Science of Reading Fundamentals

(Reading Science for Beginners)

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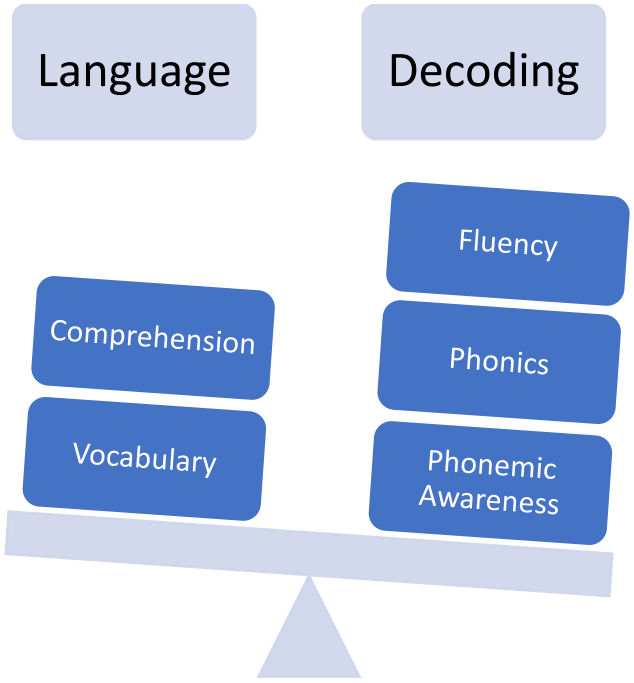

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Science of Reading Fundamentals

(Intro to Reading Science for Beginners)

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The term **Science of Reading** refers to research-based knowledge about reading that has been accruing since the very first scientific study of reading in Paris in 1879. The science in question is primarily educational (cognitive) psychology, but other social sciences have also contributed (e.g., developmental science, linguistics, cognitive neuroscience, anthropology). It relies on statistical measurement of population samples to make inferences about the probability of effects in the general population (i.e., inferential statistics). Science of Reading (SoR) is basically the same body of knowledge referred to in the 2010s as "evidence-based reading," and before that in the 2000s as "research-based reading," and before that, in the 1990s, as "scientifically-based reading."

In 2000, as the result of the Reading Excellence Act of 1998, Congress directed the National Institute of Child Health and Human Development (NICHD) to draw up a panel of reading experts to review the research literature to determine the best ways to teach reading. The result was the National Reading Panel's (NRP) *Teaching Children to Read: An Evidence-Based Assessment of the Scientific Research Literature on Reading and Its Implications for Reading Instruction* (2000). The report comprised research-based analyses of 5 topics: (1) Alphabetics (including phonemic awareness and phonics), (2) Fluency, (3) Comprehension (including vocabulary and text comprehension strategies), (4) Teacher Education and Reading Instruction, and (5) Instructional Technology and Reading Instruction.

The NRP report is often cited as the basis for the "5 Pillars of Reading"—phonemic awareness, phonics, fluency, vocabulary, and comprehension—and for its guidance on how to teach reading. Unfortunately, it is also often falsely cited for claims it never made (Shanahan, 2004). As noted by NICHD (n.d.), the report has not been updated in 22 years. Several of the determinations by the panel are no longer current. For instance, there was no research at the time on sustained silent reading, so the panel did not make a recommendation about its use—and some miscited this lack of evidence as "proof" it was ineffective—but several studies since then demonstrate the significant effect sustained silent reading practice has for vocabulary and comprehension improvement.

There is more to effective reading instruction than knowing about the 5 pillars. It is important to understand what they entail, how they relate, and why they develop over time. In the following pages we provide a skeleton key outline of key concepts behind the Science of Reading.

1. The **Simple View of Reading** (Gough & Tunmer, 1986)
    a. R = D x C

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    b. **R** = **Reading** as measured on an end-of year standardized reading comprehension test
    c. **D** = **Decoding** skills
    d. **C** = **Language comprehension** ability
    e. So: **Reading (R) is the product of students Decoding Skills (D) and their Language Comprehension ability (C)!**
    f. Both decoding and language comprehension are necessary to read well; inadequate development of **either** will result in low reading scores
    g. 12% of students who score weakly demonstrate neither D nor C deficits
    h. A low reading test score could be due to underdeveloped decoding skills, underdeveloped language ability, a bit of both, or something else as well; summative test scores do not distinguish the reasons for lower scores

2. **Definition** of **Decoding** and **Language Comprehension**
    a. **Decoding skills** = **D** = cognitive processes a reader uses to translate the marks on a page or screen into recognizable word forms
    b. Decoding skills include print concept, alphabet knowledge, *phonemic awareness*, rapid automatized naming, *phonics*, sight word reading, and *fluency*
    c. **Language Comprehension abilities** = **C** = knowledge a reader uses to recognize word forms as items of meaningful vocabulary, grammatically arranged in clauses and sentences, to understand the meaning of a text intended by the author
    d. Language comprehension abilities include (1) *language familiarity* (e.g., vocabulary, grammatical pattern recognition, knowledge of common semantic devices such as mechanics, punctuation, idioms, tropes), (2) *symbolic reasoning ability* (e.g., categorization, comparison, analogy, pattern recognition, inference, prediction), (3) *knowledge base* (i.e., prior knowledge of subject content, world, self, interpersonal relations, soft skills, “common sense”), and (4) *comprehension strategies* (e.g., text structure analysis, summarization, discussion, visualization, graphic organizers) (Pearson et al., 2020)

3. **Neuroscience Research** Validates the Decoding/Language Comprehension Distinction (Hruby & Goswami, 2011, 2019)
    a. The brain is an environmentally responsive pattern learner and anticipator
    b. It reads texts either by "sounding out" letter sequences to recognize auditory patterns (sound sequences as in spoken language) or by recognizing visual letter sequences (as in sight word reading)
    c. Younger and struggling readers rely more on the auditory method; older and better readers rely more on visual sight word recognition
    d. Note color-coded distinctions Fig. 1 (purple = auditory; orange = visual):

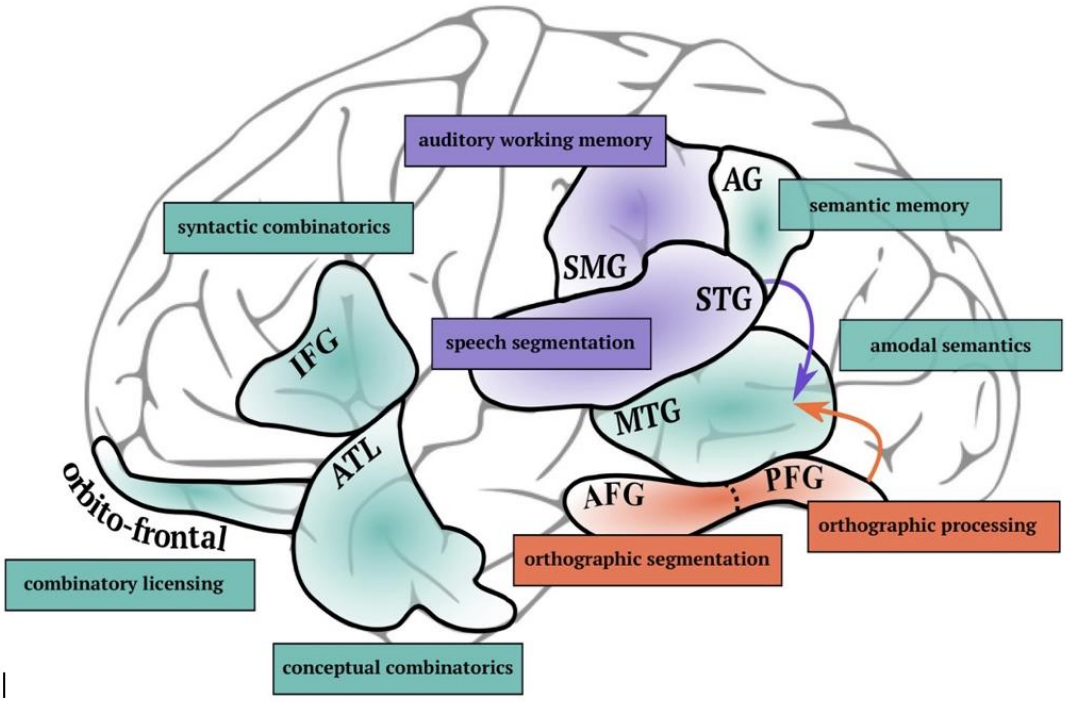


Figure 1. Putative brain regions associated with different stages of morphological processing. Orange areas refer to modality-specific written word processes. Purple areas to modality-specific spoken word processes. Turquoise refers to putative a-modal processes. Key: PFG, posterior fusiform gyrus; AFG, anterior fusiform gyrus; STG, superior temporal gyrus; SMG, supramarginal gyrus; AG, angular gyrus; MTG, middle temporal gyrus (although here rather posterior); ATL, anterior temporal lobe; IFG, inferior frontal gyrus. From Gwilliams, 2019, depicting possible language and reading loci of left-side of the cerebral cortex.

Above, a diagram of the left hemisphere of the cerebral cortex with areas related to reading and language processing identified. Purple areas = auditory pattern decoding regions; Orange areas = visual pattern decoding regions; Green areas = language comprehension regions. (Gwilliams, 2019)

Following page, a diagram mapping neural activation across the brain during decoding processes (blue arrows), and language comprehension processes (red arrows). The amount of time required to activate all areas to comprehend a single simple word is about six-tenths of a second. (Hruby & Mitra 2022)

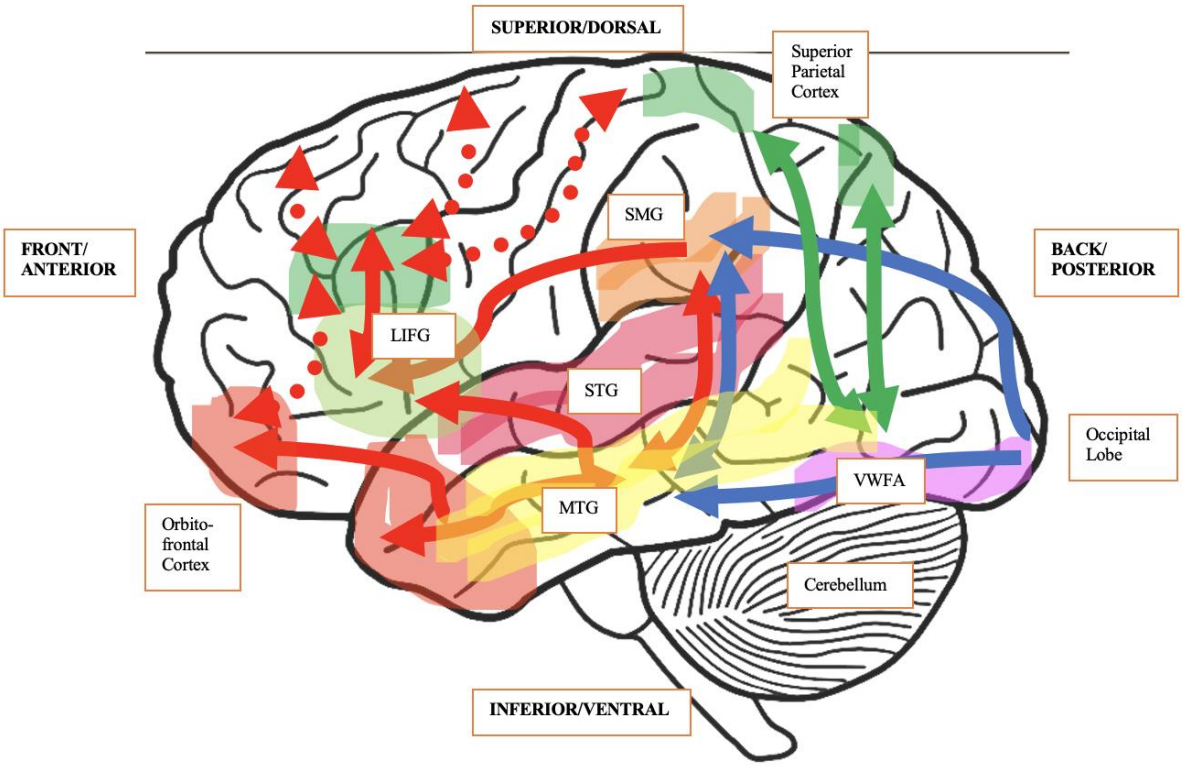
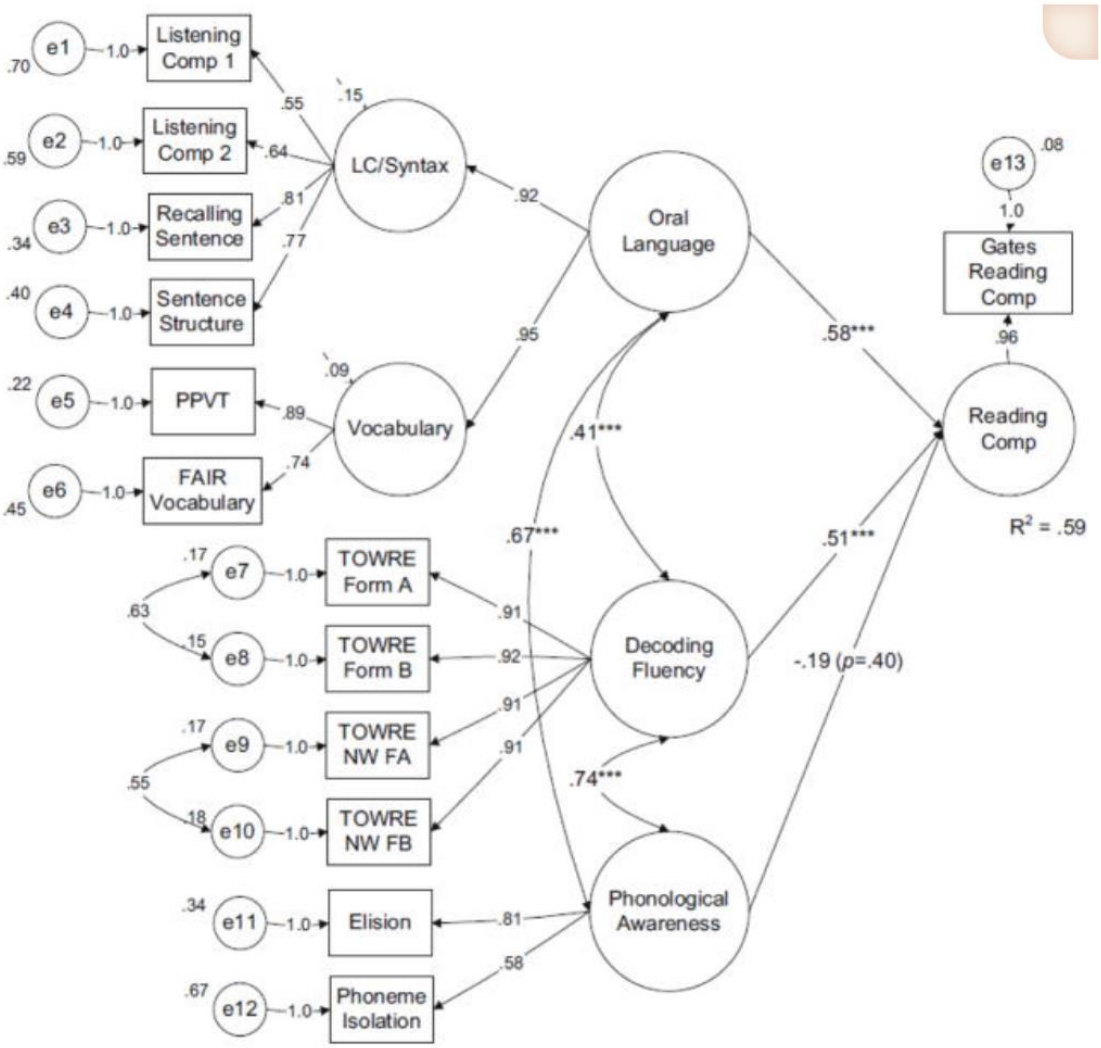


Figure 3. Potential cerebral pathways and ROIs for reading in left cerebral cortex; Blue arrows—decoding pathways; solid red arrows—language comprehension pathways [vocabulary, grammar, clausal meaning]; dotted red arrows—a-modal comprehension pathways; green arrows—semantic and scenario pattern prediction and confirmation pathways; darker green areas: semantics and scenario; lighter green area: syntax; red-orange areas: emotional meaning associations; magenta area: word sound patterns; orange area: auditory processing; periwinkle: orthographic processing.

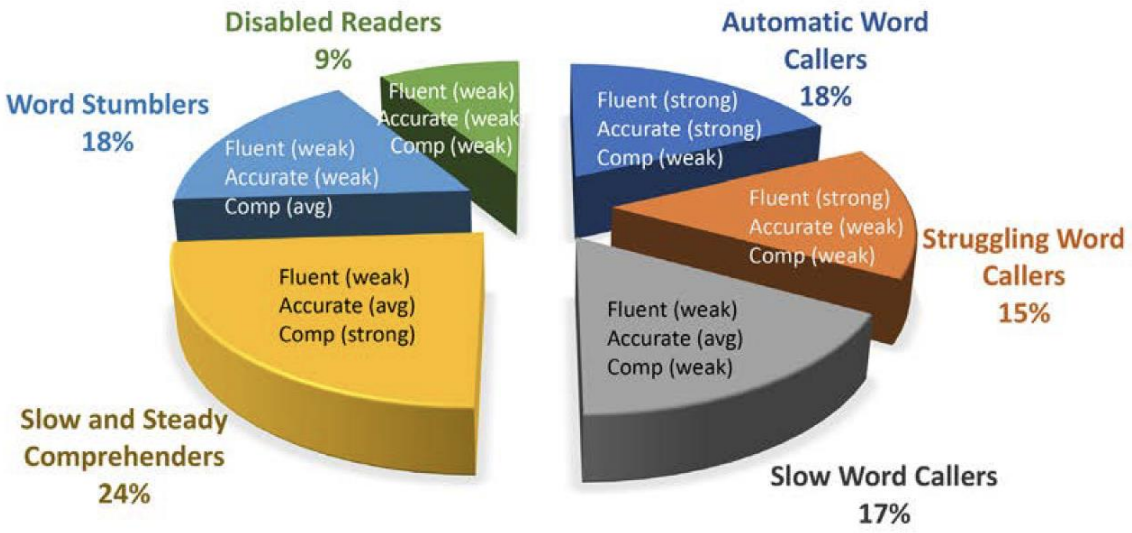
4. Predicting **Good Reading Scores**
    a. Grade-level decoding skills and language development sub-scores together predict reading score outcomes significantly
    b. Decoding and language comprehension can be broken down to their constituent sub-factors; the scores of these differ by individual and grade
    c. Averaged predictive validity of subfactors changes by grade
    d. Averaged across grade-level populations, Decoding predicts reading outcome strongly in grades K-1, moderately in grades 2-3, and weakly in grades 4 and beyond (it is not that decoding becomes unimportant, but that most students have mastered it to ceiling effect by upper grades; as a result, the distribution of decoding skills from grade 3 skews severe right, not matching the typical variation—bell curve—of reading test scores)
    e. Averaged across grade-level populations, Language Comprehension predicts reading test outcome moderately from grade 1-2, and moderate-high thereafter
    f. Decoding skills do NOT correlate with IQ, but acquisition speed may
    g. Language Comprehension ability correlates almost perfectly with IQ (.95)

h. Individual student performance on decoding and language comprehension will differ from population averages and over time



Above, hierarchical linear equation model of reading and reading factor and subfactors tests and their degree of correlation to higher level test outcomes for 2nd grade readers, from elemental/lower-order skills tests (leftmost) to higher order ability tests (middle columns) to reading comprehension test score (rightmost). Second from right, Oral Language = Language Comprehension, Decoding Fluency = Decoding Skills. (Foorman et al., 2015)

5. Why "**Struggling Readers**" Struggle
    a. Varies by grade; as an example, 2nd grade struggling readers (see pie chart below) distinguished by three reading-related difficulties: (1) decoding fluency (≈65%), (2) language comprehension (≈60%), and (3) decoding accuracy (≈40%) (Valencia, 2011). Some students struggle with one, some with two, some with all three abilities.
    b. In this urban district sample, struggling students were 22% of grade population, excluding special needs and ESL/ELL students; most readers do not struggle inordinately with learning to read



6. Common **Reading Difficulties**
    a. **Accuracy** involves accurately sounding out letter sequences and/or word forms aloud and is the result of good phonics instruction and structured practice; emphasized in grades K-1
    b. **Fluency** is the ability to read texts aloud quickly and easily, and is primarily the result of ample practice; emphasized in grades 1-3
    c. **Language comprehension** in reading involves understanding the word forms in texts as items of vocabulary grammatically arranged to indicate intended meanings. Language comprehension develops ("naturally") in response to a student's linguistic experience (from toddler years forward), and will improves with ample opportunity for active use with more verbally adept language users (e.g., teachers) and/or with structured instruction to improve vocabulary, grammatical familiarity, etc.

d. **Practice** is required to improve in all three of these key reading abilities; students need to practice out-of-school as well as in the classroom. For that reason, student **motivation** and positive learning experiences to support their willingness to practice are crucial!

7. Reading Difficulties and **Developmental Differences**
    a. On just about anything people can be measured on, they differ. This is true of reading ability, decoding skills, and language development, too
    b. Some students will be "ahead of the pack," some further behind, most will be around the middle
    c. Put another way, some students are faster learners, some need more time and effort to reach the finish line, most demonstrate average-rate learning
    d. Some students are not only faster, but start their first year of school ahead of the pack, some start further behind; this is often because of the amount of language and literacy they've experienced before their school years
    e. These home experience-effects typically continue during the school years, and if the effect is not addressed can result in a widening "achievement gap" over years between quicker and slower students on reading tests
    f. Therefore, interventions that can catch kids up to their peers are helpful
    g. Being too far behind the pack is demotivating to students and undermines their willingness to practice their skills, hampering reading improvement
    h. There are many reasons why students can have temporary reading difficulty, and it is helpful to identify these individual issues accurately to address them effectively

8. **Dyslexia** – Two (2) Definitions
    a. Temporary reading difficulties and developmental differences should not be confused with permanent reading disabilities such as Specific Learning Disorder with Impairment in Reading, or Dyslexia (APA, 2015)
    b. There are two definitions of dyslexia: clinical (literal) and vernacular (figurative); these should not be confused, and the latter term should be avoided like roadkill (granted, some make a meal of roadkill)
    c. In the strict **clinical** sense, dyslexia is a neurobiological mental disorder demonstrated by impaired phonological processing; neural or genetic deficiencies impair the reader's ability to sound out letters fluently and thus impair subsequent development of good sight word reading, fluency, vocabulary acquisition and comprehension for content learning from written texts (NICHD, 2002)

d. Because dyslexia is a neurobiological disorder, possibly genetic, it is considered incurable (phonics exercises cannot change anyone's genome); students with dyslexia are taught accommodations to "work around" their impediment (National Institute of Health, n.d.; National Institute of Neurological Disorders and Stroke, n.d.; Shaywitz, 2020; Yale Center for Dyslexia and Creative Learning, n.d.)
e. Clinical dyslexia is unrelated to age, I.Q., SES, or psychiatric co-morbidities; it afflicts between 1.5 - 6% of the population (depending on how it is measured); it is thought to be a spectrum disorder with most cases at the mild end of the distribution where they become difficult to distinguish from cases of normal developmental delay (thus the wide prevalence estimation range)
f. Prognoses for most dyslexic children is good, especially if they have average or better language development; sight word reading can often be developed despite phonological processing impairment and syntactic and semantic regularities can often facilitate reading for meaning in mild cases
g. In the widely used **figurative** sense of dyslexia found in commercial and social media, dyslexia is defined as *just any kind of reading difficulty* (Elliot & Grigorenko, 2015)
h. This definition is not helpful for reading difficulty diagnosis as it can be applied to anyone at some point in their development and covers any kind or cause of difficulty; prevalence estimates of 20-30% are inflated by the inclusion of readers with only temporary reading development delay
i. Solutions to problems are problem-specific, obviously, so accurate determination of the cause(s) of a student's reading difficulty is important to address those difficulties effectively
j. Because disability accommodations provide "work-arounds" instead of reading skills development, it is crucial to distinguish true clinical dyslexics from the larger population of slower or developmentally delayed readers to avoid cheating typical-but-delayed children of the education necessary for literate and productive lives

9. **The Literacy Diet** Instructional Pyramid – An Extended Analogy
    a. Just as a child needs a well-rounded diet of all the USDA food groups for good health and optimal growth, so too students need a well-rounded "diet" of good literacy instruction for good reading development
    b. Just as a child needs carbohydrates as part of their diet, students need an ample helping of phonics as part of their early reading diet
    c. Just as there are many ways to obtain carbohydrates, there are many ways to provide phonics instruction and research shows they are all similarly "nutritive" in the hands of competent teachers (Bowers, 2020; National Reading Panel, 2001)

d. Although a child needs carbohydrates as part of their diet, it will not do to feed them bowls of pasta three times a day; they need their fruits and vegetables, meat and fish, dairy, and healthy oils. Similarly, research shows that instruction focused on phonics to the exclusion of other "nutrients" is less effective for doing well on standardized reading tests than phonics taught in combination with other literacy skills (e.g., language use, vocabulary, writing instruction, reading aloud, reading for learning and enjoyment, oral presentation, etc.). The right mix will depend, as always, on the grade level and the needs of the individual student (Kentucky Academic Standards for Reading and Writing, n.d.)
e. In cases where a child has a demonstratable deficiency, short term use of supplements is useful, but no substitute for a balanced diet

10. **Recap and Additional Insights**:
    a. Decoding and Language Ability both matter to read well
    b. Practice makes for improvement; motivation makes for practice
    c. Most students who trail their peers in early grades decoding skills can catch up with well-focused intervention; growth spurts are not uncommon in children, including with reading and writing skills
    d. Students who trail their peers in language development will likely not catch up to peers without at least some instructional support; this is the trouble with expecting children to of learn language "naturally"
    e. Reading and writing instruction amplify the development of *both* reading and writing ability; this is called the "reading-writing connection"
    f. Practitioners and researchers often have their preferred methods, and some methods may be better suited to a particular child at a particular time, but this is a difficult thing to predict accurately in advance
    g. Standardized reading tests (like all standardized tests) are *g-weighted*, meaning their reliability is in part due to *g* (Spearman's correlate for general intelligence); this is what gives a standardized test its reliability without which it would be invalid as a comparative assessment
    h. There is evidence that early and ongoing language and literacy development improves learners' intelligence as well as their reading and writing ability, content knowledge, learning, and school success
    i. Most students with reading difficulty are only demonstrating the normal distribution of variance found in human populations on developed reading ability; most can catch up and will develop adequate reading ability with time, motivation, and the persistent support of effective interventions and skilled reading specialists

j. Dyslexia is different than typical reading difficulty: it is an incurable neurobiological mental disorder involving abnormal neural architecture for processing language sounds which makes sounding out letters and words difficult, often slowly and with many inaccuracies; it makes reading comprehension difficult and hampers text-based vocabulary and knowledge growth. It cannot be cured but only accommodated. For that reason, it is important not to misdiagnose garden variety slower readers as clinically dyslexic
k. Changing instructional regimens regularly (but coherently) to keep things interesting, avoid drudgery, giving students opportunity to demonstrate their developing abilities, and emphasizing the positive and joyful aspects of reading can **motivate children to practice** their skills so they improve, making them better and happier readers
l. There are no silver-bullet solutions. Nothing works for everyone nor for anyone all the time. Avoid misdiagnosis and over-diagnosis. Above all, **Do No Harm**.

Notes and Thoughts: