Abstract
An understanding of how genomics information, including information about risk for common, multifactorial disease, can be used to promote personal health (personalized medicine) is becoming increasingly important for the American public. We undertook a quantitative content analysis of commonly used high school textbooks to assess how frequently the genetic basis of common multifactorial diseases was discussed compared with the “classic” chromosomal–single gene disorders historically used to teach the concepts of genetics and heredity. We also analyzed the types of conditions or traits that were discussed. We identified 3957 sentences across 11 textbooks that addressed multifactorial and “classic” genetic disorders. “Classic” gene disorders were discussed relatively more frequently than multifactorial diseases, as was their genetic basis, even after we enriched the sample to include five adult-onset conditions common in the general population. Discussions of the genetic or hereditary components of multifactorial diseases were limited, as were discussions of the environmental components of these conditions. Adult-onset multifactorial diseases are far more common in the population than chromosomal or single-gene disorders; many are potentially preventable or modifiable. As such, they are targets for personalized medical approaches. The limited discussion in biology textbooks of the genetic basis of multifactorial conditions and the role of environment in modifying genetic risk may limit the public’s understanding and use of personalized medicine.

Key Words: Biology; curriculum; genetics; genomics; quantitative analysis; textbook.

As the use of genomics for assessing risk for common, multifactorial diseases increases, so too should the general public’s knowledge of the genetic and environmental components of these conditions, so that the public can become active participants in health care (Bosompra et al., 2000; Sanderson et al., 2004). Advances in the understanding of the genomic basis of chronic disease and genomic testing technologies have increased the integration of genomics into health care. As a result, the practice of medical genetics has expanded beyond the identification of those at risk for rare and often untreatable single gene disorders, to the identification of those with an increased yet potentially modifiable genetic risk for common, multifactorial chronic diseases. An estimated 95% of American high school graduates complete biology courses; therefore, integrating genomics education into the high school biology curriculum may be a good vector through which to educate the public about growing applications of genomics (Blank & Gruebel, 1995; Munn et al., 1999, Blank et al., 2007, Dougherty, 2009).

Standards for genetics curricular content are set at the state and national levels; however, textbooks, a key component of curricula, may lag behind these standards (AAAS, 2005a; National Assessment Governing Board, 2008). The AAAS Project 2061 evaluated 10 common high school biology texts on the basis of established benchmarks for genetics content and found gaps in the representation of the “molecular basis of heredity.” Specifically absent were links among the concepts of inherited mutations, mutations disrupting protein function, and the genetic contribution to multifactorial diseases (AAAS, 2005b). Wefer and Sheppard (2008) also found “low representation” of the human genome project and genomics content in secondary school science standards in 49 states.

No recently published work has quantified the information on human genetic disorders and traits or the genetic conditions present in high school biology textbooks. The purpose of the present study was to assess to what extent commonly used high school biology textbooks cover these topics, all of which are important for informing future consumers of genomic medicine applications. Specifically, our study investigated the extent to which selected biology textbooks present information about the genetic component of multifactorial diseases in comparison to presenting information about “classic” genetic disorders (chromosomal or single-gene disorders), and the types of disorders and traits included.

Materials & Methods
Data reported here are part of a larger content analysis of selected high school textbooks. “Content analysis” is broadly defined as a research method for quantifying what is usually considered qualitative data, such as the topics found in the sentences of a textbook (Krippendorff, 2012).

We reviewed previous content analyses of curricular materials to
assist in developing guidelines for the present study (Ferrell et al., 2000; Jackson et al., 2001; Nehm & Young, 2008; R. Cline et al., unpublished data).

We selected 11 high school biology textbooks on the basis of Project 2061 and state textbook adoption lists as of May 2009 (Campbell & Reece, 2005; Starr, 2005; Biggs, 2006; BSCS, 2006; Campbell et al., 2006a, b; Johnson & Raven, 2006; Miller & Levine, 2006; Parke & Enderle, 2006; Starr & Taggart, 2006; Biggs et al., 2007). We identified relevant content by searching the table of contents and index of each book. Because we wanted to quantify the discussion of the genetic component of multifactorial conditions, we also searched the index for “cardiovascular disease/heart disease,” “hypertension,” “diabetes,” “Alzheimer’s disease,” and “cancer.” These diseases were selected because they are included in the U.S. Surgeon General’s Family History Tool, which is designed to help the public identify increased risk for these conditions (Carmona & Wattendorf, 2005).

We developed a mutually exclusive and exhaustive codebook and rulebook of 169 codes in 11 categories. The full codebook is available by contacting the first author. Two authors (M.H. and A.T.) coded the entire sample and maintained 85.7% intercoder reliability; disagreements were resolved by consensus. We used SPSS version 18 to compute frequencies and percentages of each category, topic, and reference to specific diseases and traits within and across the 11 textbooks. To comprehensively describe genetics content and potential gaps, we did not eliminate topics not found in the textbooks.

Table 1. Textbook content (numbers of sentences) containing topics related to “classic” genetic disorders versus multifactorial disorders and traits.

<table>
<thead>
<tr>
<th>Topics</th>
<th>“Classic” Genetic Disordersa</th>
<th>Multifactorial Disorders &amp; Traitsb</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>% of sample</td>
<td>n</td>
</tr>
<tr>
<td>---</td>
<td>-------------</td>
<td>---</td>
</tr>
<tr>
<td>Example (no additional information)</td>
<td>67</td>
<td>1.69</td>
</tr>
<tr>
<td>Statistics (prevalence, population)</td>
<td>161</td>
<td>4.07</td>
</tr>
<tr>
<td>Description of inheritance pattern</td>
<td>428</td>
<td>10.82</td>
</tr>
<tr>
<td>Example of pedigree</td>
<td>271</td>
<td>6.85</td>
</tr>
<tr>
<td>Natural history</td>
<td>669</td>
<td>16.91</td>
</tr>
<tr>
<td>Genetic causes</td>
<td>422</td>
<td>10.66</td>
</tr>
<tr>
<td>Risk factors</td>
<td>22</td>
<td>0.56</td>
</tr>
<tr>
<td>Variable expressivity</td>
<td>81</td>
<td>2.05</td>
</tr>
<tr>
<td>Screening</td>
<td>44</td>
<td>1.11</td>
</tr>
<tr>
<td>Genetic testing</td>
<td>117</td>
<td>2.96</td>
</tr>
<tr>
<td>Other diagnostic procedures</td>
<td>106</td>
<td>2.68</td>
</tr>
<tr>
<td>Prevention and/or treatment</td>
<td>152</td>
<td>3.84</td>
</tr>
<tr>
<td>Psychosocial implications</td>
<td>17</td>
<td>0.43</td>
</tr>
<tr>
<td>Genetic counselor’s role</td>
<td>5</td>
<td>0.13</td>
</tr>
<tr>
<td>Other healthcare professional’s role</td>
<td>7</td>
<td>0.18</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
<td>0.33</td>
</tr>
<tr>
<td>Total</td>
<td>2582</td>
<td>65.25</td>
</tr>
</tbody>
</table>

- These sentences were initially stratified by category (inheritance pattern); the data have been collapsed for the purposes of this analysis.
- These particularly included cancer, hypertension, cardiovascular disease, Alzheimer’s disease, and diabetes.
- The total does not equal 100% of the sample (3957 sentences), because this content analysis was initially designed to capture sentences related to the practice of genetic counseling, family-history taking, and ethical, legal, and social issues in genetics. These categories were not included here.

Results

Quantifying Discussion of Genetic Etiology

To assess how frequently “classic” genetic diseases or traits (single-gene or chromosome disorders) were discussed in relation to multifactorial traits, we calculated the number of sentences coded in each category. Of the 3957 sentences in our total sample, we coded 2582 sentences in the “classic genetic traits and diseases” category and 1007 sentences in the “multifactorial traits and diseases” category (see Table 1). Data from our remaining categories were not used in this analysis. We wanted to focus on how often the genetic component of multifactorial disease was addressed, as opposed to the features or symptoms of a condition (natural history). We therefore compared the number of times the topic of the genetic cause of multifactorial conditions was found to the number of times the topic of the genetic cause of classic genetic conditions was found (Table 1, in italics). Three percent of the sentences falling within the multifactorial disease category were coded as discussing genetic factors,

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by contrast, >10% of classic-genetic-condition sentences reviewed genetic etiology.

**Conditions Discussed**
A majority (73.8%) of all sentences coded in the sample referred to a specific condition or trait. The most commonly encountered condition was cancer (type unspecified; 6.3% of the total sample).

### Table 2. Ten most frequently discussed “classic” genetic conditions and traits in textbooks (n = number of sentences).

<table>
<thead>
<tr>
<th>Condition or Trait</th>
<th>n</th>
<th>Percent of total sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sickle cell anemia</td>
<td>195</td>
<td>4.93</td>
</tr>
<tr>
<td>ABO blood type</td>
<td>153</td>
<td>3.87</td>
</tr>
<tr>
<td>Cystic fibrosis</td>
<td>153</td>
<td>3.87</td>
</tr>
<tr>
<td>Down syndrome</td>
<td>132</td>
<td>3.34</td>
</tr>
<tr>
<td>Hemophilia A</td>
<td>109</td>
<td>2.75</td>
</tr>
<tr>
<td>Sex determination</td>
<td>103</td>
<td>2.60</td>
</tr>
<tr>
<td>DNA fingerprints</td>
<td>68</td>
<td>1.72</td>
</tr>
<tr>
<td>Huntington’s disease</td>
<td>60</td>
<td>1.52</td>
</tr>
<tr>
<td>Phenylketonuria</td>
<td>56</td>
<td>1.42</td>
</tr>
<tr>
<td>Tay-Sachs disease</td>
<td>48</td>
<td>1.21</td>
</tr>
</tbody>
</table>

The most frequently encountered classic genetic and multifactorial conditions are identified in Tables 2 and 3, respectively.

Because past works have noted a deficit in the discussion of the interaction between genes and environment, particularly in multifactorial conditions (AAAS, 2005b; Wefer & Sheppard, 2008), we calculated the frequency of sentences discussing gene–environment interactions. This represented 1.2% of the total sentences and 4.7% of all sentences coded in the multifactorial disorder and trait category.

This topic was found at least once in all 11 books.

Because we searched textbooks for specific multifactorial conditions (cancer, heart disease, hypertension, diabetes, and Alzheimer’s disease), we may have artificially increased the incidence of multifactorial disorders and traits in the sample. To better determine whether multifactorial diseases were being discussed in the context of genetics and heredity, we filtered the data to include only the pages involved in the human genetics chapter(s) of each book. We then obtained the frequencies of the disorders discussed within these chapters specifically and categorized them as either classic genetic or multifactorial disorders. Table 3 shows the most common multifactorial conditions discussed in the textbooks and the proportion of sentences for each that were found in genetics chapter(s) specifically.

### Table 3. Multifactorial conditions representing >0.25% of the total sample of textbook sentences.

<table>
<thead>
<tr>
<th>Condition or Trait</th>
<th>Incidences in Sample (n)</th>
<th>Incidences in Sample (%)</th>
<th>Present in Genetics Chapters? (Y/N)</th>
<th>Incidences in Genetics Chapters (n)</th>
<th>Incidences in Genetics Chapters (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancer (ns)</td>
<td>250</td>
<td>6.32</td>
<td>Y</td>
<td>15</td>
<td>6.00</td>
</tr>
<tr>
<td>Heart disease (ns)</td>
<td>123</td>
<td>3.11</td>
<td>Y</td>
<td>3</td>
<td>2.44</td>
</tr>
<tr>
<td>Diabetes (ns)</td>
<td>99</td>
<td>2.50</td>
<td>Y</td>
<td>5</td>
<td>5.05</td>
</tr>
<tr>
<td>Hypertension</td>
<td>69</td>
<td>1.74</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>51</td>
<td>1.29</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Neurobiological disorders</td>
<td>37</td>
<td>0.94</td>
<td>Y</td>
<td>31</td>
<td>83.78</td>
</tr>
<tr>
<td>Type 1 diabetes</td>
<td>31</td>
<td>0.78</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Type 2 diabetes</td>
<td>31</td>
<td>0.78</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Alzheimer’s disease</td>
<td>27</td>
<td>0.68</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Skin color</td>
<td>25</td>
<td>0.63</td>
<td>Y</td>
<td>25</td>
<td>100</td>
</tr>
<tr>
<td>Eye color</td>
<td>21</td>
<td>0.53</td>
<td>Y</td>
<td>21</td>
<td>100</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>17</td>
<td>0.43</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Polydactyly</td>
<td>15</td>
<td>0.38</td>
<td>Y</td>
<td>15</td>
<td>100</td>
</tr>
<tr>
<td>Schizophrenia</td>
<td>13</td>
<td>0.33</td>
<td>Y</td>
<td>13</td>
<td>100</td>
</tr>
<tr>
<td>Skin cancer</td>
<td>12</td>
<td>0.30</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Heart attack</td>
<td>11</td>
<td>0.28</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Parkinson’s disease</td>
<td>11</td>
<td>0.28</td>
<td>N</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

Notes: ns = nonspecific (no discrete disorder or type identified). na = not applicable.
family history, is being used to identify risks for common, complex
diseases such as cancer, heart disease, diabetes, and dementia. The
public needs to be informed about the expanded scope of medical
genetics. Incorporating such information in high school biology texts
is one possible way to help accomplish this.

The purpose of the present study was to determine the extent
to which common biology textbooks discuss genetic conditions and
traits, which conditions are discussed, and how frequently classic
versus multifactorial conditions appear. Overall, textbooks discussed
classic genetic conditions relatively more often than multifactorial
ones. The genetic basis of classic genetic conditions was discussed
relatively more often than the genetic component of multifactorial
disease. Most discussion of multifactorial conditions occurred in
chapters other than the “genetics” chapter of the textbooks and, thus,
did not appear to integrate genetic factors as part of the etiology

“Classic” Genetic versus Multifactorial Conditions

Classic genetic diseases were more commonly discussed in high
school biology textbooks than multifactorial conditions. The most
common specific disorders and traits discussed were similar to those
found in an earlier review of the genetics content of biology text-
books (Mertens & Bowman, 1981). Specifically, Down syndrome,
ABO blood type, sickle cell anemia, phenylketonuria, hemophilia,
and red-green colorblindness appear on the “top 10” lists. However,
the present study found that cystic fibrosis, sex determination, DNA
fingerprints (for parental or forensic identification), and Huntington’s
disease also were among the 10 most frequently discussed. Notably
absent were examples of relatively common single gene causes of
potentially treatable adult-onset diseases such as hereditary breast
and ovarian cancer (HBOC) syndrome and Lynch syndrome, two
conditions for which national, evidence-based guidelines exist that
recommend and promote the identification of high-risk families.

Multifactorial conditions were represented in all books across
the sample; however, the topics of inheritance, genetic etiology, and
gene–environment interactions were observed noticeably less fre-
quently than natural history or features. The genetic etiologies of
benign traits, such as skin or eye color, were far more likely to be
discussed in genetics chapters than common diseases like cardio-
vascular disease. If the genetic contribution to these diseases was
discussed, we generally had to seek it outside of the human genetics
chapters. This suggests that textbooks may not be demonstrating
that common adult-onset diseases can be partially heritable. Two
exceptions were a discussion of skin cancer in two textbooks and an
extensive discussion of neurobiological disorders (bipolar disorder,
depression, and schizophrenia) in two other textbooks.

Gene–Environment Interactions

Multifactorial conditions, by definition, have an environmental com-
ponent to their etiology. In some cases, this component may be modi-
ifiable. Although we found sentences discussing gene–environment
interactions in each of the textbooks, the number of sentences
devoted to it represented ~3% of the sample. This may suggest that
students are not given the depth of information to connect the genetic
and environmental components of common diseases that are far
more likely to affect these students or their families than rare, classic
genetic disorders. To address this, as previously suggested in the liter-
ature, multifactorial traits could be used as a primer for the concepts
of heritability, variable expressivity, the influence of environment on
phenotype, and risk of disease if presented prior to classic genetic
disease. A previously proposed “inversion” of the curriculum could
assist students in appreciating the impact that environment has on
“traditional” genetic conditions, and the nondeterministic nature of
our genetic makeup (Dougherty, 2009).

Limitations

First, we specifically sought only sentences addressing certain multi-
factorial diseases for inclusion in the sample. There are a large number
of diseases that occur as the result of both genes and environment.
Because psychiatric disease was discussed in genetics chapters,
expanding our focus on multifactorial diseases to include discussions
of mental illness occurring outside of genetics chapters could have
helped to better quantify whether the genetic component of multi-
factorial conditions was being included in textbooks.

Second, although the oldest book analyzed in our sample was
published in 2005, the writing, editing, and publishing process for a
textbook may take several years. This lag between writing and pub-
lishing may account for the absence of some recent topics in the
sample.

Third, the state textbook adoption lists used for sampling were
current as of May 2009. Many states use a 5-year cycle for textbook
adoptions and have since released updated cycles including newer
editions of the books analyzed here. We cannot comment on the
human genetics content of these more recent textbooks.

Finally, we recognize that including more information about the
predictive use of genome-wide sequencing, analyses for common
traits, pharmacogenomic testing for drug
derivatives, direct-to-consumer testing, and policymaking will become
increasingly prevalent. Including

Conclusions

In high school biology textbooks, human genetics chapters often
focus on chromosomal and single-gene conditions. However, multi-
factorial conditions such as diabetes and heart disease, which can be
attributed in part to genetic or hereditary risk factors, are far more
common in the general population and place a large burden on
public health. Despite this, textbooks do not appear to be presenting
these conditions in the context of the study of genetics and heredity.
If biology textbooks continue to focus on rare classic genetic diseases,
as opposed to focusing on the genetic contribution to multifacto-
rrial diseases, readers will not be adequately prepared for the “new
specialties.” This preparation, in a world of genome-wide sequencing,
analyses for common conditions, pharmacogenomic testing for drug
therapies, direct-to-consumer testing, and policymaking will become
necessary as these options become increasingly prevalent. Including
more discussion about genetics and multifactorial diseases in text-
books could encourage risk identification and prevention of common
disease and educate the public about the benefits and limitations of
new genetic tests or screening. High school biology courses are the first, and often last, formal exposure to information about genetics for much of the American public. Barring supplementary genetics coursework provided by individual teachers, high school textbooks may be the primary opportunity that science and health educators have to present the importance of understanding genetics for future personal and public health decision making.

References


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