

## 4.1: Undirected Graphs

**Exercise 1.** What is the maximum number of edges in a graph with  $V$  vertices and no parallel edges? What is the minimum number of edges in a graph with  $V$  vertices, none of which are isolated (have degree 0)?

**Solution.** No parallel edges means that at most one edge connects any two given nodes. For any vertex  $v_i$ , there are  $V$  possible edge candidates, including  $v_0$  itself (because loops are not disallowed, we can assume they are allowed). Then, for  $v_1$ , there are  $V - 1$  edges allowed: one for  $v_1$ , and one for each other vertex, except  $v_0$ . Continuing this way, we find that there is a maximum of  $V!$  ( $V$  factorial) edges.

If  $V$  is even, then the minimum is  $V/2$ , since we can pair all vertices. If  $V$  is odd, it is  $\lfloor V/2 \rfloor + 1$ .

**Exercise 2.** Draw, in the style of the figure in the text (page 524), the adjacency lists built by `Graph`'s input stream constructor for the file `tinyGex2.txt` depicted at left.

**Exercise 3.** Create a copy constructor for `Graph` that takes as input a graph `G` and creates and initializes a new copy of the graph. Any changes a client makes to `G` should not affect the newly created graph.

**Solution.** See `com.segarciat.algs4.ch4.sec1.ex03`.

**Exercise 4.** Add a method `hasEdge()` to `Graph` which takes two `int` arguments `v` and `w` and returns `true` if the graph has an edge `v-w`, `false` otherwise.

**Solution.** See `com.segarciat.algs4.ch4.sec1.ex04`.

**Exercise 5.** Modify `Graph` to disallow parallel edges and self-loops.

**Solution.** See `com.segarciat.algs4.ch4.sec1.ex05`.

## References

- [SW11] Robert Sedgewick and Kevin Wayne. *Algorithms*. 4th ed. Addison-Wesley, 2011.  
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