoras, on his death bed, is said to have recommended the monochord as the only test of Musical perfection; and certainly, the facility with which the several intervals of the diatonic scale can be measured and determined by its use, gives it an importance that can scarcely be attached to any means of answering a similar purpose. The practical utility of such measurements is to afford a precise idea of the relation borne by the different notes of the scale, both to the key note and to each other, as also to make the nature of consonance and dissonance intelligible, in connection with the law of interference. Referring to the annexed table, if we assume for illustration merely, that the whole string vibrates once in a second, so that if audible it would give the note C, many octaves below that of 32 feet organ pipe,

TABLE I.

Length of String.	Complements.	No. of Vibrations.	Note.
1	0	1	C
$\frac{8}{9}$	$\frac{1}{9}$	$1\frac{1}{8}$	D
$\frac{4}{5}$	$\frac{1}{5}$	$1\frac{1}{4}$	E
$\frac{3}{4}$	$\frac{1}{4}$	$1\frac{1}{3}$	F
$\frac{2}{3}$	$\frac{1}{3}$	$1\frac{1}{2}$	G
$\frac{3}{5}$	$\frac{2}{5}$	$1\frac{2}{3}$	A
$\frac{8}{15}$	$\frac{7}{15}$	$1\frac{7}{8}$	B
$\frac{1}{2}$	$\frac{1}{2}$	2	C 8ve.

$\frac{8}{9}$ths of the string, with a complement of $\frac{1}{9}$th, will yield 1 and $\frac{1}{8}$th vibrations in a second, producing D, the next note, and so of the rest. With reference to the third column, it may be noticed in explanation, that $\frac{1}{8}$th of $\frac{8}{9}$ths, or, of the whole length required to make D, being equivalent to the complement, $\frac{1}{9}$th of the whole string has been added to express the fractional part of the second vibration, and so of the other fractions following.

SECTION II.

The ratios of Colorific vibration, and their comparison with those of the Musical Scale.

From the measurements of Newton, Sir John Herschell was enabled to calculate tables of the vibrations of coloured light, shewing their relative rapidity and minuteness, founded upon the estimated velocity ot light, and the assumed distance of the earth from the sun.

TABLE II.

Colours of the Spectrum.	Number of undulations per second.
Extreme Red	457,000,000,000,000
Red	477, ' ' ' '
Intermediate	495, ' ' ' '
Orange	506, ' ' ' '
Intermediate	517, ' ' ' '
Yellow	535, ' ' ' '
Intermediate	555, ' ' ' '
Green	577, ' ' ' '
Intermediate	600, ' ' ' '
Blue............	622, ' ' ' '
Intermediate	644, ' ' ' '
Indigo	658, ' ' ' '
Intermediate	672, ' ' ' '
Violet	699, ' ' ' '
Extreme Violet	727, ' ' ' '

A superficial inspection of table 2, selected for reference, would afford but little hope of reconciling the musical with the colorific ratios of vibration, but we find that extreme and intermediate tints have been calculated, without any apparent reference to the constitution of the Musical scale. Yet the great latitude of vibration permitted both in and between the intermediate and principal colours, indicate the possibility of making a right selection of the exceedingly limited spaces within which indubitable ratios may be found. It will be seen, however, that by adding the complements of the musical ratios, (Table I, column 2) instead of the ratios themselves (column 1) to the number of vibrations for the principal colours, a close approximation will result. But this approximation will be still more remarkable on adopting the number 467, (minus the cyphers) instead of 477, the number for Red, which may well be admitted by the wide range existing between the extreme Red and the intermediate Orange. (See Table III).

A cursory glance at the following table will suffice to show that there must be something more than simple coincidence in the near resemblance of the two columns of figures, inspiring a hope that all existing doubt of the truth of the analogy may yet be removed by well directed experiment. The employment of the musical ratios themselves would overshoot the mark, but however, this is to be accounted for, they may be more satisfactorily applied to the numbers given by Ganot, expressing in corresponding parts of an inch, the relative size of the undulations taken at the principal dark lines of the spectrum.

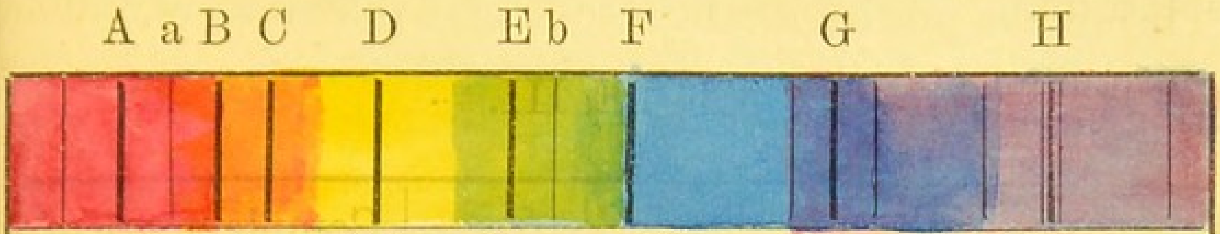
TABLE III.

Prismatic Colours.	No. of undulations per second.	Complements of the Musical ratios applied to 467.
Red	477	467
Orange......	506	518
Yellow......	535	560
Green	577	583
Blue........	622	622
Indigo	658	653
Violet	699	684

To Professor Ganot's diagram of the spectrum,* I have added: first, his measurements of the undulations occurring at the principal dark lines seriatim, secondly, Sir J. Herschell's more extended series on the same scale, and thirdly, the Musical ratios applied to the principal colours, assuming 300 to represent the base red.

* Elementary Treatise on Physics, Coloured Plate I. (Atkinson's translation.)

TABLE IV.



		Red		Orange		Yellow		Green		Blue		Indigo		Violet	
1st series.		271		256		244		207	191			169		155	
2nd.	E.R.	R.	I.	O.	I.	Y.	I.	G.	I.	B.	I.	Ind.	I.	V.	E.V.
2nd.	266	256	246	240	235	227	219	211	203	196	189	185	181	174	167
3rd.		300		264		240		225		200		180		160	150

The positions occupied by the dark lines only give a rough idea of the true localization of the prismatic colours. But on comparing the 1st and 2nd series with each other, there would appear to be no valid objection to the possible truth of the 3rd. Thus, the range of measurements embraced by the two former, cannot oppose the provisional selection of 0,0000,300 of an inch, as the length of the wave of the base red, and half that number for its octave, so that all the other colours may have the ratios applied to them in the 3rd series, by the musical analogy. It will be observed that any wide deviation occuring in the 1st series is compensated in the 2nd, and *vice versa.* The inference is therefore legitimate, that, if the analogy of the musical scale were taken as a guide, the special points of the spectrum, whose respective vibrations would compose a well tempered diatonic scale of colour, may be readily chosen. It is probable also, that the musical ratios alone can be the test of the truth of such a scale, for by shifting ever so little above or below the precise locality required, a difference of millions of millions of vibrations must result.

SECTION III.

The probable nonexistence of a Luminiferous Ether, and the consistency of such a doctrine with the exposition of all the known phenomena of light.

Ganot remarks "that in the case of sound, there is "independent evidence of the existence and vibration of "the medium (air) which propagates the undulation, "whereas, in the case of light, the existence of the medium "and its vibrations are assumed, because the supposition "connects and explains in the most complete manner, a "long series of very various phenomena. There is how- "ever, no independent evidence of the existence of the "luminiferous ether." And indeed it is just as easy to conceive that common matter may be the subject of luminous vibration, as to assume the necessary existence of a luminiferous ether, in which similar vibration must be excited, in order to induce in us the sensation of vision. Sonorous vibration, obeying precisely the same general laws, has never suggested to the philosopher the presence of any such special medium, apart from common matter. Again, if waves of light are measurable, and we can estimate the rapidity of their sequence, there is still a wide margin for the play of the so called ultimate atoms of even the grossest form of matter. It might be supposed that any change wrought in the component atoms of a body by chemical force would exert some influence upon the ether flowing between them, yet, in ordinary coloured substances, this is not enough to produce luminous vibration in the dark, and can only respond to the impression of common light from some other source. But it would seem much more rational to refer the cause of this reaction, so to speak, to the chemical constitution of the atoms themselves, and their resident chemical forces, than to the play of any hypothetical medium, which, after all must be the subjective, and not the governing agent, if it exist at all. Setting aside cases of interference, there appears to be as intimate a relation between *chemical force* and those occult conditions giving rise to colorific vibration in coloured bodies, as there is between *mechanical force* and the conditions of sonorous vibration.

This view of the case will explain to us why mechanical mixtures of coloured bodies develop intermediate compounds of the original tints, while those of colourless bodies remain colourless. On the other hand, when progressive chemical changes are attended with the evolution of colours, they generally occur in consecutive order, ascending or descending the scale, thus: the green iodide of mercury, which assumes a darker hue on exposure to light, yields a yellow sublimate when gradually heated, and thus, in turn becomes red, either by friction or after cooling; again, while the red iodide of mercury becomes yellow by the application of a gentle heat, at a higher grade, lemon chrome changes to orange chrome, and yellow ochre to light red. Autumnal tints also descending in the scale, admit of the same explanation, and many other instances might be adduced; indeed, the subject admits of a very wide application, and might be extensively treated.

If we only assume the transmission of force, from atom to atom in ordinary matter with integral vibratory motion, we have a simple principle perfectly analogous to what we know to take place in the production and propagation of sound, superseding the necessity of corpuscular emission, or ethereal undulation, while it is quite as consistent with the éxposition of all optical phenomena.

As long as chemical affinity holds the constituent atoms of a substance in union, they may be said to be in a state of tension involving specific vibration, and the persistence of this force is evidenced by their colorific reaction in the presence of common light or achromatic vibration. A musical string of definite diameter and length, in a certain state of tension, or a pipe of the necessary length and calibre will sound C, but a red substance may be divided almost infinitesimally, and all the molocules are red still, so that practically, as well as theoretically, we are obliged to acknowledge that the force in the latter instance is resident in the atomic constitution of the body. Is it not, therefore, more reasonable to look for this exquisitely fine vibration in the atoms themselves than in an interstitial ether, which would appear to carry the mystery one point further than the ultimate fact? A similar theory may yet be found applicable to all the so called imponderable agents.

CHAPTER II.

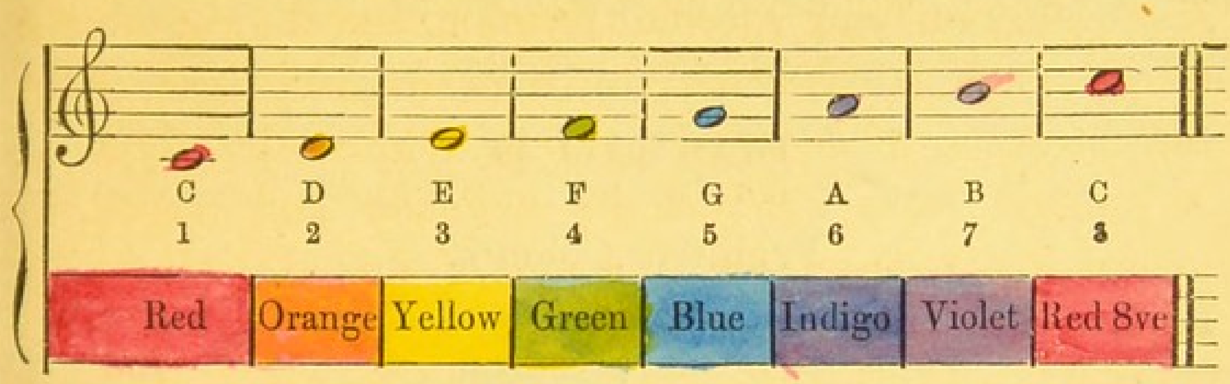
ANALOGY OF SOUND AND COLOUR.

SECTION I.

Agreement of the Musical and Colorific Scales.

Like the notes of the musical scale, the prismatic colours are seven, as shewn in the following diagram.

DIAGRAM I. (Compound Gamut.)



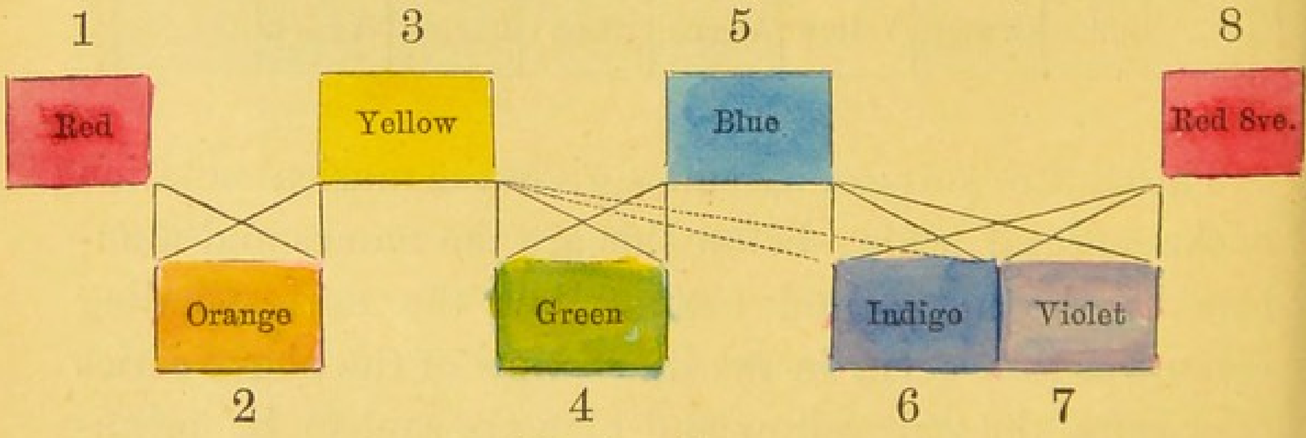
The staff, or stave of five lines, gives the musical notation of the natural scale; below this are the names and numbers of the notes, and next follow the corresponding colours as they occur in the iris. Now of the above series of colours, the red, yellow and blue are said to be primitives, as they are incapable of further analysis, whilst they themselves are variously combined, so as to produce all the remaining colours, which are therefore denominated compounds or derivatives.

The primitive colours, red, yellow and blue, occuring respectively upon the first, third and fifth intervals, in truthful analogy, independent of coincidence, or fortuity of any kind, may be said to compose the perfect chord of colour, answerable to that in music which all musicians admit to be the very ground work and basis of harmony. In favour of this combination, we have the most conclusive natural indications in the harmonics of strings and membranes, the open notes of musical instruments of inflation, and indeed under any circumstances in which the conditions for vibration exist.

The primitives, therefore, may be regarded as one family, in relation with the derivatives as in pedigree, thus:—

DIAGRAM II.

Primitive Colours.



Derivatives.

Here the derivatives are marshalled in line, in the respective order of their descent, and including them with the primitives, we have the whole prismatic scale as given in the preceeding diagram (I.)

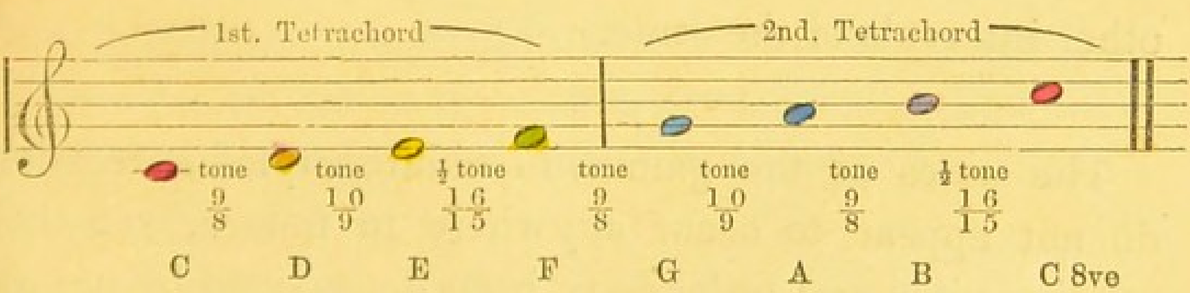
In mechanical mixture, red and yellow make orange, yellow and blue make green, and blue and red make pure purple; but, in the spectrum, arising from the diffiusibility of the yellow ray, (as indicated in the diagram) instead of simple purple, we find the two colours, indigo and violet, interposed between blue and the 8ve red, and so the number is made up.

SECTION II.

Constitution of the Musical Scale.

The diatonic musical scale, consisting (with the octave) of eight notes, is divided into two lesser scales or tetrachords, each consisting of four notes, and terminating in a semitone, as shewn in the following stave.

DIAGRAM III.



Although the intervals between C and D, and between

D and E, are said to be whole tones. The first is a little larger than the second, as expressed by the fractions, but in the second tetrachord the relative size of the corresponding intervals is reversed; that between G and A being a little smaller than that between A and B. On the other hand, the semitones between E and F, and between B and C, hold a corresponding relationship, or are, in other words, of equal value.

It may be fairly argued that *tint* or *hue* in colours determining their relations to each other, is equivalent to *pitch* in sounds, which is in like manner due to the rate or nnmber of vibrations in a given time, as previously alluded to.

In this inquiry we shall confine our attention to the natural key of music, or that commencing with the note C, assuming red to be its analogue in the colorific scale, in favour of which position, several arguments may be adduced. Thus, red is by position the first of its own series; it is the least refrangible constituent, and the vibrations producing it occupy more time and space than those of the succeeding colours, as also may be affirmed of the musical tonic or key note, with reference to the other intervals of the scale.

The notes of the gamut, in uninterrupted succession, do not appear to occur anywhere in nature, yet their relative pitch and order have been determined by natural indications, mathematical calculation and the test of the ear. On the other hand, the order of colours occuring in the rainbow and the prismatic spectrum, may be assumed to be the right one, from what has been already stated.

We are now prepared to enter upon the subject of musical harmony, with the view of tabulating the colorific agreements, so as on the one hand to submit the truth of the analogy to further test, and on the other, should the foregoing premises be correct, to afford useful examples and practical hints for the painter's guidance.

Practical music is of little use to painters, consisting chiefly of digital performance, which, like laying on colour, is simply mechanical or operative. They may, however, profit much by the study of musical principles, including a knowledge of the properties and relations of sounds, both in single sequence and in combination, governed by rhythm.

SECTION III.

Rudiments of Harmony.

1.—Sounds in unison are those whose respective undulations are of the same size and number, so that they occupy equal portions of time and space. Fig. 1, diagram IV.

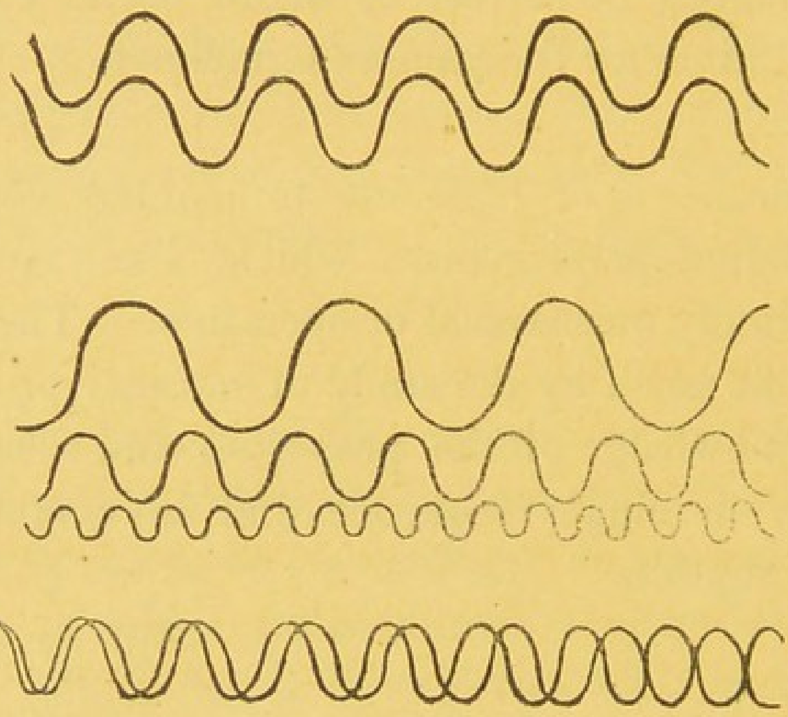
2.—All other concords must hold a relation between the numbers of their vibrations as to render it possible for them to act freely together without interfering with one another; and while this is the case, any number of notes may be combined, and they will all be in harmony. Fig. 2, diagram IV.

DIAGRAM IV.

Fig. 1. Unison

Fig. 2. Harmony

Fig. 3. Dissonance



Sound Silence

3.—Should the vibrations of one note be in irregular proportion to those of another, a coincidence between them can only happen occasionally, and they will interfere with, and neutralize each other in the intervals. This is the true nature of dissonance and the element of discord. (Fig. 3, diagram IV.) Such is the law of "interference," and the lines of *light* and *shade* occurring where two sets of luminous undulations so interfere, are analogous to the alteration of *sound* and *silence*, taking place where two notes not perfectly in tune are sounding together.

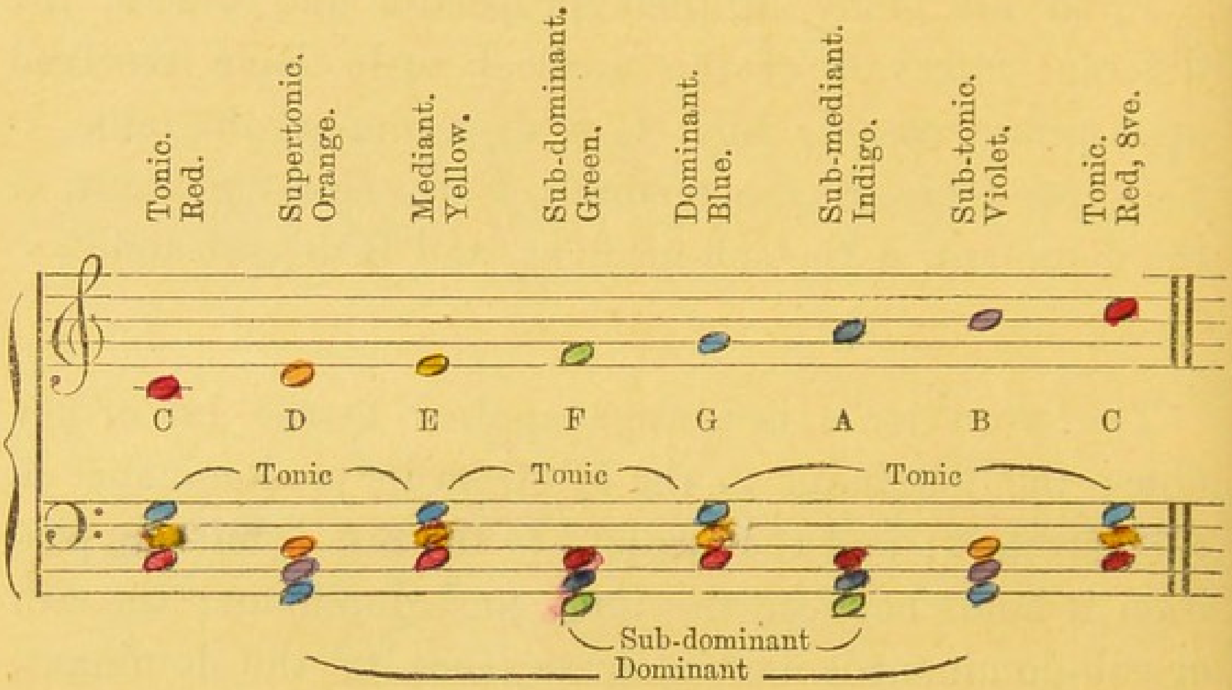
From the study of their properties and offices, the different intervals of the musical scale have received appropriate names, thus: C is denominated the tonic, D the super-tonic, E the mediant, F the sub-dominant, G the dominant, A the sub-mediant, and B the sub-tonic.

The word tonic is always applied to the 1st or key note; the dominant to the 5th from its predominance in the harmony; and the mediant to the 3rd from the position it holds between the tonic and dominant; the 4th or sub-dominant is next in precedence to the dominant, and the sub-mediant though above the mediant in position, is yet musically speaking subordinate to it, as its name implies.

The super and sub-tonic, or the 2nd and the 7th need no special remark at present, but that they are dissonant with the tonic.

The technical names of the notes here briefly alluded to, are given seriatim in the following diagram, which is also intended to show that every note in the gamut may be supported by a fundamental bass note with its third and fifth, forming what is denominated a common chord. The equivalent colours have also been supplied to the musical characters.

DIAGRAM V.



It will be observed that, only three common chords occur on the bass clef, and these are all that are required for common purposes without change of key. The first is founded on the tonic, C (red), E (yellow), and G (blue), the second on the sub-dominant, F (green), A (indigo), C (red), and the third on the dominant, G (blue), B (violet), & D (orange.) The first note of each is its fundamental bass, but this gives place to the others in the changes of position or inversions of the chords, as in the annexed diagrams

DIAGRAM VI.

Changes of position of the common chords of the tonic.

1 2 3

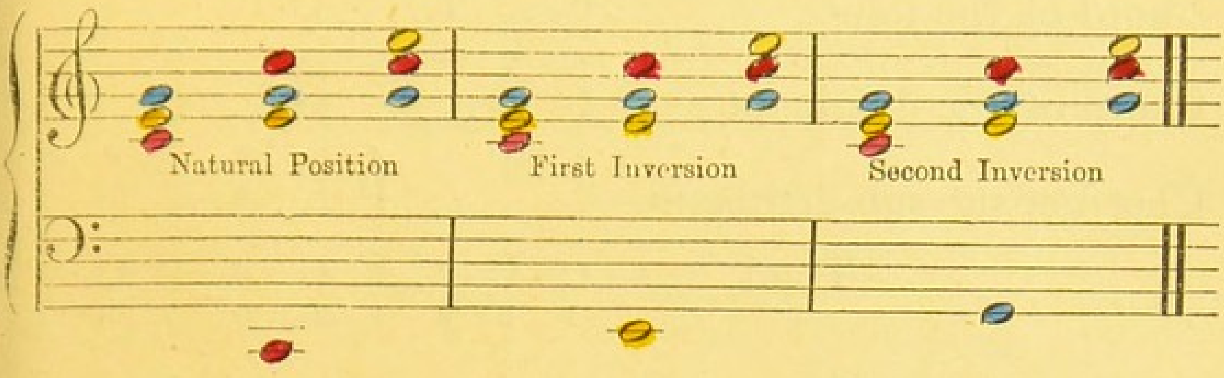


DIAGRAM VII.

Changes of position of the common chord of the dominant.

1 2 3

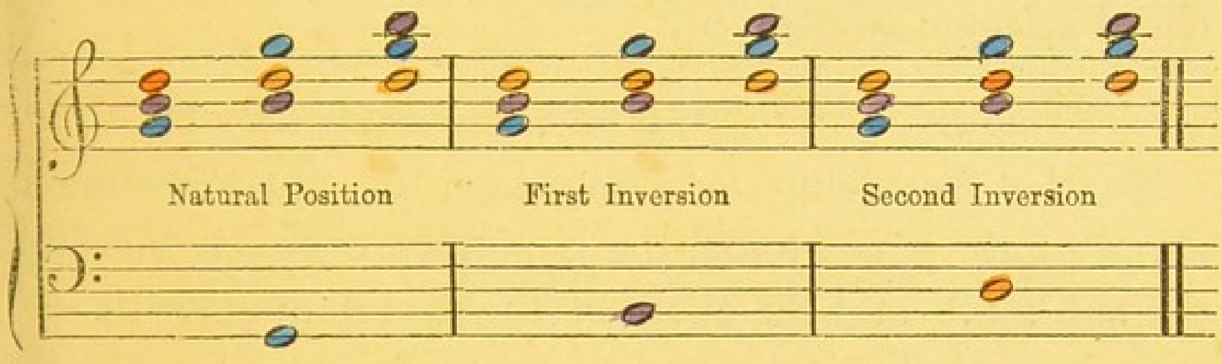
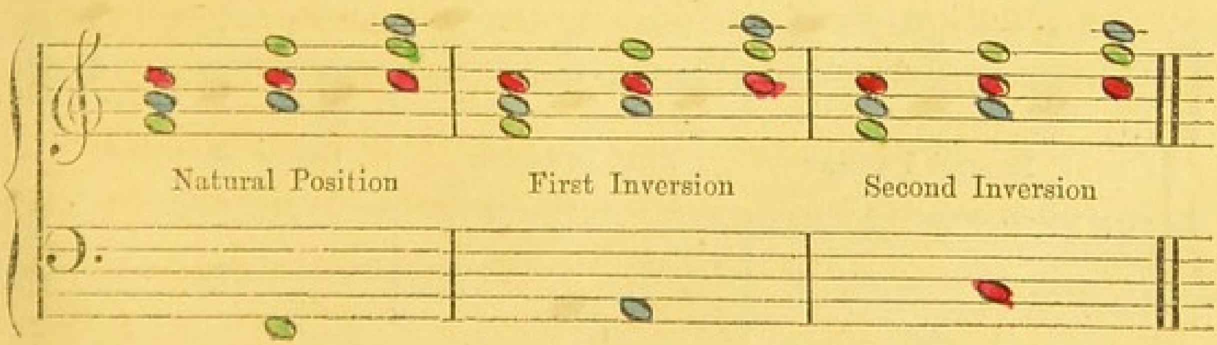


DIAGRAM VIII.

Changes of position of the common chord of the sub-dominant.

1 2 3



That the three common chords as given, include all the intervals of the scale may be thus simply shown.

	1	2	3	4	5	6	7	8
Chord of the tonic	C		E		G			
Chord of the dominant		D			G		B	
Chord of the sub-dominant				F		A		C
Total	C	D	E	F	G	A	B	C

From this it will be apparent that any plain melody may be readily harmonised, with the proviso that each note must itself occur as a component of the particular chord selected to sustain it.

To the fore-going may be added the minor common chord of the super-tonic, the imperfect common chord of the sub-tonic, and the chord of the dominant seventh.

DIAGRAM IX.

Minor common chord of the super-tonic.

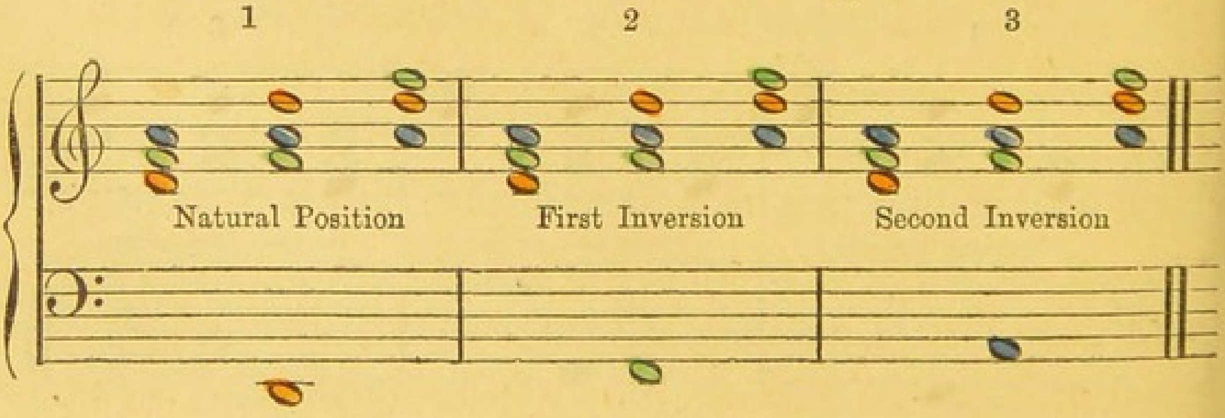
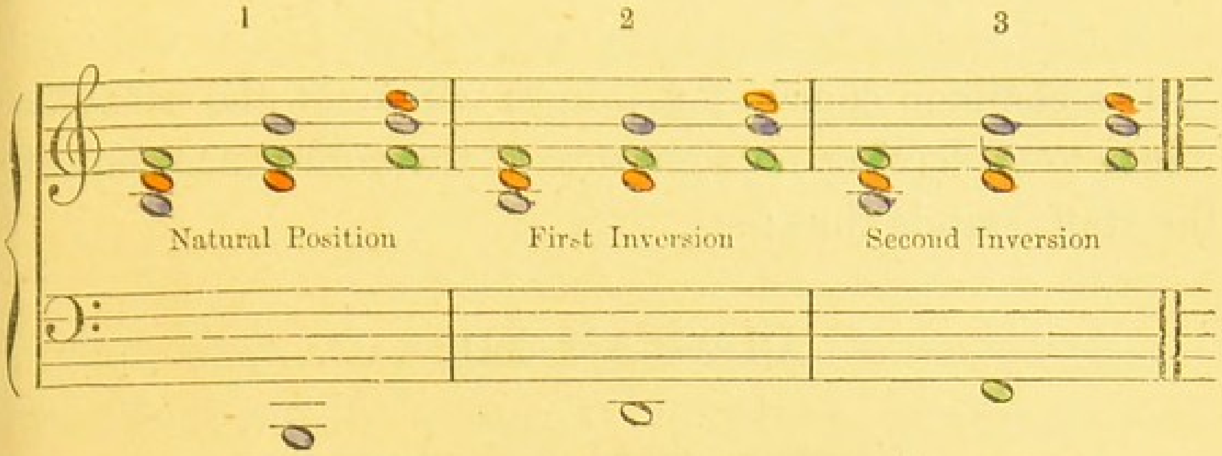


DIAGRAM X.

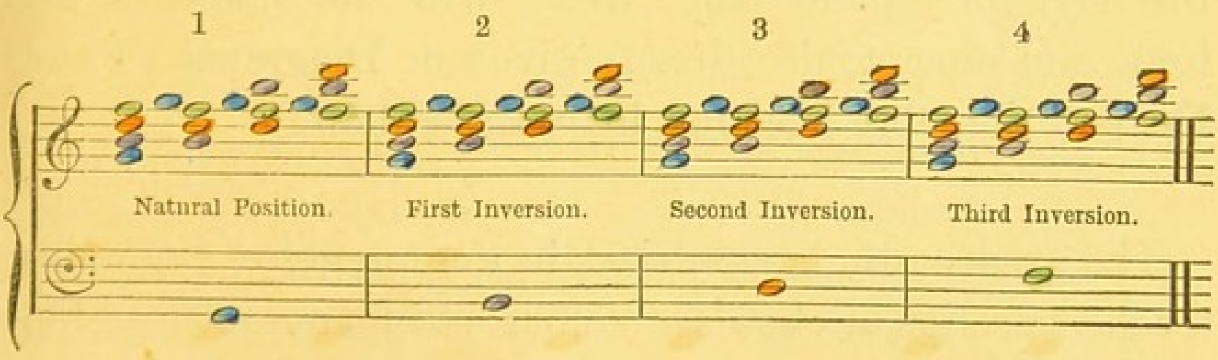
Imperfect common chord of the sub-tonic.



As B and D the first and third of the last chord form respectively the third and fifth of the common chord of the dominant, it is more usual to combine the two triads in the form, known as the chord of the seventh, consisting of the dominant with its third, fifth and seventh as follows :—

DIAGRAM XI.

Chord of the dominant seventh.

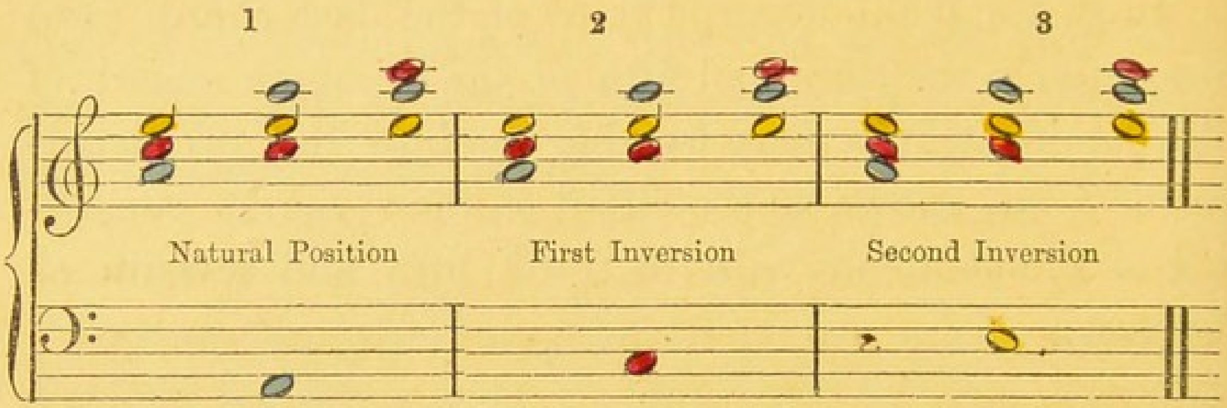


As there are four distinct notes in this chord it admits of four positions, moreover, the painter should observe the musical rule that it always requires preparation ; (*i.e.*), a particular chord to precede it, and resolution, (*i.e.*), another to follow it, which must be that of the tonic as a close.

The common chord of A minor, which is the relative minor to C, having no signature at the commencement of the staff, stands thus:—

DIAGRAM XII.

Common chord of A minor.



The sub-dominant and dominant common chords of this key, correspond respectively with the chords of the tonic and super-tonic, already given in Diagrams VI and IX, and therefore need not be repeated here.

The great latitude exhibited in the foregoing examples for the selection of chords of colour, should not mislead the painter in their promiscuous use. He should first determine his key, and then translate some good harmonic phrases into colours most befitting the nature of his subject. The method to be followed in their distribution, and other readings of the rules of art, where they can be sustained by the musical analogy, will be found in a more advanced part of this essay. I shall now merely append some of the leading principles of counter point to assist the painter in harmonizing a theme, or phrase for pictorial purposes.

Euphony in music is analogous to euphony in language, and determines the most easy transition, or sequence of accordant intervals, consistently with the physiology of hearing. The following principles are involved in it.

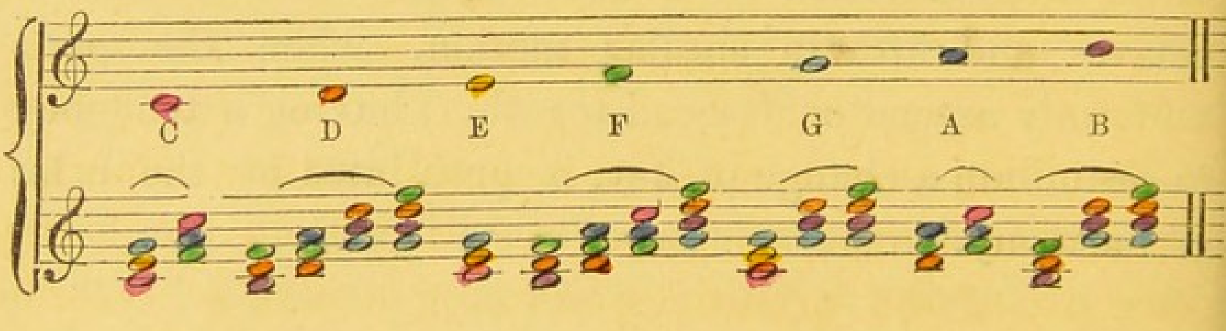
1.—A clear perception of the fifth interval is essential to the determination of a key. Hence a sequence of octaves and fifths in similar motion, when the parts uniformly ascend or descend together, having a tendency to assimilate a change of key, is prohibited by the rules of harmony.

2.—Skips from a given note to any wide interval, and dispersed harmony, so called, for the reason already given in the preceding paragraph are also to be avoided. Hence compressed harmony, or the closest possible arrangement of the parts is to be studied in composition.

3.—In supplying harmonies to an air in C major, the chords in Diagrams V to X, inclusive, are available, and they will afford the composer sufficient materials to furnish parts with the double advantage of having a theme in themselves, without infringing rules. Those chords taken singly will support any of their own parts. Hence any note in the scale taken singly will agree, or harmonize with any chord, in which, it occurs as an ingredient. See annexed diagram.

DIAGRAM XIII.

Shewing the chords in agreement with each note in the Scale.



In plain counter point, the notes of the parts added are of uniform length with those of the subject; but where it is "florid" the notes are of different lengths, and variously intermixed at least in one of the parts. In the latter case attention must be paid to the accented parts of each bar, so as to know where the harmonies should be supplied, without involving the passing notes and embelishments.

I have dwelt thus long on the subject of harmony, seeing that frequent allusion to its principles must be made in the course of this essay, moreover, even a slight primary knowledge of music will greatly facilitate the comprehension of the views and arguments advanced; while the examples given in the diagrams will stand for reference.

I have reserved special notice of the complementary colours until something had been said with reference to harmony, so as to enable us the more correctly to form a judgment of the theory which connects them with the so called "physiological basis" of the harmony of colours.

SECTION IV.

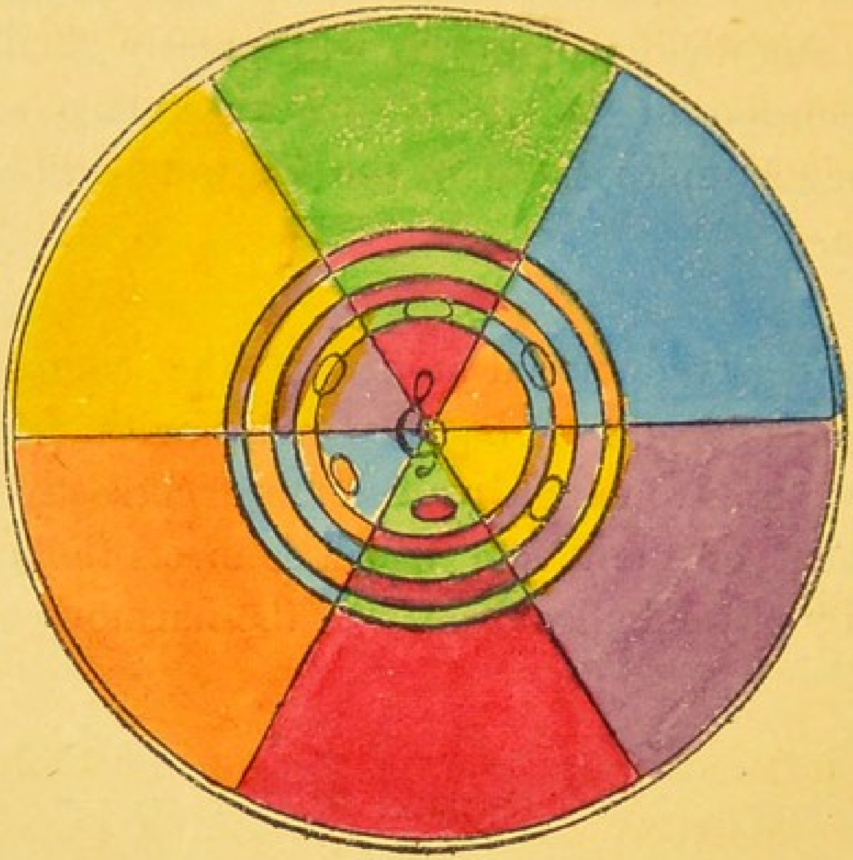
Complementary Colours.

In giving an account of the complementary colours, it is usual to adduce the series resulting from the binary mixture of the primitives, forming a sort of colorific hexachord, like the old musical one, in which the 7th interval equivalent to violet was wanting. Had Guido the monk taken the prismatic scale for his guide, instead of, in effect, making a mechanical mixture of the three major constituents of the diatonic scale, he would have transmitted a still greater name to posterity. The hexachord arranged in a circular manner, forms an instructive diagram, showing at a glance the colours that are complementary to each other.

DIAGRAM XIV.

Green.

Yellow. Blue.



Orange. Purple.

Red.

The alternate colours compose two common chords, one on the first and the other on the second interval of the scale. The opposite colours are also concords, standing in the double relation of fourths and fifths to each other, one being primitive and the other compound. Now in all the relations just mentioned, namely, the alternate simple and alternate compound, or any two opposite colours, the components are complementary, (*i.e.*), in the proportions to neutralize each other, and produce white or colourless light. It being assumed that the latter is in all cases composed of the three primitive colours in achromatic combination. Thus, if we take one primitive, say red, the other two, yellow and blue must exist in its complementary green, or separately. Or taking a compound colour, say green, composed of yellow and blue, its complementary will be found either in the opposite colour, red, or in the alternate compounds, orange and purple taken together. The complementary colours therefore, may be divided into two groups, as under:

1.—Binary group	Red—Green Yellow—Purple Blue—Orange
2.—Ternary group	Red—Yellow—Blue Green—Purple—Orange

Though the musical analogy declares all complementary colours to be accordances, I cannot think with Professor Muller, that all other combinations of colour are disharmonic, or where he says that "combinations of two of the "simple colours, the third which would render them com-"plementary being deficient, are the most offensive to the "eye; for instance, combinations of yellow and red, blue "and red, or yellow and blue." Instead of "complete disharmony," as components of the perfect chord of colour, the examples here given ought to produce rather an agreeable effect. He further states that "in the "association of two colours of which one forms a transition "to the other, there is neither harmony nor disharmony "—such colours are indifferent to each other—as yellow "to green, red to orange, or violet to blue" (probably indigo). So far as indifference goes, these intervals, musically speaking, being seconds are positive dischords. Finally he writes "the disharmony between two colours "may, however, be removed by the interposition of a "third colour, which is the harmonic of one of them, and "is indifferent with relation to the other. We have "examples of this in such combinations as red, green and "yellow; yellow, violet and red; blue, orange and red; "or red, green and blue, &c." But this doctrine, and the discordant colours suggested by it are quite opposed to the musical analogy, which teaches us to look for agreements in concordant or coincident vibrations without "interference," rather than to submit to any arbitrary rule however plausible, that may be antagonistic to so philosophical a principle.

SECTION V.

Complementary Sounds.

As before explained, musical strings have a physical tendency to divide in the production of harmonic sounds, into parts of 4, 5 and 9, so as to embrace all the intervals of the diatonic scale; and the complementary sounds so developed, when translated to colours, correspond in every instance with what the colorific analogy would demand of them.

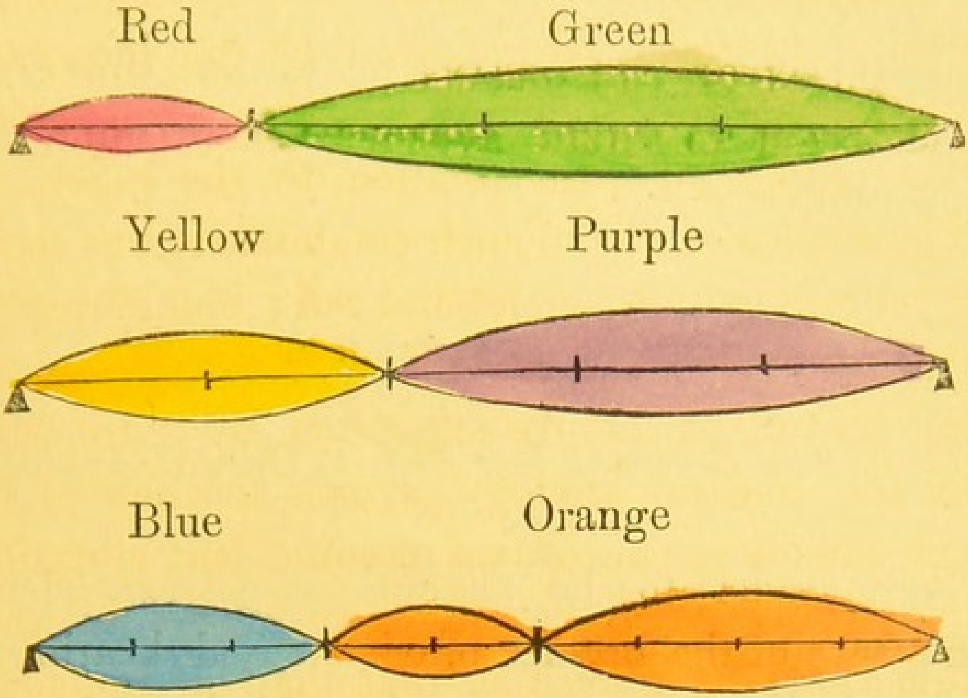
If a string sounding C, answerable to red, be divided into 4 parts, $\frac{1}{4}$th and $\frac{2}{4}$ths will also produce C, but the complement of $\frac{1}{4}$th are $\frac{3}{4}$ths yielding F, which is equivalent to green, the complementary colour to red. Diagram XV, Fig 1.

DIAGRAM XV.

Fig. 1, 4 parts.

Fig. 2, 5 parts.

Fig. 3, 9 parts.



Divide the string into five parts, and $\frac{1}{5}$th, $\frac{2}{5}$ths and $\frac{4}{5}$ths will produce E, (yellow), but the complement of $\frac{2}{5}$ths are $\frac{3}{5}$ths, yielding A, the equivalent of indigo or purple, which is the colour required. Diagram XV, Fig. 2. Again, dividing the string into nine parts, $\frac{1}{9}$th, $\frac{2}{9}$ths, $\frac{4}{9}$ths and $\frac{8}{9}$ths produce D, (orange), but $\frac{3}{9}$ths & $\frac{6}{9}$ths make G, (blue), and the complements, whether single or double make only these two notes, whose equivalent colours, orange and blue, are complementaries (Fig. 3). These facts lead to the inference that complementary colours are, as it were, chromatic harmonics; and perhaps it is in this way that complementary sensations arise in the retina, whose surface being long excited by the influence of a particular colour would appear to be more susceptible of the vibrations of the complementary in white light, but, it is not at all improbable that these are actually included in the way of harmonic vibrations in general.

CHAPTER III.

COMPARISON OF THE ORGANS OF VISION AND HEARING, IN RELATION TO THEIR APPROPRIATE STIMULI, LIGHT AND SOUND.

SECTION I.

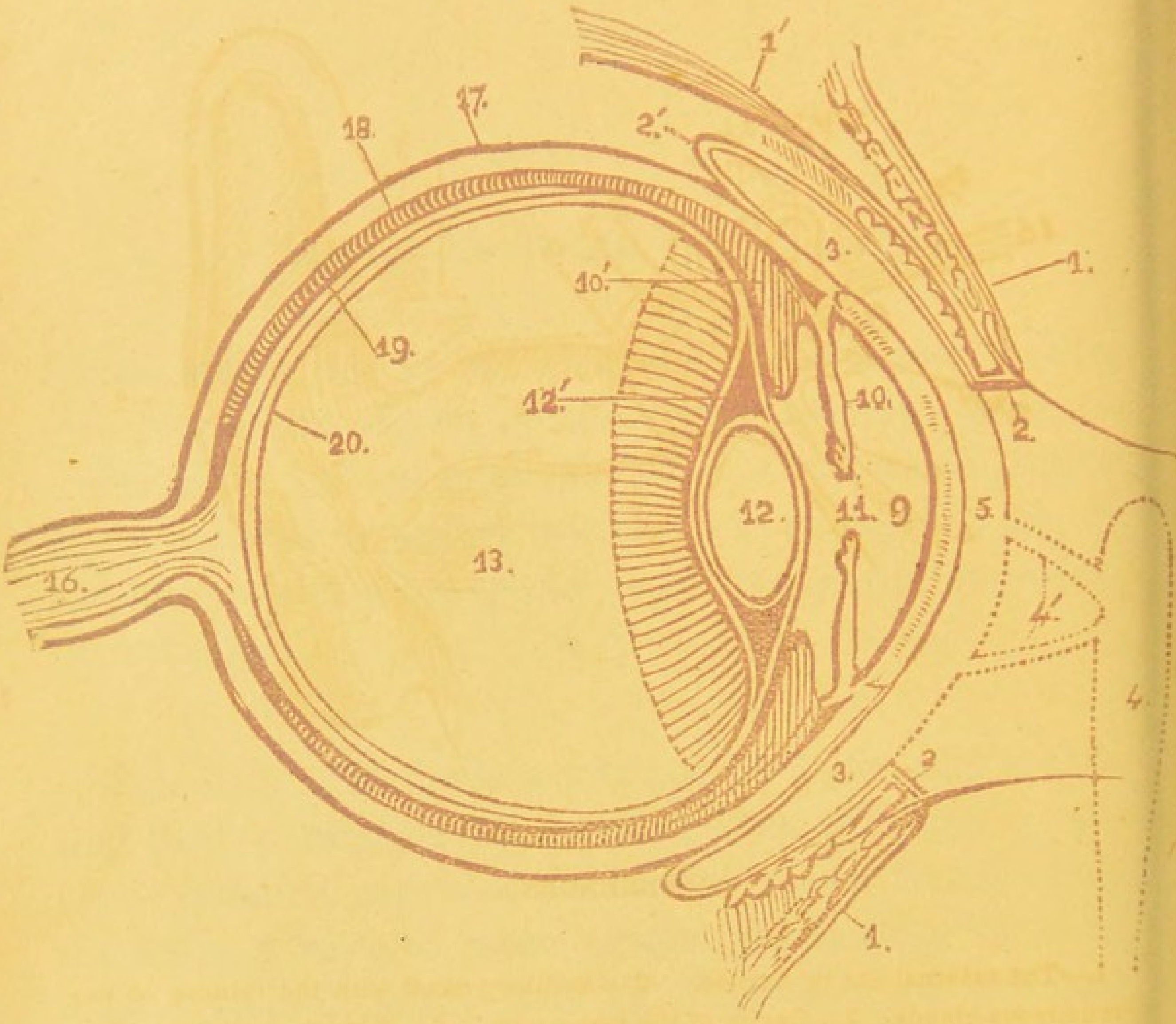
The External Ear and its Optical Analogue.

There seems to be as close a correspondence in the structure of the organs of vision and hearing, as there exists in the general properties of light and sound; while any peculiarity occurring in either will be found to be in accordance with some special requirement of its appropriate stimulus.

Agreeably with the law common to light and sound, that their power and intensity diminish with the square of the distance, nature adopts suitable means for collecting the diffused rays of those agents, preparatory to their further concentration, that an impression of sufficient strength may be conveyed to the seat of perception. Thus, in the eye the collection of the rays of light is effected by dense refracting media, (the cornea and aqueous humour), presenting an expanded convex surface anteriorly, while a funnel-shaped apparatus (the extended and generally concave surface of the auricle, with the external auditory canal) is employed for a similar purpose in the ear.

PLATE I.

Vertical section of the Eye.

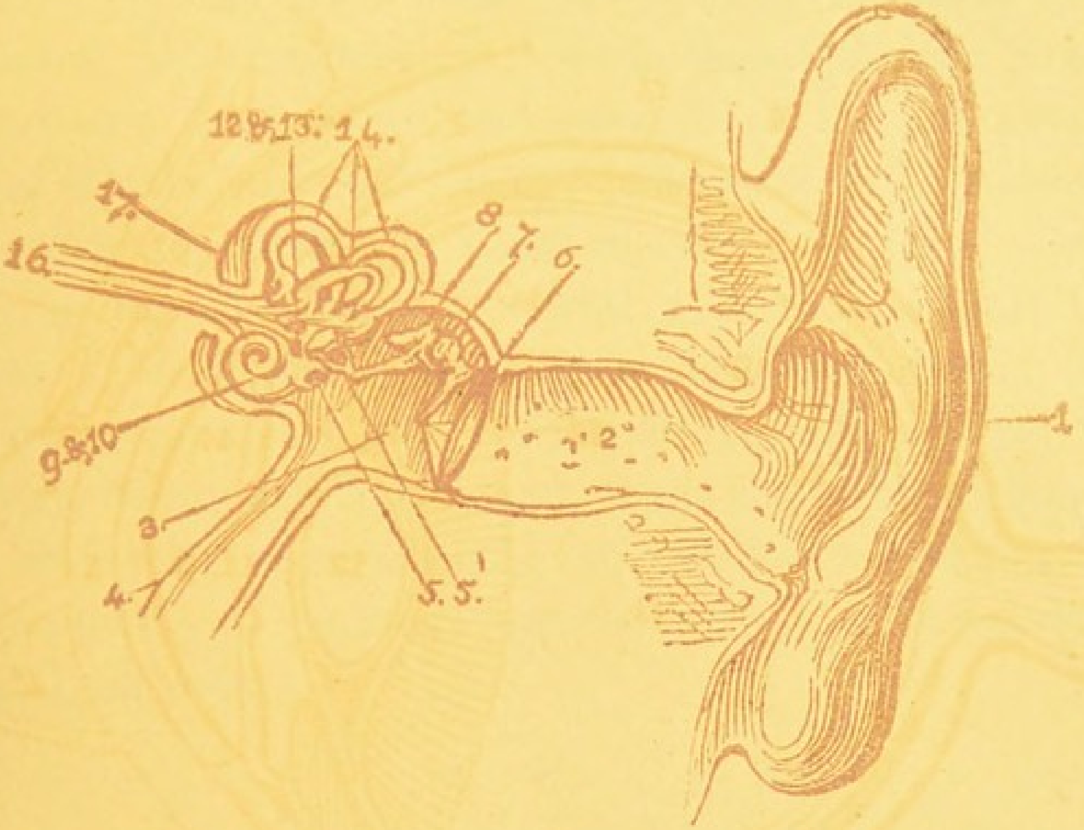


REFERENCES :—

1.—The eye lids with their different structures in section. 1'.—The elevator of the upper eye lid. 2.—The free margins of the eye lids with the eye lashes, and the orifices of the meibomian glands. 2'.—Conjunctival membrane. 3.—Cavity corresponding with the oculo-palpebral chamber of serpents. 4.—Nasal duct. 4'.—Lachrymal canals. 5.—Cornea. 9.—Aqueous humour. 10.—Iris. 10'.—Ciliary processes. 12.—Lens. 12'.—Canal of Petit. 13.—Vitreous humour. 16.—Optic nerve. 17.—Sclerotic coat. 19.—Retina. 20.—Hyaloid membrane.

PLATE II.

Scheme of the structure of the Ear.



REFERENCES :—

1.—The external ear or auricle. 2.—Auditory canal with the orifices of the ceruminous glands. 3.—Cavity of the tympanum. 5.—Fenestra rotunda. 5́.—Fenestra ovalis closed by its membrane, with which the base of the stapes is connected. 6.—Membrana tympani. 7.—Malleus. 8.—Incus. 9 & 10.—The cochlea, containing the perilymph and spiral lamina. 12 & 13.—The vestibule, containing the octoconia and endolymph. 14.—Semicircular canals. 16.—Auditory nerve. 17.—Petrous portion of the temporal bone, forming the bony labyrinth.

As analogous parts are indicated by corresponding figures in this and the preceding plate, illustrating Chapter III, it has not been considered necessary to introduce special references in the text.

Now although the *auricle and external auditory passage*, with its short hairs and glandular apparatus (anatomically considered), correspond with the eye lids, comprehending especially the *tersal fibro-catiliges*, the *cilia* and *meibomian follicles*, yet, the office of the auricle in receiving the rays of sound, and transmitting them to the middle ear, is too important a function to be passed over in the simple notice of the anatomical analogy just mentioned. Indeed, the eyelids rather tend to diminish the quantity of light entering the eye, being watchful guardians against its excess, or the injurious contact of foreign matters. In certain savage tribes, the muscles of the auricular region are remarkably developed, and their action in perking, and otherwise adjusting the auricle, bears relation to its reception of sonorous undulations for transmission to the tympanum.

SECTION II.

The Middle Ear and its Optical Analogue.

A further concentration of the rays of light and sound respectively, is necessary for distinct vision and hearing.

In the eye this requirement is fulfilled by a body (the lens) of greater density and refracting power than those employed primarily in collecting the luminous rays; and in the ear, by a membranous expansion, (the membrana tympani) having a conically depressed external surface, beautifully adapted for convening the rays falling upon it.

This membrane is connected with another of much smaller size, (the *membrana fenestræ ovalis*) through the medium of several small and dense bones, (the *assicula auditus*) and thus a communication is established with the internal ear. Some consider the membrana tympani overlaid with the lining membrane of the *meatus auditorius*, to represent the cornea of the eye, with its conjunctival investment; but Dr. Wharton Jones ingeniously supposes it to represent a natural "*mediate anchyloblepharon*," and such appears to be the correct view. The outer cornea in serpents therefore being a natural *anchyloblepharon*, may be regarded as homologous with the membrana tympani. Between it and the eye ball itself a space exists corresponding with the cavity of the tympanum, and this space is lined by the true conjunctiva, (the oculo-palpebral sac of Cloquet) agreeing with the lining of the tympanum. The lachrymal canals opening into it, and the lachrymal duct communicating with the nose are answerable to the eustachian tube which connects the cavity of the tympanum with the fauces.

SECTION III.

The Internal Ear and its Optical Analogue.

The most essential portion of the organ of hearing, or the internal ear, has been appropriately termed the ear bulb, bearing analogy to the eye ball in nearly every particular. There are however certain peculiarities in the figure and repetition of the parts of the former, rendering the subject complex.

The *membrana rotunda,* called also the *membrana tympani secondarina*, has been likened to the cornea. The *scala tympani* and *scala vestibuli* of the *cochlea,* have been respectively conceived to correspond to the anterior and posterior chambers of the eye; the perilymph being analogous to the aqueous humour, and the helicotrema to the pupil. The endolymph is answerable to the vitreous humour; and the otoconia, or caleareous concretions have been compared to the lens; while the several divisions of the auditory nerve taken collectively, represent the retina. A direct currant of sonorous undulations passes along the dense chain of ossicles to the labyrinth, through the *membrana fenestræ ovalis*; and the mere consideration of its yielding character, as bearing an analogy to the thinning of the *sclerotica* in the eye of the Greenland seal, is not satisfactory, for the functional parallel will distinctly shew that it must be recognised as fulfilling the office of cornea to the ear, as well as the *membrana rotunda.* The sonorous currant entering by the *fenestra rotunda* may be strengthened or modified in *scala tympani*, by that of the *scala vestibuli*, entering by the *fenestra ovalis*, and finally descending in the *scala tympani.* This is an important consideration in relation to the cochlea; and may possibly be connected with the perception of the pitch of musical sounds. The question may be: whether by a property of refrangibility analogous to that of colours, or by the simple law of interference, a collision of the two sonorous currants above noticed may take place at special points of the spiral lamina, according to the pitch, and thus (impressing the visicular matter of the middle scala in different localities) enable the mind to perceive the relation that one note bears to another in the musical scale. This supposition is strengthened by the fact that the most exalted function which the human ear, as well as that of the lower animals possesses, is the discrimination of the pitch of sounds; and the existence of the cochlea is the highest mark of perfection in the organization of the ear.

SECTION IV.

Perception of the Pitch, Distance and Position of Sounds by the Ear; and analogous faculties of Vision.

The perception of the distance and of the locality from whence sound originates must be regarded as two special functions of audition, and quite distinct from the sense of pitch which discriminates the relative graveness or acuteness of sounds. In the eye we also notice similar endowments, for while we form a judgment of the distance and position of objects by the light which they reflect, we can also appreciate their colours, but individuals are to be found in whom one or other of these functions is defective, either as regards the eye or ear. Thus, a person may have no power of judging the distance through which a sound may have travelled in order to reach his ear; or, what is analogous with respect to the organ of vision, he may not be able to conceive how far an object is distant from him by its image depicted on his retina. Again, he may have acute hearing in every respect, but no power of ascertaining the pitch of a musical sound, or its relative position in a scale of eight notes; or what is similar with regard to the eye, he may not be able to discriminate between one colour and another, although every object as to outline, light and shade, is distinctly perceived; so that the power of distinguishing the pitch of sounds by the ear, and the species of colour by the eye are analogous functions.

SECTION V.

Sympathetic Vibration.

When the active motion of a sonorous body excites the passing vibration of surrounding substances, they are said to vibrate sympathetically. This sympathetic vibration may be of two kinds, viz.: 1st., when the tremors of a sounding body are communicated by the atmosphere or other means, to an adjacent surface or substance, in the particles of which a corresponding motion is excited, and secondly, where sonorous bodies give out their own peculiar sound, when the vibrations of others are conducted to them in the manner just named. The motion of the fore part of the violin, occasioned by the tremor of the strings, is an instance of the former; and the excitement of one string on a harp by the vibration of another would illustrate the latter. Here the string sympathetically affected sounds its own note, and not that of the string which thus excited it.

It is probable that the membrana tympani (while it collects and transmits the sounds that subsequently impinge on the auditory nerve), may be sympathetically affected in both these ways, for in its passive state it is susceptible of the vibrations of any note falling upon it within a certain sphere, but, by its muscular adaptation it may commingle its own proper vibration with that of the sound affecting it, and thus augment the sonorous impression.

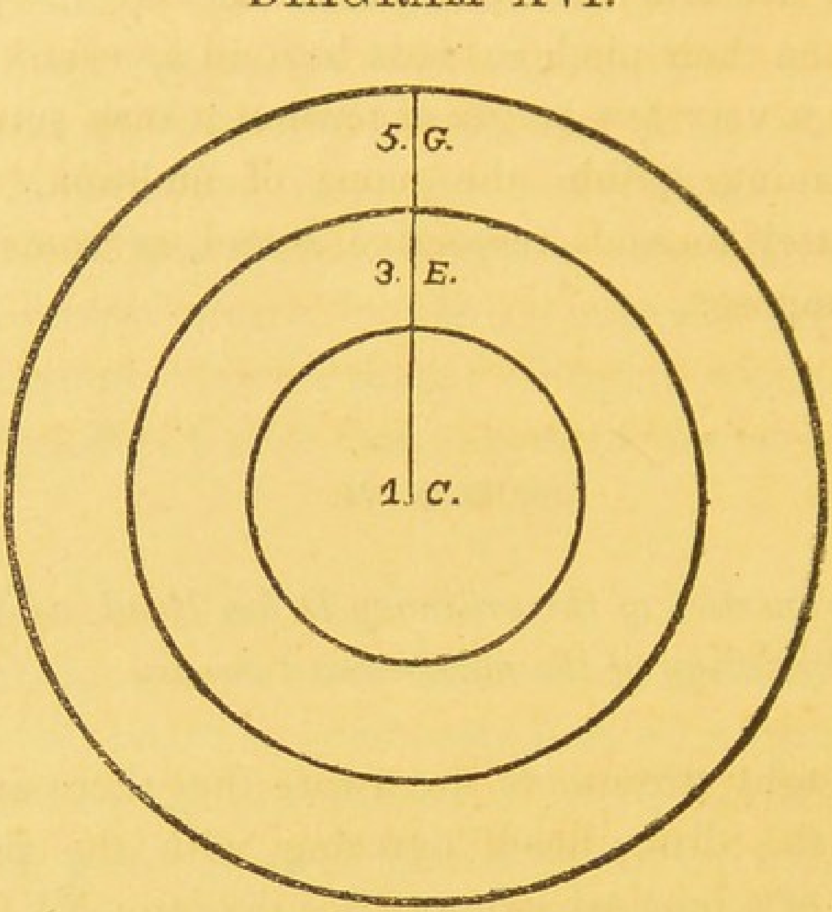
The strings of a piano-forte communicate their vibration to the sound board so accurately that their notes may be reproduced by the percussions of any loose dense body, as a small piece of steel placed upon it; and that the same particles may be simultaneously affected by two or more notes, is proved by the fact that the separate intervals of any chord, C E G, for example, may be distinctly traced in what we may call the compound percussions of the dense body. This experiment shows how the membrana tympani at the same degree of tension may transmit to the internal ear many different sounds, either simultaneously, as in a harmonious chord, or in succession, as in a melody. But as in the case of the sound-board just instanced, the drum of the ear will respond in some situations better than in others, according to the pitch of the note, suggesting the inference that all parts of the surface are not alike susceptible of the same vibration, and this we shall presently see more fully illustrated in the drum head. The fact also indicates that a certain change in the tension of the *membrana* *tympani* is necessary for the more efficient reception of sounds when their pitch extends beyond a certain range, so that by a very few stages of tension it may suit all the sounds coming within the scope of audition, without adapting itself to each respective sound, as some physiologists suppose.

SECTION VI.

Acoustic properties of the ordinary Drum Head, as supplied to the physiology of the membrana tympani.

Well taught drummers are aware that there are three notes on the drum head, agreeing with the principal harmonics of a musical string. See diagram XVI. One note is limited to the centre, a second to the circumference, and a third to the intermediate portion. The central point gives the tonic or key note of the instrument, say C; that of the circumference being a fifth or five notes higher than the central, is equivalent to G; while the note between these, which is a third above the key note, corresponds to E; thus the constituents of the perfect chord or triad of C may be produced by striking those several parts successively. Here also we perceive that the laws of vibrating chords are extended to membraneous surfaces, harmonic vibrations being developed in both. Thus, a string sounding C may have secondary or harmonic vibrations excited in several of its parts, making up the elements of the perfect chord, and this is also well exemplified in the drum head.

DIAGRAM XVI.



The consideration of the qualities of the drum head (above referred to) accounts for the extension of the handle of the malleus to the apex or centre of the membrana tympani, (as indicated by the perpendicular in the diagram) in order that it might convey to the seat of impression, the segmental vibrations, whether harmonically or sympathetically excited.

The high notes affecting the circumference of the membrane take but a short course along the handle of the malleus, agreeably with their pitch and intensity, while the vibrations of the centre, being of a grave and penetrating character, take the tragit of the entire manubrium; thus all inequality is compensated, and an important physiological end answered. Hence, it may be inferred, that the handle of the malleus, in correcting the unequal effects that would necessarily result from the diversity of the pitch and power of musical intervals, takes an analogous office to that fulfilled by the refracting media of the eye, whereby the contending refrangibilities of different colours are reconciled, and all are brought as nearly as possible to impinge upon the retina in the same plane.

It is an interesting fact that in order to establish any note as a new key, a correct conception of its fifth is necessary, as any other interval will not determine it. This constitutes the difficulty in following abrupt modulations or sudden changes of key, without notes of transition; just as the educated eye feels hurt when discordant colorific intervals are ignorantly associated, for the impression of one colour must be artfully neutralized by the juxtaposition of others having a sympathy with it. Now the three vibrating segments of the membrana tympani respecting to a key note, its third, and fifth, embrace all the requisites for determining the key; and this natural or physical division of the membraneous surface producing the perfect chord above mentioned, explains the necessity of every musical composition both commencing and ending with this combination of sounds. Moreover, on applying the laws of musical harmony to the association of colours, we shall find it necessary to establish some one colour as a key note in pictures, and upon this we may construct a colorific chord. Again, on the principle of harmonic vibration, if we suppose the note C alone to impinge on the membrana tympani, the notes E and G will be harmonically excited. Thus, the physical change affecting the membrane being communicated to the auditory nerve, induces the mental conception of the natural agreements; and this we may conclude is the mode of instruction which the mind undergoes in the formation of what is called "the musical ear," a faculty enjoyed by some favoured individuals, independently of any musical education.

The laws of the complementary colours have a similar bearing on the visual faculty, thus: the impression of red (equivalent to C) on the retina induces the perception of green, composed of yellow and blue, (third and fifth), answerable to E and G respectively, to the complementaries of which (purple and orange) the same principle will apply. The membrana tympani and the malleus accurately represent the sound board and steel rod of the experiment previously alluded to, and we may fairly infer that while the membrana communicates its vibrations to the ossicles, it also causes the *malleus* to percuss the face of the *incus*, responsively to the rapid and varied impressions made upon it. The accentuations, piano, forte, &c., in musical pieces will be marked with extreme accuracy, and should the parts of the music be deranged by a defect in time, an uneasy jog will be produced upon the auditory apparatus. Hence the antipathy of the mind to any erratic deviation in this respect. It is very remarkable that the malleus and incus (the hammer and anvil), should correspond, not only in figure, but also in function, to the objects from which their respective names are derived, for as we have already seen, the uses of the hammer and anvil as employed in mechanics are literally fulfilled by the malleus and incus, answering very important ends in the faculty of audition. By the action of one upon the other, sounds are not only correctly transmitted to the auditory nerve, but an accurate register of time is effected in the manner above explained. Thus, the mind is impressed with a faithful transcript of the harmony, style and general effect of musical pieces.

SECTION VII.

Laws of Rhythm and Time in relation to organic structure.

With regard to rhythm, it is in music what symmetry is in the arts, for as the lateral parts of symmetrical bodies or their pictorial representations must be similar, in order to maintain their special character, so the parts of a melody, although consisting of a series of intervals impinging successively on the ear, must be equal in duration as though symmetrically disposed, on the one hand preceding, and on the other following, a centre of time, for equal breadth in visual impressions is analogous to equal continuance in those of audition, space having the same relation to the organ of vision that time has to the organ of hearing. In this point of light the difficulty of philosophers in explaining the nature of rhythm appears to be in some measure cleared away, for it is no more wonderful to conceive the idea of equal partions of time, as presented to the ear in the several parts of a melody than that of similar portions of space, either as occupied by natural objects or their outlines in pictures.

It is well understood that the most difficult thing to be attained in the study of music is the correct appreciation of the value of the notes composing the bars and parts of musical pieces as regulated by a determinate time. And it is not unreasonable to presume, that the physical impulses of the malleus, whereby it percusses the incus in accordance with the measure of the music, are the very means employed by nature in thus instructing the mind to appreciate musical symmetry in rhythm.

CHAPTER IV.

PRACTICAL APPLICATION OF THE FOREGOING PRINCIPLES, HAVING SPECIAL REFERENCE TO THE WORKS OF THE GREAT MASTERS IN THE FINE ARTS.

SECTION I.

A kindredness observable in the arts of Music & Painting

It is remarkable that the great masters should have so uniformly expressed their pictorial ideas in strict accordance with the laws of harmony; but we must note the fact, that what is termed "gusto" in colouring is intuitive to the painter of genius, just as a musical taste is a natural gift to the born musician, who may compose and harmonize pleasingly, though ignorant of all rules.

Many of the great masters were practical musicians as well as painters, and profitted accordingly. In this connection the following short notices may not be uninteresting :—

Sebastian del Piombo enjoyed great reputation as a musician. Bassano and his son Leandro were admired for their attainments in music, as well as their skill in Painting. Tintorretto and his daughter Tintoretta made both music and painting their beloved studies. Bordone, a disciple of Titian, Antonio Tempesta, (patronized by Pope Greg. XIII) and Augustine Carracci were skilled in music. Carl Antonio and his son Ercole were devoted to music and painting, and distinguished for their appreciation of harmony in both arts. Bamboccio Georgione and Andrea Verocchio were eminent as painters and musical performers. Salvator Rosa was a painter, a poet and a musician. Dominichino was a scholar in the theory of music; his talent lay principally in the correctness of his style and his power of expressing the passions and affections of the mind. Guido Reni was a profound musician, and his taste in the harmony of colours has probably never been surpassed. His works were said to have been made by "hands divine." Parmigiano, whose pencil was the most graceful and elegant of his day, delighted and excelled in music; he was patronized by the Emperor Charles V. Rosso, a celebrated Florentine painter, and a favourite of Francis I, of France, was well skilled in music; he exercised great judgment in the mixture of his colours, and in chiaro oscuro, by the artful distribution of his lights and shadows. Julio Romano, said to be the most excellent of Raphael's disciples, was cherished by the muses; and Leonardo da Vinci was esteemed both a skilful musician and an able poet. Finally, Peter van Laer excelled in music, and was a painter in every line of the art. It would be easy to add other important names to those already quoted, but these will suffice to show the close relationship of musical and artistic taste. We shall bye and bye refer to the chef d'œuvres of Rubens, Titian, Guido, Veronese, Da Vinci and others, with the view of discovering how far they proceeded intuitively, in accordance with musical rule, as applicable to painting.

SECTION II.

Ordinary Vision and Hearing.

The fine arts and music enter more into the philosophy of vision and hearing than people are commonly aware of, including the perspective of visible things and sounds, as well as the special adaptations required for the perception of detail by the eye and the ear.

In surveying objects presenting an extensive surface, the eye is engaged with vigilant activity, passing from centre to circumference, and traversing the most interesting points, obedient to the will. Thus, we are enabled to appreciate the merits and beauties of artistic performances; but although the general effect may be perceived at a glance, yet only one small point can be distinctly seen at any particular moment. Standing before an architectural edifice, if we inspect the figures on the pediment we have a confused idea of the cornice and mouldings; if we direct our attention to the architrave and frieze we almost lose sight of the columns; in counting the number of niches our perception of all other accessaries is in abeyance, and it is not until we have carefully inspected the several parts in relation to the whole and committed them to memory, that we can obtain an adequate idea of the object. The auditory process in acquiring the air of a song or other musical composition is of exactly the same nature. A performer may play a piece in our hearing, but such cannot become thoroughly known to ordinary capacities until they have committed it to memory bar after bar, a work of time and careful study. Isolated sounds and simple objects (as a cube, a cone, or a sphere) may be perceived immediately, and there can be little difficulty in retaining them in the mind, but as they become more complicated and abstract, our powers of profitably hearing the former and seeing the latter require more practice. This analogy holds strictly good in most particulars, for we see and hear in detail, and the aid of memory is called in, to confirm and deepen the impressions made in both cases.

The central point of the retina is the seat of particular vision, and passing away from this point in every direction, objects in the general field become more and more obscure or ill defined. Hence it is that vignette pictures are so attractive, being somewhat circular, and fading off towards the circumference, while the central parts are carefully handled. Just as the convex mirror reflects the rays by "crescendo" with more fulness and strength towards the middle, the figures should stand out from the musical subject in bold and brilliant passages, as in pictorial representations, from the canvas or back ground. Titian told Tintoretta that a bunch of grapes was his surest guide, of course, from its rotundity, softness, central projection in light, and gradual dissipation towards the extremities. Ample broad lights encompassed with friendly shadows and delicacy in the management of his colours, raised Corregio to eminence, together with his having acquired the grand secret of knowing when to make an end of finishing; for frequently without this, nothing would ultimately remain of one's first ideas, particularly in painting.

SECTION III.

Perspective of Natural Objects and Sounds.

As the rays of light and sound proceed in straight lines from their respective sources, their intensity must diminish as the squares of the distance and the principles of common linear perspective are applicable to both. At the vanishing point of sight and hearing, impinging on the blendid auditory and visual horizons, both natural objects and sounds cease to be discernible. Acute, medium, and deep sounds of appropriate strength and quality, may represent objects in perspective, which weaken in colour as they diminish in magnitude, receding from the eye. In some instances, however, the atmosphere is so clear, (*i.e.*) free from vapours and exhalations diffused through it, that distant mountains are nearly as well defined as near ones, and the most deceptive idea of distance may be formed.

This is particularly the case in Australian scenery, what is known as aerial perspective only occurring when the atmosphere is visibly dull. In such a case the slight opacity naturally existing, becomes more and more apparent as the distance increases, or as the mass of air intervening between the observer and distant objects becomes greater. In this way hill behind hill are the more delicately tinted as they pass off into mazy remoteness from the eye. A correct knowledge of the principles of aerial perspective, perhaps above all other things, enables the painter to show the imitative power of his art. Sunlight, though itself possessing no quality of opacity or shadow, often enhances the effect of aerial perspective by secondary radiation, thus: street views of considerable length, when sunny in the distance present a body of illuminated vapour, dense from bright reflection, while the more remote objects and buildings are, as it were allegorized en masse, and the detail is lost in soft and diffused light. A similar effect is also produced in vast interiors, as in lofty cathedrals, when oblique descending beams of sunshine enter the windows and gleam from floating atoms in the air, shedding a luminous haze over the objects in their course. Sounds also grow softer by distance, and are in like manner less articulate as natural causes impede or arrest their progress.

SECTION IV.

Refrangibility of Colours.

Natural taste without demonstration has achieved great things in the graphic art, but when scientific rule can be established for its guidance, many persons not very highly favoured in that respect may take advantage of the principles, and develop results that they would little dream of otherwise. The study of the several degrees of refrangibility occurring in the prismatic scale will direct the painter in the grouping of his colours, and in carrying out numerous details in connection with his art, remembering that inversions of the chords of colour is quite as agreeable to the eye as those of the corresponding musical combinations are to the ear. In a general sense, however, colours of low refrangibility appear to the eye to possess an approximating equality, and belong more especially to the foreground, while others seem to recede from the eye, and according to their position appertain to middle or more remote distance.

We have seen that red is the least refrangible of the primitives, blue the most so, while yellow is intermediate, both in this quality and in its position; now if three lamps, one of each colour, be submitted to arrangement in different planes of distance, the effect will be pleasing or otherwise, as their natural order is preserved or violated. Contending refrangibilities producing a more jarring effect upon the retina by displacement. This would resemble a trio executed by musical performers at such unequal distances from the hearers, that the accompaniments may be considerably nearer than the subject, which is proportionably weakened by its remoteness from the ear. Indeed, we find that musicians as a rule congregate in one locality, and when this is impracticable their performance will give rise to a result often noticed in cathedrals where the choir is divided by the middle aisle, in which case the voices appear to oscillate from side to side, or from wall to wall, the organ also probably being at some considerable distance from the singers.

Red chalk drawings, or monochrome prints of the human figure, &c., are always sightly and pleasing, because any single colour is easily taken in by the eye, being of uniform refrangibility, and on a white ground, which is indifferent to every other colour; for a like reason drawings in sepia and Indian ink are agreeable to the eye. Were pictures of this class bordered with bright positive colours, the effect would be fantastic and vulgar, inducing the eye to vier between the repose of the picture and the glaring colours surrounding them. To ordinary eyes such matters would appear to be trifles, but there are no trifles in the perfection of art.

An uneducated taste is most captivated with flaring effects, both in music and painting, preferring gaudy to subdued colouring, and the racket of fifes and drums to the harmony of the full military band.

The adaptive powers of the human eye are not only brought into exercise in passing from one prismatic colour to another, but also, as it would appear, in the appreciation of the numerous gradations between the extremes of light and shadow in each. The varieties of the red denomination, for instance, diversify its quality of tone, on the musical principle to be noticed hereafter. Moreover, colours like notes may be sharpened or flattened, forming passing notes, so called, which enhance the harmony without infringing grammatical rule. These accidents are of corresponding value in both cases. Colours of medium refrangibility call forth little or no exercise of the adaptive function; hence we find the overpowering influence of solar light on a bright summers day much neutralized, and pleasing relief experienced on surveying the green fields, from the sympathizing repose they afford to the eye.

In the natural landscape there would seem to be a localization of tints in accordance with their refrangibility, thus: mellow reds, yellow browns, madder, vandyke, &c., are usually foreground colours, having the approximating qualities of their trebles. The milder tints, subdued greens, blues, &c., occupy the more central parts in middle distance, while the back ground, mountains, vapours, horizon, clouds and sky, are represented in the cool upper tints of the scale, and their compounds, comprehending every variety of gray to be found in works of a superior class, where landscape embelishes the subject, but particularly in the landscapes of Claude Lorraine. This great painter, who made nature his study, appears to have carried out the foregoing principles in his pictures. On the other hand, it may be necessary, in keeping with the circumstances of the case, to depart from the order here indicated, in illustration of which the picture of the marriage of Cana in Galilee, by Paul Veronese may be adduced. The Redeemer, who is here the principal figure, is carried somewbat back in the picture, and the painter, who could not properly distinguish him by mere lights and shadows, clothed him in red, the least refrangible and therefore the most approximating colour of the scale, so as effectually to conduct the eye to that figure. This is a striking instance of the musical and pictorial analogy, particularly in what is equivalent to an inversion of the common chord, which Paul Veronese seems to have accomplished with much musical perception.

In the perspective of colours the exercise of artistic skill is necessary, that every object may keep its own distance in the ground plane, thus: if one colour does not convene so soon as another, by approximating the one of least power, a compensation will be made, convening the less with the more refrangible colour at the same moment upon the retina. In this way blue in the foreground is equalized by red in the middle distance, which, with the mediant yellow, or simple white, will give a pictorial example of the inversion of a harmonic triad.

SECTION V.

Determination of Key.

Any two notes taken together, with the exception of two semitones, will form an agreement, so that they may be referable to some key or other, as composing a part of a characteristic chord, but unless that particular key is indicated by some of its essential harmonies a discordant effect will ensue. Now the same principle is equally applicable to colours, so that there is an actual necessity for establishing a fixed key in painting, in order to suggest the employment of colours best suited for association and pictorial effect. In composing a musical piece the first object of the composer is to decide upon a key. Here the painter has a hint well worthy his attention, viz: to commence his colouring with a definite key note, red for example, and then arrange the proper according and dependent colours, which must be localized according to his own taste and judgment.

Red amongst colours is the equivalent of a musical tonic, which occurs so frequently, either expressed or felt in compositions that its impression is persistent upon the ear; and by analogy, taking the negative side of the proposition, in such pictures as we find the tonic of colouring too sparingly employed, the key being defective, the corresponding impression will be lost to the eye. The key note must necessarily hold the most central and conspicuous position in the picture, so as to determine the arrangement of the chords of the dominant (blue) and sub-dominant, (green), should such be employed. The best colourists amongst the old masters inculcated this practice, as is exemplefied in their works, and to illustrate this we would particularly refer to the celebrated picture—" the taking down from the cross," by Reubens. Here the central figure of the standing group is that of the disciple John, clothed, for the particular purpose in question, with red drapery. This figure was the key note of Reubens, and the colours in the immediate vicinity are in keeping with this idea, thus: to the left we find the other components of the perfect chord, and to the right the common chord of the sub-dominant, the first interval of which is given in the green drapery of a female figure kneeling. Such are some of the principal points occuring in the harmony of this sublime picture, which will be noticed more particularly in its proper place.

Change of key is effected by the introduction of certain notes characteristic of the modulation, thus: if it be desired to pass from C to F, the flat seventh, B flat being introduced entails the change. Modulation may also be effected in colours by adopting some similar expedient, but this of course would require more careful management.

SECTION VI.

Quality of Tone and Compass.

Musical instruments vary in their quality of tone, and even those of the same denomination manifest certain differences, apparent even to the uneducated ear. The great diversity occurring in this respect serves to enrich the harmony of a concert, and hence also arises the value of a solo on any particular instrument, all others being in subservience, by soft contrast giving prominence to its qualities. Colours vary as much in quality of tone or tint as the sounds of musical instruments, thus: there are many species of red, brick red, rose red, &c., varying considerably in hue though included under one denomination. In like manner, C on the violin and on the flute is still the same note, yet how different it is in character and effect in the two cases.

The great organ represents most instruments in imitation, with stops ranging from the 15th to the base trumpet and stop diapason; in all these we find a wonderful variety of tone; one is soft, another sweet, and a third harsh, as in stops of the reed class. Timbry and metallic sounds also tend to neutralize or enhance the effect of others of a different quality. As far as colours are concerned this subject is perhaps one of the most difficult in the whole enquiry, for whatever quality may be observed in a single red, crimson, scarlet, saturnine red, indian red, venetian red, light red, madder, cochineal, logwood, or any other kind, a similar quality should pervade its own scale, and all the other colours should be akin to it, so as to bear comparison, each for each with the intervals of the musical scale of any single instrument, the peculiar quality of which is as apparent in one note as in another. The value of colours is much enhanced by texture, thus crimson cashmere is vastly exceeded by crimson Genoa velvet, the brightest stuffs are surpassed by silks and satins of the same colour, so that texture imparts a quality to colours equivalent in some way to peculiarity of tone in sounds. It is above all things necessary that artists should be acquainted with the principle here spoken of, that the colours they employ may be equalized in quality and strength just as all the pipes of each particular stop are voiced to prevent undue prominence of any over the rest. The incongruity of colours of different quality taking fortuitous parts in a pictorial theme may be compared to the single notes of a melody rendered by the interchange of the flute, cornet, sacbut, and all kinds of music. The blind man mentioned by Locke, as forming a notion of colour through the medium of sound, had conceptions and associations in his own mind making the comparison less absurd than readers generally imagine. This man heard of some colours, as green, being soft and soothing to the eyes of others, and he would naturally associate something soft in sound with such colours, and thus connect a visual with an auditory impression. Likewise hearing of the harshness of red on the sight of others, and such phrases as red as fire, understood by him from its effect in conflagration to be a fierce devouring element, together with red being a military colour and associated with blood shed, the harsh trumpet, the prelude to the sanguinary charge, would afford the blind personage the best idea of the colour in question.

If we refer to the musical analogy we find that scarlet, equivalent to C, when contrasted with a sober blue, (G) the true fifth of the scale, will induce an unpleasant effect on the eye, supported by the fact that a grating discord would result from such an altered relation of the tonic to its dominant.

SECTION VII.

Grace and Style.

The drawing of a picture is equivalent to the theme, or subject of a musicial piece, while the colouring represents the harmonious accompainments of a composition in score. We have seen that the quality of sounds is answerable to the tones of colour, either may be sweet, mellow, rich, harsh, &c., and both positive and broken colours in association, have their analogues in triads, chords sprinkled &c., more or less forcibly expressed, while fugues represent skilful and effective repetition in the arts.

Elegance and richness of tone, cadences, crescendo diminuendo and all the graces of style have their representatives in painting, so that a mutual gratification is administered to the senses of vision and hearing by a unity of expedients suited to affect the mind through two distinct organs. The lining of a garment is shewn with the same effect, when briefly indicated, as the appogiatura used in music for graceful embelishment. The colouring of Titian and Guido exhibits much of what may be compared to expression in music. Thus, we find purity of intonation, fine quality of tone and the power of modifying it through all the numerous shades of piano and forte for contrast and variety. We observe also judicious attention to accent and emphasis, to the former in order to mark the natural flow of the rhythm, and to the latter for the purpose of giving such occasional relief to certain notes in each musical sentence, as may serve to mark their relative importance. There is also in music a practice of introducing passing notes, which is of equal importance to the painter in reference to colours, though such elements in either case form no intrinsic part of the harmony, but are in fact most discordant when inadvertantly associated with it. Yet they are so transitory that they seem as emblishments to make concords still sweeter, and fill up vacant intervals ornamentally, without affecting the fundamental points of the musical or colorific agreements. We see then that passing colours are of great importance in the arts, and indeed are discernible, though to a limited extent, in the best paintings.

When the broad principles of accordances are attended to, it matters little what small portions of various colours may intervene between the grand chords, distinguishing the prominent groups and masses of the picture. No such passing colours should be broad or they would become too prominent, and usurp the places of the ligitimate harmonies. In music these harmonies are broad, and full, and in painting should be equally so. There is a variety in the touch or style of delivering the musical notes like what is known as handling in the arts, and implied by the terms legato, staccato, &c. Propriety and energy must be attended to in the performance of phrases, of melody, and sparkling brilliancy in those of mere execution so as to impart expression.

There is also in music and painting an identity in blending and softening, so that both may be included under one idea and expressed in the same language. The notes of the organ may be prolonged at pleasure, by holding down the keys, so that the performer is enabled to melt the tones of the instrument into each other; and in this he is especially assisted by the swell in the choir organ, which when judiciously used effects the feelings with tenderness, by its soft and fascinating impulses upon the ear. In a corresponding degree the painter avails himself of the means of softening peculiar to his art, blending his colours, while moist to attain a similar purpose.

Excess of this practice however, will neither apply in painting nor in music. The painter may be guided by the musician to use his privilege in moderation; for although it may be useful in certain cases, it cannot be admissible in all.

Mezzo-tinto engravings of the old school, were soft to mealiness, but to remedy this fault, etching has been very generally resorted to of late, to qualify the shadows and accessories. Grounding tools and roulettes cutting tissues of dotted lines are also now employed for a similar purpose. Mutes are used with wind instruments to enable the performers to imitate distant echos, and remote responses; to subdue certain musical phrases and cadences to a pianissimo point, and anon to give latitude to the qualities of sound, glazing in the arts is a mode of suppressing the obtrusivenes of colours, or toning them down, so as to mellow and refine them, mutes put sounds into perspective, and make them approach their vanishing points, and by judicious management in the hands of a clever artist a species of ventriloquism is produced, but with much more distant effect than mere vocal art can counterfeit.

Everything elegant and classic in art tends to make us appreciate the musical and pictorial analogy, for whatever delights the visual sense, finds sympathy in the auditory faculty, by judicious translation.

The accomplished lover of the arts sees much in pure classic architecture to feast his imagination, where perfect parts comprise a perfect whole. He observes the proportions of the pediment and the members composing it, and the shadows which they project wilh boldness and effect, upon the building itself, and should this be of some standard order, it will be sure to furnish a rich treat of light, middle-tint, shadow, and reflected light, duly appreciated by the connoisseur in such matters. The chastely ornamented and trimmed parts enrich the simple beauty of the design; while the columns, from their cylindrical form, exhibit every beautiful gradation of light and shade, crowned by the capitals, which in themselves are contrived on the noblest principles for displaying relief and majestic boldness, associated with the charms of beauty and grace. Contrast with this a more glowing musical picture, from the "Musical Union,"—"*Le Desert de Felicien David.*"

"The performance of the ode symphonie (says the critic) will make a distinguished epoch in music, for David has sought his inspiratiens, not in the scores of past or contemporary writers, but he has gone forth in the freshness of his young genius, and gathered up the eloquent voices of nature in her might and lovliness; he has sought for kindred symbols therewith to interpret sounds.

The soft breathing of the eastern morning, the wild rushing of the withering simoom—the tramp of the caravan, with its heavy echo on the sandy ocean of the desert—the heaving of the patient dromedary, &c., expressed by sounds denoting the presence of things signified—the burst of devotional feeling, and the shrieks and groans of the tempest-tossed way farers, are vividly and poetically expressed.

Felicien David has quaffed deeply of the desert spring: he has positively imbued himself with the nomadic feeling of the Arabs' life. Shall we then judge of this musical picture by the prosaic principle, measure its combinations with the carpenters' rule, or count its pulsations with a metronome? no! we may not measure the rainbow nor analyze the tints of a summer evening. David has conceived a glowing episode of eastern life, and has clothed it in all the hues of the palate. The outline is so perfect, and the dramatic feeling so intense, that we are fearless to assert that the execution is as perfect as the design is original and grand."

Thus, as explained in the above admirable critique, our ideas of a subject full of poetry, are carried out by music; visible objects are, as it were, suggested to the mind's eye through the medium of sounds artfully chosen, ("kindred symbols") interpreting the soft breathing of the eastern morn—the wild rushing of the withering simoom, by "sounds denoting the presence of things signified."

In the painters' palate, and the musicians' gamut, are the materials for sublime representations and intellectual works. The musical force of painting is no more difficult to comprehend, than the graphic power of music, nevertheless, both may be duly appreciated by some favoured individuals, whose art and natural genius are far in advance of their science, for neither the comprehension of such principles, nor their modus operandi, have yet been placed within the pale of prescribed rules.

In the hands of a skilful composer, the few elements of the musical scale may be made to produce effects of exquisite refinement and feeling on the cultivated ear. At one time music may breathe the purest sentiments of affection, while at another, deep and melancholy thought may be depicted. So capable are sounds of developing pictures of benign fancy, or powerful imagination, by episodes, ingenious phrases, and impassioned strains, that the auditory may be dissolved in rapture, or overwhelmed with emotion. Thus, as a single illustration: the extraordinary effect of the semitone progression of the violincello, on the 4th string, ending with the "wild shriek" of a diminished 7th on the leading note of la melancholia, by Beethoven, defies description.

SECTION VIII.

Basis of Shadow in Colours.

It is remarkable that the notes of the musical scale are of proportionate strength as they become graver, and singers aware of this fact increase the power of their voice as they ascend the scale.

The distant effect of colours also appears to increase as they pass towards the least refrangible end of the series, though by experiment, the greatest amount of illumination occurs between the yellow and the green.

The first note in a concert that strikes the ear at a little distance, is that of the lowest bass. The other sounds seem to affect us by chromatic gradation.

Band masters inform us that the most audible sound in a distant military band, is that of the basoon, and this probably arises from the deep mellowness of tone produced by the rumbling vibrations of the double reed, requiring considerable force in their production.

Deep vibrating basses are of the same use in a musical sense, as the deep tones of colour are in supporting the lights and middle tints of pictures, so that in the pictorial, as well as in the musical art, a rich bass is a *sine qua non.* This shows the value of that great mellowness of shadow always characterising the works of the old masters, and distinguishing them from those of more modern schools of art.

The great masters, with intuitive taste for harmony in colouring, availed themselves of the better qualities of brown, in the general grounding, and middle tint shadows of their pictures. Black, as a rule, is intensely cold, unless tempered with the warmer parts of the scale; but the darkest recess of any daylight scene receives reflected lights from surrounding objects, to a greater extent than is generally perceived, so that the rejection of pure black as an ingredient of shadow in pictures is sanctioned by the rules of art. Dark brown, on the other hand, retains enough of the properties of black, to afford a good agreement with the more positive colours in general. They represent the shadows of projecting coloured objects, which could not be adequately expressed without them. Indeed, the want of light itself must have a representative in the arts, and the beauty of all objects in the presence of light depends on the contrast of shadow, to enhance its value. The numerous species of humming birds are beautiful and pleasing to the eye, from the prismatic hues of their plumage, heightened by metalic lustre. To give due value to the golden and other tinting, the basses are intensely deep (dark). A volume of instructive references could be drawn from the plumage of tropical birds, and the feathered tribe generally. In the vast variety of this class, some description of black is found to constitute a considerable portion of their plumage, because as before mentioned, it accords in the way of contrast with all the prismatic colours. In particular, it adds the utmost value to the gem like parts, resembling ruby, amethyst, emerald, and tourquoise tints, with metalic reflections. The dark colours contrasting with the bright and metalic ones, go under the denomination of black, but on close inspection, they will be found in general to participate in a bluish purple, or yellowish cast, suitable for the purpose intended. In addition to the foregoing arguments, the practice of the great masters of the Roman, Venetian, and Flemish schools, confirm the principle advocated, to which may be added the approbation of the profoundest critics and connoisseurs, who are all in favour of brown, as a preparatory colour for grounding, half tinting, and shading all pictures, such as fruit, flowers, portraits, landscapes, marine views, and historical subjects; over this preparation are to be scumbled the local colouring and lights, on a drab ground purposely preserved to receive them. Even in clouds and the azure sky, the same preparatory grounding is required. This is particularly observable in the works of the Dutch school, but, the process has been mistaken in modern art by several who conceive that when the azure and clouds have been painted in their own positive colours, they should be subsequently mellowed (a la brun) by mixing vandyke brown as an ingredient in varnish, to create an effect, more admired perhaps than understood. The result by the legitimate process is so mellow and effective as to give an indirect idea in the attempt to analyze it, and hence the misapprehension noticed.

The chef d'œuvres of our national collection are painted in the manner here advocated as simply a mechanical aid to approximate colouring, for the production of effects in the arts must be under the presiding taste of the painter, really such.

SECTION IX.

Black and White.

Black and white are of great importance in nature, defining outline by their contrast, and manifesting rotundity and depth, and may be considered as a matrix, in which colour is deposited in its more or less positive character. Black appears to be the result of the absorption of light, in a decomposed state, while the reflection of undecomposed light constitutes white. Neither may be called a proper colour; and this latter characteristic explains their power in supporting the true colours, and imparting to them varied degrees of intensity, corresponding with piano and forte in music.

White light, compounded of the vibrations of all the colours, is in an achromatic state, in which the properties of its constituents are, as it were, latent. On this depends its accomodating quality, acting as a mediant, in almost every instance where a mediant is required, and relieving any chord with which it may be associated.

White is usually qualified by painters with a slight admixture of yellow, because a positive white is only employed for some very peculiar purposes; even in moonlight scenes, the resemblance of the luminary is tinted with yellow. Sunshine imparts a yellowish tint to white, imitated in the arts by white and yellow in combination; indeed, white without yellow is a cold unmanageable colour. White then may be considered as a general mediant, while yellow is a special one between Red and blue.

It is a question whether there is in nature any pigment or body of a pure black, *(i.e.)* without any of the ingredients of the scale contained in it, exhibiting themselves in some way or other. Some colours called black are merely intense specimens of the fifth and sixth intervals, or the presence of red or yellow may be slightly perceptible. Hence we recognize Brown, yellow, and blue black, as descriptive terms. So difficult is it to obtain an unexceptionable black, that Japanners and other operatives neutralize the brown tint of the black paints of commerce, by finishing their work with a coating of blue; as varnish laid over black discloses its tendency to brown, however intense it may seem in a flat or opaque state. Even dyers cannot produce an approved black by one immersion, but finish with blue, to stand the test of a searching light. Were black to hold a position in the scale, it would probably be as an intense sixth, and white, as before mentioned, acts the part of a mediant, in common with yellow, between which and the green, we find the greatest amount of illumination in the spectrum.

Two dark colours lying in immediate proximity, require one of a lighter character to be interposed, that they may be the better distinguished from one another; and this is an important office of the medient yellow, for while it reconciles the contending refrangibilities of red and blue, it admits of their separate discrimination, being lighter in tone than either. When white and yellow, or indeed any two light colours are brought together, a dark medient may be required to separate them, if the chiaro oscuro of the picture be not thereby interfered with. This is the converse of the former principle, and may be instanced in the third position of the common chord of the sub-dominant, (E, green), in which the order is red, green, and indigo, the green serving as a medient. In the same way, the second position of the dominant chord takes orange as a medient, separating violet from blue, by a happy interposition. In matters of this kind, the colorific analogy may be of importance in music.

SECTION X.

Special Reference to Works of Excellence.

That the practice of the great masters is favourable to the principles advocated in this essay, will appear obvious by reference to the best pictures in the national gallery, and gems of art in other collections. In these works we have the painters' counsel and opinions handed down to us, and the best advice as to the choice of colours for harmonious effect. Although there is no evidence that the authors of those achievements consulted musical science, as being available in the pictorial art, still we find their selections in accordance with musical principles, simply arising out of an innate gusto for the harmony of colours.

In the picture of the Virgin and Child, painted by "the ornament of his profession," as Titian himself styled Paul Veronese, we find instructive illustrations of the perfect chord of the natural key of colours, in different positions.

Harmonious intervals are everywhere employed to the exclusion of all that are nonaccordant, so that a musical translation would be simple and pleasing to the ear.

In the admirable Bourgeois collection, there is a spirited picture by Vandyke,—"The Descent from the Cross." The harmony of this production is rich and glowing; the colours are positive, and the common chord of the tonic is conspicuous in different positions, the according intervals being so localized as to produce the happiest effect; the shadows are broad, dark, and mellow, like a full, deep, and well sustained bass, admirably contrasting with the clear, well articulated harmony of the treble parts. Had Vandyke and Paul Veronese, in the paintings alluded to, chosen the colours expressed by the intervals 1, 2, 7, 8, good taste might disapprove of the selection, and inconclusive arguments might be advanced, both for and against it, but without the help of the musical analogy, its disagreeable effect would be for ever inexplicable. This test, however, shews us that the 2nd and 7th are irreconcilable dischords with the key note, and so the problem is solved. Such intervals are often heard in the creaking of a door on rusty hinges.

The musical analogy extends to every branch of the pictorial art. In "Canalettis View, or the Grand Canal," (No. 127, nat. gal.,) the common chord of the tonic, and of the sub-dominant, alternate, and inverted, shew the skill of a contrapuntist. In this picture there is a multiplicity of according tones of colour, tinting the varied architectural masses. The sky supplies a dominant, to compensate for the want of it in the buildings, and is sufficiently near to complete the perfect chord; it contrasts also with the greenness of the water in the canal, which forms the sub-dominant, or 4th interval, according with qualities of the 6th and 8th, in the architectural part of the picture. The latter chord never fails to produce an agreeable effect, when it can be introduced with propriety.

Some of the richest specimens of pictorial harmony, occur in the works of Paolo Panini, representing ruins, and architectural beauties of ancient Greece, and Rome, with landscape. The observer is struck with the prismatic effect given in the tinting peculiar to lichen-grown and fractured pediments, architraves, and friezes, with all other accessories in time-worn and dilapidated edifices; but on closer inspection, inversions of musical chords expressed in broken colours, present themselves everywhere, and go hand in hand with the deliniation of the sculptured fragments.

In the Bourgeois collection, there is a remarkable flower painting, by Van Huysum, who flourished in Amsterdam, over a century ago,—(No. 140.) We particularly refer to this picture as illustrating the want of the mediant, or yellow interval. The group of flowers represented, is both cold and hard in colouring, and deliniation, and the absence of the mediant and its compounds must at once impress the beholder; the greens have a tendency to blue; no yellow green is to be found, nor is there a single flower in the mediant interval to enliven the picture. The drawing and handling are excellent, and the style is bold and masterly, but the defect mentioned leaves no perfect chord, and the 4th is a semitone nearer the 5th than the laws of musical harmony will sanction. Whenever a musical discord is apparent, the pictorial harmony is violated.

No. 121, in the Dulwich gallery, said to be by the same master, is less carefully drawn and handled than the former, but being prismatic in its colouring, and the mediant prevailing, to sustain the perfect chord, and otherwise act as an auxiliary, the representation of the objects is more natural and lively. The 4th in the former picture is equivalent to F sharp, and therefore a discord throughout; but in No. 121, the 4th is natural, like its equivalent in the natural key of music. The eye of the connoisseur will perceive the difference, and he may account for it, (in the language of criticism), more technically, than explanatory of the cause, but the musical analogy points out at once the nature of the defect, and its remedy. Thus, from the study of painting, the musical value of the mediant is manifest, while music, *vice versa*, demonstrates its importance in painting.

We shall now refer to some of the works of Titian, the most universal genius of the Lombard school, and esteemed by M. Du Fresnoy, as the best colourist of all the great masters. In his celebrated picture of St. Peter, we find the garments coloured in the 3rd and 5th intervals, and to introduce the 1st, the artist ingeniously brings forward the red flag of St. George, (an attendant figure). The flag is in quantity, as to colour, an appropriate balance to the mediant and dominant associated with it, in the most central part of the picture. Another important advantage arising out of this expedient, is that special attention is attracted to the principal figure of the piece. Subordinate, though still striking characteristics pervade this picture, in all its accessaries and details, justified by the musical analogy.

The picture of Bacchus and Ariadne, reckoned a masterpiece of Titian's, when translated into music, affords full harmonies; but there is an undue force in the dominant, as compared with the other intervals of the perfect chord. An excess of this kind is of course, quite as possible in music as in painting. Were the notes 1 and 3 sounding smoothly together, and a 5th, of inordinate strength then introduced, the latter would naturally counterbalance the other notes, and obtrude itself painfully on the ear.

Musical rule would prescribe a reduction of the power of the 5th, to equalize the harmony; and the same principle should be recognized in painting, viz.:—to preserve equality in the breadth and strength of the components of all colorific chords. Trusting to the truth of the musical analogy, we are in no fear of incurring the charge of presumption, in thus noticing a single defect in a noble picture, so often and very justly quoted by critics as a standard of art in colouring. In the Bourgeois collection, there is a companion to this picture, by Titian,—"Jupiter and Europa," painted exactly in the same key, in which the common chord is perfect, the dominant being kept within due limits, so that the harmony is complete.

Reverting to the "Taking Down from the Cross," by Rubens, previously alluded to, in reference to a key note in painting, we notice the skilful distribution of the ingredients of the common chord of the tonic, as follows:—there are nine figures in the picture,—St. John occupies a central position, befitting the tonic, and is appropriately clothed in red. The draperies of the three Marys are in the intervals of 5 and 3, mixed, that of the Virgin being in 5. The dress of Joseph of Arimathea, (a conspicuous character in the story) consists of 1, 5, and 3, and that of a disciple, of 5 and 1, while two assistants wear clothing of 1, 5, and 3. The figure representing the key note, St. John, gives value to the attending parts of the chord, in different positions, and the utmost harmony prevails everywhere. In suitable places, passing colours of limited extent are judiciously introduced, and promote rather than impair the general harmony, like passing notes in music, which fill up, contrast with, and set off the agreements. Add to these the graces of composition, the theme, the quietly flowing melody in sustained tenderness, and whatever is soothing and enchanting in music, and it will all be found pictorially expressed in this fine production.

In Cuyps' admired picture,—"The Prince of Orange going out in the morning," (alluded to by Burnet) we find an example of the common chord of the sub-dominant: the coat of the prince is red, 1st; that of his attendant, indigo, the 6th; and the dress of a groom in waiting is green, the 4th interval. The latter acts as a foil to the coat of the prince, enhancing its value, as purple and blue would respectively affect yellow and orange, their complementaries, or musically speaking, their 5ths.

Hogarth's portrait of himself is another example of a picture in which the dominant is excluded, and the chord of the sub-dominant, green, indigo, and red, commonly prevails. The coat being a brown red, has the value of a tonic, the quality of which is repeated. The curtains are in the 4th interval, while the accessaries, in broken colours extend the harmony. These consist of a volume of Swift, indicative of wit and drollery; one of Shakespeare, for ideal beauty and sublimity; and on the palette, the "line of beauty and grace" is appropriately introduced. Out of the palette a piece appears to have been knawed, as if in allusion to the fierce opposition Hogarth experienced in defending his enlightened and admirable theory on that subject. The dog, with a countenance of poetic watchfulness, adds to the interest of the picture, contributing by the colour of his skin to extend the mediant, and to balance the other colours employed. In point of harmony, this interesting portrait is complete.

So perfect was the gusto of Hogarth in colouring, agreeably with the principles of musical harmony, that to extend the mediant, he would resort to the expedient of representing an open music book lying on a chair, the interval being essential to fill up the perfect chord, and the more so when the key note is frequently repeated for vigorous effect. On another occasion a fallen chair, upholstered in red, to increase the force of the tonic, which would be otherwise too weak. This effect of art occurs in the morning breakfast scene of the "Marriage a la mode." Hogarth was a man of consumate taste, for the age in which he lived, when the fine arts were at a lower ebb than they were in the periods immediately preceeding and following. If we refer to the costume of his day, it was grotesque and slovenly, and either as it respected the attire of ladies or gentlemen, was anything but classical. The ladies were incommoded with tokes and hoops, giving the female form the travesty appearance of a Dutch doll; and the habiliments of the men were all made too large, that they might be sure to fit. Another difficulty Hogarth laboured under, was the want of preliminary education in a school of design; but in despite of all disadvantages, he acquired by the aid of natural genius, an admirable taste. He was a proficient in perspective, and showed great skill in his grouping, and the general expression of his subject. His attainments in colouring were of a high order, combined with a profound judgment of chiaro oscuro, and keeping. His style of painting has permanency, and is accordant in all points with musical harmony. In the "Contract of Marriage," anyone conversant with the analogy of music and colour, would be struck with his conceptions of the harmonious relationships of the pictorial intervals.

"Domestic Life after Marriage," (No. 114, nat. gal.,) affords a masterly management of the dominant, where blue pillars are employed, conducting the eye into a spacious inner appartment, in which numerous accessaries recreate the imagination. The architecture and perspective display good judgment and taste, and a musical translation of the colours would be harmonious and pleasing. The toilet scene, "Marriage a la mode," is excellent in colouring: the key note is full and repeated; the mediant also is of considerable breadth, but the dominant is restricted in tone; the common chord of the sub-dominant is most prevalent; but taking it altogether, the counterpoint is without a single discord.

That the balance of musical tones to preserve graceful harmony, is a guide to the painter, in a comparative degree, will more fully appear on applying the musical test to "The Death of the Earl of Chatham in the House of Lords," that justly esteemed picture, by Copley, which is a credit to British taste and genius, and has a deserved place in the national collection. The key note, red, which is necessarily so predominant, is too overwhelming to be subdued by any device. The harmony is affected by the absence of the dominant and mediant, for which the refined ingenuity of the artist could scarcely find a place. Variety and contrast are shut out, or appearing in such small degrees, in respect of the tonic, as to leave but one broad impression of red upon the eye, equivalent to a loud and continuous key note in the accompaniment to a delightful strain, exhibited in the truthful grouping of the picture.

Francesco Francia, (179 and 180) appears to have had an instinct for the selection and classification of his colours, in accordance with the musical analogy. His groups are balanced with scrupulous precision; from the peculiarity of his perceptions, as to rigid order and disposition, every figure and object being studiously arranged for inspection. His chords of colour are full, and exhibit such changes as clothed figures are susceptible of; one colour harmonizing with another, by strict attention to colorific affinity and effect. In other respects, his views and style are rigid, as might be expected from the stiffness of the period in which he flourished.

In the portrait of Pope Julius II, by Raphael, (No. 27, nat. gal.) the sub-dominant supersedes the dominant, by necessity, though not perhaps by preference. The musical notation of the picture would be the key note and its fourth; the back ground being green, and the vestments of his Holiness, red; but as these are complementary colours, their combined effect is pleasing. The portrait, both in a pictorial and musical sense, is extremely simple. The key note is properly prominent, and repeated, while the 5th is utterly excluded, so that although containing no ingredient of discord, it exhibits but little richness of harmony; and the size of the picture, 2ft. 3in. by 3ft. 6in., would not admit of accessaries to enrich it.

Murillo's fine picture of "St. John and the Lamb," (176, nat. gal.) illustrates the effect of broken colours, the positive ones being excluded. That this lovely picture should be a favourite with the British public, is a compliment to the discrimination of the committee of selection, even at a cost of £2000, the sum paid for it. Contrasting this picture with the flare up practice, we see everything in it to be admired, for chasteness, nature, expression, and general effect.

In the Bourgeois collection, the "Peasant Boys," also by Murillo, is in the same style of painting, which for truth and nature, cannot be surpassed. No. 248, in this collection, the "Spanish Flower Girl," has equal charms. The harmony of those paintings would require a very peculiar musical notation, and instrumental performance of a very high order, to be in keeping with it in all points. The tints are so chastened and subdued by refined taste, that delicacy and suppression would constitute the principal difficulty in imitation. In that grand picture and ornament of the national collection, the "Holy Family," by the same hand, the musical analogy is so fully carried out as to show the unity of the according intervals, in both the musical and colorific scales. The figure of the Virgin is clothed in the perfect chord; the tonic is judiciously full, and the force of the dominant is chastened by the mediant, a kercheif. The drapery of the Child is tonic, to which the garments of Joseph form a leading chord; and so far we are enabled to infer that the picture is painted with consumate cleverness and musical gusto. We pass on to the aerial and cloudy parts of the picture, which consist of partly broken and positive colours, repeating with delicacy and beauty the chords of the figures. We shall not allude to the forbidden representation of Deity, for any critical purpose further than to regret that this should have been attempted in any form, much more that of an old man, a conception one would suppose too gross to make an impression, even upon a Spaniard. The other works of Murillo, to which we have alluded, are executed in broken colours; but in this instance, in consequence of the magnitude of the work, and its original design, as the altar-piece of a Roman catholic place of worship, the style is rather after the colouring of Guido, but chastened with refined judgment, avoiding the more showy practice of the Roman school.

The picture of "St. John, preaching in the wilderness," (No. 331, Dulwich collection), ascribed to Guido, is identical in style, conception, and handling, with the other pictures of Murillo, in the same gallery. Murillo appears to have adopted the method and treatment of Guido, whom he survived about 43 years. Both occasionally adopted either the suppressed or the more positive styles. In the national collection, Guido's "Lot," and Murillo's "Holy Family," are quite prismatic, and widely different from the "Spanish peasant boys," and the "Flower Girl."

The British national gallery is rich in possessing perhaps the best picture that Rembrandt ever painted: "John VIII, 27." There are two subjects in this picture, and they make a primary and a secondary light. The brightest light is central, and managed with a brilliancy of effect in chiaro oscuro, unequalled in any other picture in the collection. Judicious contrast of light, with a bold extent of shadow, and ample breadth of middle tint, is effected by superimposing the colouring upon a transparent brown ground, after the method subsequently to be described. The shadows are remarkable for their mellowness, warmth, and intensity, like the deepest musical basses, rendered with adequate richness of tone and judgment in performance.

The more brilliant focus consists of a flood of sunshine overspreading the group, when the story is told so plainly as to need no explanation.

The classification of the figures increases the charm, being executed neatly, and in the first style of art. The tenors are broad, full, and harmonious, and the basses sweet and clear in vibration, though profoundly deep; the treble articulations combine all the elements of pictorial harmony, like well executed instrumental performance in concert.

The secondary light comprehends a considerable focus, displaying the gorgeous alter of the temple, and a portion of the congregation assembled round an officiating priest. The colouring of this part of the picture is comparatively subdued, to set off the principal subject, just as a symphony would be employed in music, to give due effect to the theme.

Contrast in chiaro oscuro, peculiarly distinguishes the works of Rembrandt from those of the other great masters; and such contrasts in music, managed a la Rembrandt, by a skilful composer, would develop striking results. Here would be a model for producing an effective and brilliant subject, with a greater proportion of bass to treble, than musicians are in the habit of estimating as sufficient.

It is a maxim in the arts, that the lights should have a sufficient mass of shadow to support them; and such broad effects are called reposes, affording relief to the eye, which would be otherwise conducted from one bright object to another, so unceasingly as quickly to induce fatigue. Consistently with this principle, Rembrandt's "Adoration of the Shepherds," (No. 27), contains every variety of chord and modulation, sustained by rich basses, even suggesting the nature and quality of the instrumental parts best calculated to obtain an aural transcript of the visual impression. It is observable that the value of colours after Rembrandt's manner, is so enhanced that the slightest indication of a dulled prismatic hue tells for a clear positive one; and a constant artistic vigilance is required to suppress undue brilliancy; hence, the actual quantity of colour used by Rembrandt, was very small, compared with the extent of canvas covered.

The painter who works transparently in his grounding and shadows, only giving his high and subordinate lights due opacity, as was Rembrandt's practice, has acquired a secret worth knowing, as the best, and probably the only style leading to perfection in colouring. Transparency of colour in painting appears to be equivalent to clearness, or purity of tone in music.

An important peculiarity in this mode of colouring is the attainment of roundness or relief. Some of the portraits in the national collection, painted by men of genius, were undoubtedly, expressive likenesses, when first they came from the easel, but they have since become dull and flat, having been painted on the opaque principle, in which permanent roundness is not attainable. Were such pictures placed near those painted in the style of the old masters, their flatness would be still more apparent. In the one case we are not for a moment deceived, but regard the representation as a mere painting; in the other, however, in an abstraction of thought, we may feel our senses cheated, by a head starting, as it were, from the canvas. Of this latter kind of painting, there is a noble specimen by Guido, in the Dulwich gallery, representing St. Sebastian, in which such relief is given to the figure, that it seems as though it would disengage itself from the background.

That modern paintings are absorbed into their canvases, and lose their colour after the lapse of a few years, is a calamity much to be deplored. In accounting for this evil, we would ascribe it to an erroneous principle in the mode of colouring, involving too many "processes." Again, the mixture and intermixture of tints cause mischievous effects, from the quantity thus supplied to promote chemical changes and their consequences. This would not occur, were the pictures painted on the transparent principle of the old masters, whose works after 150 or 200 years, are still, to all appearance, improving in mellowness, and beauty.

A man of talent will accomplish a portrait in a very few sittings, and, in all probability, it would not admit of many more, without deterioration. Simplicity is the grand desideratum in colouring, and the effect should be such as we see in the portraits of Vandyke, Reubens, and Rigaud, combining excellence in style, with fidelity to nature.

The portraits by British painters in the Dulwich gallery, are much faded. The flesh tints have assumed a pale and sickly hue ; the carnations are nearly gone, and the complexions are dying away. This is especially the case with Gainsborough's portraits. In those of Mrs. Tickle and Mrs. Sheridan, the flesh colours have altogether departed ; and another picture : Mrs. Moody and her children, is so much faded, as to present the sad aspect of an unhealthy family.

In the paintings here alluded to, there is no such colour as the tonic, and the want of red, even in the faces and colour of the flesh, increases this effect, leaving to posterity but a sickly memorial of the persons represented. On the other hand, the paintings of Bassano, Vandyke, Maes, Vanderhelst, Hausman, &c., &c., stand the test of time, "in colours ever fresh and fair." As we go back to the time of Opie, the portraits grow flatter, and decay in clearness and strength of colouring, when they should improve with age, and hold their original colours in primitive value. Duration, and even improvement by time, are qualities attainable in art, by reformation in the grounding, and simplicity in the subsequent operations; for what men could do in the 15th and 16th centuries, (if we take the trouble to find out how they did it) may also be done in our own day.

It is very important to know whether the refined evanescent oils, now in general use, may not be at the bottom of the evil above alluded to. We have sufficient evidence from all that has been handed down to us, of the methods followed by the old masters, that pure linseed oil, both boiled and in the raw state, was the only vehicle for colour employed by them. There does not appear to be any proof that they ever mixed varnish of any kind with their paints, or used it in any such forced compound as maguelp.

When pigments in a finely levigated state, are mixed with oil, each molecule is, as it were, insulated by the vehicle, and thus preserved from the influence of extraneous agencies, and even from chemical changes, with the atoms of other pigments artistically commingled with them in tinting. It stands to reason that every absorbing surface, as in the bibulous grounding material of some kind of prepared canvas, added to the want of binding, and the evanescent nature of the vehicle itself, will sooner or later deprive the pigments of their protective matrix, exposing them to the action of new affinities, to the utter destruction of the pictorial effects they were intended to sustain. Soap and water would very soon undermine such colouring, whereas they may be fearlessly employed if necessary, in the superficial cleansing of pictures painted with linseed oil.

FINIS.

ON

THE PATHOLOGY

OF

FATTY DEGENERATION.

BY

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FATTY accumulation and fatty degeneration, the physiological process and its pathological counterpart, are not to be placed in strong contrast, or regarded as two functions altogether distinct and practically separable from each other. On the contrary, dissimilar as they may be in some of their phases, they shade into each other at so many points that no exact line of demarcation can be drawn between them. They are directed by the same chemical principles, and the results, as measured by the same anatomical rules, are essentially identical.

Not to lengthen these remarks by an enquiry into the laws of fatty accumulation, it is at least necessary, here, at the outset, briefly to indicate the successive steps by which the physiological merges into the pathological process.

Regarding the subject from a chemical point of view:—

1. In a condition of health, where all the organs are as yet sound and the years few, only such alimentary substances as are not available for immediate use are turned into fat. Obesity in this condition generally results from an excessive use of non-nitrogenous food. The physiological problem here is precisely the same as that which a smoky lamp presents, the carbon in both cases being supplied out of due proportion to the oxygen, and being deposited in the one case as fat, in the other as soot. And a properly devised regimen and diet are as surely successful in preventing the formation of fat in the animal, as adjusting the burner and the feeder are in preventing the formation of soot by the lamp.

2. It is a step lower than this when fatty accumulation results from a deficiency of oxygen rather than from an excess of carbon, when the fat is supplied by the carbon which enters into the composition of the nitrogenous as well as of the non-nitrogenous elements of the food. The remedies here are not so obvious nor so easily applicable, for the system may not be able to bear any considerable diminution of the class of aliments which supply the fatty matter in this case. We cannot leave these off as safely as we can suspend the use of non-nitrogenous articles of diet; and, in advancing years, with which this second stage may probably coincide, the organs have lost something ot their original integrity and reparative powers, and answer less readily to remedies.

3. The third stage into which this insensibly shades is lower still. Here the source of the fat is removed yet farther from our control; for it is not formed from the food introduced from without, but is a product of the daily waste of the tissues.

This is the lowest condition of suboxidation. The invading substance itself is more widely diffused, and permeates other parts besides the cells of the common adipose tissue. Our remedial measures are now utterly inadequate to meet the difficulty. The principles to be applied are indeed the same, but their practical application is often quite impossible.*

Again, regarding the subject from an anatomical point of view, following the guidance of Virchow,† we find that fatty matter may accumulate under three typical forms:—

1. In the first of these, which common adipose tissue familiarly illustrates, the cells in which the fatty matter is deposited are adapted for its permanent reception. This is a normal condition, the pathological equivalent of which occurs in the form of fatty tumours, and of local fatty accumulations which resist the common physiological influences to which adipose tissue generally is subordinated. The accumulation, except, usually, in the case of fatty tumours, may arise, and be dissipated, and arise again, without any detriment to the integrity of the containing tissue, whose function is to separate and retain fat for the purposes of the system.

2. The second typical form under which fat accumulates is as a temporary infiltration of parts to whose functions it is incidental to be thus temporarily loaded with fat or oil, which is permeating them for transmission onwards. Such parts are the epithelial glands of the intestines and of the liver. When in active operation they are loaded with fatty matter, and when they have discharged their share of the digestive function the fatty matter passes on and they are free. But when, from any cause, this transmission is delayed, and the oil is retained within the gland cells, and the fatty infiltration becomes permanent, then the physiological line is passed, and a morbid condition results, which is most familiarly illustrated by fatty degeneration of the liver.

3. The third form of fatty accumulation is where this substance is infiltrated into parts which do not contain it in any appreciable quantity in the physiological condition, and where the infiltration is accompanied by the disorganisation of the part. The typical normal illustration of this form is supplied by milk, where epithelium cells are produced in great abundance, only to be infiltrated with fatty matter, and then to be thrown off and die, producing milk as the result of this dis-

* See, on all this subject, Dr. H. Bence Jones's 'Lectures on the Applications of Chemistry, &c., to Pathology and Therapeutics,' 8vo. 1867, p. 170.

† 'Cellular Pathologie,' S. 288.

organisation. This form of fatty accumulation is most fully illustrated in pathology. Instance the fatty infiltration of cells which results in the formation of the compound granular cell. Such, again, are the changes in muscular fibre and in the renal epithelium, which will be considered in detail in the further progress of these remarks.

From both these points of view, anatomical and chemical, fatty degeneration seems to stand as one of the last of a series of retrograde changes by which health shades into disease. Anatomically traced, the gland-cells which should transmit fatty matter under these circumstances retain it, till that which should be a store of available nourishment becomes a permanent mechanical burden, and a hindrance to the functions of the part affected. Again, chemically traced, we find that in fatty degeneration the materials of the food and the products of the waste of the tissues are diverted from their usual destination. Their attraction for oxygen is limited by their chemical affinities, rather than measured, as heretofore, by the physiological requirements of the system generally. They are suboxidised, in chemical language, and take the form of fat.

As we descend in the series, from health to disease, the physiological force, which in the first instance rose superior to everything, and made itself felt throughout, attracting to the growing germ all that was required for its perfect development, sensibly fails. Its life-long antagonist, chemical affinity, now asserts its superiority in turn, so that fatty degeneration, in which this growing superiority seems at last to culminate, has even been regarded by some as a purely chemical change independent of all vital influences. I would venture to make a few observations on this, as it seems to me, untenable hypothesis.

First, generally. We may often find substances of fatty origin belonging to the stearic or oleic series, as, for instance, acetic, lactic, or oxalic acid, or the rancid secretions in acute rheumatism or other febrile affections, occurring as the products of disease in the living body, the results of a degradation of the higher members of their respective series. But we cannot imitate Nature's operations directly in the laboratory. We can neither ascend the scale and make fat from the lower members of the series, nor can we suspend the process of degradation at any given point; nor yet can we change a member of one series into another at will. That is quite beyond our power as chemists. The very limited success which we do reach in such experiments is obtained by working, so to say, with Nature's own tools—by putrefaction, for instance, rather than by a less complex operation. And, practically, the results are as yet rather curious tricks of the perfumer's trade than available applications of scientific chemistry.

It could hardly be otherwise. The powers by which organic substances are formed, converted, and decomposed in the ordinary physiological processes are wholly unlike those which we bring to bear upon them in our chemical experiments; and the results of Nature's operations are wholly unlike ours. To go no further than the instance before us, the strong affinity by which the elements of the hydrocarbons are bound together, their permanence and their resistance to anything short of destructive chemical agencies, contrast strongly with their extreme plasticity under the influences of the living body. By gentle continuous physiological influences results are obtained which violence and direct chemical action cannot procure. There is the same difference between Nature's chemistry and our own as between leading and driving, as between the gentle breaking up of the rocks by frost and the splitting them by gunpowder. Nature does most by the vis a fronte ; our operations are mainly applications of the vis a tergo.

When living materials are acted on, one set of changes takes place, which chemistry can interpret but cannot imitate. But when the physiological influence is withdrawn after death, and chemical affinity has full play, we have another set of products quite different to those which appear during life. Taking our illustration, again, from the subject before us, no known chemical process could make wax out of the honey or sugar in the stomach of the honey-bee. The heat indeed, the moisture, the insufficient supply of air in the dark hive while the swarm is making wax, are all more or less direct chemical agencies which tend to the conversion of the honey into wax. But these must act in live bees to produce the result. The whole process ceases with the death of the bee. Chemical affinity is not the ruling power while life lasts, it only becomes so when life has ceased. Then, under its influence the elements of the body take new forms and move in new directions, the bees fall from their curtain, they undergo putrefaction, and the honey in their stomachs is converted, not into wax, but into alcohol and carbonic acid.

Again, more particularly: observations of certain changes in dead animal matter both without and within the living body have been adduced in favour of this opinion. I. The conversion of dead animal substances by gradual decomposition into a matter known by the name of adipocere has been cited as an instance of the conversion of animal substances not containing fat into fatty matter. II. And the accumulation of fatty matter in and about certain extraneous substances introduced into the cavity of the peritonæum of living animals has been accepted as a proof that the same conversion may take place within the living organism. I think that neither of these conclusions will stand the test of examination.

I. With regard to the adipocerous transformation. Adipocere is a brittle waxy-looking substance, differing in its chemical characters according to the source from whence it has been obtained. This is the substance so familiar to us in our Museums, the eye-sore of anatomists. We may find it, whenever we want some, in the cavities of the long bones, or in the nervous foramina of the skull. The easiest way of making it is by exposing a large mass of animal matter to the action of very slowly running water. There are other methods more available on a small scale, all acting on the same principle of decomposition at a low temperature, under water, with limited access of air; but adipocere, as familiarly known, is generally obtained by this particular means.

A stock of adipocere for examination was procured from the different sources which the macerating jars of the Sussex County Hospital Museum supplied, and from a large specimen in the Museum of the Royal College of Surgeons. For the liberality with which my wishes were met, and a portion of this specimen placed in my hands for analysis, I beg to express my sincere thanks to the Committee of the College Museum, and to their zealous Curator, Mr. Flower, whose kindness on this, as on other occasions, I have much pleasure in acknowledging.

1. Adipocere obtained from the neighbourhood of the bones of the head of a sword-fish was found to be composed of margaric and oleic acids; the latter in excess, combined with lime. There was a small quantity of unaltered fat and of free fatty acids, also some undecomposed nitrogenous matter.

2. From adipocere which had gathered round human bones, the same general results were obtained; only the margarates preponderated over the oleates, and the saponification was more complete. This last result seemed due to the longer time during which the specimen had been macerating. The adipocere obtained from these sources and from a mass of human muscle burned with a clear flame, leaving a white alkaline ash; but the fat from fatty hearts burned entirely away without any residue.

3. A portion of adipocere from the human thigh (prep. No. 1832*d*, Mus. Coll. Surgeons) was submitted to a most careful analysis, to test in some way the accuracy of the previous observations. It was composed of white stringy fibres powdered over with a dry substance, which lay partly between the bundles of fibres, and partly in distinct masses. This substance had no definite form, and only obstructed the view of the fibres to which it adhered. When it was removed by ether, or, more completely, by cold liquor potassæ, regular fibrous tissue, just such as is seen in muscular fasciæ, came into view. A very little heat sufficed to gelatinise this tissue.

The nature of the different constituents having been determined on separate portions, an exact quantitative analysis was made of ten grains of the specimen, giving:

Free margaric and oleic acids	4·1
Margarate and oleate of lime, with traces of magnesia	2·4
A peculiar fibre, containing nitrogen and traces of phosphate of lime	3·4
Water	0·1
	10·0

In the fatty matter here present, margaric acid so predominated, that it was necessary to add olive oil to allow it to crystallise freely in its characteristic form. In this, as in all other respects, this adipocere agreed perfectly with other specimens of adipocere from the human subject, and contrasted strongly with the results of fatty degeneration.*

Briefly to recapitulate. When adipocere occurs in large masses, as in a whole limb which has been submitted to the action of slowly-running water, and where we have the product of the decomposition of various tissues, we find that there has not been a general uniform change of them all. The least destructible of the various tissues—such, for instance, as the fibrous sheaths and fasciæ—are still to be recognised by their microscopic characters. The more perishable, such as the muscular tissue, are represented, after a while, only by a dry amorphous powder, in which the presence of nitrogen may be detected by the usual tests.

But these remains of different tissues are not adipocere. This

* The experiments here referred to were made for me by Mr. James Peel, at that time Dispenser to the Sussex County Hospital. I regret much that I have no longer the advantage of his skill in pursuing this enquiry. The details are reproduced from the Medical Address delivered at Cambridge in 1864. 'Brit. Med. Journal,' 1864, vol. ii. p. 154. To this and to some further observations on the same subject ('Brit. Med. Journal,' 1865, vol. i. p. 475) I shall have again occasion to refer.

is a substance which varies indeed in its composition within certain limits, and which has the special characters of the fat whence it was derived impressed upon it: if, for instance, it has been derived from fish, it consists mainly of oleate of lime; if from the human subject, margarate of lime is in excess. But, otherwise, it is of an uniform and definite composition. It is, in fact, a compound of the particular fatty acid with an alkaline base, perhaps ammonia, or more commonly lime derived from the water used in the process of conversion. If we employ distilled water in our experiments, and withold an alkaline base, no adipocere will be made, but the fat will remain as fat, and will not be saponified.

Further than this. I believe that no fat whatever is made during the adipocerous transformation. Such was the invariable result of all my experiments made, with one exception, on the muscular fibre of the heart. So far from the fatty matter having increased, it was rather diminished in quantity during the process.

For this purpose, however, we must avail ourselves of some of the other processes for the production of adipocere. For however well adapted the process by slowly-running water be for the production of adipocere on a large scale, it is quite inapplicable where great accuracy is required. When the meshes of the net containing the weighed fragments of muscle were fine they became clogged, and prevented the free access of water, and then the muscle putrefied; while coarser meshes allowed fragments of the softened tissue to escape. Notwithstanding all my care, none of the experiments by this method with weighed portions of muscle, of which the fatty constituents had been previously determined by analysis, succeeded. And after varying the apparatus several times, to no purpose, I gave up this mode of proceeding, and made use of the processes by dilute nitric acid or dilute alcohol, with much more satisfactory results, as follows:—

A portion of the muscular substance of a heart which had previously been found to contain 2·14 per cent. of fatty matter, chiefly margarine, was left to soak for twenty months in dilute nitric acid, sp. gr. 1·42 (1 to 16) in a stoppered bottle. At the end of this time the fatty matters were found to amount to no more than 1·1 per cent. of the five hundred grains operated on. The mass had been changed into a substance having the smell and appearance of ointment of nitrate of mercury. The elements of the fat originally existing in the mass had been newly arranged under the influence of the nitric acid, part having assumed the form of an aromatic ether. Much of the fat had been destroyed; but never at any time during the process was there any evidence of the fat having been increased in quantity.

The muscular fibres generally retained their form, clearly recognisable under the microscope. The fibrils were broken off short into minute fragments; but each of these displayed distinctly either the transverse striæ, or that longitudinal dotting which characterises the stage of granular degeneration already spoken of.

Again, two hundred and fifty grains of pure fibrine from bullock's blood, freed from all fatty matter by ether, were treated in the same way and for the same period. Not a trace of fat, of any of the oily acids, or of the results of the decomposition, could be found on analysis.

A portion of the muscular substance of a heart, which had been previously determined to contain 2 per cent. of fatty matter, was left to soak for eight months in dilute alcohol (1 to 7) in a stoppered bottle. As with the dilute nitric acid, this bottle was nearly filled with the solution, occasionally shaken, but rarely, if ever, opened; and all observations were made on a similar trial solution. At the end of this time the mass was found to contain 1·92 per cent. of fat and fatty salts of whatever kind. The fat seemed to have been destroyed, to this extent, by the process to which the muscular fibre had been submitted.

To the naked eye, the muscle thus acted on appeared as a reddish, flocculent mass, in which the division of the fibres into bundles was indistinctly perceived. Under the microscope, however, all was obscure. A few granular fibrils could be picked out here and there; but the rest was an indistinct, flocculent mass, with something of a linear arrangement. It contained a few white, opaque grains with a radiating structure, apparently composed of a soap of lime. No loose fat appeared anywhere, and ether had very little effect in clearing the field.

I would pass over the effect of slight decomposition on muscular fibre in inducing seeming fatty degeneration, with the remark that, complete as the deception is to the eye, the truth is plain at once on chemical analysis of the suspected structure. In no sense of the word, nor at any step of the process, is adipocerous transformation a conversion into fat.

II. Again: it has been asserted, on the faith of certain experiments, that dead or extraneous animal substances may be converted into fat within the living body. In the absence of the original records of these observations, I quote from Lehmann,* and from a summary by Mr. Simon.† I am quite sure that everyone conversant with the difficulties of experiments on living animals, and sharing my dislike to witnessing them, will excuse my not having repeated them.

The experiments may be divided into three classes:—

1. Portions of animal substances containing little or no fat, as for instance of the crystalline lens, of coagulated albumen, and such like, were inserted into the peritonæal cavities of living animals. After periods of from four to eight weeks they were removed and examined, when they were found much reduced in size and altered in chemical composition, containing very little protein-substance, but a large quantity of fatty matter (Wagner, Michaelis).

2. Porous substances, such as cancellous bone or elder-pith, inserted in the same way, were found, after a certain time, to contain much fatty matter in their pores, and the coagulable lymph with which they had become invested was also rich in fatty matter (Burdach).

3. The same class of substances as were used bare in the first series of experiments, when covered with collodion, or enclosed in glass bottles, underwent no fatty transformation (Burdach).

These experiments seem to me to prove that if the extraneous substance be protected from contact with the fluids of the living body, no fat is deposited in its interior. But wherever this contact is permitted, fatty deposition takes place, and this whatever the nature of the extraneous body. The substance, animal or vegetable, sponge, elder-pith, pumice-stone, or muscular fibre, is infiltrated with fatty matter simply according to its permeability to the fluids of the living body which contain the fatty matter. And there is no more reason to suppose the fatty matty to have been derived from one than from another class of extraneous substances, from the muscular fibre than from the elder-pith. In all of them alike it is merely an infiltration and deposition, deeper and more abundant according to their porosity, and to the facility with which the living fluids bringing fatty matter from the blood can enter them.

The process of fatty degeneration, if I am correct in these inferences, is not adipocerous transformation, nor does it ensue in dead animal substances—dead as we commonly understand the word. What it is may be more positively stated, after we

* 'Physiologische Chemie,' 2te Auflage, S. 345.

† Holmes's 'System of Surgery,' vol. i. p. 11, article Inflammation.

have carefully examined the mode of its occurrence in some of its well-marked forms.

A complete history of fatty degeneration should be coextensive with physiological histology. It would require an account of how each and every tissue is affected by this morbid process, and a description of their characters severally, under this condition. Instead of following out the subject in such detail, I propose to myself to investigate the general principle which is common to all these manifestations, rather than to recount the varied forms which fatty degeneration may present in different structures. For this purpose it will be necessary to examine thoroughly the process of fatty degeneration as displayed in a few typical instances. And it seems best, on all accounts, to select these instances from the structures which have been made the subject of special study by other observers. In no other way could an equal security against errors, either of observation or of judgment, be obtained.

I propose, in this view, to commence with the instance to which I have paid much attention during many years, namely, fatty degeneration of the muscular structure of the heart, connecting with this the fibre of voluntary muscle. Fatty degeneration of the liver and kidneys supplies two well marked and well studied instances of this process in glandular structures. Fatty degeneration of the placenta offers another instance well adapted to our present purpose, both by the peculiar structure of the organ, and by the fact of this change having been closely examined by other observers. To these instances, having long waited in vain for specimens on which to repeat Mr. Canton's observations on arcus senilis, I have added an abstract of his conclusions without any re-examination.

I trust, at some future time, should opportunities allow, to publish the results of the study of fatty degeneration of some other structures. The pathological conditions known as acute yellow atrophy of the brain, rickets, and cirrhosis of the lungs are those which chiefly invite attention as offering the means of testing the correctness of my present conclusions from different points of view. But the appearance of this paper has been so long delayed from various causes, that I prefer to publish it in its present form, rather than to wait for time to carry out another series of observations. The accordance of all the results hitherto obtained, whether from my own observations, or the independent researches of others, gives me confidence that a farther extension of the enquiry will only tend still more to confirm them.

Fatty Degeneration of striated Muscle.

Fatty degeneration of voluntary or transversely striated muscular fibre has a particular claim to our notice as the instance in which this pathological process has been chiefly studied. There are some differences observable in the process as transacted in the heart and in the voluntary muscles respectively, such as to require a separate description in each of these parts. And, first, of fatty degeneration of the heart.

Our knowledge of this disease does not run very far back. Frequent notices, indeed, occur in the older writers of sudden deaths which one can scarcely doubt were due to this change in the structure of the heart; and there are recorded observations of pale soft hearts which one feels sure the microscope would have found to be fatty. But there were no microscopes then available, or they did not stand, as now, at the anatomist's elbow, and fat hearts then arrested the attention which should have been given to the fatty hearts which we have only recently learned to distinguish as such.

A full bibliography of the subject has been compiled by Dr. E. Wagner,* and the labours of British pathologists have not suffered at the hands of their generous fellow-workman. Some later additions to the list may be found in Blachez's† thesis on fatty degeneration in general. The English student will find in Dr. Stokes's valuable work ‡ a complete summary of all that has been made out on this subject, and references to the writings of the pathologists of the Dublin school, with whom fatty disease of the heart has long been a favourite study. I need scarcely allude to the classical essay of Dr. R. Quain,§ which perhaps has contributed more than any other paper to spread the knowledge of this disease, nor to Mr. Paget's lectures,‖ where the pathological picture is put before us with all an artist's skill; and if I add a reference to my own writings ¶ here, it is as my plea to be heard on a subject which is still a favourite with me, and still, I think, capable of further elucidation by such studies.

Fatty degeneration of the heart, strictly so called, occurs in

* 'Die Fettmetamorphose des Herzfleisches.' Gr. 8vo. Leipzig, 1864.

† 'La Stéatose.' 8vo. Paris, 1866.

‡ 'The Diseases of the Heart and the Aorta.' 8vo. Dublin, 1854, p. 302.

§ On Fatty Diseases of the Heart. 'Med.-Chir. Trans.' vol. xxxiii. p. 121.

‖ 'Lectures on Surgical Pathology.' Second edition, p. 94.

¶ 'London Medical Gazette,' 1849, vol. ii. p. 739; 'British Medical Journal,' 1864, vol. ii. p. 152; and 1865, vol. i. p. 475.

two forms:* viz., a circumscribed and a diffuse form; the first being a chronic, the latter generally an acute form of disease. A third division may conveniently be added, which anatomically might be said to be allied to the circumscribed form, but pathologically takes its place among the most acute affections of the heart.

1. In the first form the disease occurs in minute pale specks chiefly found on and in the substance of the carneæ columnæ of the left ventricle. Sometimes the whole lining of the ventricle may be mottled with little spots of this kind seeming to run in zigzag lines; and sometimes they are observed beneath the pericardium. But their most familiar seat is in the musculi papillares of the left ventricle. They are found in connection with debilitating influences, such as hæmorrhage, long continued cachexia, and habitual intemperance. The circumstances under which they occur allow the disease to go on to produce those further changes which in the more widely diffused forms are necessarily interrupted by an earlier death. Within the narrow limits of these little specks the process may be traced from beginning to end; though, as these changes require time for their development, it is not in the same specks, nor always in the same heart, that the complete history can be followed out. The pale zigzag spots, the appearance most frequently displayed, belong to the later stage of the process where actual fatty infiltration has taken place, and perhaps atrophy of the fibres subsequently ensued. The indications of the early stage, of the actual commencement, are to be sought for in the little purpurous spots which dot the interior of the left ventricle in fever, hæmorrhage, phthisis, and other such-like exhausting diseases. Sometimes these spots are no more than what they appear to the unassisted eye, namely, mere ecchymoses beneath the lining membrane. At other times we may trace within these narrow limits the anatomical history of the lesion. In the muscular structure of the heart of a poor girl who died of pyæmia—to quote a carefully observed instance of this change in its minuter manifestations—were red patches, looking like ecchymoses, of a deep purple mixed with grey in the centre, becoming gradually paler at the edges. In the grey part there was a mixture of pus and blood, with fragments of muscular fibres. Surrounding this was a zone, in which the muscular fasciculi had lost all traces of striæ both transverse and longitudinal, they were simply granular all over. Then, for a space,

* Wagner, op. cit. p. 9.

the fasciculi were longitudinally striated, just as is seen in degeneration of the voluntary muscles. Outside this zone the muscular structure presented its normal appearance.

2. In the second or intermediate form the muscular structure is affected over a much wider extent. It seems to commence deep in the muscular structure, the wall of the left ventricle being affected by preference. As it spreads it approaches nearer the inner than the outer surface, involving whole layers of fibres in its progress, and following the direction of the fasciculi. The muscular fibres thus affected are of a bright yellow colour, so bright as often to give the idea of purulent infiltration. However, there is no purulent infiltration here; there is neither pus nor fatty matter in these discoloured patches, the yellow appearance being entirely due to decoloration of the muscular tissue. After a short exposure to air the bright yellow colour fades, and it is not long distinguishable in preparations preserved in spirits.

These broad patches are separated from the surrounding healthy structure by a deep red zone, the existence of which here, as in the form just described, marks an early active stage in the process of degeneration. We do not find the buff coloured spots in the interior of the carneæ columnæ, where the advanced stage of the disease leads us to infer that it has been long in progress, thus encircled. But it is round the seemingly recent purpurous specks, and round the bright yellow patches where the disease is still in an early stage, that the zones are found. The line of demarcation is not a line of separation like that which surrounds masses of so-called capillary phlebitis in the spleen and kidney. At least I never have found any satisfactory evidence of such separation having been effected. It looks like a sign of the presence of inflammation, which yet, judged by its results, as we understand the term inflammation, we can scarcely call it. Thus much at least, however, we may infer from its presence, namely, that increased vascular action is necessary for the process of complete disorganisation which ensues within the limits circumscribed by this zone.

The causes of this form of the affection are peculiar. It is found in connection with inflammation of the heart, by whatever means this may have been induced. Rheumatic inflammation extending from the pericardium seems, though I have never actually seen this change on dissection under these circumstances, to be a frequent cause of it. Over-training and athletic exercises pushed to foolhardiness do mischief in this way, and so, more rarely, does overwork accompanied by misery and privation.

3. In the third form we find the affection generally diffused over the whole organ, which is then of a dull fawn colour, soft and rotten, moulding itself on the hand like a wet glove. In connection with this general change we may often find the familiar traces of the first form of this disease dotting the interior of the left ventricle; and habitual intemperance is a condition common to both these forms. This form, as a rule, is the anatomical expression of that peculiar cachexia, whether of old age or of less advanced years, which centres in and is often limited to the heart. It owns no recognised cause, and yields to no known method of treatment. Sometimes it is betrayed by the general signs of pallor and debility and cachexia during life. It is more frequently only discovered after, and as the explanation of sudden death.

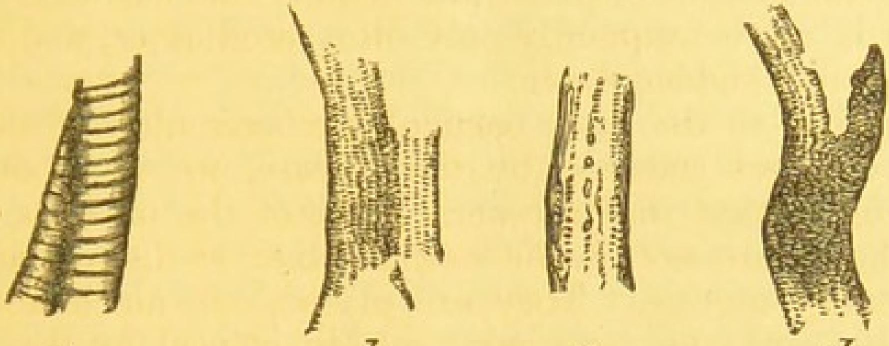
Proceeding to the more particular examination of the anatomical changes induced by the disease, we must observe, at the outset, that the transverse striæ of the muscular fibres of the heart are not, in the normal state, so distinct as those of voluntary muscle. They are placed, too, much nearer to each other, and they are more readily effaced by the use of glycerine in their preparation for the microscope.

In the commencement of fatty degeneration the striæ become less distinct, breaking up into rows of dots or granules, which, transverse in the first instance, in a somewhat more advanced stage affect the longitudinal direction. This appearance of granular disintegration is induced by other influences besides fatty degeneration. It is due to disintegration or disruption of the various elements contained in the primitive fasciculus.* It may be induced in the living body by inflammation, and after death it accompanies commencing decomposition, or attends on the action of certain chemical agents.

Commencing decomposition simulates very closely that change in the heart's muscular structure which is known as the first or granular stage of fatty degeneration. I have been deceived by it myself; and such a mistake is all the more likely to occur, because granular degeneration, like decomposition, may involve the heart uniformly over a very wide extent; much more widely than distinct fatty degeneration ever does, probably because the destruction of the muscular fibres is less complete.

* Todd and Bowman, 'Physiological Anatomy,' vol. i. p. 152. 8vo. London, 1845.

The pathological process is most perfectly imitated by prolonged maceration in dilute alcohol. By this the sarcous elements are disintegrated along the longitudinal lines of cleavage. By prolonged maceration in dilute nitric acid, disintegration is effected in both the longitudinal and transverse directions, and the fasciculus is resolved into small squarish powdery fragments. By varying these processes the results may be modified; and by such means the muscle may be disintegrated at will, in either direction and to any extent, independent of fatty degeneration. But, whether in the living or the dead body, and by whatever means induced, whether real or artificial, there is no increase of fatty matter in the product;



a *b* *c* *d*

Changes induced in the muscular fibre of the heart in the course of fatty degeneration—

a. Healthy muscular fibre.

b. Granular degeneration, the transverse striation exchanged for longitudinal dotted markings.

c. Commencing fatty infiltration; the granular dots have been partially removed, and the centre of the fibre contains a few drops of oil.

d. Completed fatty infiltration and shrinking of the fibre where it is not distended by retained fatty matters.

All these figures are reduced to a scale of about 300 diameters, from drawings made by the aid of the camera lucida, with a one-eighth object glass.

the optical appearance is due to a mechanical change in the structure of the fibre. It is not a degeneration into fat, but a disintegration into granules—granular disintegration. Chemical analysis tells us distinctly what it is not, and microscopic examination is equally explicit as to what it is.

The granular fasciculi which result from the pathological process, or from any of these chemical reactions pushed only so far as to imitate it, require a high power to display the exact nature of the changes which have taken place. With a magnifying power of about 240 diameters only, it seems as if the transverse striæ had been replaced by longitudinal rows of dots, divided here and there by other rows of larger and darker dots, and by fine lines. These appearances are explained by the application of a power of 450 diameters or more, which shows that the transverse striæ are not really lost. They are paler indeed than in the normal condition, but they preserve their normal distance from each other. The primitive fasciculus seems to be split into ribbons of unequal width by longitudinal fissures interrupting the transverse striæ. In consequence of these interruptions, such striæ as catch the eye with a lower power seem to run into rows of dots, and this false impression is heightened by the rows of larger and darker dots which occupy some of these longitudinal fissures.

The examination of this altered structure of the heart is much facilitated by the use of glycerine, according to Dr. Beale's directions. Unfortunately, this medium, so very useful in unravelling the fasciculi, greatly obscures their transverse markings. But this is remedied, to some extent, by the application of ether, which dissolves away the large dark dots in the fissures, and brings the transverse striæ again into view, drawing them at the same time nearer to each other, so that eight now occupy the space where only six were found before the ether was applied. Without the use of ether, the transverse striæ may be brought again into view by means of a condenser and a narrow stop. As the various objects in the field come out more distinctly, some longitudinally striated fasciculi may perhaps be recognised among the degenerated fibres; and from the ends of some of these which have been broken during the manipulation, ragged filaments may be seen projecting, just as we shall see presently in degenerated voluntary muscle. These filaments vary in length and breadth, but all have the transverse markings; some are broader; some are so fine that they might be fairly said to represent the old so-called ultimate fibres of muscle, their dimensions scarcely admitting of the presence of more than a single row of the component granules.

In the next stage all traces of transverse marking are lost. The few granules which still affect any regular arrangement are disposed in the longitudinal direction; they are no longer of uniform size, and oil-globules are to be seen mixed with the other molecules. Besides the optical evidence of the presence of minute oil-globules which have, at this stage, infiltrated themselves among the disintegrated sarcous elements, and of larger oil-drops which crowd the field of view, we now have chemical proof that a new element has been introduced into the mass of tissue, and that the nitrogenous constituents have been replaced to this extent by fat. Not by margarine, the fat which is to a great extent characteristic of the human body, but by oleine, which is the fat of old age, the fat of disease.

The shortness and brittleness of the fibres which have undergone this change are qualities not very obvious under the high powers which are most conveniently employed in the enquiry, but they are nevertheless very important in relation to the connection which exists between rupture of the heart and fatty degeneration. Unnoticed, perhaps, in an ordinary microscopic examination, it is obvious enough, when we attempt to trace a fibre for any considerable distance, that fatty or granular fibres cannot be traced out with the same facility or to the same extent as healthy ones. By this mode of proceeding, we also find that a fibre is not always uniformly affected along its whole course, but that it may be granular in one part and fatty, or perhaps healthy, in another. Sometimes the outer part of the fibre may still display traces of the normal structure, while a row of oil-globules runs up the centre. The fact of the development of muscular fibres proceeding from more than one nucleus would lead one to expect that their decay might also proceed simultaneously from more than one point.

The third stage of this process is, as has been already remarked, more often reached in the circumscribed than in the more diffused forms. At this point the regular arrangement of the internal structure ceases to be distinguishable. At the same time, the fibre loses its symmetrical outline, swelling up in the parts where it is permanently distended with opaque fatty matter; or, where this is not the case, dwindling away. At last, a bundle of irregular threads, or the appearance of a cicatrix, may be all the evidence of the former occurrence of fatty degeneration which has passed through all its stages and gone on to its natural termination in obsolescence of the affected fibres.

We must not confuse this obsolescence, which is the ultimate result of fatty degeneration, and, as such, always of very limited extent, with that general induration of the muscular structure of the heart to which the term fibrous degeneration is, perhaps, more commonly, though less accurately, applied. This is an obsolescence, and betrays, in the irregular shrunken elements of which the resulting structure is composed, the history of its origin. Such a structure is merely the remnant of the frame which has collapsed on the decay and removal of the parts which it held in connection.

The other process is the substitution of one healthy tissue for another in obedience to the altered requirements of the organ. The fibrous tissue in such indurated hearts replaces a certain proportion of the muscular tissue over a large extent, perhaps over a whole auricle or ventricle. It is found chiefly, but not exclusively, in connection with mixed hypertrophy and dilatation, affecting by preference the thinner portions of the heart's walls. The muscular tissue, under these circumstances, becomes hard and elastic; the cavity retains its shape when cut open; the muscle creaks under the knife; and the cut surface looks paler than natural, but of a white rather than a yellow hue. And under the microscope the explanation of these changes appears in the substitution or the addition of an unusually large amount of fibrous or fibro-cellular tissue.

In the heart this fibrous adventitious structure is employed to resist dilatation; it is the alternative of hypertrophy, the substitution of a mechanical for a vital force. The same substitution is occasionally found in the neck of the pregnant uterus. But the differing functions of the heart and of the uterus lead to different results from the presence of this misplaced tissue in the two organs respectively; and in its occurrence, I believe, lies the explanation of that terrible accident, rupture of the uterus during labour. As far as I have seen, a ruptured uterus does not give way from rupture of fibres which have undergone fatty degeneration; indeed, I am not aware that this form of disease occurs at all in the pregnant uterus. It is ruptured, not at its weakest, but, mechanically speaking, at its strongest point, the torn edges displaying strong fibrous tissue, and not degenerated fibres.* On the other hand, it appears that hearts which have undergone fibrous transformation are not liable to rupture. But, while this change resists dilatation most efficiently, at the same time it limits the contraction of the chamber of the heart thus involved, and reduces it so far to the condition of a mere containing vessel.

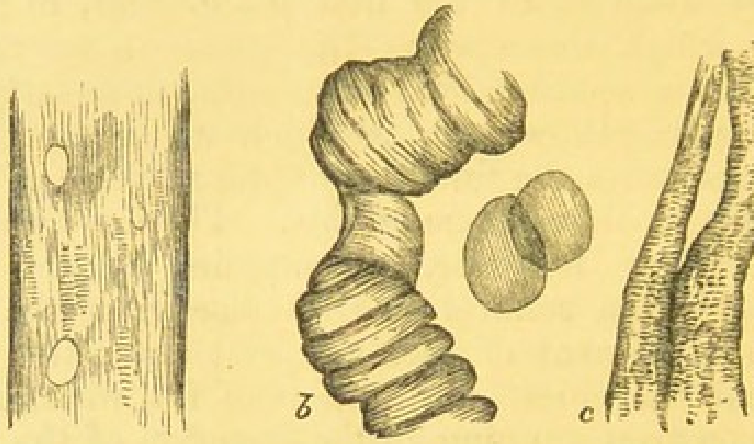
Fatty degeneration of the voluntary muscles is essentially the same process as fatty degeneration of the muscular structure of the heart. But there are certain differences, most strikingly shown in the ultimate results, referable to differences in the functions and the anatomical structure of the two fibres

* See some observations on the subject in the 'Lancet' for 1860, vol. ii. p. 306.

respectively. None of the pathological differential characters are absolutely foreign to the muscular tissue of the heart, but some of them are very rarely met with and indistinctly seen there, and can only be thoroughly understood by studying them in their more usual seat, and in their fuller manifestation, in the voluntary fibres. The necessity for a continual action of the heart for the maintenance of life, which affects the process and ultimate results of fatty degeneration of this organ, does not apply to the voluntary muscles, and in these, accordingly, the process more often goes on to its natural termination. In these ultimate results, the anatomical differences of the two kinds of fibre are to be traced.

We may observe, in the first place, that, in a voluntary muscle in which this change has gone on to the extreme degree, there is as much fatty accumulation as fatty degeneration. The pale yellow muscles which we find occasionally in sheep's backs or in the forearms of the subjects of lead-palsy, supply the best illustrations of this. The most readily-accessible illustrations, however, are supplied by the muscles of limbs atrophied in connection with disease of the joints. If we tear up a fragment of such a muscle under the microscope, we find that the chief bulk consists of fat, which is deposited in lines or strings running in the direction of the fibres; not replacing them, but lying in their interspaces—lying, in fact, just where fat lies in healthy, well-fed animals. Between these lines of fat, and occupying much less space than they do, we find muscular fibres in all conditions—from perfect health to the most extreme degeneration. And, besides, bands of fibro-cellular tissue occur, which add very much to the difficulty of the dissection. Such, and such general fatty degeneration as we find in the heart occurs very exceptionally in voluntary muscles.

The first stage of fatty degeneration of the voluntary muscles, as far as I have been able to satisfy myself, is characterised by swelling of the affected fasciculi. For a greater or less length they appear uniformly dilated to about twice the size of the healthy fasciculi, smooth on the surface, seemingly wanting the transverse striæ, but streaked longitudinally with fine linear markings running the whole length of the fibre. These may not be very distinct in their even course, but where the fibre has been stretched, or twisted, or broken across, they come out quite clearly. Sometimes they are gathered up into a point like the end of a camel-hair pencil; at other times the broken fibres look like the unravelled ends of a rope with the strands hanging out, having undergone at these points complete longitudinal disintegration. A higher power shows here, as in the muscular structure of the heart, that the transverse striæ still exist, only they are much paler than natural. They are not interrupted by the longitudinal markings. They are approximated to half the normal distance, sixteen of them occupying the same space as eight do in a healthy fibre. Ether does not cause them to approximate more closely, though it seems to shrink up the fasciculus; and it displays the longitudinal markings very clearly, at the same time that it extracts some fatty matter from its interior.



Changes induced in voluntary muscular fibre in the course of fatty degeneration:—

a. Swelling of the fasciculi with longitudinal streaking. The transverse striæ approximated where still visible.

b. Transverse disruption of the swelled fasciculi. Two fragments have separated entirely from their original connection. The articulated masses are held in connection by an empty string of thickened sarcolemma.

c. Granular disintegration with atrophy of the fasciculus.

These figures were drawn in the same way and to the same scale as those of the changes in the heart's fibres, but they are here represented enlarged only about 150 diameters.

This longitudinal cleavage would seem to hold nearly the same relation to fatty degeneration of voluntary muscle as granular disintegration bears to that of the heart. Nearly, for it passes more directly into fatty degeneration than the corresponding change in the heart does, ether readily extracting oil from the streaked fasciculi. And it is more specifically a pathological process, being much less readily imitable by any artificial reactions. For chemical decomposition and putrefaction do not induce this particular appearance, but seem, as far as I have observed, to pass over it to a further stage, converting the fasciculus at once into a finely granular mass, which retains only the outline of its former structure. This process of conversion may be traced in some of the transverse striæ which have survived the rest. These appear distinctly granular, broad, and uneven; as if falling to pieces under the action of the dilute nitric acid which has disintegrated the sarcous elements elsewhere. The striæ seem to persist longest just beneath the sarcolemma. Some fasciculi which appear granular owe this deceptive appearance to the striæ on the two opposite apposed sides of the flattened fasciculi crossing each other diagonally, the regular arrangement persisting on the surface for a while after the sarcous elements in the interior have been deranged or have been dissolved entirely away.

Sometimes these large pale waxy-looking fibres occur alone. More commonly, however, we find mixed with them round or oval masses, which seem, from their general appearance and dimensions, to have originated in the breaking up of the longer fibres. These may be either striated longitudinally, or minutely granulated, like the fibres from which they seem to have originated by a transverse fracture of the brittle fibre. This transverse cleavage is displayed most strikingly in fragments of a very peculiar form which are rarely met with. It was from the neighbourhood of an aneurism that I have been supplied with the best specimens of muscle which had undergone this very peculiar form of disintegration. The transverse divisions were in this instance so very regular, and the appearance was so unlike muscle and so like muscular entozoa, that it was only on Dr. Beales's corroboration I ventured to conclude that the masses in question were, or rather had been, really muscular.

These are neither granulated nor streaked longitudinally, but they are cracked and broken transversely, and they are often connected at either end, as if they had but partially escaped, with a string of sarcolemma. They have a singular affinity for the colouring matter of carmine, which tinges them more deeply than any of the other structures which the altered tissue presents. Though they are found under the same circumstances as, and in connection with, the pale waxy-looking fibres already described, yet I am not sure that this transverse splitting is one of the series of pathological changes which lead to fatty degeneration. I am, as yet, uncertain whether these fragments, with the rounded granular masses and the more enigmatical articulated forms, do not melt away without undergoing any further change.

Coincidently with the disintegration of the sarcous elements the investing membrane of the fibre is thickened. It may be traced in its passage from one wrinkle of the fibre to another, stretching across between two portions which have been displaced, or, perhaps, lying in folds, like a loose stocking, where the fibre has been pressed in at the ends. The thickening of the sarcolemma is accompanied by the appearance of numerous irregular fragments which cloud the field of the microscope. Some few of these are the nuclei of the muscular tissue; others, and these the most numerous, are apparently the rudiments of fibro-cellular structure; others are of uncertain nature; and many are undoubtedly collections of oil-globules, arranged like rows of squarish beads. These last are removed by ether, which clears the field a good deal, while acetic acid has very little effect in this way. And with these are a number of larger loose oil-globules, which have been set free during the manipulation of the tissues.

As in granular disintegration of the fibres of the heart, so in that of voluntary muscle; the longitudinal markings, which have replaced the transverse striæ, are in their turn obliterated. Dots appear, first in regular lines, then without order; and the total disruption of the sarcous elements and all their subsequent changes follow in the order which has already been traced, and might be described in the same words as have been employed to tell the complete history of fatty degeneration of the heart.

As in the muscular fibre of the heart, these preliminary changes occur in connection with other processes besides fatty degeneration, and notably with any local irritation. Like granular disintegration of the heart, they indicate a condition which may terminate in fatty degeneration, but in which, thus far, no fatty degeneration, no change of the chemical composition of the structure has taken place. Here, as in the heart, the results of commencing decomposition are, as far as we can trace them, identical with these organic processes. Here, as in the heart, is a common point from which the two series of changes—the chemical and the pathological—diverge to their respective terminations. And, before dismissing this branch of the subject, it will be of interest to point out some of the various pathological conditions which tend to this common point.

The changes which we have just been considering as preliminary to fatty degeneration are identical with those which Dr. Zenker* has described, and most beautifully delineated, as

* Zenker, 'Veranderungen der willkührlichen Muskeln in Typhus abdominalis.' Leipzig, 1864.

occurring in the voluntary muscles in the course of typhus fever. The pale swelled fibres with linear markings, the rounded granular fragments, the scattered nuclei and embryonic connective tissue, as displayed in his plates, might be taken as exact illustrations of the stages of fatty degeneration. The same familiar forms appear again in Dr. Bennett's* figure of the changes induced by cancerous tumours in the muscles in their immediate neighbourhood. But perhaps the most interesting observations on this subject are those made by Mr. A. Stuart,† of Petersburg, detailing the results of an enquiry into the effects of inflammation on living muscle.

By the application of nitrate of silver to the muscles of frogs, changes were induced in them identical with those which we have just traced in the heart. The parts directly exposed to the chemical action of the caustic swelled or shrunk up, and their texture was destroyed. But those a little further off underwent a regular series of changes, of inflammation in fact, which Mr. Stuart describes with great minuteness. Thus, briefly, first the muscle became pale and more transparent than natural; then the sarcous elements seemed to break up and arrange themselves in longitudinal rows; then these dots became larger, though still remaining sarcous elements. These changes occupied two or three weeks, the process thus far being disintegration rather than degeneration, no fat having as yet appeared in the altered fibres. Then the last stage set in, namely, the conversion of the albuminous substance into fatty matter.

The conclusions which seem fairly deducible from these observations on fatty degeneration of both kinds of striated muscle may be expressed in a few sentences.

Inflammation, anæmia, cachexia, want of nutrition, and all the other causes to which fatty degeneration of the heart has been ascribed, have thus much in common, that they disorganise the fibre and prepare it for ulterior changes. The fibre is functionally destroyed by these means, and the disintegration is a change which ensues in the disorganised tissue.

The first step which we can recognise in the process of, or towards, fatty degeneration of muscular tissue, is longitudinal or transverse disintegration of the sarcous elements into filaments, or discs, as the case may be. Circumstances will determine which of these forms the disintegration shall take, and, probably, the exciting cause of the disease has a certain

* 'On Cancerous and Cancroid Growths,' p. 105, fig. 121.

† Schultz's 'Archiv für microscop. Anatomie,' i. S. 415.

influence in this particular. But, although the exciting cause may have a modifying influence, the general course of the degenerative process is guided and transacted by the ordinary agency of the living body, irrespective of these partial influences.

The actual fatty degeneration is secondary in every sense to this disintegration. Its occurrence depends on the existence of fatty matter in the blood available for this purpose. And it is conceivable that, for want of an available supply of fatty matter, disintegration should not be followed by fatty degeneration at all. If this be true, a question suggests itself, whether this explanation be limited to fatty degeneration of muscular tissue, or whether it has a wider bearing. The answer to this question must be sought in the examination of fatty degeneration of other tissues.

Fatty Degeneration of the Liver.

Fatty degeneration of the liver supplies at once the most familiar and convenient illustration of this form of disease as it affects glands. There are difficulties in the investigation, arising partly from the complexity of the organ, and partly from the fact that fatty infiltration is, to a certain extent, a normal condition of the hepatic glandular structure. But we have nothing to do with these sources of difficulty just now. For, in the first place, we are, from the present point of view, only concerned with the proper secreting structure. When fatty degeneration of the liver is spoken of, unless some other structure is specially named, it is generally understood to denote fatty degeneration of the glandular epithelium which fills, in whatever way, the lobules of this organ. Again, we have not here to determine the precise point at which fatty infiltration of the hepatic cells passes the physiological limits and constitutes a morbid change. For it is only when the nature and degree of the change is quite unequivocal that it comes within our present scope. These questions, all-important in considering the history of fatty degeneration of the liver in itself, have but a secondary importance in relation to the subject of our present enquiry, namely, the general pathology of this affection.

As in the heart, so here in the liver, fatty degeneration may pursue its course in different ways, and with different degrees of rapidity. We may find general fatty infiltration pervading the whole organ, in a form whose progress we measure by months or weeks, and which we connect with excessive absorption of fat from the alimentary canal or with its defective elimination from the lungs. Or we may find the results of a more chronic change, where we date by years or months, and where the history of the disease may be traced in the successive stages of its progress, as displayed in different parts of the organ. And yet again, though more rarely, we may find in a very unusual form of disease, known as acute yellow atrophy of the liver, a clue to the general pathology of fatty degeneration of this as well as of other organs. The diffused form of fatty degeneration of the heart finds a parallel in the changes which occur in the liver. And so, too, though the total amount of the changes which the heart displays, under the circumstances, falls far short of those which cirrhosis induces in the liver, does that circumscribed form which runs on uninterrupted to its termination in the carneæ columnæ of the left ventricle. Nor, as we shall presently see, is acute yellow atrophy of the liver a change so entirely sui generis. The mode of its extension and its results are strictly comparable to those of what we have already described* as a special form of affection of the muscular structure of the heart.

Fatty degeneration of the liver, as familiarly known, appears, in the first instance, to be merely an increase of the amount of oily matter which is found in the physiological state in nearly all the hepatic cells. The gland-cells at the outer edge of the lobule are chiefly thus affected. The oil-globules may be larger as well as more numerous than those which occur in health, but this does not seem to impair the functional activity of the cells which contain them. For these cells still retain their nuclei, and still, mostly, contain bile; and, doubtless, many a liver advances thus far in the appearance of disease, and then returns within the physiological limits.

When the change is more widely extended, involving the lobules more deeply, as in some cases of pulmonary phthisis and in the cachexia of drunkards, we cannot doubt that we have to deal with something more than a temporary infiltration of fat. We find now a large number of loose oil-globules, which have been set free by rupture of the hepatic cells that had contained them. And in a large proportion of cells no nuclei are to be seen. These cases, however, illustrate only one stage of fatty degeneration, and give less insight into its anatomical history than do those where the affection has been more

* Page 42.

partial and less rapid in its progress, such in fact as cirrhosis supplies.

In the next stage, so abundantly illustrated in the dissecting room of every hospital, the fatty infiltration may seem to have changed its situation. It no longer appears in zones corresponding to the capillaries of the portal circulation, but in the form of little opaque ochrey spots, surrounded by rings of clearer pale tissue. The microscope tells us that these opaque yellowish specks owe their peculiar appearance to the presence of numerous hepatic cells which are loaded with fatty matter and stained with bile. These cells are unusually coherent, and the fatty matter which they contain is not, I think, so easily soluble in ether as that which is found nearer the edges of the lobules in an earlier stage of the affection. The proportion of cells which have no visible nuclei is constantly on the increase, with the advance of the disease. The pale somewhat transparent tissue which surrounds these opaque yellow specks seems to be composed of a fibro-cellular substance containing the vessels, now shrunken and obsolete, but no trace of the glandular epithelium of the original structure.

The history of the process seems complete, as gathered from different specimens representing these successive stages. Apparently the process of degeneration has travelled from the circumference of the lobules to the centre. First the cells became permanently infiltrated with fatty matter; then they were shed, and none were produced in their places; while the space which they had occupied—the cavities, if I may assume thus much, in which they grew—collapsed. And a tough fibro-cellular tissue resulted, traversed by shrunken vessels suggestive of the cause of the portal obstruction and of the dropsy by which the last stage of fatty degeneration of the liver is so commonly attended.

The mutual connection of these changes is very distinctly shown in the form of disease already alluded to as acute yellow atrophy of the liver.* For the most part this is an acute form of disease effecting the disorganisation of the liver in a few days, accompanied by fever and delirium, and characterised by the brightest yellow jaundice. In such cases few or no hepatic cells are to be found in the parts of the liver which the disease has invaded—perhaps the whole of the organ—only loose oil-globules and particles of bile. These cases, however, are less intelligible, and less applicable to our present purpose than those where the progress of the disease has been slower. For, under

* Rokitansky, 'Path. Anat.' ii. S. 313, 2te Aufl

such circumstances, as the longer period allows, the line of demarcation between healthy and diseased tissue is more strongly drawn, and the successive stages by which the final disorganisation is reached are more clearly to be traced. To this less common form of the disease I wish particularly to call attention.

The healthy tissue, in this form, is represented by bright yellow round nodules easily separable from the rest of the organ, some appearing even to be encysted, on account of the consolidation of the interlobular connective tissue which surrounds them. If the yellow colour is not apparent at first it is brought out on exposure to the air, when the whole surface appears mottled with bright yellow and deep purple in the strangest manner. These yellow nodules contain hepatic cells, which are altered more or less according to their distance from the centre of the lobule. As in the commoner forms of fatty degeneration, the disease advances from without inwards. As we follow the steps of the pathological change we notice first that the cells become granular. They contain a little oil, but certainly in no excessive quantity; there is perhaps even less than in the normal condition. The biliary matter, on the contrary, seems to accumulate within the affected cells. The cells lose all tendency to cohesion to each other, and, where the disease has advanced farthest, they part from the basement membrane also; for in the circumference of the lobules no cells whatever are visible—they seem to have dropped off, and to have been dissolved or discharged.

The present seat of the disease, the tract within which these changes are proceeding, is indicated by a deep purple stain, while the parts which have not as yet been involved are in a state of biliary congestion indicated by a bright yellow colour. This congestion, however, means no more than puerile respiration does under parallel conditions of the lungs, namely, that a part is undertaking the duty of a whole organ. The purple stains are wider in proportion as the disease is more active and its progress more rapid. In the chronic forms these are narrowed down to thin lines and rings, which separate the parts still capable of performing their functions from those which have been disorganised. The microscope finds in these purple patches few or no oil-globules; a few hepatic cells which may possibly belong to the yellow part; and a few small granular masses of very variable size; but no pus corpuscles or large compound granular cells. The line which, as it were, separates the living from the dead is, in the liver, as in the heart, the seat of excessive vascular congestion. Inflammation may ensue, as a secondary consequence of the local action, showing itself by the formation of adhesions along those lines where they happen to crop out on the surface of the organ. But there is no reason to consider the disorganising process as essentially inflammatory.

The parts where the process has gone on to complete disorganisation differ in appearance according to the length of time that may have subsequently elapsed. In recent acute cases they are dark, much below the level of the surrounding tissues, and of a soft yielding texture. In chronic cases, where the history gives us reason to believe that a longer time has intervened since the invasion of the disease, they are collapsed and pale, and, though flexible, they resist the knife like the tissue of a cicatrix. The microscope here, as in the results of ordinary cirrhosis, shows nothing but a fibrous structure in which the course of the different vessels can still be traced, the epithelium cells having been all shed, leaving nothing to indicate that we have under examination what was once glandular tissue. In one case of several months' duration, where death had been preceded by all the usual signs of portal obstruction, the small bloodvessels in the interlobular spaces were convoluted like the vessels in the spermatic cord. A few oil-globules lay in this disorganised tissue here and there, but no hepatic cells could be seen anywhere in it.

Fatty Degeneration of the Kidney.

The analogy between fatty degeneration of the kidney in its different forms and fatty degeneration of the liver is very close. The different mode of arrangement of the glandular tissue in the two organs respectively involves certain differences in the disposal of the effete products of the disease. The secondary constitutional results, too, vary, of course, according as urea or bile is retained in the system. But where these do not interfere, the identity of the disease in the two organs is almost absolute.

We owe our knowledge of this subject to the labours of Dr. G. Johnson.* Venturing to draw from his observations conclusions somewhat different to his own, I feel that I could have no greater security from being led astray by my preconceived notions than to adopt his classification and his excellent descriptions in detail, and I have reproduced them accordingly. Further, never having made this class of diseases of the kidney

* 'On Diseases of the Kidney' and 'Med.-Chir. Trans.' vols. xxix., xxx., xxxiii.

the subject of particular examination, I gladly avail myself of the opportunity of testing the correctness of my views by his independent observations.

Fatty degeneration of the kidneys occurs in two forms. In one the kidneys are large, smooth, soft, and mottled. 'The convoluted tubes are found to be everywhere greatly distended with oil, which has accumulated in their epithelial cells. The detached epithelial cells, when filled with their oily contents, have often a remarkable resemblance to the cells of the liver in the same condition. The fatty accumulation occurs in the epithelial lining of those portions of the tubes whose office is the secretion of the solid constituents of the urine. In some of the tubes the epithelial cells cannot be seen; they appear to have undergone a process of atrophy, and the tubes are occupied only by their oily contents.'* 'It is this form of fatty degeneration of the kidney which occurs in animals, as a consequence of confinement in a dark room.'†

In the other form, also, the kidney is generally large and soft. As time goes on it may shrink, and in such case become harder. But the character which marks this form of the disease is the uneven granular surface of the organ. 'In the granular kidney, many of the tubes contain a number of detached oily cells, which are readily washed out by the stream of urine passing through the tube; while in the mottled kidney there is commonly only a single layer of epithelium, which still remains adherent to the basement membrane.'‡ 'The greater part of the oil is contained in distinct cells; and these can readily be traced through a gradual series of transitions up to the gland cells of which they are, evidently, a degenerated offspring.'§ 'The convoluted tubes are found filled in different degrees with oil, some tubes being quite free, while others are ruptured by the great accumulation in their interior. The opaque yellow spots scattered throughout the kidney are convoluted tubes distended, and many of them ruptured by their accumulated fatty contents; just as the red spots are convoluted tubes filled with blood. In parts of the same kidney, there may commonly be seen some of the appearances already described as indicative of desquamative nephritis.'‖

The analogy of these two pathological conditions of the kidney to general fatty infiltration and cirrhosis of the liver

* 'On Diseases of the Kidney,' p. 388.
† 'Med.-Chir. Trans.' vol. xxx. p. 183.
‡ Op. cit. p. 391. § Page 384.
‖ 'Med.-Chir. Trans.' xxx. p. 183.

respectively are sufficiently obvious. I am not aware of any affection of the kidney which could be strictly compared to acute yellow atrophy of the liver. For, although the acute desquamative nephritis which sometimes follows scarlatina presents some points of comparison, yet the power of repair which the kidney possesses affects the resemblance in a most important point. In the kidney the glandular epithelium is reproduced, and the organ is restored to perfect integrity; while in the liver, as we have seen, the secreting structure is not restored, and the organ collapses. Stripping of the glandular lining of the renal tubes and subsequent—consequent—collapse of the organ does, however, occur, as a result of what Dr. Johnson calls chronic desquamative nephritis, in the small contracted kidney. In the cortex of one of these kidneys the appearances described as occurring in the portal zones of a cirrhous liver are reproduced. The framework is there, the vessels and tubes and the hard connective tissue, but the gland tissue is gone, and the empty tubes lie collapsed where they are not distended by effete epithelial cells.

I believe that these independent observations on the kidney confirm in every particular my own conclusions from the examination of the liver. Though, in the absence of such a test as acute yellow atrophy supplies, the renal could scarcely be made the basis of such a general inference as the hepatic changes. Both alike seem to show that fatty degeneration is not the first step, but a secondary affection of disorganised cells. If the cells are thrown off simultaneously with their disorganisation, and pass away, there will be no evidence of fatty degeneration at all. But if retained, whether free in the cavities of the gland, as in the granular, or still adherent to the basement membrane, as in the mottled kidney, they will be infiltrated with oil. Lastly, these observations on the kidney show that, after the cells are shed, the cavities which contained them collapse, and the organ, to this extent, undergoes the same retrograde changes as obsolete structures display everywhere else.

Fatty Degeneration of the Placenta.

Fatty degeneration of the placenta has been so fully described* that it might seem almost superfluous to open the subject anew. But, after a careful anatomical examination of

* Barnes and Hassall On Fatty Degeneration of the Placenta, 'Med.-Chir. Trans.' vols. xxxiv. and xxxvi.; Druitt, 'Med.-Chir. Trans.' vol. xxxvi.; Kilian, 'Brit. and For. Med.-Chir. Rev.' vol. vii. p. 272; Handfield Jones, 'Path. Trans.' vol. iv. p. 238.

the whole subject, I must venture to express my dissent from some of the conclusions which are generally received with regard to this pathological condition. I would suggest, as the result of my observations, a somewhat different arrangement of the description of the various anatomical changes, and certain qualifications of the inferences which have been deduced from them.

Few human placentæ are entirely free from a peculiar local change, which shows itself in the form of hard white lobular patches, chiefly affecting the edge of the organ and its maternal aspect. In the collapsed state in which we find this organ after delivery, they are sensibly elevated above the surface. A vertical section of one of these patches shows the change of colour and consistency to extend from the surface into the substance of the placenta, to a greater or less depth, sometimes through the whole thickness of the organ. As we trace its lateral extension, we find the lobules of the placenta to coalesce into broad hard white tracts where few or no pervious blood-vessels are to be seen, and in which the proper functions of the organ must have been entirely suspended. Sometimes the change seems to have begun on the fœtal surface, and occasionally it would appear as if the fœtal and the maternal surfaces had been affected simultaneously, a line of comparatively healthy structure separating the confines of the two tracts of disease. In these white patches the evidences of fatty degeneration of the placenta are to be sought for.

Not every white placenta, however, is fatty, for the organ may be blanched throughout its entire extent, merely from the fact of its having been drained of blood, in the course of, or as the cause of, a miscarriage. Not even every placenta which displays to the unassisted eye the familiar broad white patches just described is fatty. For the disorganisation which is indicated by these obvious characters may be of more than one kind, to only one of which the name of fatty can be properly applied. Two of these I propose to describe as the typical forms of placental degeneration, the fatty and the fibrous, as chiefly displayed in the villi of the chorion.

In the first form, these patches are of a loose texture; they are separated from the healthy tissue by no very distinct line of demarcation, and on pressure they give issue to a creamy fluid. By the action of ether, we may obtain unequivocal chemical proof of the existence of a fatty matter in abundance in the disorganised tissue, rather soft, but solid at ordinary temperatures. And, by the help of the microscope, we may trace in these patches all the morbid appearances which have been so well described by the authors already alluded to.

These patches want the smooth hard surface which characterises the other form, to be described presently. On tearing them up with the dissecting needles, we find them to consist of villi closely packed together, so closely, indeed, that it is difficult to unravel any considerable length of tube continuously from the friable mass. The tubes are granular and opaque in parts: the glandular epithelium is indistinct, little oil-globules appear here and there, and the extremities and lateral diverticula of the tubes are, many of them, filled with opaque yellow granular matter. This may be cleared by a solution of caustic potash, but the colour and opacity reappear on neutralisation by acetic acid. It is a granular-fibrinous rather than a fatty matter. Little oil-globules are, however, distinctly visible on the walls of the tubes, and in a more advanced stage of the degeneration, larger drops may be seen lying within the cavity of the tubes, or loose among the tissues. As we recede farther from the maternal surface of the placenta, which is the apparent starting-point and chief seat of the change, the tubes gradually resume their normal characters; the ends and diverticula become clear, and the epithelial glandular edging—as it appears—of the canal is again visible.

In the other form, the change does not seem always so closely connected with the maternal surface of the organ as in that just described. The white patches, too, have characters of their own. They are hard and compact, and are separated from the healthy tissue by well-defined abrupt boundaries. They are smooth, almost polished, on the free surface. When they have been cut or torn, no creamy fluid exudes on pressure; and the microscope finds no fatty matter in them. The action of ether gives the same negative results. By agitating equal portions of one of the hard and one of the softer white patches in separate test-tubes with ether, and evaporating the solution, the fact may be placed beyond a doubt that the soft patch contains fatty matter in large quantity, and the hard one little or none at all. With pains and patience the villi of the chorion of a fatty placenta may be unravelled almost up to the maternal surface. We cannot, indeed, follow a single tube so far, but we may disentangle the soft friable mass, in some fashion, to this depth. In a typical specimen of the fibrous form under consideration, however, this is quite impracticable. Up to the edge of the hard white mass, as seen on a vertical section, the villi are quite healthy and of their normal size. But there they suddenly shrink into threads, which can only be followed separately for a very short way. By the help of acetic acid, which clears, and somewhat softens, the hard opaque mass, the course of some of the tubes may be traced a little farther, rather by the eye than the dissecting needle, the arrangement of their nuclei, and the points where the section has crossed their direction, showing the lines of obsolete tubes. Near the maternal surface minute oil-globules are scattered here and there; and deeper in the centre of the mass a few may be seen, not scattered, but gathered into clusters, as if within some vessel. But the fatty matter forms no appreciable proportion of the bulk of the substance, whether examined by the microscope or by chemical reagents. The mass is almost wholly made up of obsolete tissue, apparently of collapsed, contracted, and mutually adherent villi. And its texture and appearance strongly resemble those of the tissue which we find in the interlobular spaces of the liver after the destruction of its glandular elements. Limiting the application of the term fatty degeneration to the form already described, I would designate this as cirrhosis of the placenta.

There are two forms of fatty degeneration, which I have not met with in the placenta, wanting to complete the series, so as to render the history of the disease here parallel to what we find in other organs.

I have not met with an instance of fatty degeneration of the placenta parallel to that form of the disease when a whole organ seems to be infiltrated with oil. Dr. Barnes * cites a case where fatty degeneration of the placenta occurred in a fat woman; and, as no disease appeared in the child, the change in the placenta was referred to some affection of the mother. I have myself seen just such another case. But it cannot be said that these differ in any essential point from other cases, except so far as the probable excess of fatty matter in the blood of the mother allowed the fatty infiltration of the placenta to proceed with greater rapidity than it would have done had fatty matter been less easily available. And it seems to me that a fatty infiltration of the placenta, strictly comparable to the fatty infiltration of the liver—to take this instance—which occurs in connection with tuberculous cachexia, would not take the form of local disease. It would probably have its seat in the cells of the decidua, as well as of the chorion generally, and not in certain parts only which had been prepared by previous changes to receive the fatty deposit. The physiological peculiarities of

* Op. cit. vol. xxxvi. p. 167.

the placenta render such an occurrence exceedingly improbable. Like general fatty degeneration of the heart, it could not go on far without involving the death of all that depended on the particular organ, and so cutting short the pathological process. And I do not find any evidence of the occurrence of this form of disease, in any of the cases recorded by Dr. Barnes or Dr. Druitt.

Another condition which I have also, as yet, failed to notice, is a change in the placenta parallel to that which accompanies acute yellow atrophy of the liver. Such a condition might perhaps be found in connection with abortion in fever, and be traced in the cells of the decidua and chorion.

The physiological peculiarities of the placenta are reflected in its pathology, and we cannot rightly interpret its morbid appearances without a full consideration of the normal relations of the different elements which enter into its composition. The chorion is not merely a frame on which the bloodvessels are extended, a means of adhesion between the ovum and the uterus: it is as truly a glandular structure as the liver or the kidneys. Not only is the fœtal blood depurated in its radicles by apposition to the mother's blood, but a supply of new material is constantly being elaborated by the layer of glandular epithelium which is spread over the decidua, as well as the chorion at the surface of contact. The placenta discharges the functions of the stomach as well as of the lungs.*

For this purpose, two separate systems of vessels are brought into mutual apposition during a certain portion of their course. From this point the umbilical veins bring back the blood depurated, oxygenated, and, as from other ductless glands, carrying in it the secretions of the placenta. If the maternal circulation fails at any single point, or if, as from a shock over the whole surface, the decidual glands fail to that extent in consequence, the fœtal elements of the placenta repeating the failure, the blood returns from that point, or that surface, as it came, neither depurated nor enriched with nourishment for the embryo; and then the corresponding fœtal portion of the placenta fails and shrinks up with the abolition of its functions. Conversely, the failure of the fœtal circulation at any point will be followed by the obsolescence of the corresponding maternal structures of that portion of the placenta.

On these grounds, the explanation of fatty degeneration of the placenta seems quite clear, and coherent in its analogy to that of fatty degeneration and its allied changes in other

* See Goodsir, 'Anatomical and Pathological Observations,' p. 50.

organs. An effete gland-cell exposed to the influence of passing blood containing oil will become infiltrated with oil. But if the interruption of the circulation be sudden, and with it the access of oil be cut off, there will be no fatty infiltration. The tissue will collapse, and cirrhosis, or fibrous degeneration, will ensue. This was well shown in a placenta which had been separated suddenly by hæmorrhage along a line a few weeks before delivery. It might seem as if the alternative between fatty and fibrous degeneration of the placenta were merely a question of the sudden or gradual interruption of the circulation in its vessels.

In relation to the general pathology of fatty degeneration, an argument may be derived from this part of the subject, which has been strangely overlooked by those who insist on the direct convertibility of animal tissues into fatty matter. And, perhaps, the same fact might be adduced as support of the opinion that fatty degeneration proceeds from the maternal, and fibrous from the fœtal, vessels. Merely this: that the tissues of a dead fœtus are not liable to fatty degeneration under any circumstances. The products of extra-uterine fœtation may remain enclosed in the living body for years without undergoing this change. The little embryo which is found in a mass of so-called uterine hydatids has undergone no fatty degeneration. And the fœtus which has lain for months and years in the uterus of a cow is found shrunk and blackened, but not converted into fat. This is quite in accordance with what has been previously stated. The dead fœtal tissues are removed from any supply of oil by which they could be infiltrated. There must be molecular apposition if not absolute continuity between the disorganised tissue which is to receive the oil and the living tissue whose moving blood is to supply it; though, as in the case of fatty degeneration of the cornea, an actual capillary continuity is not required.

If these inferences be correct, fatty degeneration of the placenta, such as has just been described, can scarcely be regarded as a change of any importance with regard to the condition of the fœtus. And, as a rule, large healthy children are born in connection with extensive degeneration of the placenta, having derived their nourishment from the portions which were not involved in the local change. Nor, again, can it be looked upon as having anything to do with one of the great perils of childbirth—adherent placenta. For the edge of the organ, where these patches chiefly occur, is just the part where adhesion of the placenta to the uterus is least frequently found.

On the contrary, from recorded cases, it might seem that these hard unyielding masses, already in such loose connection with the uterus, were more likely to induce a still farther separation of the placenta, and consequent hæmorrhage. Nor, lastly, can we regard it as the natural termination of the life of the placenta, for, certainly, this organ is not least active at the completion of the period of gestation. It is a local, not a general disease, a consequence, not a cause, and, interesting in the highest degree as a pathological study, is, I believe, devoid of all clinical importance.

I have had no opportunity of studying the changes induced in the cornea by fatty degeneration, as displayed in the arcus senilis, so well described by Mr. Canton.* So I will merely extract from his pages an account of this morbid appearance.

In the first instance, the corneal cells are the seat of the affection. These cells, in form comparable to the lacunæ and canaliculi of bone, lie between the lamellæ of the cornea. They are so numerous that their opacity imparts a cloudiness to the whole structure, though the lamellæ may not be affected. The superficial laminæ are first involved, and thence the change extends deeper into the substance of the cornea. Presently, the lamellæ themselves are changed, infiltrated by myriads of minute oil-globules, which, as they coalesce into larger drops and collect between the lamellæ, add notably to the thickness of the cornea. The opacity due to changes coincident with old age has much in common with that which results from injury and inflammation of this part.† They both consist essentially of infiltration of the corneal cells with oily matter, but, in the former the change is permanent; in the latter it is—that is, as far as it depends on oily infiltration of the corneal cells—remediable.

The term atrophy does not seem to me to express the correct pathology of this affection. Dr. His,‡ as cited by Mr. Canton, has put this very pointedly. Demurring to the opinion that the arcus is the result of simple atrophy, he asks, 'How is it that it is just in the margin of the cornea (which is in the most favourable position for nutrition) that such atrophy should occur; and how does it happen, in connection with such an atrophied margin, that the centre of the cornea can preserve its complete integrity through years? These are questions which at present appear to be quite insoluble.' I believe that

* Canton, 'On the Arcus Senilis.' 8vo. London, 1863.
† Canton, op. cit. pp. 30, 32. Virchow 'Cellular Pathology,' transl. p. 301–306.
‡ 'Histologie der Cornea,' p. 138. Basel, 1856.

the solution of the problem is to be found in the close parallel to be traced between arcus senilis and the other instances of fatty degeneration which have been described in this paper.

The pathology of fatty degeneration may be summed up in a few lines. And, as a preliminary, I must confess that a very attentive study of fatty degeneration continued through many years has much diminished, in my eyes, the importance of the specific character from which the process takes its name. Grave as are the diseases with which it is connected and on which it ensues, the fatty change itself is comparatively of little moment, and quite secondary to the degeneration, in date as well as in importance.

It is an infiltration of fatty matter which is derived immediately from the passing blood, or is made on the spot under its influence. And, as far as concerns the human subject, it is not the physiological form of fat, margarine, which is thus infiltrated, but oleine.

The structures which are infiltrated in this manner must be previously disorganised, the infiltration being a consequence, not a cause, of the disorganisation. Structures in healthy vital activity either do not admit of such infiltration; or, where their physiological constitution allows of this, they have the power of clearing themselves of the oil. They must be disorganised, but they must not be dead, as far as death implies liability to chemical decomposition or disconnection with the current of the circulation. For, experiments show that, under such circumstances, fatty degeneration, as expressed by the formal replacement of healthy structure by fatty matter, never ensues.