DISCOURSE PROCESSES, *43*(2), 121–152

Reversing the Reverse Cohesion Effect: Good Texts Can Be Better for Strategic, High-Knowledge Readers

Tenaha O'Reilly
Educational Testing Service

Danielle S. McNamara
Department of Psychology
University of Memphis

Students with low knowledge have been shown to better understand and learn more from more cohesive texts, whereas high-knowledge students have been shown to learn more from lower cohesion texts; this has been called the *reverse cohesion effect*. This study examines whether students' comprehension skill affects the interaction between text cohesion and their domain knowledge. College students (n = 143) read either a high- or a low-cohesion text and answered text-based and bridging inference questions. The results indicated that the benefit of low-cohesion text was restricted to less skilled, high-knowledge readers, whereas skilled comprehenders with high knowledge benefited from a high-cohesion text. Consistent with McNamara (2001), the interaction of text cohesion and knowledge was restricted to text-based questions. In addition, for low-knowledge readers, the benefits of high-cohesion texts emerged in their responses to bridging inference questions but not text-based questions. The results suggest a more complex view of when and for whom textual cohesion affects comprehension.

Written text is one of the most important means of conveying information. For example, a significant proportion of information in college and high school classrooms is presented via textbooks. Unfortunately, many students are poor readers or have difficulty understanding textbooks (Bowen, 1999; Snow, 2002). Their difficulties can arise from several deficits, ranging from inefficient decoding abilities (e.g., Perfetti, 1985) to problems with higher level comprehension skills (Cornoldi, De Beni, & Pazzaglia, 1996; Hoover & Gough, 1990; Stothard & Hulm,

---

Correspondence should be addressed to Tenaha O'Reilly, Educational Testing Service, Rosedale Road, MS 10-R, Princeton, NJ 08541. E-mail: toreilly@ets.org

1996). Another important source of readers' comprehension difficulty stems from the nature of the textbooks themselves. Many school texts are difficult to understand because important background information is omitted and relations between concepts are not explicit (Beck, McKeown, & Gromoll, 1989; Chi, De Leeuw, Chiu, & LaVancher, 1994; Wilson & Anderson, 1986).

The purpose of this study was to examine how characteristics of the reader (i.e., prior knowledge and comprehension skill) and characteristics of the text (i.e., text cohesion) affect reading comprehension. More specifically, we were interested in determining whether comprehension skill mediates the interaction between prior knowledge and text cohesion (McNamara & Kintsch, 1996), which we refer to as the *reverse cohesion effect*. The reverse cohesion effect is the counterintuitive finding that high-knowledge readers learn better with less cohesive texts (McNamara & Kintsch, 1996). We propose that the reverse cohesion effect can be explained as a function of the reader's comprehension skill and that only less skilled high-knowledge comprehenders benefit from low-cohesion text. In this article we outline the relevant research on how the characteristics of reader and the text influence comprehension and how both characteristics interact with each other. Then we describe our study, which provides evidence that cohesive text can benefit both low-knowledge readers and skilled high-knowledge readers.

READER CHARACTERISTICS

Reader characteristics such as prior knowledge and comprehension skill have been shown to have a large impact on reading comprehension. Essentially, readers who have more prior knowledge about the text (either via schematic information or prior experience) better understand and learn more from text (e.g., Arbuckle, Vanderleck, Harsany, & Lapidus, 1990; Bransford & Johnson, 1972; Shapiro, 2004; Spilich, Vesonder, Chiesi, & Voss, 1979; Willoughby, Waller, Wood, & Mackinnon, 1993). In addition, skilled comprehenders understand more information from text because they have better word representations (Perfetti, & Hart, 2002), make more inferences (Cain, Oakhill, Barnes, & Bryant, 2001; Long, Oppy, & Seely, 1994; McNamara & O'Reilly, in press; Oakhill, 1984), use more reading strategies (Bereiter & Bird, 1985; Brown, 1982; Goldman & Saul, 1990; Lau & Chan, 2003; Long et al., 1994; Magliano & Millis, 2004; Magliano, Wiemer-Hastings, Millis, Muñoz, & McNamara, 2002; Oakhill, 1984; Oakhill & Yuill, 1996), and have more intrinsic motivation (Lau & Chan, 2003) than less skilled comprehenders.

CHARACTERISTICS OF THE TEXT

In addition to characteristics of the reader, characteristics of the text also influence comprehension (Linderholm et al., 2000; McNamara & W. Kintsch, 1996;

Voss & Silfies, 1996). The degree to which the concepts, ideas, and relations within a text are explicit has been referred to as *text cohesion*, whereas the effect of text cohesion on readers' comprehension has been referred to as *text coherence* (Graesser, McNamara, & Louwerse, 2003; Graesser, McNamara, Louwerse, & Cai, 2004; McNamara, 2001; McNamara & Kintsch, 1996; McNamara, Kintsch, Songer, & Kintsch, 1996). In an analysis of cohesion in social studies texts, Beck et al. (1989) found that many texts have structures that are far from optimal in promoting deep comprehension or coherence. Beck's analysis revealed that texts often present too much information with too little detail, contain loosely connected statements, and have poor integration with previous sections. Disjointed text structures impede comprehension by forcing the reader to form a disconnected and superficial mental representation of the material. Indeed, manipulations designed to improve text cohesion by increasing casual and referential cohesion have been successful in elevating student comprehension (Beck, McKeown, Sinatra, & Loxterman, 1991; Britton & Gülgöz, 1991; Lehman & Schraw, 2002; Linderholm et al., 2000; Vidal-Abarca, Martínez, & Gilabert, 2000).

INTERACTIONS AMONG COHESION, KNOWLEDGE, AND COMPREHENSION ABILITY

In sum, knowledge, comprehension skill, and text cohesion improve understanding. However, research has further shown that effects of cohesion interact with individual differences such as knowledge and comprehension ability (McNamara, 2001; McNamara & Kintsch, 1996; McNamara et al., 1996; Voss & Silfies, 1996). For instance, McNamara and colleagues found that high-cohesion texts may not be optimal for all readers. In three studies conducted by McNamara and colleagues (McNamara, 2001; McNamara & Kintsch, 1996; McNamara et al., 1996), text cohesion was manipulated by increasing argument overlap and causal cohesion of an original (low-cohesion) text. The text topics included heart disease (McNamara et al., 1996), the Vietnam War (McNamara & Kintsch, 1996; see also Britton & Gülgöz, 1991), and cell mitosis (McNamara, 2001). These studies found with middle-school students (McNamara et al., 1996) and college students (McNamara, 2001; McNamara & Kintsch, 1996) that only low-knowledge readers significantly benefited from high-cohesion texts. Low-knowledge readers benefit from high-cohesion text because they lack the knowledge to infer information that is not stated in the text. However, these studies also found a reverse cohesion effect, such that high-knowledge readers showed better comprehension when they read the low-cohesion version of a text.

According to McNamara and colleagues (1996), high-knowledge readers are less likely to access and use their knowledge to make inferences when the text is highly cohesive. They generate fewer inferences because comprehension of high-cohesion text is seemingly successful; that is, the inferences are not called for by the text. In contrast, the inference processes engaged to bridge the conceptual gaps within and between sentences in low-cohesion text result in greater integration between the text and prior knowledge. Thus, low cohesion induces high-knowledge readers to integrate their knowledge with the text, and that process enhances comprehension. High cohesion, in contrast, induces high-knowledge readers into more passive, perhaps *minimalist*, processing of the text (e.g., McKoon & Ratcliff, 1992).

Other work by Voss and Silfies (1996) indicated that the effect of text cohesion depends on comprehension skill. Voss and Silfies gave readers two fictitious history texts that varied in terms of cohesion. Cohesion for one version was increased by adding information about the causal factors between the events described in the less cohesive text. Comprehension skill was measured by the Nelson–Denny reading test, whereas prior knowledge was assessed with a general measure of history knowledge. A general measure of history knowledge was used as opposed to a domain-specific measure because the information contained in the experimental passages was fictional. The authors used correlational analyses to assess the relations among prior knowledge, reading skill, and text cohesion. The results indicated that comprehension skill was primarily correlated to improved performance on the high-cohesion text, whereas prior knowledge was correlated to better performance on the low-cohesion text. In other words, skilled comprehenders were better able to take advantage of the added information provided in the high-cohesion text. Voss and Silfies concluded that comprehension skill was primarily related to developing an effective textbase, whereas knowledge was primarily related to developing a coherent situation model.

In contrast to the results reported by Voss and Silfies (1996), Linderholm et al. (2000) found that both skilled and less skilled comprehenders equally benefited from reading a high-cohesion text. In their study, causal cohesion was increased by rearranging the temporal order, making goals more explicit, and repairing coherence breaks. However, the benefit of increasing cohesion was only evident for more difficult texts. Linderholm et al. did not find any benefit of increasing cohesion when the text was easy as judged by analyses of the goal structure, causal organization, and referential overlap.

THIS STUDY: DOES COMPREHENSION SKILL MEDIATE THE REVERSE COHESION EFFECT?

Collectively, the findings of Voss and Silfies (1996) and Linderholm et al. (2000) have important implications for interpreting the reverse cohesion effect by McNamara and colleagues. One explanation for the reverse cohesion effect is that the high-cohesion text promotes passive processing for high-knowledge readers. When there is a large overlap between the text and the reader's knowledge, high-knowledge readers fail to process the information at a deep level because they do not use their knowledge to help them develop a coherent model of the text (McNamara, 2001). However, this explanation and previous studies on the reverse cohesion effect did not take into account the level of the reader's comprehension skill. In contrast to less skilled comprehenders, skilled comprehenders are active processors of text and are more likely to remember more information from the text, make more inferences, use more reading strategies, and integrate the text with prior knowledge (Cain et al., 2001; Hannon & Danemon, 2001; Lau & Chan, 2003). In particular, skilled, high-knowledge readers should actively process a high-cohesion text despite the potential overlap with their existing knowledge. Provided that the text is difficult enough (Linderholm et al., 2000), high-cohesion text should help skilled (Voss & Silfies, 1996), high-knowledge comprehenders. In contrast, for less skilled, high-knowledge readers, comprehension should be best when they read the low-cohesion text (reverse cohesion effect) because gaps in the texts force the high-knowledge reader to actively process the text (McNamara, 2001). In sum, we predicted that only less skilled, high-knowledge readers would comprehend more from the low-cohesion text, whereas skilled, high-knowledge readers would not display a reverse cohesion effect. In fact when the text is difficult, high-cohesion text should help (Linderholm et al., 2000) the skilled (Voss & Silfies, 1996), high-knowledge reader understand more from the text.

Our predictions were less precise for low-knowledge comprehenders. We expected first that their comprehension would be relatively poor, as found by McNamara (2001), given that we were using McNamara's difficult texts on the topic of mitosis. In that study, participants consecutively read two versions of the same text that varied in terms of cohesion. Participants read either the same text twice (high cohesion twice or low cohesion twice) or different cohesion texts (high cohesion then low cohesion, or low cohesion then high cohesion). Comprehension was assessed at both the textbase and situation-model level of understanding. The textbase representation was measured by short-answer, text-based questions that required the reader to provide an answer that could be found within a single sentence of the text. The situation model was assessed by short-answer, bridging-inference questions that required the reader to integrate information from multiple sentences to form a correct answer. The results indicated that low-knowledge readers benefited from cohesion when the high-cohesion text was read first, whereas high-knowledge readers scored higher on text-based questions when they read the low-cohesion text first. However, overall comprehension was relatively low (less than 35% overall correct).

The text used here and in the McNamara (2001) study concerned cell mitosis, and the low-cohesion version is quite difficult for students to understand. One reason for this difficulty is because students often have little knowledge about cells and biological processes related to cells. Cell mitosis is a complex process in that it contains numerous, unfamiliar scientific terms (e.g., "telophase") and interconnected subcomponents and processes. Hence, we expected low-knowledge readers' understanding of the text to be aided by both comprehension skill and cohesion. We expected comprehension skill to contribute because McNamara (2004) found that low-knowledge readers' comprehension of the low-cohesion version of this cell mitosis text was greatly enhanced by reading-strategy training. Similarly, we expected comprehension skill to help the low-knowledge reader because skilled comprehenders are more likely to monitor their comprehension and use whatever knowledge they possess to understand the text. We expected cohesion to benefit the low-knowledge readers' understanding because the added cohesion makes the relations among the concepts more explicit and reduces the number of inferences.

As mentioned previously, because we used the same texts as those in McNamara (2001, 2004), we predicted that, overall, readers would have difficulty understanding the material. McNamara (2001) argued that the difficulty of the text impeded readers' ability to develop a situation model of the material, and because so few readers were able to develop a coherent situation model of the text, the default representation for the reader was the textbase. This notion was supported by a difference of over 50% correct comparing participants' scores on text-based questions and bridging-inference questions. This result contrasts with previous studies in which the overall performance for text-based and bridging-inference questions was, on average, only 3% higher for text-based questions as compared to bridging-inference questions (McNamara & Kintsch, 1996, Experiments 1 and 2; McNamara et al., 1996, Experiment 2).

In this study, comprehension skill was measured by a standardized reading comprehension test, the Nelson–Denny Reading Test (Brown, Fishco, & Hanna, 1993) and a measure of metacognitive reading strategy knowledge, the Metacomprehension Strategy Index (MSI; Schmitt, 1990). Domain knowledge was measured by a combination of multiple-choice questions on general biology and open-ended questions on cell knowledge. Participants read either a high- or a low-cohesion version of a text about cell mitosis (from McNamara, 2001) and answered open-ended comprehension questions.

In summary, we predicted that the reverse cohesion effect would only appear for less skilled, high-knowledge comprehenders. For skilled, high-knowledge comprehenders, cohesion should facilitate comprehension because the readers would actively process the difficult mitosis text and the more coherent textbase in the high-cohesion version should lead to a more complete text representation. Finally, we predicted that both comprehension skill and cohesion would help low-knowledge readers because skilled comprehenders are more likely to use strategies and make inferences, and the increased cohesion should allow readers to form a partial model of the text.

METHOD

Participants

The participants included 143 college students from Old Dominion University with a mean age of 22.59 years (*SD* = 5.18) and an age range from 19 to 58 years. Ninety-nine of the students were women and 44 were men. The participants' average number of years in college was 2.5 years (*SD* = 1.18) and ranged from 1 to 5 years. Participants were recruited though the psychology department's participant pool system and were given credit for their participation.

Materials

Prior knowledge tests. Participants' general and science knowledge was measured by multiple-choice and open-ended questions. The multiple-choice section included a 54-item test on biology ($n = 29$), the humanities (e.g., art, literature, history, political science; $n = 19$), and general science knowledge (e.g., research methods, psychology; $n = 6$). Cronbach's alpha for all 54 items of the prior knowledge test was .77. Cronbach's alpha for the biology, humanities, and science questions was .61, .76, and .72, respectively, using the Spearman–Brown formula adjusted for 30 items (see Lord & Novick, 1968). An example of a multiple-choice prior knowledge question is "A part of a neuron that carries nerve impulses toward the cell body is called (a) a nerve, (b) white matter, (c) a neurotransmitter, (d) a dendrite, (e) an axon." For the multiple-choice prior-knowledge questions, only the biology questions were used to form our domain knowledge measure. The purpose of the general knowledge questions was primarily to confirm that the science questions were particularly predictive of comprehension performance. The general science questions were not included in the main analysis.

Participants were also given an eight-item open-ended test that specifically queried students' knowledge about cells. An example of an open-ended cell question is "What is a eucaryotic cell?" Two questions were eliminated from scoring because it was determined after the study was completed that the answers to the questions could have potentially been inferred from the mitosis passage. Cronbach's alpha for the remaining six questions was .90 using the Spearman–Brown formula adjusted for 30 items. A scoring key was developed that included all the elements that were required for a correct answer. Each question was worth 1 point, but fractional credit was given for partially correct answers. If a student provided all the necessary information, he or she was given full credit; alternatively if the student provided only a portion of the correct answer, partial credit was given in quarter point increments depending on the question. Fifteen percent of the cell-knowledge data was scored by an independent grader who was blind to condition. The independent grader and an experimenter who was also blind to condition achieved a 98% agreement in scoring the data. All discrepancies between the graders were resolved by discussion, and the independent grader scored the remaining data. The biology multiple-choice questions and the cell-knowledge questions were standardized and averaged together to produce a composite biology domain prior knowledge score.

Comprehension skill tests. Comprehension skill was measured by the Nelson–Denny adult reading comprehension test and the MSI (Schmitt, 1990). The Nelson–Denny adult reading comprehension test (form G) consisted of 38 multiple-choice questions designed to assess comprehension on several short text passages. Reliability for the comprehension section of the test was $\alpha = .82$. Due to time constraints, only the reading comprehension section of the Nelson–Denny test was administered (i.e., the vocabulary section was not administered), and the overall time allotted to answer the questions was reduced to 15 min (see e.g., Magliano et al., 2005; McNamara & McDaniel, 2004).

The MSI is a 25-item multiple-choice questionnaire that is designed to measure knowledge of metacognitive reading strategies such as predicting and verifying, previewing, purpose setting, self-questioning, drawing from background knowledge, and summarizing and applying comprehension-monitoring strategies. The original scale was developed to be used with narrative passages (Schmitt, 1990); however, the scale was adapted for use with expository passages by Forget (1999). In this study, Cronbach's alpha for the MSI was .61. A sample MSI question is "Before I begin reading, it's a good idea to (a) see how many pages are in the reading, (b) look up all of the big words in the dictionary, (c) make some guesses about what I think the reading is about, (d) be sure I can answer the questions at the end of the last chapter." Previous research in our lab has confirmed its appropriateness for college students (Cottrell & McNamara, 2002).

High- and low-cohesion texts. The high- and low-cohesion versions of the cell mitosis text and the accompanying set of questions were developed previously by McNamara (2001). As described by McNamara, the original low-cohesion version of the text (see Appendix A) was taken from a high-school biology text. The high-cohesion version of the text (see Appendix B) was created by identifying potential cohesion gaps within the original version and supplying information required to make the necessary inferences. There were seven aspects of the text that were modified to increase cohesion: (a) replacing pronouns with noun phrases, (b) adding descriptive elaborations, (c) adding sentence connectives, (d) replacing or inserting words to increase conceptual overlap, (e) adding topic headers, (f) adding theme sentences, and (g) moving or rearranging sentences. For more details, see McNamara.

Both passages described the same content and included all the necessary information required to answer the open-ended questions. As shown in Table 1, the

TABLE 1
Traditional and Coh-Metrix Cohesion Measures
for the High- and Low-Cohesion Texts

Cohesion Measure	*High-Cohesion Mitosis*	*Low-Cohesion Mitosis*
Number of words	901	650
Reading ease	48.163	52.935
Reading grade level	10.468	9.171
Causal cohesion	0.326	0.182
LSA global cohesion	0.369	0.315
Type–token ratio	0.595	0.623
Connectives	63.687	52.795

Note. LSA = latent semantic analysis.

high-cohesion text was 901 words in length and had a Flesch Reading Ease of 48 and a Flesch–Kincaid Grade Level of 10.5. The low-cohesion version was 650 words in length and had a Flesch Reading Ease of 53 and a Flesch–Kincaid Grade Level of 9.2. Collectively, traditional measures of text difficulty, the number of words, Flesch Reading Ease, and Flesch–Kincaid Grade Level suggest that the low-cohesion text is likely be easier to understand than the high-cohesion text. However, there is often a reverse relation between cohesion and traditional measures of readability such as grade level and reading ease (Graesser et al., 2004; McNamara, Ozuru, Louwerse, & Graesser, 2005). That is, as cohesion is increased, reading ease decreases, and the grade level estimates increase. This trend generally occurs because traditional measures of text difficulty rely on sentence length; the implication is, the shorter the sentence length, the easier the text. However, increasing cohesion typically results in an increase in sentence length and thus increases in text difficulty as indexed by traditional measures. Consequently, we offer some additional measures of text cohesion to supplement traditional measures of readability.

Table 1 presents an additional set of cohesion measures that were obtained with Coh-Metrix, an automated program used to measure text cohesion (Graesser et al., 2004). The four additional measures listed in Table 1 are a selection of measures output by Coh-Metrix Version 1.0 that can be used to calculate text cohesion. Causal cohesion is the extent to which sentences are related by causal relations (e.g., *because*, *so that*). Causal cohesion is measured by the ratio of causal verbs and particles. The high-cohesion text had a higher ratio, reflecting that the casual relations are more explicit in the high-cohesion version. Latent semantic analysis is a statistical technique for representing world knowledge, based on a large corpus of texts. Latent semantic analysis uses singular value decomposition, a general form of factor analysis, to condense a very large corpus of texts to 100 to 500 dimensions (Landauer & Dumais, 1997). The conceptual similarity between any two text excerpts (e.g., word, clause, sentence, text) is evaluated by these 100 to 500 functional dimensions. The *cosine* value between vectors is used to measure the similarity between excerpts. The high-cohesion text used in this study had a higher average cosine than the low-cohesion text, indicating a higher degree of global semantic similarity among the concepts of the high-cohesion text.

The type–token ratio is the number of unique words divided by the number of tokens of the words. When the type–token ratio approaches 1, each word occurs only once in the text; comprehension should be comparatively difficult because many unique words need to be encoded and integrated. The type–token ratio was lower for the high-cohesion texts, reflecting fewer unique concepts as compared to the low-cohesion text. Finally, the connectives measure is an indicator of how well words and phrases are connected to one another (e.g., *when, such as, that is, consequently*). The connective measure was higher in the high-cohesion text than the low-cohesion text, indicating that there were more explicit ties in the high-cohesion text.

Comprehension questions. The comprehension questions consisted of 10 open-ended questions (see Appendix C); 5 were text-based and 5 were bridging-inference questions. The 10 questions were taken from a set of 12 questions used in McNamara (2001). Two of the 12 questions were eliminated from the McNamara set because they did not satisfy our definition of text-based and bridging-inference question types. We classified text-based and bridging-inference questions based on whether the answer to a question could be found in a single sentence. Text-based questions could be found in a single sentence within the passage. The bridging-inference questions required the reader to integrate information from two or more sentences. A sample text-based question is "During which phase do the chromatids become aligned at the midregion, or equator, of the cell?" An example of a bridging-inference question is "How does cytokinesis differ for plant and animal cells?" Cronbach's alpha for the mitosis questions was .89 using the using Spearman–Brown formula adjusted for 30 items. A specific scoring key was created that incorporated all the components necessary to score a full point. Each question was worth 1 point; however, partial credit was awarded for components of the correct answer. Full credit was awarded if the student provided all the necessary information; partial credit (i.e., with .25 or .5 increments depending on the question) was given if the student provided only a portion of the correct answer. Fifteen percent of the data was scored by an independent grader who was blind to condition. The independent grader and an experimenter who was also blind to condition achieved a 97% agreement. Discrepancies between the graders were resolved by discussion, and the independent grader scored the remaining data.

Design and Procedure

The complete set of materials was presented in a single booklet with "stop" pages inserted between sections. This arrangement was to prevent participants from moving on to the next section after finishing the previous section before the allotted time had elapsed. The instructions stated that participants could recheck their answers but could not go on to the next section when they finished early. The participants were tested in small groups of 5 to 10 participants, and the experiment was completed in a single 90-min session. The procedure was conducted in the following order and time frame: mitosis passage (10 min) and questions (untimed), Nelson–Denny (15 min), MSI (8 min), prior knowledge (i.e., 54-item multiple-choice test; 20 min), and cell knowledge (5 min).

The prior-knowledge test was presented after the mitosis test so as to not to affect performance on the mitosis passage. Presenting questions about biology and cell knowledge was expected to prime relevant knowledge and potentially mitigate the impact of comprehension skill. If we assume that comprehension skill is one of the mediating factors involved in the access and use of relevant knowledge, then presenting additional cues to participants (administering knowledge tests) may weaken the impact of comprehension skill. For high-knowledge participants, we expected that priming would reduce the differences between skilled and less skilled comprehenders' knowledge access and use of knowledge. For low-knowledge participants, presenting a knowledge test before the mitosis passage may not only affect knowledge activation (of what little knowledge they have) but also may affect the results by causing anxiety or disinterest in the study; participants may expect a difficult test because they have little domain knowledge (see, e.g., McNamara & Kintsch, 1996). In a conservative effort to ensure that there were no prior-knowledge questions that could be correctly answered from the mitosis passage, two questions in the cell-knowledge test were eliminated from the analyses because of the potential overlap between the mitosis passage and the cell-knowledge questions.

RESULTS

The rejection level for all analyses was set at the .05 level, and the dependent measure was the proportion correct on the text-based and bridging-inference questions.

General Descriptive Statistics and Correlations

Table 2 presents the means and standard deviations as well as the minimum and maximum scores for each of the individual difference measures and the dependent

TABLE 2
Proportion Correct, Standard Deviations, and Minimum and Maximum Scores for Individual Difference and Dependent Measures

Measure	*M*	*SD*	*Minimum*	*Maximum*
MSI	.48	.14	0.20	0.92
Nelson–Denny	.57	.12	0.32	0.89
Humanities knowledge	.56	.18	0.21	1.00
Biology knowledge	.45	.13	0.10	0.86
Cell knowledge	.26	.21	0.00	0.83
Mitosis text-based	.54	.28	0.00	1.00
Mitosis bridging	.29	.22	0.00	0.90

Note. MSI = Metacomprehension Strategy Index.

measures. Table 3 presents correlations between the measures. The correlations between the individual difference measures indicate that the MSI correlated with the Nelson–Denny but not with the prior-knowledge measures. The Nelson–Denny correlated most highly with general humanities knowledge but also correlated significantly with the biology and cell-knowledge measures. This result is to be expected because performance on a comprehension skill test involves knowledge use and the topics in the Nelson–Denny tend to be general rather than related to science. The correlations between the aptitude measures and the comprehension measures indicate that the measures of domain knowledge (biology, cell, and combined) show higher correlations with comprehension than do the reading measures (MSI, Nelson–Denny) and humanities knowledge.

TABLE 3
Correlations Among the Individual Difference and Dependent Measures

	MSI	*ND*	*Hum PK*	*Bio PK*	*Cell PK*	*BC*	*TB*	*Brid*
ND	.34**	—						
Humanities knowledge	.13	.46**	—					
Biology knowledge	.18*	.41**	.47**	—				
Cell knowledge	.07	.28**	.25*	.55**	—			
Biology cell combined	.15	.39**	.41**	.88**	.88**	—		
Mitosis text—based	.20*	.35**	.31**	.40**	.33**	.42**	—	
Mitosis bridging	.35**	.38**	.36**	.55**	.48**	.58**	.51**	—
Mitosis total	.31**	.42**	.38**	.54**	.45**	.57**	.90**	.84**

Note. MSI = Metacomprehension Strategy Index; ND = Nelson–Denny; Hum PK = humanities prior knowledge; Bio PK = biology prior knowledge; Cell PK = cell prior knowledge; BC = biology cell; TB = text-based; Brid = bridging.

$^{*}p < .05$. $^{**}p < .001$.

Prior Domain Knowledge

Proportion correct on the 29 biology multiple-choice questions and the 6 open-ended cell-knowledge measures were converted to *z* scores and averaged to create a combined domain knowledge score. Participants were classified as high-knowledge ($n = 72$; $M = .70$, $SD = .63$; minimum = –.16, maximum = 2.70) or low-knowledge ($n = 71$; $M = -.71$, $SD = .39$; minimum = –1.59, maximum = –.17) using a median split on the resulting domain knowledge score. The difference between the two groups on the combined domain knowledge score was reliable, $t(141) = 15.89$, Cohen's $d = 2.69$.

Comprehension Skill

Only the Nelson–Denny was used as a measure of comprehension skill, rather than a combination of the Nelson–Denny and the MSI, because of the low correlations between the MSI and comprehension performance. However, the pattern of data as a function of the MSI scores, and the combined scores, was very similar to the pattern obtained using only the Nelson–Denny.

Participants were classified as skilled and less skilled comprehenders based on the total number correct on the Nelson–Denny test. Keeping in line with the prior-knowledge analysis, performance on the Nelson–Denny measure was converted to *z* scores. Participants were classified as less skilled comprehenders ($n = 69$; $M = -.81$, $SD = .53$; minimum = –2.14, maximum = –.17) or skilled comprehenders ($n = 74$; $M = .74$, $SD = .71$; minimum = .05, maximum = 2.68) based on a median split. The *z* score means translate to the following raw scores on the Nelson–Denny: $M_{\text{less skilled}} = 18.07$, $SD = 2.42$; minimum = 12, maximum = 21; $M_{\text{skilled}} = 25.16$, $SD = 3.23$; minimum = 22, maximum = 34.

ANALYSES

Full Analysis: Reading Comprehension

A mixed 2 × 2 × 2 × 2 analysis of variance was conducted on the proportion of correct responses on the mitosis passage. The analysis included the within-subjects factor of question type (text-based or bridging) and the between-subjects factors of text type (high cohesion, low cohesion), comprehension skill (skilled, less skilled), and science knowledge (high, low). The means and standard deviations as a function of knowledge, text type, skill, and question type are provided in Table 4. Overall, participants correctly answered more text-based questions ($M = .54$, $SD = .28$) than bridging questions ($M = .29$, $SD = .22$), $F(1, 135) = 147.73$, $MSE = 0.03$, Cohen's $d = .99$. There was a main effect for comprehension skill, $F(1, 135) = 15.07$,

TABLE 4
Proportion Correct on the Mitosis Passage as a Function of Question Type, Text Type, Comprehension Skill, and Knowledge

	Low Knowledge						*High Knowledge*					
	Low Cohesion			*High Cohesion*			*Low Cohesion*			*High Cohesion*		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Less skilled												
Text-based	.41	.21	20	.39	.24	19	.66	.27	14	.44	.29	16
Bridging	.12	.11	20	.22	.11	19	.33	.25	14	.26	.21	16
Skilled												
Text-based	.51	.25	17	.53	.25	15	.61	.25	21	.77	.24	21
Bridging	.17	.14	17	.33	.23	15	.44	.17	21	.44	.28	21

MSE = .07, Cohen's *d* = .63, indicating that skilled comprehenders (*M* = .48, *SD* = .22) scored higher than less skilled comprehenders (*M* = .35, *SD* = .19). There was also a main effect for knowledge, $F(1, 135) = 25.56$, *MSE* = 0.07, Cohen's *d* = .76, indicating that the high-knowledge participants scored higher (*M* = .49, *SD* = .22) on the comprehension questions than the low-knowledge participants (*M* = .34, *SD* = .17).

The main effect of text type was not reliable, $F(1, 135) < 1$, but there was a significant two-way interaction between text type and comprehension skill, $F(1, 135) = 4.69$, *MSE* = .07. The two-way interaction indicated that cohesion did not benefit comprehension for less skilled readers, $F(1, 67) < 1$ ($M_{\text{low cohesion}} = .36$, *SD* = .20, $M_{\text{high cohesion}} = .32$, *SD* = .18), whereas there was a marginal benefit of cohesion for the skilled readers, $F(1, 73) = 3.37$, *MSE* = .045, $p = .07$, Cohen's *d* = .43, ($M_{\text{low cohesion}} = .44$, *SD* = .20, $M_{\text{high cohesion}} = .53$, *SD* = .22). This two-way interaction was modified by the four-way interaction among text type, question type, knowledge, and comprehension skill, $F(1, 135) = 3.96$, *MSE* = .03, $p < .05$ (see Figure 1). To better understand this interaction and to answer the central question of this study, we performed separate analyses for the high-knowledge and low-knowledge comprehenders. (No other effects or interactions were significant.)

Low-Knowledge Readers

A mixed 2 × 2 × 2 analysis of variance was conducted with text type and comprehension skill as between-subjects factors and question type as the within-subjects factor. The left panel of Figure 1 depicts performance on the comprehension questions as a function of comprehension skill, text type, and question type. For low-knowledge readers, there was a main effect of question type, $F(1, 67) = 87.56$, *MSE* = .026, Cohen's *d* = 1.24, indicating that participants answered more

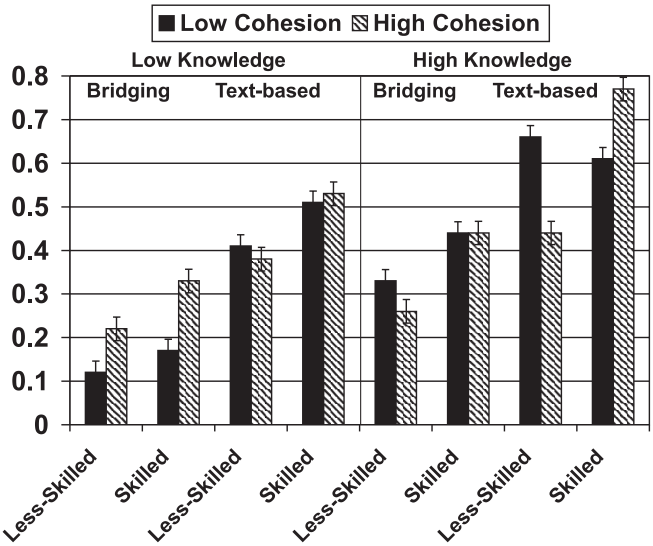

FIGURE 1 Proportion of correct bridging-inference and text-based questions on the mitosis passage as a function of text cohesion, comprehension skill, and knowledge. The panel on the left represents data for the low-knowledge readers, and the panel on the right represents data for the high-knowledge readers.

text-based questions correctly (M = .46, SD = .24) than bridging questions (M = .21, SD = .16). In addition, there was a significant effect of comprehension skill, F(1, 67) = 7.08, MSE = .053, Cohen's d = .56, indicating that skilled comprehenders (M = .37, SD = .18) scored higher than less skilled comprehenders (M = .28, SD = .14) on the comprehension questions. There was a marginal effect of text type, F(1, 67) = 2.76, MSE = .053, p = .055 (one-tailed), Cohen's d = .53, such that participants scored higher on the high-cohesion text (M = .37, SD = .19) as compared to the low-cohesion text (M = .30, SD = .15). However, a two-way interaction between question type and text type, F(1, 67) = 5.59, MSE = .053, indicated that this benefit of cohesion emerged only on the bridging inference questions, F(1, 69) = 11.61, MSE = .024, Cohen's d = .83 ($M_{\text{high cohesion}}$ = .27, SD = .18; $M_{\text{low cohesion}}$ = .14, SD = .13) and was not reliable for the text-based questions, F(1, 69) < 1 ($M_{\text{high cohesion}}$ = .45, SD = .24; $M_{\text{low cohesion}}$ = .46, SD = .23). No other effects were significant.

In sum, low-knowledge participants better understood the texts if they were skilled readers, indicating that comprehension skill helped to partially compensate for their knowledge deficits. Text cohesion also helped their comprehension; however, this benefit emerged only on the bridging questions. It appears that cohesion helped the low-knowledge readers to understand some relations among ideas in the text, at least enough to raise their performance above floor.

High-Knowledge Readers

A 2 × 2 × 2 mixed analysis of variance with question type as the within-subjects factor and comprehension skill and text type as the between-subjects factors was conducted for the high-knowledge readers. There was a significant effect of question type, $F(1, 68) = 63.99$, $MSE = .035$, Cohen's $d = .96$, indicating that more text-based questions were answered correctly ($M = .62$, $SD = .28$) than bridging questions ($M = .37$, $SD = .24$). The between-subjects factors revealed a reliable effect of comprehension skill, $F(1, 68) = 8.13$, $MSE = .086$, Cohen's $d = .65$, no effect of text type, $F(1, 68) \leq 1$, but a reliable interaction between text type and comprehension skill, $F(1, 68) = 5.23$, $MSE = .086$. This two-way interaction was qualified by a significant three-way interaction among question type, text type, and comprehension skill, $F(1, 68) = 6.51$, $MSE = .035$.

The right panel of Figure 1 depicts the interaction between text type, comprehension skill, and question type. For bridging questions, the interaction between text type and comprehension skill was not significant, $F < 1$. However, there was a significant interaction between text type and comprehension skill for text-based questions, $F(1, 68) = 9.78$, $MSE = .068$. Accordingly, less skilled, high-knowledge participants better comprehended the low-cohesion text ($M = .66$, $SD = .27$) than the high-cohesion text ($M = .44$, $SD = .29$), $t(28) = 2.12$, Cohen's $d = .79$, for text-based questions. This result is a reverse cohesion effect. In addition, for text-based questions, skilled, high-knowledge readers remembered significantly more from high-cohesion text ($M = .77$, $SD = .24$) than low-cohesion text ($M = .61$, $SD = .25$), $t(40) = 2.16$, Cohen's $d = .65$.

One of our claims was that the less skilled, high-knowledge readers are induced to utilize their knowledge to understand the low-cohesion text. We also claimed that the skilled, high-knowledge readers use their knowledge, or generate inferences, for both types of cohesion. If this assumption is true, then the performance of the less skilled, high-knowledge readers should be similar to the performance of skilled, high-knowledge readers when reading the low-cohesion text. This is because both less skilled and skilled high-knowledge readers are assumed to recruit their knowledge to understand the text but for different reasons. Skilled high-knowledge readers actively process a text for both types of cohesion, whereas the less skilled high-knowledge readers incorporate their knowledge when the text contains gaps (i.e., low cohesion). This assumption is supported by the lack of difference between the performance of the less skilled and skilled high-knowledge readers' performance on the text-based questions when they read the low-cohesion text, $t(33) < 1$.

A second claim was that the less skilled, high-knowledge readers do not actively recruit and integrate their knowledge when the text is highly cohesive. In contrast, skilled, high-knowledge readers are assumed to incorporate their knowledge even when reading the high-cohesion text. Support for this assumption is provided by comparing the performance of less skilled and skilled high-knowledge readers who read the high-cohesion text. If the less skilled, high-knowledge readers did not use their knowledge actively when reading the high-cohesion text, then their performance should be lower than the skilled, high-knowledge readers who read the high-cohesion text. Indeed, for text-based questions, less skilled, high-knowledge readers ($M = .44$, $SD = .29$) scored significantly lower when reading the high-cohesion text than did skilled, high-knowledge readers ($M = .77$, $SD = .24$) who read the high-cohesion text, $t(35) = 3.83$, Cohen's $d = 1.24$. In fact, comprehension performance of the less skilled, high-knowledge readers who read the high-cohesion text ($M = .44$, $SD = .29$) was significantly lower on text-based questions than the skilled, high-knowledge readers who read the low-cohesion text ($M = .61$, $SD = .25$), $t(35) = 1.93$, $p < .05$ (one-tailed), Cohen's $d = .63$.

COMPARISONS ACROSS KNOWLEDGE LEVELS

One explanation for the reverse cohesion effect is that less skilled, high-knowledge readers' process the high-cohesion text passively, and thus they fail to utilize their knowledge. If less skilled, high-knowledge readers fail to utilize their knowledge when reading the high-cohesion text, then their performance should be similar to that of the skilled, low-knowledge readers. Indeed, the results indicate that textbase comprehension for skilled, low-knowledge readers who read the low-cohesion text, $t(34) < 1$, and high cohesion text, $t(33) < 1$, was equivalent to that of less skilled, high-knowledge readers who read the high-cohesion text.

In contrast, the performance on text-based questions by the less skilled, high-knowledge readers who read the low-cohesion text ($M = .66$, $SD = .27$) was higher than the performance of the less skilled, low-knowledge readers who read the low-cohesion ($M = .41$, $SD = .21$), $t(32) = 3.10$, Cohen's $d = 1.03$, and high-cohesion texts ($M = .39$, $SD = .24$), $t(31) = 3.11$, Cohen's $d = 1.06$. We take this difference to be evidence that the less skilled, high-knowledge readers who read the low-cohesion text utilized their knowledge to monitor comprehension and make elaborations.

For low-knowledge participants, the high-cohesion text helped readers to score higher on the bridging-inference questions. We presume that the added cohesion helped the low-knowledge participants because it provided them with the necessary information to understand the relations among the ideas in the text that were targeted by the bridging-inference questions. In essence, the added cohesion helped the low-knowledge readers escape the floor-level performance on bridging questions exhibited by low-knowledge readers who read the low-cohesion text. Their performance was still not stellar by any means (i.e., $M = .27$), but the added cohesion helped to alleviate some of their knowledge deficits. Given that the text was very difficult, we predicted that neither the low- nor the high-knowledge readers would develop a strong situation model (McNamara, 2001), and thus performance on the bridging-inference questions between the knowledge groups would be similar. If this assertion is true, then low-knowledge participants who read the high-cohesion text should perform similarly on bridging-inference questions to the high-knowledge readers who read the low- or high-cohesion texts. Indeed, analyses revealed that there was no significant difference on bridging-inference questions comparing less skilled, low-knowledge readers who read the high-cohesion text to less skilled, high-knowledge readers who read either the low-cohesion text, $t(31) = 1.49$, or high-cohesion text, $t(33) < 1$.

Similarly, there was no significant difference on bridging questions between skilled, low-knowledge readers who read the high-cohesion text and skilled, high-knowledge readers who read either the low-cohesion text, $t(34) = 1.76$, $p = .08$, or the high- cohesion text, $t(34) = 1.24$, $p = .225$. In other words, the data support the notion that the high-cohesion text provided low-knowledge readers with cues that helped them to understand some of the relations in the text (as assessed by the bridging-inference questions). Second, this added cohesion helped the low-knowledge readers develop a weak situation model that was comparable to high-knowledge readers. Consequently, for bridging questions, there was little impact of knowledge above the effect of added cohesion.

SUMMARY

In summary, low-knowledge readers benefited from text cohesion but only according to their performance on the bridging-inference questions. However, irrespective of cohesion, low-knowledge readers benefited from comprehension skill. On the other hand, less skilled, high-knowledge readers showed better textbase comprehension of the low-cohesion texts (i.e., they exhibited the reverse cohesion effect), whereas skilled, high-knowledge readers benefited from reading the high-cohesion text.

DISCUSSION

Research has shown that students often have problems understanding texts because they are written in a manner that is suboptimal for learning (Beck et al., 1989). Thus, improving text cohesion improves comprehension (Beck et al., 1991; Britton & Gülgöz, 1991; Lehman & Schraw, 2002; Linderholm et al., 2000; Vidal-Abarca et al., 2000). However, research also suggests that creating highly cohesive texts may not be beneficial for all readers (McNamara, 2001; Voss & Silfies, 1996). The catch–22 arising from the interaction between cohesion and individual differences was the focus of this study. The goal of this study was to determine whether the reverse cohesion effect would be offset by comprehension skill.

Explaining the Reverse Cohesion Effect: The Role of Active Processing

The explanation proffered by McNamara et al. (1996) for the reverse cohesion effect is that the cohesion gaps induce inferences that enhance comprehension and that high-knowledge readers are able to generate those inferences. This explanation relies on the assumptions that increased active processing leads to improved learning (Bereiter & Scardamlia, 1987; Chi et al., 1994; Einstein, McDaniel, Owen, & Coté, 1990; Rauenbusch & Bereiter, 1991; Slamecka & Graf, 1978) and that many readers do not actively process the texts and thus need the gaps in the text to induce active processing (McNamara, 2001; McNamara et al., 1996; Vidal-Abarca et al., 2000).

By *active processing* we mean two things: Learners use prior knowledge and reading strategies to build a coherent mental representation of the text, and readers closely monitor whether their mental representation of a text corresponds to the situation described in the text. Skilled readers, by definition, are more active processors. Skilled readers use more strategies, make more inferences, more effectively monitor their comprehension, and are better able to integrate their knowledge with the text than are less skilled readers (Cain et al., 2001; Lau & Chan, 2003). Consequently, we proposed that skilled comprehenders actively process the text even when the text has a high overlap with the learner's knowledge.

Skilled, High-Knowledge Readers Benefit From Cohesion in Difficult Text

The results of this study support this hypothesis. There was no impairment from increasing cohesion for skilled, high-knowledge comprehenders. In fact, skilled, high-knowledge readers performed better on the high-cohesion text. This result is congruent with the findings of Voss and Silfies (1996) who found that skilled comprehenders scored higher than less skilled comprehenders when they read a high-cohesion text. It is also consistent with Linderholm et al. (2000) who found that cohesion particularly benefits comprehension of difficult texts. Our findings also build on the results of O'Reilly and McNamara (2002, in press) and Adams, Bell, and Perfetti (1995) who found that comprehension skill can benefit even high-knowledge readers.

Only Less Skilled, High-Knowledge Readers Display a Reverse Cohesion Effect

Our findings indicate that the reverse cohesion effect occurs only for less skilled, high-knowledge readers. When less skilled, high-knowledge readers read a high-cohesion text, the partial overlap between the text and knowledge creates a situation in which readers become passive. Such passive processing can lead to a sense of false understanding (i.e., poor comprehension monitoring), and, as such, less skilled, high-knowledge readers may only skim the text. Skimming could lead learners to miss important details in the text, and therefore they may score lower on questions that tap into details or single ideas (e.g., text-based questions). Support for the notion that less skilled, high-knowledge readers did not actively process the text comes from a comparison with low-knowledge participants. Skilled, low-knowledge participants performed as well on the text-based questions as did the less skilled, high-knowledge participants who read the high-cohesion text. If the less skilled, high-knowledge participants who read the high-cohesion text actively incorporated their knowledge while reading, they should have shown better comprehension than the low-knowledge participants. We do not mean that the less skilled comprehenders are not capable of active processing but that they are less likely to do so on their own. Cohesion gaps scaffold less skilled readers to generate knowledge-based inferences.

Cohesion Helps Low-Knowledge Readers on Bridging-Inference Questions

With respect to low-knowledge learners, the results of this study suggest that learning is improved when they read the high-cohesion text. However, the effect of cohesion in this study was restricted to bridging-inference questions. In general, comprehension is best on the bridging-inference questions when the low-knowledge learners are given the high-cohesion text because the high-cohesion text makes the connections among ideas in the text more explicit. Indeed, our results indicate that low-knowledge readers who read the high-cohesion text performed similarly to high-knowledge readers on bridging-inference questions. However, performance for all participants was still quite low on the bridging-inference questions, indicating that few participants (low or high knowledge) formed a coherent situation model.

Active Processing Helps Low-Knowledge Readers

We also confirmed previous results showing that comprehension skill improves learning for the low-knowledge readers (Adams et al., 1995; O'Reilly & McNamara, 2002, in press). The skilled, low-knowledge reader can still make sense of a text by actively using their general knowledge and strategies. One example of how skilled comprehenders make strategic use of their knowledge is through elaboration. The production of elaborations can improve comprehension by making the text more memorable (e.g., Pressley et al., 1992). Recent work has shown that skilled comprehenders were more likely than less skilled comprehenders to produce a higher number and quality of elaborations than less skilled comprehenders (Best, Ozuru, & McNamara, 2004). Furthermore, McNamara

(2004) found that reading-strategy training helped low-knowledge participants perform as well on the same low-cohesion mitosis text used in this study as did high-knowledge participants who were not provided with such reading-skill training. Both the results of McNamara and the results of this study underscore the importance of comprehension skill for understanding difficult texts.

There are several other reasons why comprehension skill may help low-knowledge readers, such as increased working memory capacity (e.g., Daneman & Carpenter, 1980), better text-based inferencing ability (e.g., Long et al., 1994), better lexical knowledge and lexical identification (Perfetti, 1985; Perfetti & Hart, 2002), and motivation (e.g., Alexander, 1997; Guthrie & Alao, 1997). Although the design of this study makes it difficult to discern the precise nature of how comprehension skill helps low-knowledge readers, we forward the view that comprehension skill is primarily a function of readers' effective use of knowledge and strategies (e.g., McNamara, de Vega, & O'Reilly, in press; McNamara & O'Reilly, in press).

Reinterpreting Earlier Findings by McNamara and Colleagues

In the early research by McNamara and colleagues, it was predicted and found that the reverse cohesion effect arises primarily at the situation-model level of processing (McNamara & Kintsch, 1996; McNamara et al., 1996). The theoretical basis for this result was that inference processing would most benefit deeper levels of comprehension. According to Kintsch's (1988, 1998) construction-integration model, comprehension includes surface, textbase, and situation-model levels, which differ in degree of depth. The surface level comprises the words and syntax; the textbase is the deeper meaning of those words; and the situation model is the integration of the textbase and prior knowledge. Because the reverse cohesion effect arises from the integration of the textual information with related knowledge, it was expected that the effects would be most apparent on measures that tapped into that integration. Indeed, McNamara et al. found the reverse cohesion effect on accuracy for problem-solving and bridging-inference questions and according to a keyword sorting task. McNamara and Kintsch found the reverse cohesion effect on bridging-inference questions and according to a keyword sorting task. These tasks require a deep understanding and thus a coherent situation model to perform well on them (e.g., Chi, 2000; Kintsch, 1994).

In contrast to the two previous studies by McNamara and colleagues (McNamara & Kintsch, 1996; McNamara et al., 1996), the results reported in McNamara (2001) and in this study showed a reverse cohesion effect only on text-based questions, which were assumed or designed to tap into the readers' textbase level of understanding. These findings are congruent with other findings

(Britton & Gülgöz, 1991; Magliano et al., 2005) that high-cohesion text benefits comprehension on text-based questions. A highly cohesive text has more connections among concepts and thus facilitates the development of the textbase. In turn, this improves performance on text-based questions.

Why did high-knowledge readers, here and in McNamara (2001), not benefit from low-cohesion text as measured by the bridging-inference questions? The answer is likely to lie in the difference between the texts used in these studies and the two previous studies (i.e., McNamara & Kintsch, 1996; McNamara et al., 1996). The texts in these more recent studies are more difficult; students often have little knowledge about cells and biological processes related to cells. In addition, cell mitosis is a complex process in that it contains numerous, interconnected subcomponents and processes. The idea that the mitosis text used here (and in McNamara, 2001) is more difficult than the texts used in the previous studies is supported by the data. In this study and in McNamara, there was a large difference (approximately 50%) for the students' performance on text-based questions as compared to bridging-inference questions. In contrast, in the previous studies, the overall proportion correct for text-based and bridging-inference questions was similar, and approximately only 3% higher for text-based questions over bridging inference (McNamara & Kintsch, 1996, Experiments 1 and 2; McNamara et al., 1996, Experiment 2). Thus, in the previous studies that found the reverse cohesion effect for situational model questions (McNamara & Kintsch, 1996, Experiments 1 and 2; McNamara et al., 1996, Experiment 2), participants were assumed to have formed an effective situation model. In contrast, for this study and McNamara, which used the more difficult cell mitosis text, participants' relative ability to form a coherent situation model was lacking in relation to their ability to form an adequate textbase.

As such, one explanation proposed by McNamara (2001) to account for the three studies was that the high-knowledge readers were not affected by cohesion according to text-based questions in the McNamara et al. (1996) and McNamara and Kintsch (1996) studies because few gains were possible at the textbase level of understanding. In those studies, the text topics were easier, and the high-knowledge participants potentially answered the text-based questions from their own knowledge as opposed to the text itself. McNamara proposed that high-knowledge readers benefit from low-cohesion texts at the level of processing that is in most need of improvement. In the case of the McNamara et al. and McNamara and Kintsch studies, in which the texts were easier, high-knowledge readers were able to easily construct the textbase. However, the deep-level processing induced by the low-cohesion text enhanced the situation-model level of understanding. In the case of McNamara. in which the text was more difficult, high-knowledge readers were unable to construct the textbase without scaffolding, and thus the low-cohesion text enhanced comprehension at that level.

Knowledge Can Affect the Textbase and Comprehension Skill Can Affect the Situation Model

Voss and Silfies (1996) found that knowledge was primarily related to the development of the situation model, whereas comprehension skill was related to the development of the textbase. They also found that the effect of comprehension skill was higher for the high-cohesion text. Our results are consistent with Voss and Silfies in that we found evidence that comprehension skill is important for the development of the textbase and that the effect of comprehension skill was higher for the high-cohesion text as compared to the low-cohesion text. However, we also found that comprehension skill can support the development of the situation model (as revealed by bridging-inference questions) for low-knowledge readers. That is, there was a main effect of comprehension skill for low-knowledge readers. Increased reading skill can help readers make some of the inferences to help form a partial situation model. This is congruent with work that shows skilled readers make more appropriate inferences (Cain et al., 2001). We also found that knowledge can support the textbase; however, this depends on both comprehension skill and text cohesion. For instance, there was a large effect of knowledge for less-skilled comprehenders who read the low-cohesion text when students answered text-based questions (and presumably the textbase level of understanding). Conversely, there was an effect of knowledge when skilled comprehenders read the high-cohesion text and answered text-based questions. These two findings indicate that knowledge can also have an effect on the reader's textbase.

Our findings may differ from Voss and Silfies's (1996) for a number of reasons. First, the knowledge measures in the two studies were different. In Voss and Silfies, the history passage was fictitious, and consequently what could be measured was more general knowledge of history as opposed to a domain-specific measure of knowledge used in our study. A more specific measure of knowledge may be more sensitive in detecting a relation between knowledge and the formation of the textbase. Second, the history texts used in Voss and Silfies contained a narrative text structure, or schema, that could be used to scaffold the integration of new information. For instance, a war narrative usually involves at least two groups (characters) that compete for resources (motive) by attacking each other (means) to gain control over the other group (outcome). Although the text content in Voss and Silfies was fictitious, learning was facilitated because readers have a general narrative schema about war and conflict that they can use to fill in the new information. In contrast, the texts used here contained relatively unfamiliar concepts and difficult vocabulary (e.g., "kinetochores"). Arguably, many participants had almost no prior schema, or at best a highly impoverished schema, that they could use to help them learn the new material. When the text topic is very difficult and unfamiliar such that the reader has little knowledge of the domain, prior knowledge could help to form the textbase. However, future research is required to determine precisely how text difficulty and familiarity affect a reader's ability to form both the textbase and the situation model.

Implications for Education

Although the results of this study are limited by the fact that we included only a single text, we propose that they nonetheless have potentially important implications for educational practice. Our solution to the catch–22 regarding text cohesion is to improve both text cohesion and comprehension skill. Although revising all current textbooks may not be feasible, educators and publishers should consider creating new texts that are written in a manner that is consistent with the level of prior knowledge that is required before a student takes the particular course. In addition, we propose that interventions that target reading comprehension and reading strategies are particularly needed in the U.S. school system: Teachers rarely provide instruction on strategies that emphasize comprehension (e.g., Durkin, 1978–1979; Taylor, Pearson, Clark, & Walpole, 1999), and students rarely engage in such strategic processing (Garner, 1990; Pressley et al., 1992; Rothkopf, 1988). According to our results, comprehension skill is critical for both high- and low-knowledge students to help them understand science text. Most important, comprehension skill opens the door to focusing on text improvement. That is, science comprehension in the schools is most likely to improve if efforts are made to increase text cohesion (e.g., by publishers) alongside efforts to provide reading-strategy training to students (e.g., McNamara, 2004). We recommend that future studies be directed at testing whether our results generalize to different text domains and also explore how text difficulty and familiarity affect the reverse cohesion effect.

ACKNOWLEDGMENTS

This work was conducted while Tenaha O'Reilly was a postdoctoral fellow at the University of Memphis. Tenaha is currently at Educational Testing Service.

REFERENCES

Adams, B, Bell, L., & Perfetti, C. (1995). A trading relationship between reading skill and domain knowledge in children's text comprehension. *Discourse Processes, 20,* 307–323.

Alexander, P. (1997). Knowledge-seeking and self-schema: A case for the motivational dimensions of exposition. *Educational Psychologist, 32,* 83–94.

Arbuckle, T., Vanderleck, V., Harsany, M., & Lapidus, S. (1990). Adult age differences in memory in relation to availability and accessibility of knowledge-based schemas. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 305–315.

Baker, L. (1982). An evaluation of the role of metacognitive deficits in learning disabilities. *Topic in Learning and Learning Disabilities, 2,* 27–35.

Beck, I., McKeown, M., & Gromoll, E. (1989). Learning from social studies texts. *Cognition and Instruction, 6,* 99–158.

Beck, I. L., McKeown, M. G., Sinatra, G. M., & Loxterman, J. A. (1991). Revising social studies text from a text-processing perspective: Evidence of improved comprehensibility. *Reading Research Quarterly, 26,* 251–276.

Bereiter, C., & Bird, M. (1985). Use of thinking aloud in identification and teaching of reading comprehension strategies. *Cognition and Instruction, 2,* 131–156.

Bereiter, C., & Scardamlia, M. (1987). *The psychology of written composition.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Best, R., Ozuru, Y., & McNamara, D. S. (2004). Self-explaining science texts: Strategies, knowledge and reading skill. *Proceedings of the Sixth International Conference of the Learning Sciences,* Santa Monica, CA.

Bowen, B. A. (1999). Four puzzles in adult literacy: Reflections on the national adult literacy survey. *Journal of Adolescent and Adult Literacy, 42,* 314–323.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11,* 717–726.

Britton, B. K., & Gülgöz, S. (1991). Using Kintsch's computational model to improve instructional text: Effects of repairing inference calls on recall and cognitive structures. *Journal of Educational Psychology, 83,* 329–345.

Brown, A. (1982). *Learning how to learn from reading.* In J. A. Langer & M. T. Smith-Burke (Eds.), *Reader meets author: Bridging the gap* (pp. 26–54). Newark, DE: International Reading Association.

Brown, J., Fishco, V., & Hanna, G. (1993). *Manual for scoring and interpretation, Forms G and H.* Chicago: Riverside.

Cain, K., Oakhill, J., Barnes, M., & Bryant, P. (2001). Comprehension skill, inference making ability, and their relation to knowledge. *Memory & Cognition, 29,* 850–859.

Chi, M. (2000). Self-explaining: The dual processes of generating inference and repairing mental models. In R. Glaser (Ed.), *Advances in instructional psychology: Educational design and cognitive science* (pp. 161–238). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Chi, M. T. H., De Leeuw, N., Chiu, M., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science, 18,* 439–477.

Cornoldi, C., De Beni, R., & Pazzaglia, F. (1996). Profiles of reading comprehension difficulties: An analysis of single cases. In C. Cornoldi & J. Oakhill, (Eds.), *Reading comprehension difficulties: Processes and intervention* (pp. xx–xx). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Cottrell, K., & McNamara, D. S. (2002). Cognitive precursors to science comprehension. In W. D. Gray & C. D. Schunn (Eds.), *Proceedings of the Twenty-Fourth Annual Meeting of the Cognitive Science Society* (pp. 244–249). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Daneman, M., & Carpenter, P. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19,* 450–466.

Durkin, D. (1978–1979). What classroom observations reveal about reading comprehension instruction. *Reading Research Quarterly, 14,* 481–533.

Einstein, G. O., McDaniel, M. A., Owen, P. D., & Coté, N. C. (1990). Encoding and recall of texts: The importance of material appropriate processing. *Journal of Memory and Language, 29,* 566–581.

Forget, M. A. (1999). *Comparative effects of three methods of staff development in content area reading instruction on urban high school teachers.* Unpublished doctoral dissertation, Old Dominion University.

Garner, R. (1990). When children and adults do not use learning strategies: Toward a theory of settings. *Review of Educational Research, 60,* 517–529.

Glenberg, A., Wilkinson, A., & Epstein, W. (1982). The illusion of knowing: Failure in the self-assessment of comprehension. *Memory & Cognition, 10,* 597–602.
Goldman, S., & Saul, E. (1990). Flexibility in text processing: A strategy competition model. *Learning and Individual Differences, 2,* 181–219.
Graesser, A. C., McNamara, D. S., & Louwerse, M. M. (2003). What do readers need to learn in order to process coherence relations in narrative and expository text? In A. P. Sweet & C. E. Snow (Eds.), *Rethinking reading comprehension* (pp. 82–98). New York: Guilford.
Graesser, A. C., McNamara, D. S., Louwerse, M. M., & Cai, Z. (2004). Coh-Metrix: Analysis of text on cohesion and language. *Behavioral Research Methods, Instruments, and Computers, 36,* 193–202.
Guthrie, J., & Solomon, A. (1997). Designing contexts to increase motivations for reading. *Educational Psychologist, 32,* 95–105.
Hannon, B., & Daneman, M. (2001). A new tool for measuring and understanding individual differences in the component processes of reading comprehension. *Journal of Educational Psychology, 93,* 103–128.
Hoover, W., & Gough, P. (1990). The simple view of reading. *Reading and Writing, 2,* 127–160.
Kintsch, W. (1988). The use of knowledge in discourse processing: A construction-integration model. *Psychological Review*, *95,* 163–182.
Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist, 49,* 294–303.
Kintsch, W. (1998). *Comprehension: A paradigm for cognition.* Cambridge, MA: Cambridge University Press.
Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction and representation of knowledge. *Psychological Review, 104,* 211–240.
Lau, K., & Chan, D. (2003). Reading strategy use and motivation among Chinese good and poor readers in Hong Kong. *Journal of Research in Reading, 26,* 177–190.
Lehman, S., & Schraw, G. (2002). Effects of coherence and relevance on shallow and deep text processing. *Journal of Educational Psychology, 94,* 738–750.
Linderholm, T., Everson, M., van den Broek, P., Mischinski, M., Crittenden, A., & Samuels, J. (2000). Effects of causal text revisions on more- and less-skilled readers' comprehension of easy and difficult texts. *Cognition and Instruction, 18,* 525–556.
Long, D. L., Oppy, B. J., & Seely, M. R. (1994). Individual differences in the time course of inferential processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 1456–1470.
Lord, F. M., & Novick, M. R. (1968). *Statistical theories of mental test scores.* Reading, MA: Addison-Wesley.
Magliano, J. P., & Millis, K. K. (2004). Assessing reading skill with a think-aloud procedure. *Cognition and Instruction, 21,* 251–283.
Magliano, J. P., Todaro, S. Millis, K. K., Wiemer-Hastings, K., Kim, H. J., & McNamara, D. S. (2005). Changes in reading strategies as a function of reading training: A comparison of live and computerized training. *Journal of Educational Computing Research, 32,* 185–208.
Magliano, J. P., Wiemer-Hastings, K., Millis, K. K., Muñoz, B. D., & McNamara, D. S. (2002). Using latent semantic analysis to assess reader strategies. *Behavior Research Methods, Instruments, and Computers, 34,* 181–188.
McKoon, G., & Ratcliff, R. (1992). Inference during reading. *Psychological Review, 99,* 440–466.
McNamara, D. S. (2001). Reading both high and low coherence texts: Effects of text sequence and prior knowledge. *Canadian Journal of Experimental Psychology, 55,* 51–62.
McNamara, D. S. (2004). SERT: Self-explanation reading training. *Discourse Processes, 38,* 1–30.
McNamara, D. S., de Vega, M., & O'Reilly, T. (in press). Comprehension skill, inference making, and the role of knowledge. In F. Schmalhofer & C. A. Perfetti (Eds.), *Higher level language processes in the brain: Inference and comprehension processes.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

McNamara, D. S., & Kintsch, W. (1996). Learning from text: Effects of prior knowledge and text coherence. *Discourse Processes, 22,* 247–287.

McNamara, D. S., Kintsch, E., Songer, N. B., & Kintsch, W. (1996). Are good texts always better? Text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction, 14,* 1–43.

McNamara, D. S., & McDaniel, M. (2004). Suppressing irrelevant information: Knowledge activation or inhibition? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30,* 465–482.

McNamara, D. S., & O'Reilly, T. (in press). Theories of comprehension skill: Knowledge and strategies versus capacity and suppression. In F. Columbus (Ed.), *Progress in experimental psychology research.* Hauppauge, NY: Nova Science.

McNamara, D. S., Ozuru, Y., Louwerse, M. M., & Graesser, A. (2005, January). *Coh-Metrix: An automated measure of cohesion.* Paper presentation at the 16th annual Winter Text Conference, Jackson, WY.

Oakhill, J. (1984). Inferential and memory skills in children's comprehension of stories. *British Journal of Educational Psychology, 54,* 31–39.

Oakhill, J., & Yuill, N. (1996). Higher order factors in comprehension disability: Processes and remediation. In C. Cornaldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and Intervention* (pp. xx–xx). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

O'Reilly, T., & McNamara, D. S. (2002). What's a science student to do? *Proceedings of the twenty-fourth annual meeting of the Cognitive Science Society* (pp. 726–731).

O'Reilly, T., & McNamara, D. S. (in press). The impact of science knowledge, reading skill, and reading strategy knowledge on high school students' science achievement. *American Educational Research Journal.*

Perfetti, C. (1985). *Reading ability.* New York: Oxford University Press.

Perfetti, C. A., & Hart, L. (2002). The lexical bases of comprehension skill. In D. Gorfien (Ed.), *On the consequences of meaning selection* (pp. 67–86). Washington, DC: American Psychological Association.

Pressley, M., Wood, E., Woloshyn, V. E., Martin, V., King, A., & Menke, D. (1992). Encouraging mindful use of prior knowledge: Attempting to construct explanatory answers facilitates learning. *Educational Psychologist, 27,* 91–109.

Rauenbusch, F., & Bereiter, C. (1991). Making reading more difficult: A degraded text microworld for teaching reading comprehension strategies. *Cognition and Instruction, 8,* 181–206.

Rothkopf, E. (1988). Perspectives on study skills training in a realistic instructional economy. In C. E. Weinstein, E. Goetz, & P. A. Alexander (Eds.), *Learning and study strategies: Issues in assessment, instruction, and evaluation* (pp. 275–286). San Diego, CA: Academic.

Schmitt, M. (1990). A questionnaire to measure children's awareness of strategic reading process. *The Reading Teacher, 49,* 454–461.

Shapiro, A. M. (2004). How including prior knowledge as a subject variable may change outcomes of learning research. *American Educational Research Journal, 41,* 159–189.

Slamecka, N. J., & Graf, P. (1978). The generation effect: delineation of the phenomenon. *Journal of Experimental Psychology, 16,* 272–279.

Snow, C. (2002). *Reading for understanding: Toward an R&D program in reading comprehension.* Santa Monica, CA: RAND.

Spilich, G., Vesonder, G., Chiesi, H., & Voss, J. (1979). Text processing of domain-related information for individuals with high and low domain knowledge. *Journal of Verbal Learning and Verbal Behavior, 18,* 275–290.

Stothard, S. E., & Hulme, C. (1996). A comparison of reading comprehension and decoding difficulties in children. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties* (pp. 93–112). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Taylor, B., Pearson, P. D., Clark, K., & Walpole, S. (1999). Beating the odds in teaching all children to read: Lessons from effective schools and accomplished primary grade teachers. *The Reading Teacher, 53,* 156–159.

Vidal-Abarca, E., Martínez, G., & Gilabert, R. (2000). Two procedures to improve instructional text: Effects on memory and learning. *Journal of Educational Psychology, 92,* 107–116.

Voss, J., & Silfies, L. (1996). Learning from history text: The interaction of knowledge and Comprehension skill with text structure. *Cognition and Instruction, 14,* 45–68.

Willoughby, T., Waller, T. G., Wood, E., & MacKinnon, G. E. (1993). The effect of prior knowledge on an immediate and delayed associative learning task following elaborative interrogation. *Contemporary Educational Psychology, 18,* 36–46.

Wilson, P. T., & Anderson, R. C. (1986).What they don't know will hurt them: The role of prior knowledge in comprehension. In J. Orasanu (Ed.), *Reading comprehension: From research to practice* (pp. 31–48). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

APPENDIX A
Low-Cohesion Text

Cell Division

In eucaryotic cells there are two distinct but overlapping stages of cell division. In the first stage, mitosis, one complete set of chromosomes goes to each daughter cell. Mitosis guarantees that all of the genetic information in the nuclear DNA of the parent cell will go to each daughter cell.

In the second stage of cell division the cytoplasm and its contents divide. This process is cytokinesis. Cytokinesis is not as precise a process as mitosis. The amount of cytoplasm in a daughter cell will be about half of that in the parent cell. Each daughter cell will have about half of the organelles from the cytoplasm of the parent cell. But there is no precise mechanism working during cytokinesis to guarantee that each daughter cell will receive exactly half of the parent cell's cytoplasm and its organelles.

There are four distinct phases of mitosis: prophase, metaphase, anaphase, and telophase. These phases are well known because it is possible to observe them with the light microscope.

The first phase of mitosis is called prophase. During this phase the invisible threadlike chromatin of the nucleus condense into doubled chromosomes, each unit of which is called a chromatid. In the human cell there are 92 chromatids, which result from replication of the 46 chromosomes during the S phase of the interphase. The chromatids are attached at one place, like Siamese twins. The place where they are attached is called the centromere.

In animal cells, two small structures called centrioles move to opposite ends of the cell. Around each centriole, filaments develop and radiate in all directions. These filaments resemble a flower and are called asters. During later prophase, many of the filaments between the centrioles lengthen and connect with each other.

This network of filaments is called the spindle. Late in prophase some filaments of the spindle become attached to the kinetochores, which link the chromatids. In human cells, prophase lasts from 30 to 60 seconds.

In the second phase of mitosis, called metaphase, the chromatids become aligned at the midregion, or equator, of the cell. At this time the centrioles, if present, are at opposite ends of the cell. These regions are called the poles. Also during metaphase, the formation of the spindle is completed. Metaphase in human cells requires from two to six minutes.

At the beginning of anaphase, the third phase of mitosis, the kinetochores all divide at one time. This causes the chromatids to separate into daughter chromosomes. They then move equally to each pole.

The fourth stage of mitosis, called telophase, begins when all the chromosomes reach the two poles. During telophase the spindle begins to disappear. Later, the nuclear membrane reappears and encloses the two groups of chromosomes. While this is happening, the chromosomes begin to disappear as the chromatin material spreads throughout the nucleus.

Cytokinesis, the division of the cytoplasm, also begins during telophase. In animal cells the cytoplasm begins to pinch inward. In plant cells a partition, called the cell plate, begins to grow and divide the cytoplasm. Telophase in humans is quite variable, requiring from 30 to 60 minutes.

The preliminary steps of cytokinesis occur during the G phases of the cell cycle. In the G phases, various membrane structures, such as the endoplasmic reticulum and Golgi bodies, are produced out of components in the cytoplasm. Therefore, before cytokinesis, there is growth in the size of the cytoplasm and in the number of its organelles.

During the G phases there is reproduction of the mitochondria and chloroplasts. These organelles contain their own DNA, called organelle DNA, and their reproduction includes its replication.

Cytokinesis usually begins during telophase and continues after the nuclei of the daughter cells are completely formed. However, cytokinesis does not always occur when mitosis occurs. In some cells, such as those found in certain molds, mitosis occurs repeatedly without cytokinesis taking place. This results in cells with several nuclei.

APPENDIX B
High-Cohesion Text

Cell Division

Cell division occurs to reproduce and replace cells. The division of cells with a membrane-bound nucleus and organelles (eucaryotic cells) involves two distinct but overlapping stages, mitosis and cytokinesis. Mitosis occurs to replicate the cell's genetic material in the nucleus, whereas cytokinesis occurs to divide the gel-like liquid surrounding the cell's nucleus, called cytoplasm. Mitosis includes four phases which will be described here. Cytokinesis begins during the last of the four phases.

Mitosis

In the first stage of cell division, mitosis, one complete set of chromosomes goes to each new cell, which are called daughter cells. Mitosis guarantees that all of the genetic information from chromosomes in the nuclear DNA of the parent cell will go to each new daughter cell.

There are four distinct phases of mitosis called prophase, metaphase, anaphase, and telophase. These four phases are well known because it is possible to observe them with the simple light microscope.

1. Prophase

The first phase of mitosis is called prophase. Pro- means "before," hence this phase takes place before the other three phases. During prophase, invisible, threadlike DNA fibers of the nucleus, which are called chromatin, condense and double into two chromosomes, each unit of which is called a chromatid. Each pair of chromatids is attached at one place, like Siamese twins, to form a single chromosome. The place where these chromatids are attached is called the centromere. In the human cell there are 92 chromatids, which result from the replication of 46 chromosomes.

Soon after the chromatin material has condensed into doubled chromosomes, centrioles begin to migrate away from each other. Centrioles are two small structures located outside the cell's nucleus that help to produce a spindle which later divides the chromosomes between the two daughter cells. In cells with centrioles (which include all animal cells), the two centrioles move to opposite ends of the cell. Threadlike filaments, called asters, then develop around each centriole and radiate in all directions, resembling a flower. During later prophase, many of the filaments between the two centrioles lengthen and connect with each other. This network of filaments is called the spindle. Late in prophase some filaments of the spindle become attached to the kinetochores, which are protein structures located within the centromere of the chromatids. In human cells, prophase lasts from 30 to 60 seconds.

2. Metaphase

The second phase of mitosis is called metaphase because meta- means "mid." During metaphase the chromatids become aligned at the midregion, or equator, of the cell. At this time the centrioles, if present, are at opposite ends of the cell, which are called the poles. Also during metaphase, the formation of the spindle between the two centrioles is completed. Metaphase in human cells requires from two to six minutes.

3. Anaphase

At the beginning of the third phase of mitosis called anaphase (ana- means "away"), the kinetochores all divide at one time. This division causes the chromatids to separate into daughter chromosomes. The daughter chromosomes then move equally to each cell pole, which is why this is called the "away" phase.

4. Telophase

The fourth stage of mitosis is called telophase, because telo- means "end," and it begins when all the daughter chromosomes reach the two cell poles. During telophase the spindle that was completed in metaphase begins to disappear. Later, the nuclear membrane reappears and encloses the two groups of chromosomes at the two poles. While this is happening, the chromosomes begin to disappear and turn back into threadlike chromatin material, or DNA, which spreads throughout the nucleus. Cytokinesis, the division of the cytoplasm, also begins during telophase. Telophase in humans is quite variable, requiring from 30 to 60 minutes.

Cytokinesis

Cytokinesis, the second stage of cell division, begins to occur before mitosis is complete (usually during telophase) and continues after the nuclei of the daughter cells are completely formed. The preliminary steps of cytokinesis occur during the growth interphases (called the G phases) of the cell cycle. In the G phases, various membrane structures and organelles, such as the endoplasmic reticulum and Golgi bodies, are produced out of components in the cytoplasm. Therefore, before cytokinesis begins, there is growth in the size of the cytoplasm and in the number of its organelles. During the G phases there is also reproduction of the mitochondria and chloroplasts. These organelles contain their own DNA, called organelle DNA, and the organelles' reproduction includes the replication of the organelle DNA.

During cytokinesis, the cytoplasm and its contents divide. In animal cells, the cytoplasm divides by pinching inward, whereas in plant cells, a partition, called the cell plate, begins to grow and divide the cytoplasm. Cytokinesis is not as precise a process as mitosis because the amount of cytoplasm in a daughter cell will be about half, but not exactly half, the amount of cytoplasm in the parent cell. In addition, each daughter cell will have about half of the organelles from the cytoplasm of the parent cell. In contrast to mitosis, there is no precise mechanism working