

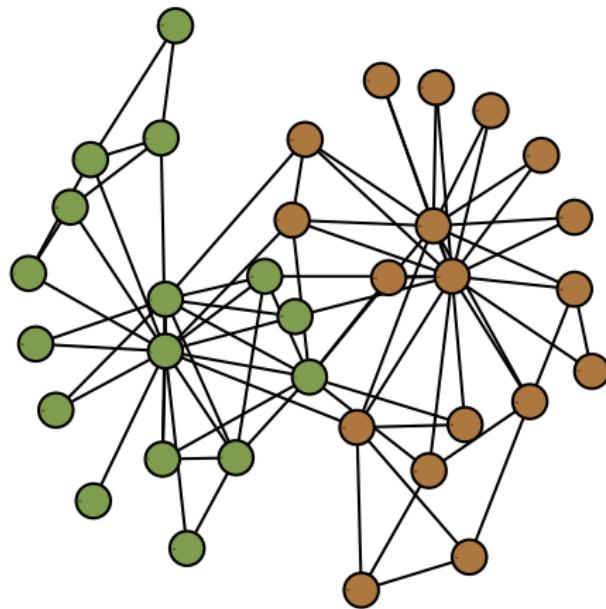
## *community* structure

introduction to *network science in Python* (*NetPy*)

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## community *structure*

karate club *network split* [Zac77]

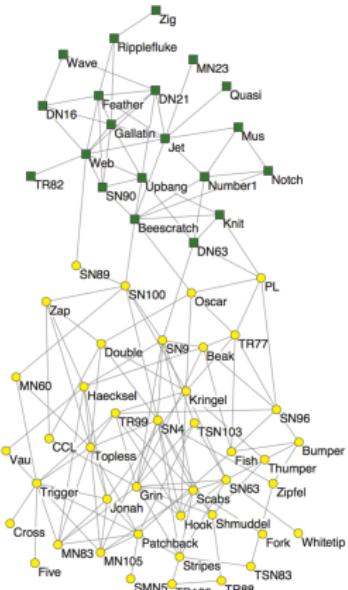


## community *detection*

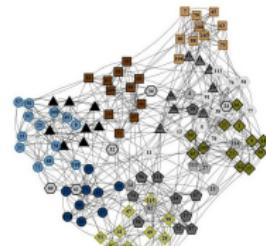
karate club *split detection* [RAK07]

# community *examples*

*most social networks* contain *communities* [GN02]



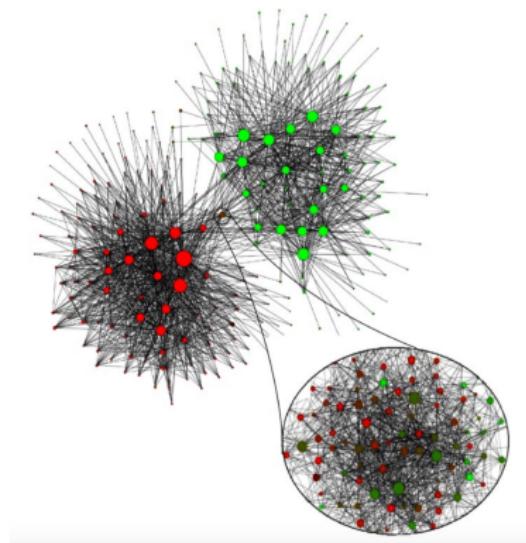
bottlenose dolphins [LSB<sup>+</sup>03]



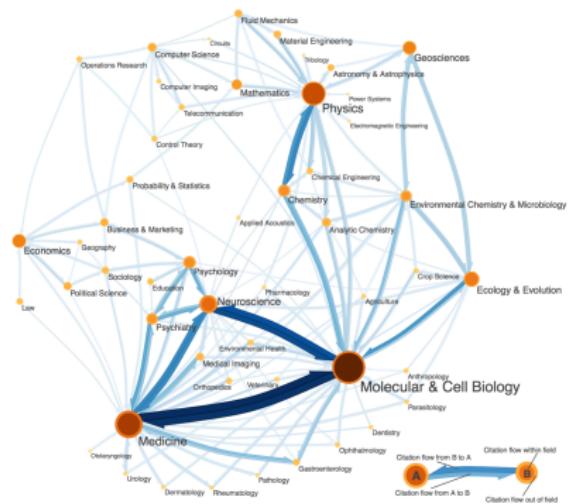
college football [GN02]

# community *examples*

many *information networks* contain *communities* [FLG00]



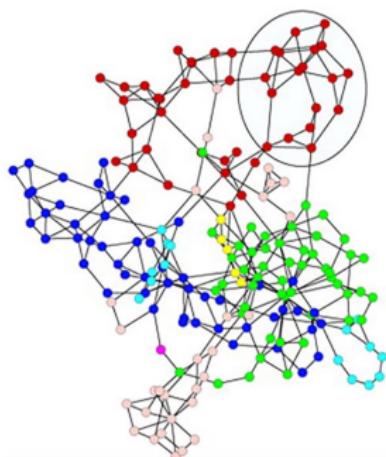
mobile communications [BGLL08]



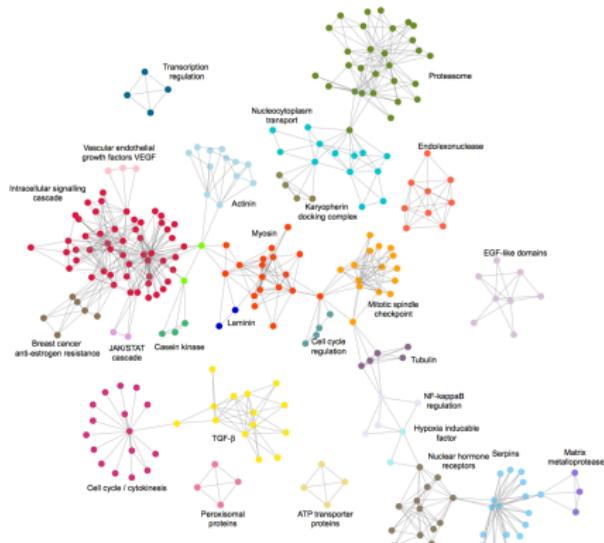
journal citations [RB08]

# community *examples*

*many biological networks* contain *communities* [RSM<sup>+02</sup>]



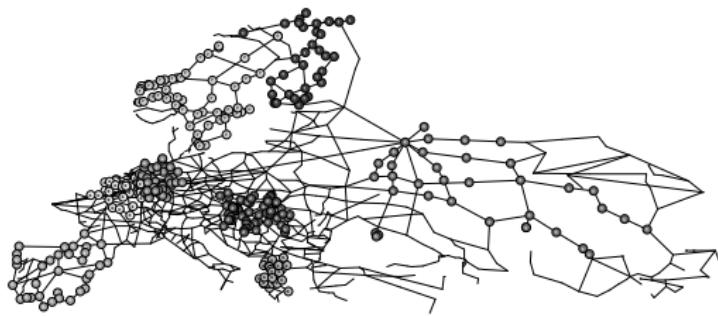
*E. coli* metabolism [RSM<sup>+02</sup>]



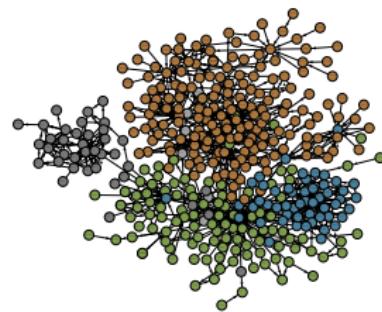
protein interactions [JCZB06]

## community *examples*

*technological networks* rarely contain *communities* [ŠB11a]



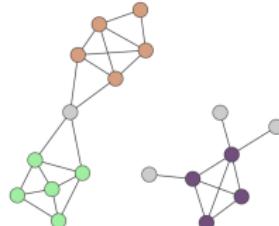
European highways [ŠB11b]



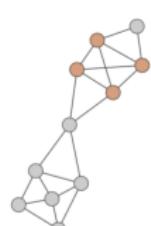
JUNG dependencies [ŠB11a]

## community *definition*

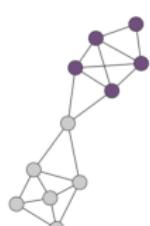
- *clique* is *complete subgraph of some graph*
- *community* is *dense subgraph of sparse network* [GN02]
- *strong* and *weak community*  $C$  [FLG00, RCC<sup>+</sup>04] defined as
  - $k_i^{\text{int}}$  and  $k_i^{\text{ext}}$  are *internal* and *external degree* of  $i$
$$\forall i \in C : k_i^{\text{int}} > k_i^{\text{ext}} \quad \sum_{i \in C} k_i^{\text{int}} > \sum_{i \in C} k_i^{\text{ext}}$$
- *community detection* is  $\gg$  *graph partitioning* [For10]



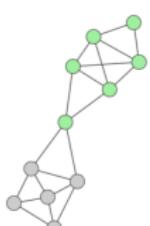
*connected communities*



*maximum clique*



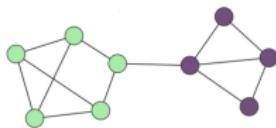
*strong community*



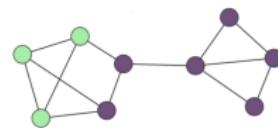
*weak community*

## community *modularity*

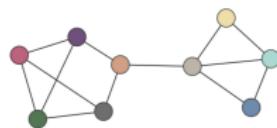
- random graphs should lack community structure
- modularity  $Q$  [GN02] of communities  $\{C\}$  defined as
$$Q = \frac{1}{2m} \sum_{ij} \left( A_{ij} - \frac{k_i k_j}{2m} \right) \delta_{c_i c_j}$$
- $p_{ij} = \frac{k_i k_j}{2m}$  is link probability in configuration model [NSW01]
- modularity  $Q$  popular quality/optimization function [For10]



optimal  $Q = 0.41$



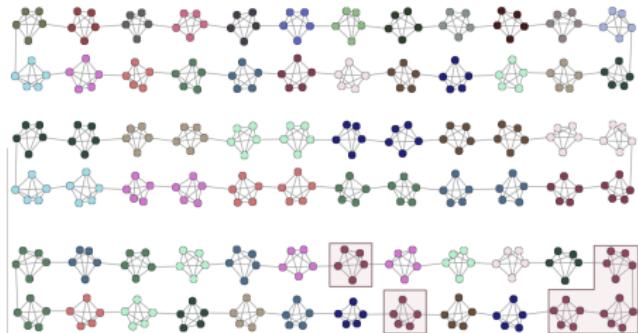
suboptimal  $Q = 0.22$



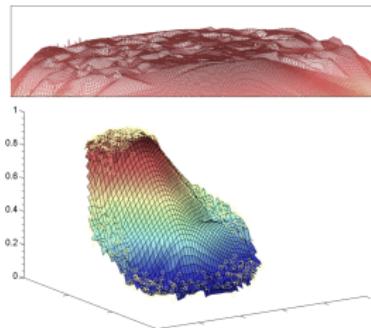
isolates  $Q = -0.12$

# community $\neg$ modularity

- modularity  $Q \gg 0$  also in random graphs [GSPA04]
- modularity  $Q$  has resolution limit at  $k_c \leq \sqrt{2m}$  [FB07]
- modularity  $Q$  lacks clear optimum in real networks [GdMC10]

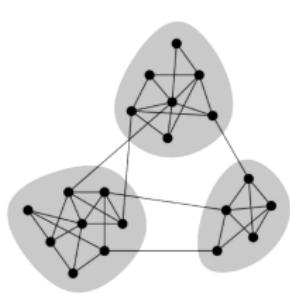


intuitive  $Q = 0.867$ , optimal  $Q = 0.871$  and random  $Q = 0.8$

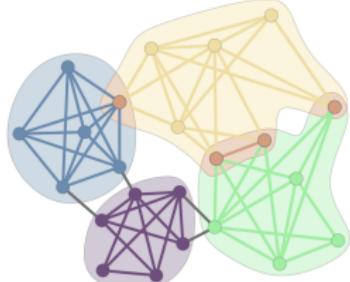


$Q$  plateau and maxima

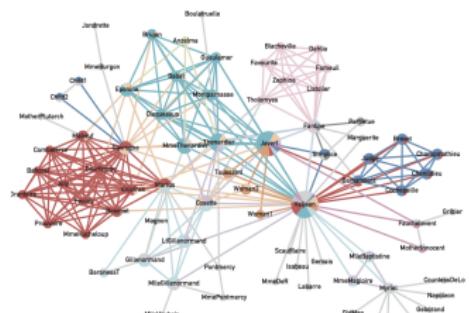
# community *overview*



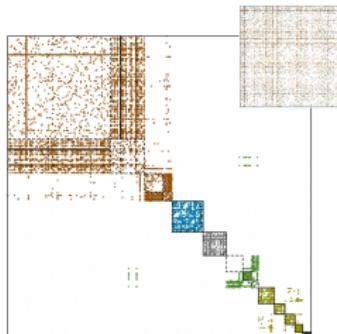
communities [GN02]



overlapping communities [PDFV05]



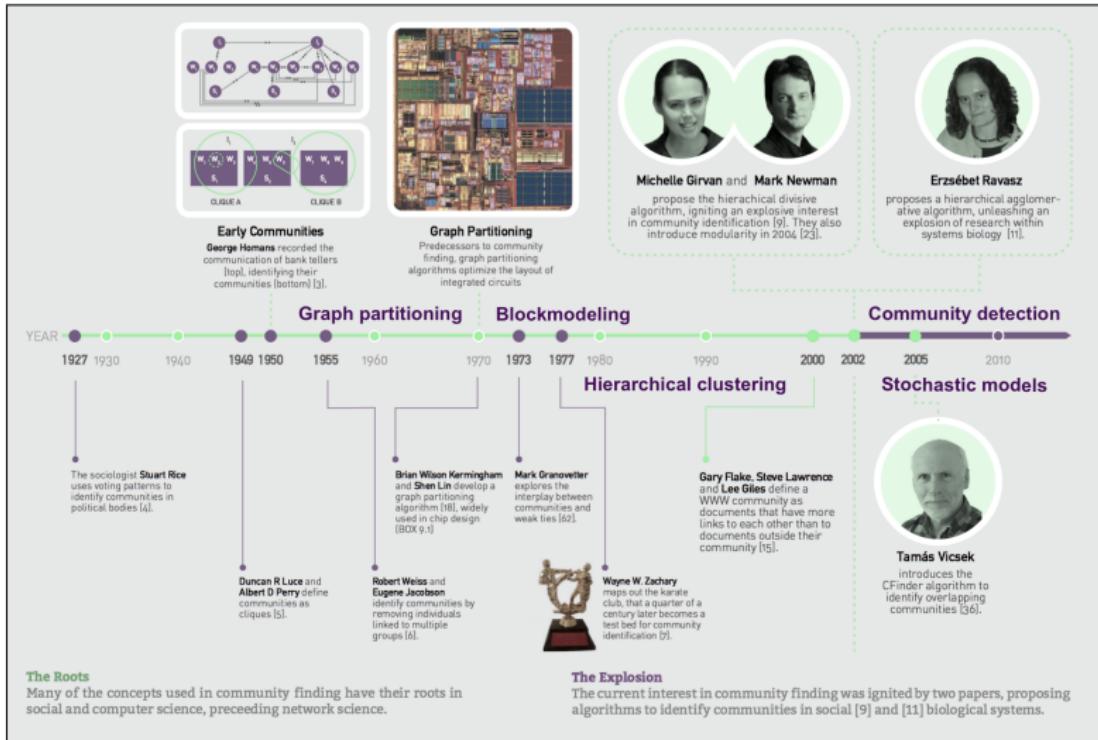
link communities [EL09, ABL10]



block models, blockmodeling etc.

`javax.swing, javax.management, javax.xml, javax.print, javax.naming, javax.lang`

# community *history*



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