

# JAMES LIND AND THE CURE OF SCURVY: AN EXPERIMENTAL APPROACH

by

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JAMES LIND's place in the development of nutritional thought derives primarily from his publication *A treatise of the scurvy* (1753).<sup>1</sup> The contents reveal his considerable familiarity with almost everything of significance that had been written about scurvy and the section "Bibliotheca scorbutica" is still of considerable value to students of the history of the disease. Lind presented a balanced and carefully reasoned assessment of contemporary ideas regarding the origin, nature and cure of scurvy. Certainly it would be churlish to deny to him the credit that he merits for this not inconsiderable achievement. Nevertheless, there are indications that Lind was perhaps not as conscious of the tenets of experimental science as some recent commentators would have us believe. Some of his *ex cathedra* judgments on scorbutic remedies were born more of enthusiasm and faith than of experimental science. Subjecting them to modern tests has quite palpably demonstrated their false nature.

## I

Lind's reputation as an experimental nutritionist rests mainly on his classical experiment in which he compared the potencies of a number of supposed anti-scorbutic remedies. Here is Lind's description of it:

On the 20th of May, 1747, I took twelve patients in the scurvy, on board the *Salisbury* at sea. Their cases were as similar as I could have them. They all in general had putrid gums, the spots and lassitude, with weakness of the knees. They lay together in one place, being a proper apartment for the sick in the fore-hold; and had one diet common to all, viz. water-gruel sweetened with sugar in the morning; fresh mutton-broth often times for dinner; at other times puddings, boiled biscuit with sugar etc. and for supper, barley and raisins, rice and currants, sago and wine, or the like. Two of these were ordered each a quart of cyder a day. Two others took twenty-five gutts of *elixir vitriol* three times a day, upon an empty stomach; using a gargle strongly acidulated with it for their mouths. Two others took two spoonfuls of vinegar three times a day upon an empty stomach; having their gruels and their other food well acidulated with it, as also the gargle for their mouth. Two of the worst patients, with the tendons in the L arm rigid, (a symptom none of the rest had) were put under a course of sea-water. Of this they drank half a pint every day, and sometimes more or less as it operated, by way of gentle physic. Two others had each two oranges and one lemon given them every day. These they eat with greediness at different times, upon an empty stomach. They continued but six days under this course, having consumed the quantity that could be spared. The two remaining patients took the bigness of a nutmeg three times a day, of an electuary recommended by an hospital-surgeon, made of garlic, mustard seed, *rad. raphan.* Balsam of Peru, and gum myrrh; using for common drink, barley

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water well acidulated with tamarinds; by a decoction of which, with the addition of *cremor tartar*, they were gently purged three or four times during the course.

The consequence was, that the most sudden and visible good effects were perceived from the use of the oranges and lemons; one of those who had taken them, being at the end of six days fit for duty. The spots were not indeed at that time quite off his body, nor his gums sound; but without any other medicine, than a gargarism of *elixir vitriol*, he became quite healthy before we came into *Plymouth* which was on the 16th of June. The other was the best recovered of any in his condition; and being now deemed pretty well, was appointed nurse to the rest of the sick.<sup>2</sup>

Lind's experiment had obvious commendable features. He selected six groups that were as similar as possible at the beginning of the experiment and maintained them throughout under the same general environmental and dietary conditions. The groups differed from each other only in respect of the type of treatment used. At first sight this would appear to be an early example of the type of scientific procedure proposed by Descartes in 1637 for eliminating all but one of a number of possible relationships.<sup>3</sup> In the ideal type of "critical" experiment, however, each "possibility" should be derived from existing data (or be a logical extrapolation of it) and the whole should be structured so that alternative possible explanations are excluded. Failure to satisfy these requirements reduces an experiment to a level of controlled empiricism. This was the weakness of Lind's work; the six "possible" cures that he compared were presumably selected empirically from those currently favoured by ships' surgeons; he gives no indication that his choice was governed by any other consideration. His experiment "succeeded" simply because one of the "remedies" contained vitamin C (the anti-scorbutic factor) whereas the other five did not.

It is interesting to speculate what effect a different choice of "remedies" would have had on the course of events. Had Lind used, in place of his oranges and lemons, a sixth remedy devoid of vitamin C—say the mineral waters favoured by writers such as Linden<sup>4</sup> or Bishop Berkeley's tar-water cure<sup>5</sup>—then all six groups would have given a negative result. On the other hand, Lind could well have used six remedies all of which contained vitamin C. In 1745 John Wesley published his *Primitive physic*, a popular manual of remedies, which by 1791 had reached its twenty-third edition. Suppose that Lind had selected the following six remedies from Wesley's list of eleven antiscorbutics.

- Three spoonfuls of nettle juice daily (609)
- A cupful of goose grass juice daily (611)
- Sweetened pulped whole orange (612)
- Juice of half an orange in milk daily (613)
- Two spoonfuls of lemon juice and sugar daily (615)
- Water and garden cresses, mustard and scurvy grass (616)<sup>6</sup>

It is virtually certain that all six groups would have recovered,<sup>7</sup> and the experiment would have done little more than confirm the observations of Wesley and others. Wesley's notes make it clear that he had already compared the virtues of some of his different remedies; he wrote "tried" after the nettle-juice preparation, "last year I knew many persons cured by it" with reference to number 611 (goose-grass juice) and he asterisked number 615, (taken from MacBride), as the one he "preferred to the rest".

Lind's investigation was a clear advance on Wesley's empiricism because he worked with comparable groups of subjects and under controlled conditions of time and environment. The use of controlled conditions of experimentation was Lind's main contribution to medical science; the demonstration that oranges and lemons cured scurvy was an essentially fortuitous happening, and scientifically a non-significant one. As Lind well knew, previous workers had already named citrus fruits as the antiscorbutic remedy *par excellence*. Lind himself quoted Kramer's observations ". . . if you have oranges, lemons or citrons, or their pulp and juice preserved with sugar in casks . . . you will, without other assistance cure this dreadful disease".<sup>8</sup> John Woodall in his *Surgeon's mate* (1612) wrote of the importance of "Lemons, Limes, Tamarinds and Oranges" as antiscorbutics, and he referred to the juice of lemons as "the most precious helpe that ever was discovered against the 'Scurvie'";<sup>9</sup> and in his *Essay on sickness and health* (1725) Edward Strother indicated that "eating Lemons and Oranges" was the cure for scurvy in sailors.<sup>10</sup> Lind was almost certainly aware of these and similar statements; indeed he referred in his treatise to earlier writers (such as Mead, Francis Russell, Lord Anson and James Lancaster) who had commented on the antiscorbutic efficacy of citrus fruits.<sup>11</sup>

## II

### LIND AND THE EXPERIMENTAL METHOD

Lind's *Salisbury* experiment has been described as "the first deliberately planned therapeutic trial".<sup>12</sup> Certainly the use of controlled trials was a rare event in early medicine. It was not, however, an entirely unknown procedure; a simple clinical trial was used by Rhazes in the tenth century A.D. to assess the value of blood-letting in cases of suspected meningitis.<sup>13</sup> The *Salisbury* experiment was, in this sense, a clinical trial and in the eyes of subsequent commentators it established Lind as an uncompromising experimentalist. Such commentators have not always recognized the difference between rationally-derived experimentation and controlled empiricism. Stewart, in his notes accompanying a reprinting of Lind's classic in 1953, wrote that "Lind specifically discarded hypothesis and rightly based his recommendations on experimental observation".<sup>14</sup> Stewart was presumably using the word hypothesis in the sense of "supposition" and certainly in this sense Lind eschewed hypothesis—although, as we shall see later—not as completely as some commentators would have us believe. Lind knew how to carry out a scientific experiment; it is not so evident that he knew which scientific experiments should be done. Even if he believed that experimentation should always supplant supposition, there is no evidence that he put this belief into practice.

Stewart is not the only commentator to have underlined Lind's supposed rejection of hypothesis. Stockman has made a similar claim: he wrote: "His therapeutical recommendations are based not only on his general clinical experience, but on exact comparative observations carried out on patients in hospital under different remedies, a method which must have been a novelty at the time."<sup>15</sup>

The same assessment is implicit in the title of Thomas's article "Experiment versus Authority."<sup>16</sup>

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Even Lind himself stated quite categorically: “. . . I shall propose nothing dictated merely from theory; but shall confirm all by experience and facts, the surest and most unerring guides.”<sup>17</sup> This latter statement is of some considerable significance when it is recalled that Lind’s recommendations for the cure or prevention of scurvy include a number that were apparently not derived from the result of clinical trials. His book contains a large number of antiscorbutic treatments but the only one for which any experimental evidence is adduced is oranges and lemons. It is of course conceivable that all Lind’s quoted remedies were derived either from simple experiments of the *Salisbury* type (and that, for some reason, he did not bother to present his experimental data) or that they were based on general observations over a period of years. On the other hand, they could be supposition on Lind’s part—although this would be in striking contrast to his professed rejection of unsubstantiated claims.

Modern nutritional science has provided us with a simple method for deciding between these two possibilities. It has been known since the 1930s that the antiscorbutic factor is L-xyloascorbic acid (vitamin C), a water-soluble vitamin easily measured by a simple chemical method. The recommended daily intake of vitamin C in Britain is 30mg/day although there is evidence that much lower intakes—in the neighbourhood of 5–10mg—will protect against scurvy.<sup>18</sup> Determination of the vitamin C content of Lind’s remedies should provide some indication of the experimental status of his claims; remedies based on experiment or observation would be expected to contain sufficient vitamin C to prevent scurvy whereas remedies devoid of vitamin C must be assumed to be suppositional and unsubstantiated. The remainder of this report records vitamin C analyses of Lind’s antiscorbutic remedies: as far as possible the method of preparation of the remedy was as described by Lind himself or, in the absence of such information, obtained from other contemporary sources. The vitamin C was measured by the dichlorophenolindophenol technique after preliminary extraction of the foodstuff with metaphosphoric acid.<sup>19,20</sup>

### III

#### LIND’S ANTISCORBUTIC REMEDIES

##### 1. *Extract of Oranges or Lemons*

After describing the antiscorbutic efficacy of oranges and lemons Lind gave details of “a method of preserving their virtues entire for years in a convenient and small bulk . . . as oranges and lemons are liable to spoil and cannot be obtained at every port”.<sup>21</sup> His instructions for the preparation of inspissated juice or “rob” were as follows:

Let the squeezed juice of these fruits be well cleared from the pulp and depurated by standing for some time; then poured off from the gross sediment; or, to have it still purer, it may be filtered. Let it then be put into any clean open earthen vessel, well glazed; which should be wider at the top than bottom so that there may be the largest surface above to favour evaporation. For this purpose a china basin or punchbowl is proper; or a common earthen basin used for washing, if well glazed will be sufficient as it is generally made in the form required. Into this pour the purified juice; and put it into a pan of water, upon a clear fire. Let the water come almost to boil, and continue nearly in a state of boiling (with the basin containing the juice in the middle of it) for several hours, until the juice is found to be of the consistence of oil when

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warm, or of a syrup when cold. It is then to be corked up in a bottle for use. . . . In this manner prepared, it must be kept in bottles where it will remain good for several years . . . and our navy may be supplied with it at a much easier rate than anything as yet proposed.<sup>22</sup>

According to Lind two dozen “good oranges” should produce five ounces of the extract.

2. *Gooseberries and other fruit*

. . . Green gooseberries will keep for years, if, after being put into dry bottles, their moisture is exhaled by putting the bottles slightly corked into a pot of water, which is allowed to come nearly to boil, and continue so for a while; when a very small quantity of juice yielded by them is to be thrown away, and they are afterwards kept close stopt. These would prove a sovereign remedy for the sick; and, by such methods, ships in long voyages, when touching at any place for water and provisions, may likewise lay up a store of berries and fruits.<sup>23</sup>

3. *Fermented liquors*

Lind was of the opinion that fermented liquors had antiscorbutic properties, and that, in general, fermentation resulted in an increase in antiscorbutic potency.

. . . fermented liquors of all sorts are found beneficial in this disease. By my own experience, I found cyder the best of any I had occasion to try. . . . I am persuaded that [fermented liquors] will be found preferable to many medicated antiscorbutic ales and wines by infusion, that might be recommended<sup>24</sup> . . . A simple decoction of the tops, cones, leaves or even bark and wood of these trees [spruce] is antiscorbutic, but it becomes much more so when fermented as in making spruce beer. . . . In extremity tar water may be tried, fermented in a like manner, by which it will certainly become much more antiscorbutic.<sup>25</sup>

4. *Onions*

Every common sailor ought to lay in a stock of onions. I never observed that any that used them fall into the scurvy at sea . . . when this stock is exhausted the captains may have recourse to pickled small onions. . . . It is demonstrable from the most incontestable experience that a soup of boiled cabbage and onions will cure an adventitious scurvy.<sup>26</sup>

5. *Others*

. . . There are, besides other herbs, whose juices are of eminent value. . . . And an antiscorbutic inferior to none, is the juice of the tender sprouting tops of green wheat in the months of June and July, mixed with the juice of Seville oranges.<sup>27</sup>

IV

ASSESSMENT OF THE ANTISCORBUTIC POTENCY OF LIND'S REMEDIES

The remedies 1–4 above were prepared, as far as possible, according to Lind's instructions and the vitamin C content determined by standard methods.<sup>28</sup>

*Extract of Oranges*

Four samples of orange inspissate were prepared as described by Lind. Twenty-five small-medium oranges gave 800ml of juice which in turn produced 80ml of the

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inspissate; Lind obtained 140ml of inspissated juice from 24 oranges so he presumably used large oranges. Half the original vitamin C content was lost during the inspissation procedure and there were further extensive losses during storage (Table 1). After 28 days' storage at room temperature only 13 per cent of the original vitamin C content remained.

TABLE 1  
VITAMIN C CONTENT OF LIND'S INSPISSATED ORANGE JUICE  
(preparation made from 25 oranges)

	Volume (ml)	vitamin C content		% loss of vitamin C
		mg/100ml	Total (g)	
Fresh juice .. ..	800	48	3.84	
Inspissate—Freshly made	80	240	1.92	50
After 7 days' storage ..		220	1.76	54
After 14 days' storage ..		180	1.44	63
After 28 days' storage ..		62	0.50	87

#### *Bottled gooseberries*

Fresh gooseberries had a vitamin C content of 65mg/100g—somewhat greater than the value of 40 quoted in standard food tables.<sup>29</sup> Fresh gooseberries (like most fruits) would therefore possess considerable antiscorbutic potency. "Preservation" of gooseberries as described by Lind and storage for five weeks reduced the vitamin C content to zero.

#### *Fermented liquors*

A sample of commercially produced cider had a vitamin C content of 0.33mg/100ml; standard food tables give the concentration as "a trace".<sup>30</sup> Spruce beer was prepared from the leaves of the spruce (*Picea abies*). As Lind gave no details of the recommended procedure the method adopted was in essence as described by Thornton in 1812;<sup>31</sup> this is similar to the method used by Captain Cook during the *Resolution* and *Adventure* voyages of 1772–1775.<sup>32</sup> An infusion of spruce leaves was fermented after addition of sugar molasses; the vitamin C content was determined during the preparation and after storage for twelve days. The results are given in Table 2 (p. 348).<sup>33</sup>

#### *Onions*

Onions, two months after harvesting, had a vitamin C content of 4.5mg/100g; McCance and Widdowson quote a value of 10.0mg/100g, presumably for freshly-harvested material.<sup>34</sup> Samples of commercially produced pickles contained no measurable vitamin C.

The sprouting wheat tops/orange preparation was not analysed as it is well

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established that both components are rich in vitamin C and the preparation would therefore be expected to possess a considerable antiscorbutic-potency.

TABLE 2  
CHANGES IN VITAMIN C CONCENTRATION DURING PREPARATION  
AND STORAGE OF SPRUCE BEER

							Vitamin C content (mg/100g or 100ml)
Untreated spruce leaves*	..	..	..	..	..	..	55
Aqueous infusion	..	..	..	..	..	..	14
After fermentation	..	..	..	..	..	..	<0.5
After storage for 14 days	..	..	..	..	..	..	0

\*There is considerable seasonal variation in the vitamin C content of conifers: the vitamin C content of *Pinus sylvestris* needles is 65mg/100g in late October increasing to 120 in early spring. The spruce leaves used in the fermentation experiment were gathered during late November.

V

COMMENT

The picture that emerges from the analyses quoted above is that the majority of Lind's antiscorbutic preparations were either completely lacking in vitamin C or contained the vitamin at concentrations below those estimated to provide an adequate protection against scurvy. The considerable losses in vitamin C during the preparation and storage of the inspissated juice of oranges do not support Lind's claim that this was a method for "preserving their virtues for years".<sup>35</sup> Lind's preparation never really attained any level of general acceptance; those who tried it soon rejected it in the light of experience. Sir Gilbert Blane "knew for certain" that rob of orange and lemons was inferior to the fresh fruit<sup>36</sup> and Captain Cook, who had wide experience of their use as possible antiscorbutics wrote, in a letter to Sir John Pringle, that he had no great opinion of them.<sup>37</sup> Thornton commented in 1810: "The extract recommended so warmly by Dr. Lind, has been found by Captain Cook and others of little or no effect. It would scarcely, indeed, be expected that any preparation of this kind could retain the virtue of the recent fruit",<sup>38</sup> a point underlined by George Budd, the London physician and pioneer of the vitamin theory, who wrote, in 1842: "Dr. Lind's "rob . . . was extensively tried but found very inferior to the fresh fruit".<sup>39</sup>

Lind's claims for the antiscorbutic potency of bottled gooseberries and fermented drinks would similarly appear to be based on surmise and conjecture rather than on experience and observations. Kodicek and Young, in commenting on the antiscorbutic efficacy of spruce beer preparations, suggested that it "might have contained a fair amount of ascorbic acid".<sup>40</sup> This would be true of an infusion of spruce or pine needles but not of the fermented product—even when freshly prepared (see Table 2). Captain Cook prized beer as an antiscorbutic agent and Lind attributed

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similar powers to cider.<sup>41</sup> Yet animal tests have shown that in fact beer has no antiscorbutic potency,<sup>42</sup> and the vitamin C content of cider is negligible. Hess has claimed that Cook and Lind referred to freshly-brewed beers with a possibly appreciable vitamin C content but this again is surmise.<sup>43</sup> No organism is known to be capable of effecting the biosynthesis of vitamin C during fermentation; indeed, the opposite is probably true and under the general conditions of fermentation one would expect a complete destruction of any preformed vitamin C.

Onions contain moderate amounts of vitamin C and if consumed raw and in large quantities, could certainly offer a protection against scurvy. A daily intake of ten pounds of onions per man (the amount issued by Cook after seven weeks at sea during the *Endeavour* voyage<sup>44</sup>) would have ensured a daily intake of vitamin C far in excess of the level necessary to prevent scurvy. Lind's suggestion however, that pickles could be substituted for onions could have had no observational basis as the whole of the vitamin C is destroyed or leached out during the pickling process—which in Lind's day was very similar to the procedure followed today.<sup>45</sup>

The absence of vitamin C from many of Lind's "antiscorbutic remedies" and their consequent inability to offer any adequate protection against scurvy forces one to query the validity of his claim that he would "confirm all by experience and facts".<sup>46</sup> This, he patently had not done.

From our present-day vantage point of modern nutritional knowledge it is easy to point out Lind's sins of omission. It should be recalled, however, that even Lind probably did not think of scurvy as primarily a nutritional disorder and the theory that antiscorbutics functioned by replacing a missing dietary component did not emerge until formulated by George Budd over half a century later.<sup>47</sup> Had Lind realized that scurvy was a deficiency disease and had he been aware of the thermo-lability, general instability and water-solubility of the antiscorbutic factor then it is unlikely that he would have unqualifyingly assumed that inspissation, fermentation, canning and pickling were without effect on antiscorbutic potency. Lind appeared to believe that antiscorbutics acted by "correcting the quality of hard and dry food"<sup>48</sup>—a mode of action that to the mid-eighteenth-century mind, would be unlikely to be rendered less effective by, say, the conversion of fresh onions to pickled ones.

Lind's work emphasizes, above all, his obvious ability to observe carefully and to draw correct conclusions from his observations. Less convincing is the evidence that he was, even in the context of his period, a strict practitioner of experimental science; his apparent failure to reject supposition and unwarranted speculation is in contrast with his own professed "code of practice" in this respect.

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