Glutathione:
Metabolism and Physiological Functions

Edited by
José Viña
PREFACE

In the last two decades our knowledge of the functions of glutathione in cell metabolism has been constantly increasing. Bibliometric studies show a growing interest in glutathione by the scientific community. There is strong evidence that this peptide has a prominent role in several cell functions ranging from antioxidant defense to regulation of metabolic pathways or of hormonal action.

Furthermore, methods for the accurate measurement of glutathione levels, specially oxidized glutathione, have appeared recently and have led us to revise old concepts regarding glutathione status of cells. On the other hand, it is possible to modify the glutathione levels in cells. This has advantages and shortcomings: if used well it may help us to understand and to treat important diseases. However, knowledge of the side effects of changing the glutathione status of cells is also of primary importance.

In the past years the role of glutathione in areas such as detoxication of xenobiotics or maintenance of cell structure and function was established. However, more recently, a prominent role of glutathione in fields such as nutrition, aging, and immunology is becoming fully recognized. It is obvious that a good knowledge of the physiological properties of glutathione will help the clinician to understand the physiopathology and therapeutics of glutathione-related diseases.

Thus, understanding the metabolism and physiological functions of glutathione and related enzymes may be of great importance to the investigators or the students in various areas of scientific knowledge and also to the professionals that note that glutathione becomes relevant in their fields of interest and who want to keep up with the changing scene in their areas of expertise.

The aim of this book is to provide not only well-established thought but also up-to-date information that will help those interested in the metabolism and properties of glutathione.
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Dr. Viña received his M.D. and his Ph.D. (cum laude) in 1978, both at the University of Valencia. He carried out postgraduate research at the Metabolic Research Laboratory, University of Oxford, under the direction of Sir Hans A. Krebs. Part of his research was supported by a FEBS fellowship awarded to Dr. Viña.

Dr. Viña is a member of the American Physiological Society, the Biochemical Society, the Spanish Society of Physiological Sciences, and the Spanish Biochemical Society. He has received the Boehringer Prize for biochemical research.

Dr. Viña is the author of over 60 scientific papers. His current major research interests relate to the role of sulfur amino acids and glutathione in cell functions, especially the aging process.
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DEDICATION

To my wife Pilar and to our children Pepe, Tomás, and María-Aurora
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Chapter 1

PUBLICATIONS ON GLUTATHIONE, 1983 TO 1987. A BIBLIOMETRIC STUDY

M. L. Terrada and M. L. Muñoz

Publications on glutathione are disseminated within the international scientific community which uses the English language as lingua franca through bibliographic databases and indices, two of which are exclusively biomedical: the American Index Medicus/MEDLARS and the Dutch Excerpta Medica/EMBASE. From 1983 to 1987, these two databases and the French PASCAL indexed a similar number of publications on the subject (Table 1).

In order to know the structure of this literature on glutathione, we turn to the Index Medicus/MEDLARS mainly due to the precise semantic specification of contents as provided by its thesaurus which is referred to as Medical Subject Headings.

Foremost, we should insist once again that the area covered by the Index Medicus/MEDLARS does not, as in the case of the rest of Western bibliographical databases, correspond in a balanced way to the international distribution of biomedical publications. In general terms, it should be remembered that (1) the Index Medicus/MEDLARS presents a marked bias in favor of English-speaking countries, particularly the U.S., (2) it satisfactorily reports on production from West Germany, the Netherlands, and the Scandinavian countries, but considerably less so in the case of Latin Europe and above all, the East Block countries, and (3) it is of very little use for Soviet and Japanese production.1,2 In spite of these limitations, its contents undoubtedly reflect the biomedical literature disseminated within the international scientific community which uses the English language as lingua franca.

The annual distribution of indexed publications on glutathione, according to this database for the mentioned 1983 to 1987 period, is as follows (Table 2).

It should be mentioned that the relatively low number of publications corresponding to 1987 is a result of the delay with which certain journals appear or are indexed.

The great majority of these publications are articles (2731 = 99.7%) that appeared in 508 journals (Table 3).

This distribution fits Bradford’s law of scattering,3,4 whereby “if scientific journals are arranged in order of decreasing productivity of articles on a given subject, they may be divided into a nucleus of periodicals more particularly devoted to the subject, and several groups or zones containing the same number of articles as the nucleus, when the number of periodicals in the nucleus and succeeding zones is 1:n:n^2 . . .” (Table 4).

According to this table, the Bradford nucleus consists of a single journal (the American Biochemical Pharmacology), the second zone has three journals (the American Journal of Biological Chemistry, Applied Pharmacology, and Biochemical and Biophysical Research Communications), and so on. The distribution according to countries for those journals included in the first seven zones is as follows (Table 5).

On the other hand, it is worth knowing the distribution of articles on glutathione according to country of origin. This information is supplied in 2522 cases, i.e., 92.07% of all articles indexed in the Index Medicus/MEDLARS (Table 6).

As mentioned above, the bias of the coverage of Index Medicus/MEDLARS explains in part the high figure corresponding to the U.S., the low figure for the Soviet Union, and the absence of countries such as China. In this sense, the fact that Japan holds second place is of considerable significance. The same distribution with countries grouped in terms of geographical area is given below (Table 7).
TABLE 1  
Number of Publications on Glutathione Indexed from 1983 to 1987

<table>
<thead>
<tr>
<th>Source</th>
<th>Number of Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excerpta Medica/EMBASE</td>
<td>2307</td>
</tr>
<tr>
<td>Index Medicus/MEDLARS</td>
<td>2739</td>
</tr>
<tr>
<td>PASCAL</td>
<td>2225</td>
</tr>
</tbody>
</table>

TABLE 2  
Annual Distribution of Publications

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Publications</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1983</td>
<td>453</td>
<td>16.53</td>
</tr>
<tr>
<td>1984</td>
<td>560</td>
<td>20.44</td>
</tr>
<tr>
<td>1985</td>
<td>559</td>
<td>20.40</td>
</tr>
<tr>
<td>1986</td>
<td>661</td>
<td>24.13</td>
</tr>
<tr>
<td>1987</td>
<td>506</td>
<td>18.47</td>
</tr>
<tr>
<td>Total</td>
<td>2739</td>
<td></td>
</tr>
</tbody>
</table>

Almost half of this literature comes from 54 institutions with 10 or more publications each (Table 8).

These 54 institutions belong in turn to 12 countries (Table 9).

The 2739 publications on glutathione indexed by the Index Medicus/MEDLARS corresponded to 5528 authors. Their distribution fit \( r = 0.9817 \) Lotka's productivity law, whereby regardless of the scientific discipline involved the number of authors of \( n \) publications is inversely proportional to \( n^2 \) (Table 10).

According to Lotka's law, the productivity index of an author is the logarithm of the number of his/her publications. Thus, in terms of this index, we can group the authors of literature on glutathione into three productivity levels (Table 11).

Through the classical studies by Price, it is known that this productivity index is not correlated to the Platz visibility index (logarithm of the number of personal citations in the scientific community). This can also be seen in the case of the 43 large producers of publications on glutathione by noting the number of citations they have received during the period from 1974 to 1987 according to SCISEARCH (Table 12).

The sole consequence deduced from this comparison is that all large-productivity authors of publications about glutathione are cited by the international scientific community according to three visibility levels (Table 13).

Finally, we will mention the distribution of publications on glutathione according to the number of authors (Table 14). The mode of this distribution (3) and mean authors per publication (3.26) are indicators that the study of a scientific subject is strongly institutionalized.
### TABLE 3
Distribution According to Journals

<table>
<thead>
<tr>
<th>Journals</th>
<th>Number of articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical Pharmacology</td>
<td>205</td>
</tr>
<tr>
<td>Journal of Biological Chemistry</td>
<td>97</td>
</tr>
<tr>
<td>Toxicology and Applied Pharmacology</td>
<td>82</td>
</tr>
<tr>
<td>Biochemical and Biophysical Research Communications</td>
<td>72</td>
</tr>
<tr>
<td>Biochimica et Biophysica Acta</td>
<td>71</td>
</tr>
<tr>
<td>Cancer Research</td>
<td>69</td>
</tr>
<tr>
<td>Chemical and Biological Interactions</td>
<td>51</td>
</tr>
<tr>
<td>Journal of Pharmacology and Experimental Therapeutics</td>
<td>49</td>
</tr>
<tr>
<td>Carcinogenesis</td>
<td>44</td>
</tr>
<tr>
<td>Archives of Biochemistry and Biophysics</td>
<td>42</td>
</tr>
<tr>
<td>Drug Metabolism and Disposition</td>
<td>41</td>
</tr>
<tr>
<td>Biochemical Journal</td>
<td>39</td>
</tr>
<tr>
<td>Toxicology Letters</td>
<td>39</td>
</tr>
<tr>
<td>International Journal of Radiation Oncology, Biology, and Physiology</td>
<td>38</td>
</tr>
<tr>
<td>Comparative Biochemistry and Physiology</td>
<td>37</td>
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<td>Toxicology</td>
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<td>International Journal of Radiation Biology</td>
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<tr>
<td>Research Communications in Chemical Pathology and Pharmacology</td>
<td>32</td>
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<tr>
<td>Archives of Toxicology</td>
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<tr>
<td>FEBS Letters</td>
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<tr>
<td>Mutation Research</td>
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</tr>
<tr>
<td>Current Eye Research</td>
<td>23</td>
</tr>
<tr>
<td>European Journal of Biochemistry</td>
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<td>Journal of Toxicology and Environmental Health</td>
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<td>Experimental Eye Research</td>
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<td>16</td>
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<td>Mechanisms of Ageing and Development</td>
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<td>Proceedings of Clinical Biological Research</td>
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<td>Blood</td>
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<tr>
<td>British Journal of Cancer</td>
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<tr>
<td>Bulletin of Environmental Contamination and Toxicology</td>
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<tr>
<td>Drug Chemistry and Toxicology</td>
<td>11</td>
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<tr>
<td>Journal of Bacteriology</td>
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</tr>
<tr>
<td>Biomedica Biochimica Acta</td>
<td>10</td>
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<tr>
<td>British Journal of Radiology</td>
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<tr>
<td>Diabetes</td>
<td>10</td>
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<tr>
<td>International Journal of Biochemistry</td>
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### TABLE 3 (continued)
**Distribution According to Journals**

<table>
<thead>
<tr>
<th>Journals</th>
<th>Number of articles</th>
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<tr>
<td>Prostaglandins</td>
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</tr>
<tr>
<td>10 journals with</td>
<td>8 articles each</td>
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<tr>
<td>249 journals with</td>
<td>1 article each</td>
</tr>
</tbody>
</table>

Total 2731

### TABLE 4
**Distribution of Journals According to Bradford Zones**

<table>
<thead>
<tr>
<th>Zones</th>
<th>Number of articles</th>
<th>Number of journals</th>
<th>n</th>
</tr>
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<tbody>
<tr>
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<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>251</td>
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</tr>
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<td>240</td>
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</tr>
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<td>247</td>
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<td>8</td>
<td>277</td>
<td>32</td>
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<td>2.07</td>
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</table>

\[ \bar{x} = 248.27 \pm 26.19 \quad 1.79 \pm 0.50 \]

### TABLE 5
**Distribution According to Countries of the Journals Included in the First Seven Bradford Distribution Zones**

<table>
<thead>
<tr>
<th>Zones</th>
<th>U.S.</th>
<th>U.K.</th>
<th>Netherlands</th>
<th>West Germany</th>
<th>Denmark</th>
<th>Switzerland</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
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<td>—</td>
<td>—</td>
<td>—</td>
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</tr>
<tr>
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<td>3</td>
<td>—</td>
<td>—</td>
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<td>—</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>4</td>
</tr>
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<td>4</td>
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<td>1</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>3</td>
<td>—</td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>2</td>
<td>1</td>
<td>—</td>
<td>1</td>
<td>1</td>
<td>16</td>
</tr>
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</table>

Total 32 7 5 3 1 1 49
<table>
<thead>
<tr>
<th>Countries</th>
<th>Number of publications</th>
<th>%</th>
</tr>
</thead>
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<td>1234</td>
<td>48.93</td>
</tr>
<tr>
<td>Japan</td>
<td>180</td>
<td>7.14</td>
</tr>
<tr>
<td>U.K.</td>
<td>176</td>
<td>6.98</td>
</tr>
<tr>
<td>West Germany</td>
<td>154</td>
<td>6.11</td>
</tr>
<tr>
<td>Italy</td>
<td>128</td>
<td>5.06</td>
</tr>
<tr>
<td>Sweden</td>
<td>123</td>
<td>4.88</td>
</tr>
<tr>
<td>Canada</td>
<td>81</td>
<td>3.21</td>
</tr>
<tr>
<td>France</td>
<td>58</td>
<td>2.30</td>
</tr>
<tr>
<td>Netherlands</td>
<td>55</td>
<td>2.18</td>
</tr>
<tr>
<td>Australia</td>
<td>43</td>
<td>1.70</td>
</tr>
<tr>
<td>India</td>
<td>41</td>
<td>1.62</td>
</tr>
<tr>
<td>Spain</td>
<td>21</td>
<td>0.83</td>
</tr>
<tr>
<td>Finland</td>
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</tr>
<tr>
<td>Israel</td>
<td>19</td>
<td>0.75</td>
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<tr>
<td>Norway</td>
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<td>0.75</td>
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<td>East Germany</td>
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<tr>
<td>Belgium</td>
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<td>0.63</td>
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<tr>
<td>Chile</td>
<td>16</td>
<td>0.63</td>
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<tr>
<td>Hungary</td>
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<td>0.63</td>
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<tr>
<td>Poland</td>
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<td>0.52</td>
</tr>
<tr>
<td>Argentina</td>
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<td>0.48</td>
</tr>
<tr>
<td>New Zealand</td>
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<td>0.48</td>
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<tr>
<td>Switzerland</td>
<td>12</td>
<td>0.48</td>
</tr>
<tr>
<td>Turkey</td>
<td>9</td>
<td>0.36</td>
</tr>
<tr>
<td>Mexico</td>
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<td>0.24</td>
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<td>0.24</td>
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<tr>
<td>Austria</td>
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<td>0.20</td>
</tr>
<tr>
<td>Czechoslovakia</td>
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<td>0.16</td>
</tr>
<tr>
<td>Jamaica</td>
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<td>0.16</td>
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<tr>
<td>Denmark</td>
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<td>0.12</td>
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<tr>
<td>Jordan</td>
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<td>0.12</td>
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<td>0.08</td>
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<tr>
<td>Bulgaria</td>
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<td>0.08</td>
</tr>
<tr>
<td>Soviet Union</td>
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<td>0.08</td>
</tr>
<tr>
<td>Taiwan</td>
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<td>0.08</td>
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<tr>
<td>Yugoslavia</td>
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<td>0.08</td>
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<tr>
<td>Egypt</td>
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</tr>
<tr>
<td>Hong Kong</td>
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<td>0.04</td>
</tr>
<tr>
<td>Iraq</td>
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<td>0.04</td>
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<tr>
<td>Kenya</td>
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<td>0.04</td>
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<tr>
<td>Libya</td>
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<td>0.04</td>
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<tr>
<td>South Africa</td>
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<tr>
<td>Venezuela</td>
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</table>

Total 2522
## TABLE 7
Distribution of Publications According to Geographical Areas of Origin

<table>
<thead>
<tr>
<th>Geographical areas</th>
<th>Number of publications</th>
<th>%</th>
</tr>
</thead>
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<tr>
<td>U.S.</td>
<td>1234</td>
<td>48.93</td>
</tr>
<tr>
<td>Other American English-speaking countries</td>
<td>85</td>
<td>3.37</td>
</tr>
<tr>
<td>Latin America</td>
<td>37</td>
<td>1.47</td>
</tr>
<tr>
<td>Western Europe</td>
<td>798</td>
<td>31.64</td>
</tr>
<tr>
<td>Soviet Union</td>
<td>2</td>
<td>0.08</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>54</td>
<td>2.14</td>
</tr>
<tr>
<td>Japan</td>
<td>180</td>
<td>7.14</td>
</tr>
<tr>
<td>Other Eastern Asiatic countries</td>
<td>44</td>
<td>1.74</td>
</tr>
<tr>
<td>Arabic countries</td>
<td>6</td>
<td>0.24</td>
</tr>
<tr>
<td>Israel</td>
<td>19</td>
<td>0.75</td>
</tr>
<tr>
<td>Black Africa</td>
<td>7</td>
<td>0.27</td>
</tr>
<tr>
<td>South Africa</td>
<td>1</td>
<td>0.04</td>
</tr>
<tr>
<td>Australia and New Zealand</td>
<td>55</td>
<td>2.18</td>
</tr>
<tr>
<td>Total</td>
<td>2522</td>
<td></td>
</tr>
</tbody>
</table>

## TABLE 8
Institutions with Ten or More Publications

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Number of publications</th>
<th>Percentage</th>
<th>Cumulative percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Karolinska Institute</td>
<td>Sweden</td>
<td>80</td>
<td>3.17</td>
<td>3.17</td>
</tr>
<tr>
<td>University of California</td>
<td>U.S.</td>
<td>75</td>
<td>2.97</td>
<td>6.14</td>
</tr>
<tr>
<td>University of Texas</td>
<td>U.S.</td>
<td>63</td>
<td>2.50</td>
<td>8.64</td>
</tr>
<tr>
<td>National Cancer Institute</td>
<td>U.S.</td>
<td>47</td>
<td>1.86</td>
<td>10.50</td>
</tr>
<tr>
<td>North Carolina Research Triangle Institute</td>
<td>U.S.</td>
<td>43</td>
<td>1.70</td>
<td>12.20</td>
</tr>
<tr>
<td>University of Duesseldorf</td>
<td>West Germany</td>
<td>34</td>
<td>1.35</td>
<td>13.55</td>
</tr>
<tr>
<td>University of Minnesota</td>
<td>U.S.</td>
<td>33</td>
<td>1.31</td>
<td>14.86</td>
</tr>
<tr>
<td>Veterans Administration Medical Center</td>
<td>U.S.</td>
<td>33</td>
<td>1.31</td>
<td>16.17</td>
</tr>
<tr>
<td>University of Luebeck</td>
<td>West Germany</td>
<td>30</td>
<td>1.12</td>
<td>17.29</td>
</tr>
<tr>
<td>Institut National de la Santé et de la Recherche Médicale</td>
<td>France</td>
<td>27</td>
<td>1.07</td>
<td>18.36</td>
</tr>
<tr>
<td>Cornell University Medical College</td>
<td>U.S.</td>
<td>25</td>
<td>0.99</td>
<td>19.35</td>
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<tr>
<td>Oregon State University</td>
<td>U.S.</td>
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<td>20.26</td>
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<td>U.S.</td>
<td>23</td>
<td>0.91</td>
<td>21.17</td>
</tr>
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<td>U.S.</td>
<td>22</td>
<td>0.87</td>
<td>22.04</td>
</tr>
<tr>
<td>Baylor College of Medicine</td>
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<td>0.83</td>
<td>22.87</td>
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<td>U.S.</td>
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<td>0.83</td>
<td>23.70</td>
</tr>
<tr>
<td>University of Tuebingen</td>
<td>West Germany</td>
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<td>0.71</td>
<td>24.41</td>
</tr>
<tr>
<td>Vanderbilt University</td>
<td>U.S.</td>
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<td>0.71</td>
<td>25.12</td>
</tr>
<tr>
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<td>U.S.</td>
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<td>0.67</td>
<td>25.79</td>
</tr>
<tr>
<td>Medical Research Center</td>
<td>U.K.</td>
<td>17</td>
<td>0.67</td>
<td>26.46</td>
</tr>
<tr>
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<td>U.S.</td>
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<td>0.63</td>
<td>27.09</td>
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<td>0.63</td>
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<td>0.63</td>
<td>28.35</td>
</tr>
<tr>
<td>University of Santiago</td>
<td>Chile</td>
<td>16</td>
<td>0.63</td>
<td>28.98</td>
</tr>
<tr>
<td>University of Michigan</td>
<td>U.S.</td>
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<td>0.63</td>
<td>29.61</td>
</tr>
<tr>
<td>University of Turin</td>
<td>Italy</td>
<td>16</td>
<td>0.63</td>
<td>30.24</td>
</tr>
<tr>
<td>Industrial Toxicology Research Center</td>
<td>India</td>
<td>15</td>
<td>0.59</td>
<td>30.83</td>
</tr>
</tbody>
</table>
# TABLE 8 (continued)
## Institutions with Ten or More Publications

<table>
<thead>
<tr>
<th>Institution</th>
<th>Country</th>
<th>Number of publications</th>
<th>Percentage</th>
<th>Cumulative percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Heart, Lung, and Blood Institute</td>
<td>U.S.</td>
<td>15</td>
<td>0.59</td>
<td>31.42</td>
</tr>
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<td>U.S.</td>
<td>15</td>
<td>0.59</td>
<td>32.01</td>
</tr>
<tr>
<td>Duke University Medical Center</td>
<td>U.S.</td>
<td>14</td>
<td>0.56</td>
<td>32.57</td>
</tr>
<tr>
<td>Kansas State University</td>
<td>U.S.</td>
<td>14</td>
<td>0.56</td>
<td>33.13</td>
</tr>
<tr>
<td>Rockefeller University</td>
<td>U.S.</td>
<td>14</td>
<td>0.56</td>
<td>33.69</td>
</tr>
<tr>
<td>University of Florida</td>
<td>U.S.</td>
<td>14</td>
<td>0.56</td>
<td>34.25</td>
</tr>
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<td>U.S.</td>
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<td>University of Kansas Medical Center</td>
<td>U.S.</td>
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<td>35.37</td>
</tr>
<tr>
<td>University of Toronto</td>
<td>Canada</td>
<td>14</td>
<td>0.56</td>
<td>36.93</td>
</tr>
<tr>
<td>Wadsworth Veterans Administration Medical Center</td>
<td>U.S.</td>
<td>14</td>
<td>0.56</td>
<td>37.49</td>
</tr>
<tr>
<td>Kyoto University</td>
<td>Japan</td>
<td>13</td>
<td>0.52</td>
<td>38.01</td>
</tr>
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<td>University of Genova</td>
<td>Italy</td>
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<td>0.52</td>
<td>38.53</td>
</tr>
<tr>
<td>University of Stockholm</td>
<td>Sweden</td>
<td>13</td>
<td>0.52</td>
<td>39.05</td>
</tr>
<tr>
<td>University of Washington</td>
<td>U.S.</td>
<td>13</td>
<td>0.52</td>
<td>39.56</td>
</tr>
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<td>40.05</td>
</tr>
<tr>
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<td>U.S.</td>
<td>12</td>
<td>0.48</td>
<td>40.53</td>
</tr>
<tr>
<td>University of Leiden</td>
<td>Netherlands</td>
<td>12</td>
<td>0.48</td>
<td>41.01</td>
</tr>
<tr>
<td>University of London</td>
<td>U.K.</td>
<td>12</td>
<td>0.48</td>
<td>41.49</td>
</tr>
<tr>
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<td>U.S.</td>
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<td>0.48</td>
<td>41.97</td>
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<td>Australia</td>
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<td>43.73</td>
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<td>0.40</td>
<td>44.53</td>
</tr>
<tr>
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<td>0.40</td>
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<td>0.40</td>
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</table>

**Total**: 1119

*Note:* Percentage of the total number of publications (2522) where the country of origin is indicated.
**TABLE 9**

Distribution According to Country of Origin of the Institutions with Ten or More Publications

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of institutions</th>
<th>Number of publications</th>
<th>Percentage of publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>37</td>
<td>768</td>
<td>30.45</td>
</tr>
<tr>
<td>West Germany</td>
<td>3</td>
<td>82</td>
<td>3.25</td>
</tr>
<tr>
<td>Italy</td>
<td>29</td>
<td>1.15</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>2</td>
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<tr>
<td>Sweden</td>
<td>2</td>
<td>93</td>
<td>3.69</td>
</tr>
<tr>
<td>U.K.</td>
<td>2</td>
<td>29</td>
<td>1.15</td>
</tr>
<tr>
<td>Australia</td>
<td>1</td>
<td>11</td>
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<td>Canada</td>
<td>1</td>
<td>14</td>
<td>0.56</td>
</tr>
<tr>
<td>Chile</td>
<td>1</td>
<td>16</td>
<td>0.64</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
<td>27</td>
<td>1.07</td>
</tr>
<tr>
<td>India</td>
<td>1</td>
<td>15</td>
<td>0.64</td>
</tr>
<tr>
<td>Netherlands</td>
<td>1</td>
<td>12</td>
<td>0.48</td>
</tr>
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<td><strong>Total</strong></td>
<td><strong>54</strong></td>
<td><strong>1119</strong></td>
<td></td>
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</table>

*Note:* Percentage of the total number of publications (2522) where country of origin is indicated.

**TABLE 10**

Distribution of Publications According to Authors

<table>
<thead>
<tr>
<th>Number of articles</th>
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<tbody>
<tr>
<td>1</td>
<td>4096</td>
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<tr>
<td>2</td>
<td>747</td>
</tr>
<tr>
<td>3</td>
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</tr>
<tr>
<td>34</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5528</strong></td>
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</table>
TABLE 11
Distribution of Authors According to Productivity Level

<table>
<thead>
<tr>
<th>Productivity level</th>
<th>Productivity index ($p$)</th>
<th>Number of authors</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large producers</td>
<td>$p &gt; 1$</td>
<td>43</td>
<td>0.78</td>
</tr>
<tr>
<td>Medium producers</td>
<td>$1 &gt; p &gt; 0$</td>
<td>1389</td>
<td>25.13</td>
</tr>
<tr>
<td>Low producers</td>
<td>0</td>
<td>4096</td>
<td>74.09</td>
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<tr>
<td>Total</td>
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<td>5528</td>
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TABLE 12
Comparison of the Productivity and Visibility Indices of the Large Producers

<table>
<thead>
<tr>
<th>Number of publications on glutathione (MEDLARS)</th>
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<th>Number of citations (SCI-SEARCH)</th>
<th>Visibility index</th>
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<tr>
<td>34</td>
<td>1.53</td>
<td>1038</td>
<td>3.02</td>
</tr>
<tr>
<td>32</td>
<td>1.50</td>
<td>852</td>
<td>2.93</td>
</tr>
<tr>
<td>31</td>
<td>1.49</td>
<td>2661</td>
<td>3.42</td>
</tr>
<tr>
<td>29</td>
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<td>646</td>
<td>2.81</td>
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</tbody>
</table>

TABLE 13
Distribution of Large Producers According to Visibility Level

<table>
<thead>
<tr>
<th>Visibility level</th>
<th>Visibility index ($p$)</th>
<th>Number of authors</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great visibility</td>
<td>$p &gt; 3$</td>
<td>4</td>
<td>9.30</td>
</tr>
<tr>
<td>Medium visibility</td>
<td>$3 &gt; p &gt; 2$</td>
<td>32</td>
<td>74.42</td>
</tr>
<tr>
<td>Small visibility</td>
<td>$2 &gt; p &gt; 1$</td>
<td>7</td>
<td>16.28</td>
</tr>
<tr>
<td>Total</td>
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<td>43</td>
<td></td>
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</table>

TABLE 14
Distribution of Publication According to the Number of Authors

<table>
<thead>
<tr>
<th>Number of authors (n)</th>
<th>Number of publications with (n) authors</th>
<th>%</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>230</td>
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</tr>
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<td>726</td>
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<td>780</td>
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<tr>
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<td>488</td>
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<td>6</td>
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<td>0.18</td>
</tr>
<tr>
<td>Total</td>
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<td>2739</td>
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</table>
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