On literature Review

Table of content

1. Introduction

In these notes we study what makes a literature review, focusing on two key types of writing contained in this, namely a summary and a synthesis. In the context of writing, a

- *summary* is about reporting in a brief and yet accurate manner the main idea, objective, methodology, results, and success/failure of intended aim, etc., of the original paper.
  - The goal of summary is not to offer an evaluation or opinion of the original article.
  - A summary is far more concise than the original paper. It is a self-contained piece of writing which is fully formed and able to make sense on its own.
  - See term 1 notes on critiquing and summarising in order to revise this.
- *synthesis* is about summarizing the *fundamental themes* which occur across multiple sources (it is not simply a summary of each individual source). This means you have to read multiple sources to see what are the common themes, hypotheses, approaches to investigation, inferences, methodologies, and/or conclusions, etc.
- *literature review* is a synthesis.

2. Synthesising literature: The literature review

2.1. Introduction

A literature review can then be defined simply as the synthesis of other peoples' work. A synthesis is really about organising information by topic or theme not than by author. When compiling multiple sources, a tendency can be to summarize each source and then compare and contrast the sources at the end. Instead, organize your source information by your identified themes and patterns. This organization helps demonstrate your synthesis of the material and actually demonstrates your understanding of the literature (because the only way you can say that three aspects of science come under the same theme or category is if you understand the science).

So, recall that a summary is simply a description in shortened form, i.e. a paraphrase, of the key ideas of one person's work. On the other hand, a synthesis is not a re-description of information. It is the comparing and contrasting of multiple information with the view to highlighting common aspects which cuts across all of this information.

A synthesis can then be said to be

> paraphrasing (in your own words) the common themes across multiple sources.

By comparing/contrasting I mean that we aim to identify key connections, a common idea or perspectives, an underlying concept, etc. between peoples' work. Other aspects of comparing and contrasting which can be included in a synthesis include identifying similarities and differences, advantages and disadvantages, etc. of other peoples' work.

As such, a synthesis involves critical thinking: one needs to read all the information carefully in order to be able to identify the common, underlying aspects which thread across all the information. A simple example of this is shown below and relates to the experiments done separately by Hertz and Thomson to determine whether or not cathode rays (what we would now call a stream of electrons) were electrically charged. If they were, they would be deflected by an electric field. If they weren't they would not be deflected.

<u>Experimental work on cathode rays</u>

Summary	Hertz conducted his experiment in the late 1800s using an evacuated glass tube. Inside this tube he passed a cathode ray through an electric field and noticed that the ray was not deflected.
Summary	Thomson repeated Hertz' experiment and obtained the same results, seemingly confirming that cathode rays were not deflected by electric fields.
Comparison and common aspect	However, it was later found that both Hertz's and Thomson's experiments were flawed as neither scientist had evacuated their glass tube sufficiently enough. This means that there was still enough air in the tube to ionise the cathode ray thus rendering it neutral to electric fields.
= Synthesis	= Synthesis

2.2. Examples and language analysis

There must be some kind of language and/or phrasing which highlights synthesis as the "bringing together" of common ideas or information under one category or theme. The kind of language used is of two types:

- References to multiple sources;
- Standard words and generalistic phrasing, usually in the plural, such as below:

common	connection	underlying
combining	comparing	generalising
key	much of	in contrast
taken together	several studies	a number of …

Two artificial examples of synthesis language are:

a) "There are two competing theories about how … One theory (Smith (2000) and Jones (2002)) relates to … whilst another theory (Brent and Wilson (1990), Xander (1995)) ascribes to the approach …"
b) "Radically different approaches to gathering data / conducting have been used in the past (Smith (2000), Jones (1990), Carter (1995)"

The phrasing "two competing theories" suggests that there are two groups of authors who believe in one theory of the other. Similarly, the phrasing "Radically different approaches to gathering data" refer to ideas which cut across the multiple authors/sources.

The following are examples of synthesis taken from the literature review sections of journal papers.

1) "Hicham and Karim [5] and Turkmen [6] compared some clustering approaches for customer segmentation. Their studies achieved Silhouette Scores of 0.72 and 0.6, respectively. These studies are similar to ours, but differ in terms of methodology and results. Thus, our contributions can be summarised as follows …" (John (2023))

   Note that the above is a summary but more than just a summary because it brings together two different sources (line 1) to discuss the common work done by these sources ("compared some clustering approaches for customer segmentation.")

2) "Thermal contact conductance (TCC) at an interface between two solids is a composite interfacial property [1] and it depends on the material properties [2–4] as well as the surface properties [5–7] of the materials which form the interface. The contact pressure at the interface [8–10] and the interface material softening [11] also influence the value of TCC. For proper thermal management of any aerospace, outer space or nuclear systems TCC at all the interfaces needs to be estimated accurately [12–16]. Determination of TCC at any interface is challenging as placing thermocouple to measure the temperature at the interfaces is difficult [17], hence non-intrusive temperature measurements are often employed to determine the TCC [18]. TCC at an interface can be determined experimentally [19–21] theoretically [22–24] or by numerical means [25–27]." (Kishor et al. (2024)).

The whole text is a synthesis of a specific topic of heat transfer. But more particularly we can see in lines 2 and 3 that several sources have been brought together, i.e. [2–4] and [5–7], and summarised under the themes of material properties and surface properties respectively. The same can be said for the rest of the text. What are the general themes identified by each group of sources?

3) "During the first three decades of Bulletin publication, classification and correlation of the Phanerozoic systems were undergoing explosive investigation. Several papers discussed the principles that should be applied to these problems, probably triggered by E. O. Ulrich's "Revision of the Paleozoic Systems" (1911). F. H. Knowlton (1916) published a short paper on the use of fossil plants in correlation, W. D. Matthew (1913) discussed theoretical problems affecting the use of fossil vertebrates in correlation and in phylogenetic studies, H. S. Williams (1913) considered correlation problems from the perspective of his work in the Eastport area, Maine; Charles Schuchert evaluated correlations and chronology on the basis of paleogeographic reconstructions (1916)." (Dutro (1988))

Here we see that lines 1-3 form a synthesis because lines 4-10 because it identifies the common principle of palaeontology (i.e. "correlation") being studied by the authors mentioned thereafter. To see this more clearly lines 1-3 could be rewritten as "Several papers discussed the principles that should be applied to the problems of classification and correlation of the Phanerozoic systems". This is a synthesis sentence, with specific examples of the problem of correlation given by the references.

The rest of the test gives one-sentence summaries of each source. Ultimately, one would have to read the referenced sources in order to really know if the synthesis is scientifically correct. We can assume it is because Dutro (1988) is a published paper.

The language aim when writing a literature review is also to not only about bringing together different sources and summarising their common work, ideas, themes, etc., is what makes a literature review, but also about using appropriate language/phrasing around the sources so that your writing reads like a synthesis. Informally speaking I might say that

Literature review = Summary in the form of a synthesis (i.e. common theme)
+ suitable phrasing used to identify the bringing together of different sources.

For example

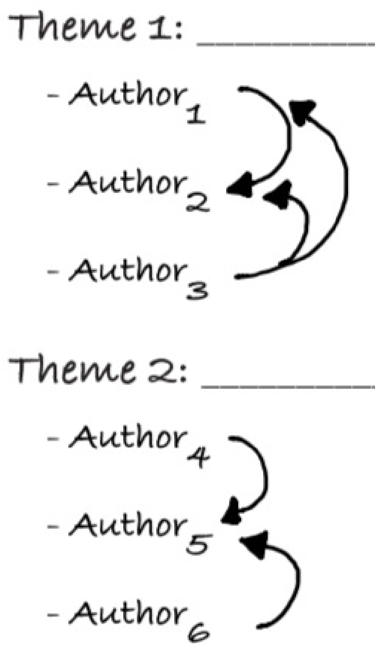
- For example 1) above: "Hicham and Karim [5] and Turkmen [6] compared some clustering approaches" = <*two sources brought together*> <*summary of common approach/method*>.
- For example 2) above: "… it depends on the material properties [2–4] as well as the surface properties [5–7] of the materials …" = <*summary of common property*><*three sources brought together*> *as well as* <*summary of common property*><*three sources brought together*>.
- For example 3) above: lines 1–2 and lines 3–10: <*summary of common principle*><*five sources used*>. Note here that lines 3–10 as a whole act as the "bringing together of relevant sources" relating to the theme of correlation.

2.3. How to write a literature review

Based on the examples of the previous section, the way to write a literature review is to write thematically. By thematically I mean that you write about *the single common idea seen across multiple sources*. If there are multiple common ideas then you would need to write a synthesis for each one. These ideas can be about anything: concepts, theories, procedures, methods, methodologies, results, etc.

So, to repeat, a synthesis is not an author by author write-up, i.e. it is not a summary of the work done by each separate author. This would more likely be a summary. On the other hand, a synthesis is a summarising of the common elements or themes across multiple sources.

An illustration of the idea of writing the literature review thematically is shown below.



(adapted from Cisco, J. (2014)). Here the arrows indicate identifying the common theme between authors. You would then write “Theme 1” and “Theme 2” as summaries and list the relevant sources relating to these summaries.

As an example relating to mathematics, if I was writing a paper about types of non-homogeneous ordinary differential equations (ODEs) I would synthesise the literature on this topic not by each author but by type of ODEs solved:

1) Author 1 and author 2 solve under-damped ODEs; Author 3 solves critically damped ODEs; Authors 4 and 5 solve systems of ODEs;

or by the types of methods used to solve ODEs:

2) Analytical methods for solving ODEs: Author 1 uses direct methods; Authors 2 and 3 use substitution methods; most authors use power series methods;
   Numerical solutions for solving ODEs: Author 1 uses finite differences; Authors 2 and 3 also use finite difference but of a different order; Author 4 uses finite elements,

with each synthesis containing a comparison and contrast between the types of ODEs or methods of solution.

Another example: If I was writing a paper about the misuse of *p*-values and significance testing in statistics (an actual topic of debate in the statistics literature) then I would synthesise the literature on this topic

- not by each author since this would lead to a summary,
- but by the theme would be p-values and significance testing, and by those who argue in favour of significance testing and those who don't. Then I would critically compare and contrast between the pros and cons, advantage and disadvantages of p-values and significance testing.

Then we can write up our synthesis, paying attention to the type of comparing-and-contrasting manner the authors have used, i.e. are they

- agreeing or disagreeing?
- talking pros and cons?
- talking advantages and disadvantages?
- talking similarities and differences?
- talking about what is significant or not?

etc? Note that the effort of a synthesis doesn't come so much in the writing of it but in the time it takes to read and analyse all the relevant papers.

3. On the synthesis of scientific ideas (optional)

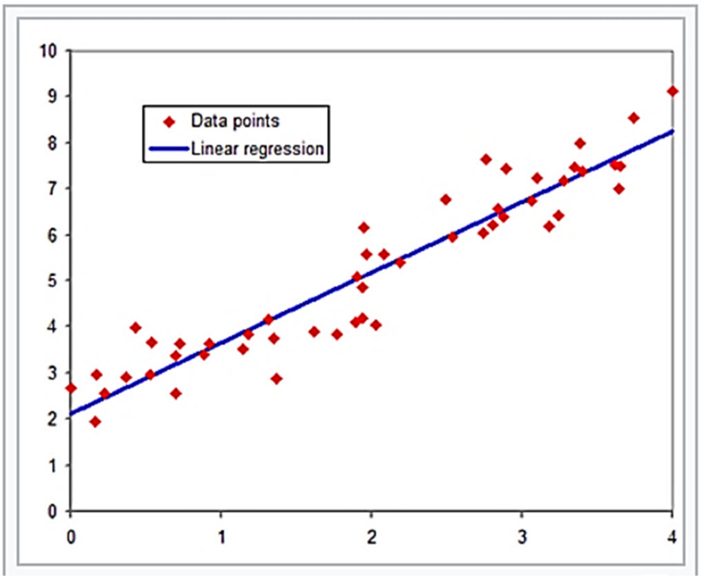
The following are examples of synthesising actual scientific ideas themselves. In order to do this you need to be a specialist in the particular discipline. Since my background is mathematics I can therefore only present examples of syntheses based on maths.

3.1. Example 1: Synthesising data – The visual display of data.

Note that one of the fundamental aspects of statistics is to synthesis data. Such synthesis can help us determine underlying significances, patterns or trends. For example, consider the case of lines of best fit (regression lines). Such lines can be considered as a form of synthesis of scatter data.

To see this, consider the red dots in the graph below. These represents data points (data collected from an experiment). Clearly these are scattered across the graph but their overall trend seems linear, so we want to find the best line that goes through the data. What does "best" mean? It means the minimum distance between all the red dots and the blue line.

Technically speaking we want to minimise the sum of the distances of the red dots to the line. An example of such a line is shown in blue in the diagram below.

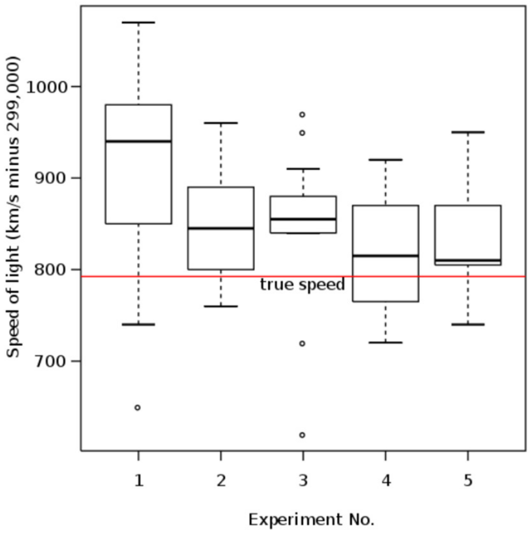


The blue line represents what might be called the average direction, or trend, of the data as a whole. It is this trend which can be interpreted as a synthesis of the data. The mathematics of calculating the line of best fit is based on finding the distances of each data point from the ideal line $y = mx + c$, adding up all these (absolute) distances, and then using calculus to minimise this total distance. This calculus can be described as the method for synthesising the data values in such a way that we obtain new information about the data, namely the average direction of the data as a whole.

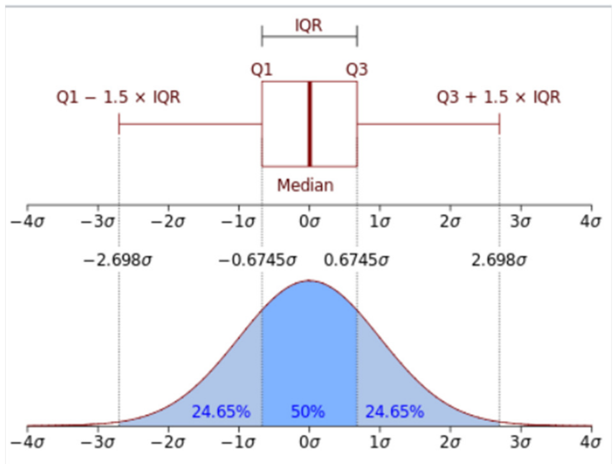
Beyond synthesising the data to produce the best fit line we can also synthesis the data to produce a correlation coefficient. The correlation coefficient is a value which represents the degree to which the data has a linear trend or not. It's values lie between -1 and 1, with the value 1 telling us that the best fit line has positive gradient going exactly through all data points, and the value -1 telling us that the best fit line has negative gradient going exactly through all data points.

The correlation coefficient then represents a synthesis of the data simply by the fact that the data has been manipulated in such a way as to give useful information about the strength of the trend (i.e. strong positive correlation, weak positive correlation, no correlation, weak negative correlation, strong negative correlation).

Other examples of visual displays include box plots and bell curves as shown below.



Diag (i): An example of multiple box plots



Diag (ii): Comparing a box plot with a normal distribution in terms of quartiles, standard deviation and area of coverage.

In one sense the diagrams above are simply re-presentation of data from numeric form to visual form. They can be considered as "summaries" of the data since not every individual data point is shown, and they can be considered as "synthesis" because they represent the underlying pattern of the data as a whole.

Even at a numerical level we can talk of synthesis. To synthesise data is to manipulate it in such as way as to produce new information which is not in each data point itself. Hence means, IQRs, standard deviations, lines of best fit, etc. are syntheses of data.

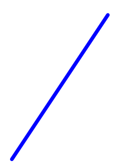
For example, given a set of data we can find

- the mean, i.e. the sum of all the data points divided by the number of data points, this producing a new value which is a "synthesis" of all the data points;
- the inter-quartile range (for box plots, this being the rectangle itself in diags (i) and (ii) above), which is simply calculated as the distance between Q1 (the first quartile) and Q3 (the third quartile);
- The standard deviation (for normal distributions), which is based on how far each data point is from the mean, and represent the extent to which the data is spread out as a whole.

3.2. Example 2: Synthesising two mathematical concepts – Coordinate geometry

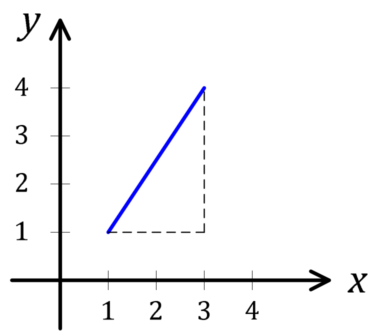
In the middle of the 17th century two French mathematicians, Fermat (1607 – 1665) and Descartes (1596–1650), were responsible for creating a new branch of mathematics now known as coordinate geometry. This new mathematics was a result of the merging of what was at the time two separate aspects of maths: geometry and the newly developing algebra.

Originally, geometric figures we conceived of as being free-floating objects in space. They were not located in any reference frame, i.e. they were not drawn in a Cartesian coordinate system as, for example, the line in diagram (a) below. But over the course of time Descartes and Fermat's contribution led to geometrical object being located/embedded in a frame of reference (diagram (b) below). This allowed people to associate variables to different parts of the objects, thus allowing them to set up algebraic equation. These equations were then (relatively) much easier to solve than the old way of having to manipulate the geometric figure by compass and ruler.



(a)

A line free-floating in space



(b)

A line located in a reference frame /coordinate system

The effect of embedding geometry within a measuring system then allows us to algebraicalise geometry, i.e. to analyse geometric objects via the algebraic expressions or equations which represent these objects. How might the above be a synthesis? Possibly as follows:

> "Consider diagrams (a) and (b) above. In the past the length of any linear distance had to be measured physically with a ruler. The angle any linear distance made with the horizontal also had to be measured physically with a protractor. This would need to be the case for the line diagram (a).
>
> However, this does not have to be the case with the situation illustrated by diagram (b). By placing our line in a coordinate frame of reference we can find

lengths of lines, and angles of lines to the horizontal, without having to use a ruler or a protractor. For example, the length of the line in (b) is found using Pythagoras' theorem and is given as $\sqrt{13}$, and its angle to the horizontal is given by $\theta = \tan^{-1} 3/2 \approx 56.31°$.

But more than this, we can create algebraic equation for a line located in such a frame of reference, this being $y = mx + c$ where m is the gradient and c is the y-intercept. And we can find the slope m purely from the coordinates, namely

$$m = \frac{4-1}{3-1} = \frac{3}{2}$$

and c (which represents where the line crosses the y-axis) can be found by using the m value and one coordinate. Hence

$$y - 1 = \frac{3}{2}(x - 1).$$

This leads us to being able to describe the line algebraically as $y = \frac{3}{2}x - \frac{1}{2}$.

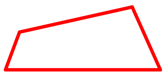
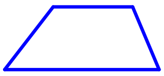
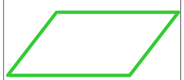
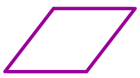
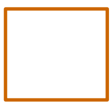
So, by constructing a two-dimensional coordinate frame of reference we are able to locate lines and curves in space. Such a location, given by coordinates (x, y), allow us to transform geometric objects such as lines and curves into algebraic equations, which may then be solved much more easily than if we used geometry to solve the original geometric problem. Even finding the slope, which is the angle the line makes with the horizontal x-axis can be done numerically instead of geometrically (i.e. a slope of 3:2 instead of 56.31°). Thus we can say that we have unified geometry with algebra and arithmetic. We use the term *coordinate geometry* to emphasise this unification."

The text above illustrates the synthesis of two different mathematical ideas, namely geometry and algebra. People such as René Descartes and Pierre de Fermat in the Sixteenth century were the first ones to take this synthesis seriously. Before that algebra and geometry were seen as two separate or distinct areas of maths. But now that these two areas of maths have been combined we can construct algebraic equations for all sorts of geometric objects, solve these equations and refer the answers back to the geometric situation.

For example, a unit circle can be drawn as a circle of radius 1 or can be written as $x^2 + y^2 = 1$. All conic section, i.e. circles, ellipses, parabolas, and hyperbolas, used to be seen only as curve resulting from slicing a cone with a rectangular plane. Now these curves can be expressed as algebraic equations.

3.3. Example 3: Synthesising the common feature of similar geometrical objects.

The diagram below is self-explanatory. It illustrates how the different geometric shapes all share a common feature.

Shape	Characteristics	Name
	No sides are parallel	Quadrilateral
	Two sides are parallel	Trapezium
	Two pairs of sides are parallel	Parallelogra m
	Parallelogram with congruent sides	Rhombus
	Parallelogram with right angles	Rectangle
	Rectangle with congruent sides	Square

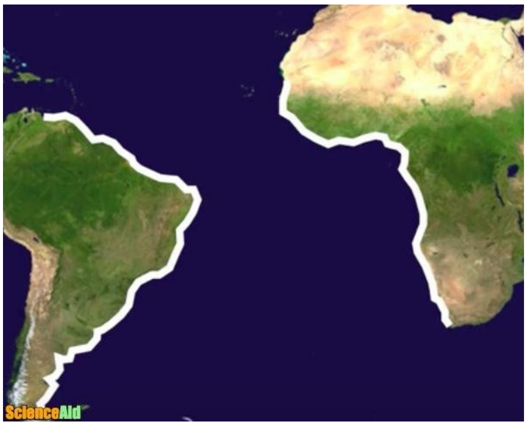
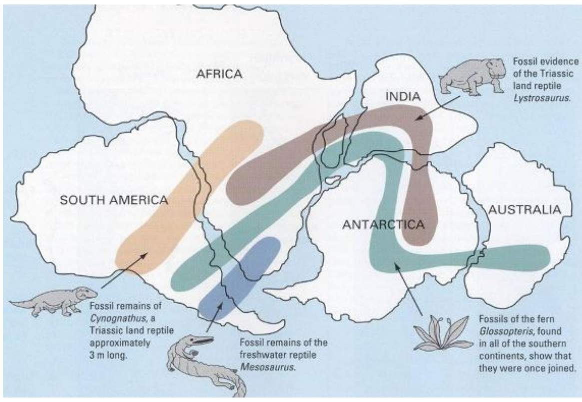
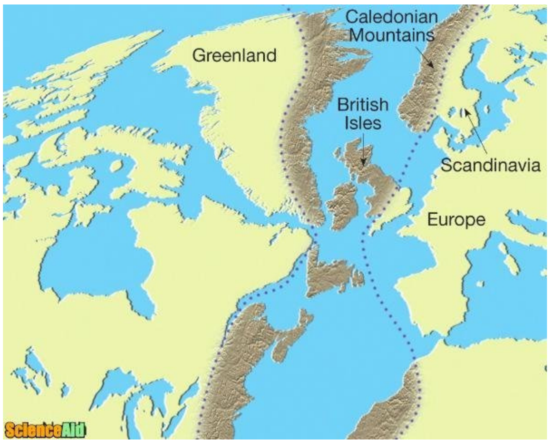
Synthesis

Name: Polygon.

Description: Any closed curve consisting of straight line segments such that no two segment intersect.

3.4. Synthesising multiple lines of evidence – Continental drift

Since the 1800s scientists had recognised that certain continents looked as they could fit together like a jigsaw puzzle. For example, the outline of the east coast of South America looks like it fits into the outline of the west coast of Africa (see diagram below). Such puzzle-like fitting could also be seen with other continents. This was one of many different lines of evidence (ref diagram below) which seemed to suggest that the continents had previously been joined together as one single land mass.

<table>
<tr><th>The matching of continents</th><th>Fossil correlation</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Correlation between
rocks and mountains</th><th>Past climate data</th></tr>
<tr><td>
</td><td>"He began with glaciers which are ordinarily found in large rivers in the coldest parts of the world such as the North and the South poles. Glacier streams are constantly moving, and while they do, they scratch the rock beneath them, leaving evidence of their trajectory. These scratches are called glacier striation. The interesting finding was that he discovered glacier striations in the tropical rainforest of Africa and South America. His theory was that those regions were not always located on the Tropic, but might have been down closer to the south pole and slowly drifted away."

</td></tr>
</table>

(source: [What Is the Theory of Continental Drift - ScienceAid](). URL no longer working)

Initially, and for many decades, this hypothesis was considered fantastical. It wasn't until the 1960s that such a hypothesis gained credibility. The reason it took so long to gain traction was because nobody could describe how the continents could have moved at all. Since the continents were made of solid rock it was thought that they could not move at all, and therefore they had remained ever static. And the reason why the hypothesis finally gained traction was that, by the 1960s technology had advanced sufficiently so as to be able to investigate the nature of the ocean floor. As a result, lava flows were discovered coming from the ocean floor which, upon contact with the cold and pressure of the ocean depth, immediately cooled and solidified thus producing new crust/ocean flooring. Also discovered was the fact that certain areas of the ocean floor were being pushed underneath other parts of the ocean floor. These are now known to be zones of subduction between continental plates (such movement between plates is what causes earthquakes). The mid-Atlantic ridge is one famous example of this.

All of this implies that the rock beneath the continental plates is not static and rigid but dynamic and flowing. This causes stress in the land masses, and after a certain time caused so much stress in the original landmass (Pangea) that it broke apart (into Gondwanaland). The flow underneath the land masses continued thus breaking Gondwanaland apart, and so on over the millions of years. It is simply that the flow occurs extremely slowly so that it takes millennia before any large-scale movement can be seen. This then explains all the other evidence such as correlation between fossils spread over widely separated continents, between rocks and mountains spread over widely separated continents, and glacier striations spread over cold and tropical regions.

(source: What Is the Theory of Continental Drift - ScienceAid. URL no longer working)

3.5. Synthesis leading to unification

The previous example of coordinate geometry represents the synthesising of the ideas of two separate fields of geometry and numbers/arithmetic. Such a synthesis results in the unification of these two fields to arrive at the new field of coordinate geometry. Other examples of synthesis leading to unification include:

- for the statistics examples: by synthesising data mathematician were able to come up with the mean and standard deviation. More generally by synthesising the ideas of means, medians and modes mathematicians were able to unify them into the new concept of central tendency (i.e. the tendency for the average to lie somewhere in the middle of the data). Similarly, for the ideas of interquartile range and standard deviation whose essential feature is synthesised under the idea of measure of spread.
- for physics: Newton's theory of gravitation which unified the study of moving objects in space (i.e. astronomy) with the study of moving objects on Earth (then known as natural philosophy, and now called physics). Newton's unifying idea was the concept of "force" and this concept allowed everyone to study the motion of stars and falling apples in exactly the same way;
- for physics: By synthesising the ideas of two separate fields of electricity and magnetism physicists were able to unify these two fields to arrive at the concept of electromagnetic theory. The theory of electromagnetism was then unified with the (previously separate) theory of the weak nuclear force (a force which acts inside the atom) to produce the electroweak theory of matter. I think that even this last theory has been unified with the strong nuclear force to produce quantum electrodynamics?
- for chemistry: The periodic table of chemical elements developed by Mendeleev in 1869. This organised seemingly disparate elements into a structured table according to the elements' atomic number (i.e. number of protons in the nucleus) and similar chemical properties. It provides a unifying description of the nature of the elements. We could even say that synthesis occurs at the level of individual elements. By synthesising hydrogen and oxygen in a particular way we are able to unify them into water: H_2O. This perspective of synthesis and unification therefore applies to all chemical compounds.

In each case fundamental commonalities were synthesised from (seemingly) distinct ideas which ultimately resulted in these ideas being unified under one new underlying concept. So synthesis is the process by which unification is achieved.

4. References

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