Evolution of genome complexity: are bacteria as trivial as we expect?

A story about secondary replicons

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Intro

Most bacteria we know contain only one large replicon, the bacterial chromosome. However, bacteria are known that have several large replicons. The structures of the genomes of such bacteria are quite diverse, there are both 2 or 3 large replicons, which are considered to be bacterial chromosomes, and a greater number of smaller replicons, which are considered megaplasmids. The influence of the presence of such elements in the genome on the life of bacteria is not yet fully understood, so we tried to answer some questions about secondary replicons.

Total size of genomes

We found that the size of bacterial genomes varies greatly between genera (Figure 1). Genome size is highly dependent on the lifestyle of the bacteria. In addition, there is no clear correlation between the number of replicons and the total size of the genome.

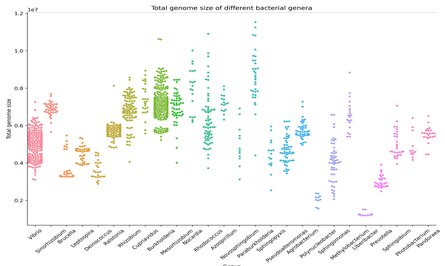

Fig. 1. The size of the genome depending on the genus.

Chromosome sizes

Bacteria in our sample have two or three chromosomes. We noticed that bacteria with three chromosomes, on average, have a smaller first chromosome than bacteria with two chromosomes (Figure 2). For the second chromosomes, it was not possible to draw an unambiguous conclusion, because they are approximately comparable (Figure 3).

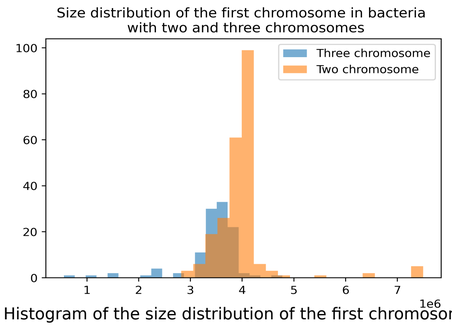

Fig. 2. Histogram of the size distribution of the first chromosomes..

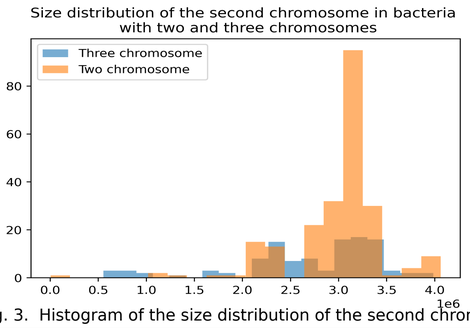

Fig. 3. Histogram of the size distribution of the second chromosomes..

Excluding of Rhizobium and Sinorhizobium

Bacteria of the genera Rhizobium and Sinorhizobium have an atypical structure of secondary replicons. They contain from 3 to 5 large plasmids, the sizes of which are in the range from 0.34 Mb. up to 1.2 Mb. These bacteria have no significant correlation between replicon sizes (Figures 4 and 5).

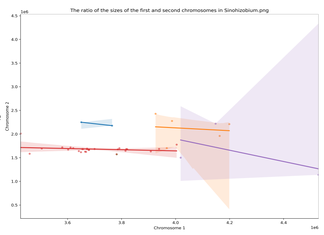

Fig. 4. The ratio of the sizes of 1 and 2 chromosomes in Sinorhizobium

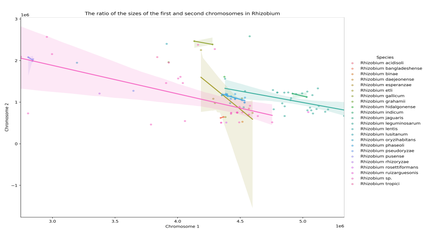

Fig. 5. The ratio of the sizes of 1 and 2 chromosomes in Rhizobium

Correlation of chromosome sizes

For genera with one and two secondary replicons, we plotted the dependence of the size of the second chromosome on the size of the first. The correlation coefficient of the sizes of the first and second chromosomes for all species is 0.66 (Figure 6). For each genus, it is slightly different (Figure 7), but, apparently, does not depend on the presence of the third chromosome (Figure 8).

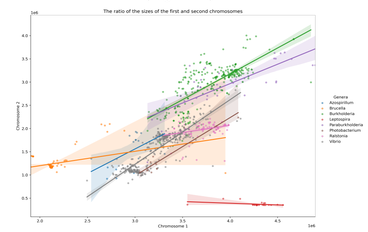

Fig. 6-8. The ratio of the sizes of 1 and 2 chromosomes for: for all bacteria under consideration, each genus and for bacteria with 2 and 3 replicons

Distribution of gene densities by chromosomes

When examining the gene density on two chromosomes, we found two interesting features - a dip and a peak (Figures 9 and 10). The first contains more than 4.5 kb of one gene, which can encode proteins with different functions. The peak includes densely packed housekeeping genes of various types, from coding tRNAs to membrane and ribosomal proteins.

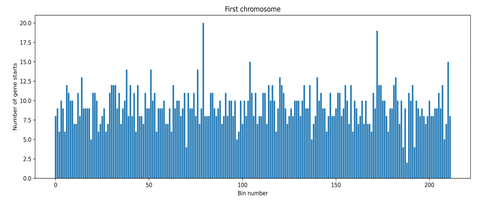

Fig. 9. The number of gene starts falling into the 10 bases window. for the first chromosome

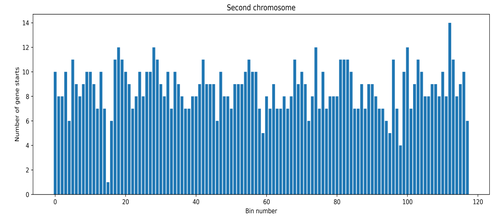

Fig. 10. The number of gene starts falling into the 10 bases window. for the second chromosome

Conclusions

1) The presence of secondary replicons is not determined by relationship.
2) The size of the first chromosome is smaller in bacteria with two secondary replicons than in bacteria with three.
3) There is a correlation between the sizes of the first and second chromosomes.
4) The structure of the genome of Rhizobium and Sinorhizobium is very different from the rest of the genera from the sample. Due to the presence of several massive secondary replicons, it is difficult to distinguish a megaplasmid among them.
5) There are 2 unusual regions in chromosomes - one contains a gene encoding a massive protein whose function can vary, and the other contains densely packed housekeeping genes.

Gratitudes

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