Systemic Functional Linguistic (SFL) Analysis and Explanation of Language Demands
Chemistry Textbook Exemplar

According to Fang and Pace (2013), linguistic concepts of vocabulary, grammatical metaphor, lexical density, grammatical intricacy and cohesion explain what make sentences easy or difficult to read. Consider the linguistics of the complex sentence below sourced from an exemplar chemistry text. As you read the exemplar sentence, you will see that:

- Subject-specific and general academic vocabulary are underlined to highlight vocabulary and lexical density concepts.
- Author use of grammatical metaphor to explain scientific processes is underlined and italicized.
- The clauses of the sentence are marked with backslashes to highlight grammatical intricacy.
- Pronouns are in bold font to highlight the cohesion of the sentence.

Temperature induces **these** *transitions* /by changing the speed and amplitude /at **which** molecules vibrate. An *increase* in the temperature of ice to above 0^0C (32^0F), for example, /causes *molecular vibrations* /to increase to the point /**that** individual molecules jiggle *loose* /and the crystal structure starts /to break apart.

Source: Tiefel, J & Hazen, R.M. (2001). *The sciences: An integrated approach.* John Wiley & Sons. Page 223.

Vocabulary. According to Fang and Pace (2013), authors use academic vocabulary with "specialized words and phrases that encapsulate key disciplinary concepts" (p. 105). This academic vocabulary is both subject-specific and general. Together these two types of academic vocabulary contribute to a text's complexity. *Subject-specific* vocabulary include low frequency words with precise meanings, such as the words temperature and molecules underlined in the exemplar sentence. *General academic* vocabulary includes words with multiple meanings that may be adapted to convey subject specific knowledge. For example, dancers jiggle as they dance, and the food known as Jello gelatin also jiggles. But the exemplar sentence from a chemistry textbook relies upon an alternative meaning for the word jiggle that applies to the vibrations of molecules. The multiple meanings of general academic words can be as difficult for readers to comprehend as the subject specific vocabulary words.

Lexical Density. Lexical density refers to the average number of complex vocabulary words per sentence in a typical paragraph within a text. The exemplar sentence above is lexically dense because the authors squeeze a number of subject specific and general academic vocabulary words, such as *jiggle, transitions* and *molecules*, into one sentence. For example, this exemplar sentence has a lexical density ratio of 14—14 subject specific and general academic vocabulary words for the one sentence. This ratio contrasts with less dense reading material, such as newspapers, which typically have a ratio of 4 or 5 complex vocabulary words per sentence. Lexically dense writing conveys a lot of information all at once, and science writers try to achieve this purpose without overwhelming a reader's comprehension.

Grammatical Metaphor. The exemplar sentence contains the words *transitions* (from the verb *transit*), *vibrations* (from the verb *vibrate*), and "*the increase*" (from the verb *increase*). Grammatically, these are verbs that have been morphed into nouns (or "nominalized") to explain multiple chemical processes within one sentence. Functional linguists see this atypical use of vocabulary they call *grammatical metaphor* as a characteristic of science writing. The use of grammatical metaphor enables scientists, as well as authors in other content areas, to transform *things* into verbs and *processes* into nouns through the metaphorical processes of verbalization and nominalization. For example, the verb *to vibrate* is nominalized into the noun *vibrations* in the exemplar sentence. Grammatically nominalizing scientific

processes, like vibrating and transitioning, enable these processes to become static, quantifiable observations (i.e. "Temperature induces **these** *transitions*... ").

Grammatical Intricacy. Grammatically intricate sentences have multiple clauses that are arranged to explain complex concepts. Fang and Pace (2013) calculated a grammatical intricacy score by dividing the number of clauses over the number of sentences in a text. For example, the exemplar sentence above boasts eight clauses. And so eight clauses divided by one sentence yields a mathematical average of eight clauses per sentence expressed as 8.0 or 8:1. Chemistry readers must understand, sequence, and combine eight different clauses of information in the exemplar sentence to comprehend changes in solid, liquid, and gas states. This ratio contrasts with a typical newspaper's grammatical intricacy of 3.0 or 3:1.

Cohesion. Cohesion unifies personal pronouns (i.e. *he, she, it*) and relative pronouns (i.e. *this*, *that, which*) with their referents. Cohesive complexity increases with the number of pronouns an author uses, as well as the distance an author creates between pronouns and their referents. As the number of pronouns and the distances between pronouns and referents increase, identifying or generating a referent within or across sentences can become more difficult (Fang & Pace, 2013). The exemplar sentence illustrates this type of text complexity. The number of pronouns in the exemplar sentence are few, yet the cohesion of the text is complex because of the *referential distance* between pronouns and their referents. For example, what does the indefinite pronoun ***that*** in the exemplar sentence about changes in state refer to? Does it refer to molecules? Jiggling? Crystal structure? Note that a reader must traverse three clauses after the indefinite pronoun ***that*** is read to understand what this pronoun refers to: "...individual molecules jiggle loose /and the crystal structure starts /to break apart." Referential distance is typically calculated by linguists as the average number of clauses between pronouns and referents within a 200 word sample. Less referential distance makes a text more cohesive. Greater referential distance makes a text less cohesive.

Source: Fang, Z., & Pace, B.G. (2013). Teaching with challenging texts in the disciplines: Text complexity and close reading. *Journal of Adolescent and Adult Literacy, 57*(2), 104-108.

Questions to Discuss with Chemistry Readers

About Vocabulary: What other examples of subject specific and general academic vocabulary do you see in the exemplar sentence? How do you explain these examples?

About Lexical Density: How does lexically dense text help a reader learn more from a concise and precise text? What combination of comprehension strategies—predicting, checking for details, summarizing, visualizing, questioning—would a chemistry text reader need to rely on to learn from a lexically dense text? Why?

About Grammatical Metaphor: How do you define the meaning of the grammatical metaphor *transitions* you see in the exemplar sentence? Has the word been verbalized or nominalized? How do you know? How does the author's way of morphing typical parts of speech help a reader comprehend this complex sentence? What language demands do grammatical metaphors make on readers?

About Grammatical Intricacy: How do grammatically intricate sentences help a reader learn more precise definitions of subject specific concepts like changes in state? What combination comprehension strategies—predicting, checking for details, summarizing, visualizing, questioning—would a reader need to rely on to learn from a grammatically intricate text? What demands for grammatical knowledge do grammatically intricate sentences make on readers?

About Cohesion: How do incohesive texts prompt readers to think deeper and explain subject specific chemistry concepts like changes in solid, liquid, and gaseous states? What combination of comprehension strategies—predicting, checking for details, summarizing, visualizing, questioning—do science text readers rely on to learn from an incohesive text? How do foundational documents in other disciplines [The Quran, The Bible, the U.S. Constitution, the Gettysburg Address, or Galileo's book *Di Motu* ("On Motion")] depend upon incohesion to prompt deeper interpretation? Why is this incohesion important?

Changes of Solid, Liquid, and Gas States

Place a tray of liquid water in the freezer and it will turn to solid ice. Heat a pot of water on the stove and it will boil away to a gas. These everyday phenomena are examples of changes of state—transitions among the solid, liquid, and gas states. Freezing and melting involve changes between liquids and solids, while boiling and condensation are changes between liquids and gasses. In addition, some solids may transform directly to the gaseous state by sublimation.

[Temperature induces **these** *transitions* /by changing the speed and amplitude /at **which** molecules vibrate. An *increase* in the temperature of ice to above 0^0C (32^0F), for example, /causes *molecular vibrations* /to increase to the point /**that** individual molecules jiggle *loose* /and the crystal structure starts /to break apart.] A liquid forms. Then, above 100^0C (212^0F), individual water molecules move fast enough to break free of the liquid surface and form a gas. These changes require a great deal of energy, because a great many chemical attractions must be broken to change from a solid to a liquid, or from a liquid to a gas, Thus, a pot of water may reach boiling temperature fairly quickly, but it takes a long time to break all the attractions between water molecules and boil the water away. By the same token, a glass of ice water will remain at 0^0C for a long time, even on a warm day, until enough energy has been absorbed to break all the ice attractions. Only after the last bit of ice is gone can the water temperature begin to rise.

Source: Tiefel, J & Hazen, R.M. (2001). *The sciences: An integrated approach.* John Wiley & Sons. Page 223.