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A nested sequence of topological spaces implies a sequence of homology groups connected by maps. For each pair, we call the image of the earlier in the later group a persistent homology group. Given a function on a topological space, the sublevel sets form such a nested sequence of spaces. The corresponding persistent homology groups can be encoded by the persistence diagram: a multiset of points in the extended plane. This diagram is stable and has a fast algorithm. Given a time-series of functions, we can develop the family of diagrams into a collection of curves, which we call vines that form a vineyard. We justify the introduction of the above concepts and the design and implementation of their algorithms by a number of applications, in mathematics and elsewhere.

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