The Use of Mnemonics as Aids in Biology Instruction

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The Problem

There seems to be a consensus among teachers of Biology that there are some weaknesses in the content and aims of our current courses, that there are many deficiencies in our teaching technique and that a goodly portion of our pupils are either not of the best intellectual timber, or are not sufficiently well prepared for the tasks they tackle. It is the purpose of this paper to contribute to our methods of instruction so as to assist our pupils, such as they are, to think more clearly, learn more readily and recall more effectively the information they are supposed to gain in our courses.

It is generally agreed that one of the aims of a high school or college course in Biology should be the formulation of a better way of life. But if our pupils cannot and do not recall the factual information and principles we teach, they cannot be expected to make the worthwhile changes they are supposed to make.

A Partial Solution

Though the phenomena of learning are thought to involve the establishment of so-called "stimulus-response bonds" in pupils' minds, we are confident that though this may be true in simple memorization processes, learning is not simple habit formation as this widely accepted view implies. Many writers have expressed this opinion. Understanding, appreciation, and associations seem to us learning methods which make for better retention, more effective integration, and more intelligent application. Accordingly, science teachers have been challenged to make pupils do reflective thinking. In our own case, we have been able to encourage reflective thinking and increase retention by the use of *mnemonics.*[1]

Some of the mnemonics mentioned below have been in my mind since school days; many have been so assimilated that I do not know their source. But most are, I believe, original, and swept into mind during the exigencies of actual teaching. A few are offered here in the hope that they might help science teachers and suggest methods of procedure.

The many mnemonics used successfully during the last few years fall into three general classes: (a) Mnemonics based on an understanding of the etymology of words; (b) Mnemonics based on association or correlations; and (c) Miscellaneous Mnemonics.

[1] A mnemonic may be defined as any method of aiding the memory. The values of mnemonics have been recognized since the days of the Ancients. Plato and Aristotle, and Cicero and Quintilian, devised and used complex mnemonic systems. Later, extensive and often elaborate systems have been developed by men whose names are well known to students of science, as Roger Bacon (died 1294), Giordano Bruno (died 1600), and more recently by H. Kothe (1852; 1857), Colegrove (1901), Roth (1918), Bruno Furst (1939), and others.

Mnemonics Based on Etymology

A fundamental appreciation of many English words is made easy by understanding the component parts and the meanings of Greek or Latin prefixes, roots, and suffixes. In science the debt to these parent languages is great.[2] The word *science* is itself derived from *scientia* (Latin), meaning *knowledge;* if a pupil understands this, the true significance of modern science becomes evident. If a youngster gets from his high school Latin, Greek, French, or Spanish no more than a vocabulary of prefixes, suffixes, and certain fundamental roots, he will have gained tools which enable him to use his native tongue much more lucidly and intelligently. And too, he will be better able to appreciate, and hence to recall, his scientific information. The accompanying tables are suggestive.

From a knowledge of etymology pupils find the word *aldehyde* derived from *al* (an abbreviation of alcohol), and *dehyde* (from Latin *dehydratus*). Since literally al-dehydratus means "dehydrated alcohol," there is a natural relation between the method of preparation of aldehydes, their chemical structure and the meaning of the word.

In a similar way the pupil learns and recalls readily the meanings of such words as *Hermaphrodite* (Hermes, the god Mercury (male), and Aphrodite, the goddess Venus (female)). *Paleontology* is derived from the Greek *palaios* —ancient, *ontos*—living things, and *logos*—study, discourse. There is mnemonic relation between the *pubis,* a bone, and *pubic* hairs, which arise on the anterior pubic area at the time of *puberty. Psychology* is derived from *psyche,* soul or mind, and *logos.* The examples in the tables show how the meanings of many common words as well as technical ones are derived and how their significance can be understood and recalled.

[2] It is interesting to note here, however, that high school pupils have as difficult a time with non-scientific English words as with purely scientific ones (Curtis '39).

Mnemonics from Associations and Correlations

It is commonly acknowledged that the most skillful teachers are those who depart from the beaten path of a text-book and wander into the wide area of human experiences, especially into those that are of real interest and are related to the material being studied. A good teacher searches far and wide for persons, places, facts, incidents, and human experiences of interest to pupils, including both their likes and dislikes. He draws freely on these for a flow of student interest. The breadth of a teacher's knowledge determines his ability to stimulate and maintain interest and hence indirectly, is a measure of his skill.[3] If teaching success is to be based on the pupil's ability to retain what he has learned with the teacher's help, then those teachers skillful enough to use the associations and correlations of human experiences and provide vicarious experiences should certainly be the most successful. The parables of Jesus, into the fabric of which he wove the precepts for which he stood, are excellent examples of how a skillful teacher can present abstract truth and principles so as to have them remembered. Jesus' parables are as stimulating today as they were 2000 years ago, and are still easy to remember.

Coincidences are always of interest.

[3] This is another reason why a teacher should be as in Goldsmith's poem, a person with a large fund of knowledge, instead of the type satirized in the well known quip: "He who can, does; he who cannot, teaches."

When I tell my pupils that both Abraham Lincoln and Charles Darwin were born in 1809 and that in the same year, too, J. B. Lamarck published his *Philosophie Zoölogique* they rarely forget the correlations between Lamarck's view of Evolution and Darwin's "Survival of the Fittest" theory. Both of these men set free men's minds from slavery to theological dogma just as the Great Emancipator freed from chattel slavery the bodies of millions of black folk. Again Darwin's theory was first set forth in his book *The Origin of Species* published 1859–60, and Negro pupils tie in and recall easily the fact that Booker T. Washington was born either 1859 or 1860.

THE SIMILARITY OF SOUNDS are also of value. Since the second syllable of *concave* suggests a cavity in the ground, concave is understood to be an "in" curve; conversely, *convex,* its opposite, is a bulge. When one discusses bicon-

TABLE I

PREFIXES FREQUENTLY MET WITH

Prefix	Meaning	Examples (including variations of Prefix)
Ana- Gr.	up	*Ana*-bolism; *ana*-phylaxis
Cata- Gr.	down	*Cata*-bolism (*Kata*-bolism)
Com- (cum) Lat.	with, together	*Co*-agulate; *col*-lect; *com*-mute *con*-nect; *cor*-rode; *coun*-cil
Di- Gr.	double	*Di*-lemma; *di*-genetic; *di*-oecious
Dia- Gr.	through	*Dia*-betes; *dia*-lysis
Di- Lat.	apart, away	*Dis*-sect; *di*-gest; *di*-late
En- Gr.	in	*En*-grave; *en*-cyst
Endo- Gr.	within	*Endo*-crine; *endo*-skeleton
Epi- Gr.	upon	*Epi*-dermis
Hetero- Gr.	other	*Hetero*-geneous
Holo- Gr.	entire	*Holo*-blastic; *holo*-caust
Homo- Gr.	same	*Homo*-geneous
Hyper- Gr.	above, beyond	*Hyper*-bole; *hyper*-trophy
Hypo- Gr.	below	*Hypo*-chrondriac; *hypo*-tenuse; *hypo*-thesis
Inter- Lat.	between	*Inter*-collegiate; *inter*-cellular
Intra- Lat.	within	*Intro*-mittent; *intra*-mural
Mal-, Male- Lat.	evil, bad	*Mal*-ignant; *mal*-aria
Meta-, Lat.	within, with, after, among	*Meta*-genesis; *meta*-bolism
Mono- Gr.	single, alone	*Mono*-tone; *mono*-graph·
Multi- Lat.	many, much	*Multi*-cellular
Panto-, Pan- Gr.	all	*Pan*-theist; *panto*-morphic
Peri- Gr.	around	*Peri*-meter; *peri*-cardium
Poly- Gr.	many	*Poly*-gamist; *poly*-gon
Post- Lat.	after, behind	*Post*-erior
Pre- Lat.	before	*Pre*-vious; *pre*-molar; *pre*-natal
Pro- Lat.	instead; before	*Pro*-American; *pro*-test; *pro*-ceed; *prog*-nosis
Pseudo- Gr.	false	*Pseudo*-podium
Retro- Lat.	behind, backwards	*Retro*-gress; *retro*-version
Sub- Lat.	under	*Sub*-cutaneous
Semi- Lat.	one half	*Semi*-conscious
Super- Lat.	above, over	*Super*-human; *super*-ior
Syn- Gr.	with	*Syn*-arthrosis; *sym*-pathy; *syn*-apse
Trans- Lat.	across, through	*Trans*-parent; *trans*-Atlantic
Ultra- Lat.	beyond	*Ultra*-conservative; *ultra*-marine
Unus- Lat.	one	*Uni*-cellar

cave lenses in a physics or physiology lesson, there should then be no confusion.

In the convolutions of the mammalian brain are folds called *gyri* and *sulci*. The latter resembles *sulk* in sound; as one sulks when "down" in spirit, the sulci are remembered as the downfolds; hence, gyri are the up-folded portions of the convolutions.

"Humorous" Associations. The two phases of metabolism, anabolism and catabolism, are hard to forget when one imagines Anna, a girl, building a toy house of blocks. *Anabolism* is thus, the constructive phase of the living process. At the same time, her *cat* is busy pulling down the blocks; this represents *catabolism* (or katabolism), the destructive phase. The analogy can be carried further; if Anna works more rapidly than the cat, the house increases in size, *i.e.*, when anabolism exceeds catabolism, growth occurs. The reverse also follows.

Associations Involving Imagination. Imaginative pictures and analogies prove valuable in teaching new facts and in introducing new concepts. Few beginning students of the sciences appreciate the true magnitude of a microscope's powers. When they look into the instrument and see a *Paramecium* travelling at apparently express train speed, they often doubt that all they see is happening in the little drop of water on the slide. To indicate the significance of magnification we asked our pupils to determine the average time for several organisms to cross the circular microscopic field. From the measured size of the organism and of the distance travelled, the class calculation revealed that in spite of this speed, if a Paramecium kept going in a straight line, it would require eighty-eight hours (three and one half days) to travel one mile.

Analogies are good to explain the concepts of microscopic images. For example, cartilage (or gristle) is visualized as a block of ice (to represent the homogeneous, translucent matrix); in the ice we imagine many water-filled

TABLE II

Some Common Roots

English Words	Greek Roots	Latin Roots	Words Suggested
Life	Bios	Vita	Biology; Vitality*
Light	Photos, (Phos)	Lumen (Lux)	Photograph; Luminous
Health	Hygieia	Sanitas	Hygiene; Sanitary
White	Leukos	Albus	Leucocyte; Albino
Man	Anthropikos	Homo	Anthropoid; Homicide
Horse	Hippos	Equus	Hippopotamus; Equestrian; Equine
Black	Melas, Melanas	Niger, (Spanish Negro)	Melanocyte; Negro
Arms	Brachion	Brachium	Brachial (Muscles)
Head	Cephalon	Caput (Capit-)	Cephalic; Capital
Air (lung)	Pneuma (air)	Pulmo (lung)	Pneumonia; Pulmonary
Blood	Haimor (aima)	Sanguis, -inis	Hemorrhage; Sanguinary
Body	Soma	Corpus	Somatic, Somite; Corporal, Corpse, Corpuscle
First	Protos	Primus	Protoplasm, Protozoan, Protein; Primary
Skin	Derma	Pellis	Dermatologist; Pellicle
Poison	Toxicon	Virus	Toxin; Virulent

* In this list the first words are of Greek origin, the second, Latin.

cavities (*lacunae* containing *cartilage fluid* or *lymph*) and in the water of each cavity, peaches (*cartilage cells*), each with a central peach stone (the cartilage cell *nucleus*). After a pupil has seen models, pictures and the cartilage tissue through the microscope, an imaginative picture of this sort clears his thinking and the concept of gristle in three dimensions is no longer insurmountable. Similar imaginative pictures can help to explain other concepts and functions which involve facts and ideas new to the pupils.

Association with Other Knowledge —External Correlations. Correlation of new material with information already gained in other subjects or in hobbies, serves both to refresh the mind on the old material and also to supply good stimuli for recalling the new. Every boy or girl who has read detective stories will easily visualize a hinged trap door in the ceiling of a room. Attached to the underside is a strong rope just as long as the room is high so that though the trap door may let objects fall, it cannot be raised above the level of the ceiling. In such a picture one has a working model of a ventricle of the heart (the room), with the inelastic, tendinous cords (the rope) which hold the valves (the trap door) attached to the ventricle floor and prevent them from being forced up into the atrium (the attic above our ceiling). Thus, when the trap door (valve) fits well and the ropes (tendinous cords) are not too long or too weak, there will be no passage from the room up through the trap door. Hence, there will be no leaking valve and no defective heart action.

The similarities between a flame and a living body are well known, but often require two lessons. However, nearly all boys and an increasing number of girls already know the science of the internal combustion engine. It is thus easy to teach the analogies between the gasoline fuel and the food; the intake (ingestion) is followed by carburetion, by which the fuel is broken up into small particles and then vaporized so that it can be burned in the cylinder. This is similar to the food being chewed into small particles and then digested by enzymes to molecules which can be absorbed and "burned" (by metabolism) in the body tissues. The gasoline mixture needs air before it will explode in the engine; so too, oxygen from the respiratory organs and the blood is required to make metabolism possible. Finally, the spark which makes the explosion possible is likened to the insulin which enables absorbed carbohydrates to be oxidized. In both cases energy is produced as heat and motion, and the waste products, carbon monoxide, carbon dioxide, and water of the engine correspond to the metabolic end products excreted by the body. The unburned smoke of the exhaust is analogous to the unused, undigested food masses expelled from the digestive tract.

Miscellaneous Mnemonics

The old trick of using initial letters to remember items is so good that there is danger of its overuse, with the result that more effort is spent recalling the mnemonic than in the material to be remembered. In meeting many new students at once, I use a variety of schemes to recall their names by means of initials, but such are usually forgotten soon after they have served their purpose. In scientific matters, however, many initial-letter mnemonics have remained in mind and have repeatedly proved valuable.

In the mammalian eye, the *A*nterior chamber (initial letter A) contains the *A*queous humor; and A (aqueous

humor) in the alphabet comes before V (in the vitreous humor of the posterior chamber).

The initial letters of the three meninges of the central nervous system, *P*ia Mater, *A*rachnoid, *D*ura Mater named in their correct order from the inside out, spell PAD which also explains in part their function.

The names of the twelve Cranial nerves of mammals can be recalled from the jingle—

"*O*n *O*ld *O*lympus' *T*ipmost *T*op,
*A F*inn *A*nd *G*erman *P*icked *A H*op."[4]

The correct order of the categories used in biological classification (Taxonomy), which is difficult to appreciate and hard to remember when first met, offers no hardships even to a secondary pupil when the initial letters in their correct order are combined into the sentence—

"*S*ome *G*ood *F*olks *O*rder *C*hicken *P*ie," hence the correct taxonomic order, *S*pecies *G*enus *F*amily *O*rder *C*lass *P*hylum.

Thirteen essential elements in protoplasm are easily recalled when their symbols are arranged as follows—

C, H, O, P, K, I, N, S, Ca, Fe, Mg, Na, Cl;
"C. Hopkins' Cafe mighty good—
(if taken with a grain of salt)."

USING JINGLES. Almost everyone has at some time or other whispered to himself:

"I before E except after C,"

but few know subsequent helpful lines, two of which are—

"And in words such as Weigh,
"Where they both sound like A."

Most of us recall the number of days in any month by the well known

"Thirty days hath September. . . ."

[4] These nerves are: Olfactory, Optic, Oculomotor, Trochlear, Trigeminus, Abducens, Facial, Auditory, Glossopharyngeal, Pneumogastric (Vagus), Accessory, and Hypoglossal.

Rhymes and jingles have the disadvantage of being sometimes misleading, as is evidenced by the man weak in Anatomy who on first meeting a Mr. Gummick, decided that the name rhymed with "stomach," yet greeted that gentleman some time later as Mr. Kelly. Thus, even the best tools may fail occasionally.

These few examples are given here to indicate that there are great possibilities for teachers with vision. The questions of the choice of the subject in our science courses and the background, interest, and future of our pupils are urgent. But facing the facts as they are, we must meet the challenge with imagination, and so vitalize our teaching that we help our pupils to recall more and more of the valuable things to which we are exposing them. Thus perhaps we may make our science teaching bear more fruit. We can; and we must; for as Emerson wrote, "The man who can make hard things easy is the real educator."

PERMANENT METAL LABELS

At Chicago Teachers College partially labelled demonstrations, especially of muscles, have been used in vertebrate anatomy to help students establish landmarks. These labels have been made with pencil or ink letters on small common cardboard tags which were then dipped into melted paraffin to coat them. The chief criticism is that of disintegration with use, particularly if subjected to moisture. Plastics in solution have also been used to cover the tags but the result is not entirely satisfactory, because of disintegration, discoloration, and finally, the necessity for making several successive applications, which is tedious. Even metal rimmed tags were