Editorial Board Member

Dr. Sheereen Majd

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Biography

- Dr. Majd received her B.S. in Mechanical Engineering from Amirkabir Institute of Technology, Tehran, in 2003. She completed her Ph.D. in Biomedical Engineering at the University of Michigan, Ann Arbor, in 2009. Her doctoral work, under the supervision of Prof. Michael Mayer, focused mainly on studying molecular processes on biological membranes such as lipid-protein interactions, drug-membrane interactions, and membrane-associated enzymatic reactions using engineering- and nanotechnology-based platforms.

- After a short postdoctoral training at the University of Michigan, Dr. Majd joined the Department of Bioengineering at the Pennsylvania State University as an Assistant Professor in January of 2011. She currently has a courtesy appointment in Department of Engineering Science and Mechanics. Research efforts and interests in Dr. Majd's group lie at the interface of membrane biophysics, electrophysiology, biomateri¬als, micro/nano fabrication, and biosensing for diagnostic and therapeutic applications. Currently, the main focus of her research group is the molecular processes within and across cell membranes and the role of these molecular events in normal and diseased cellular functions.

Research Interests

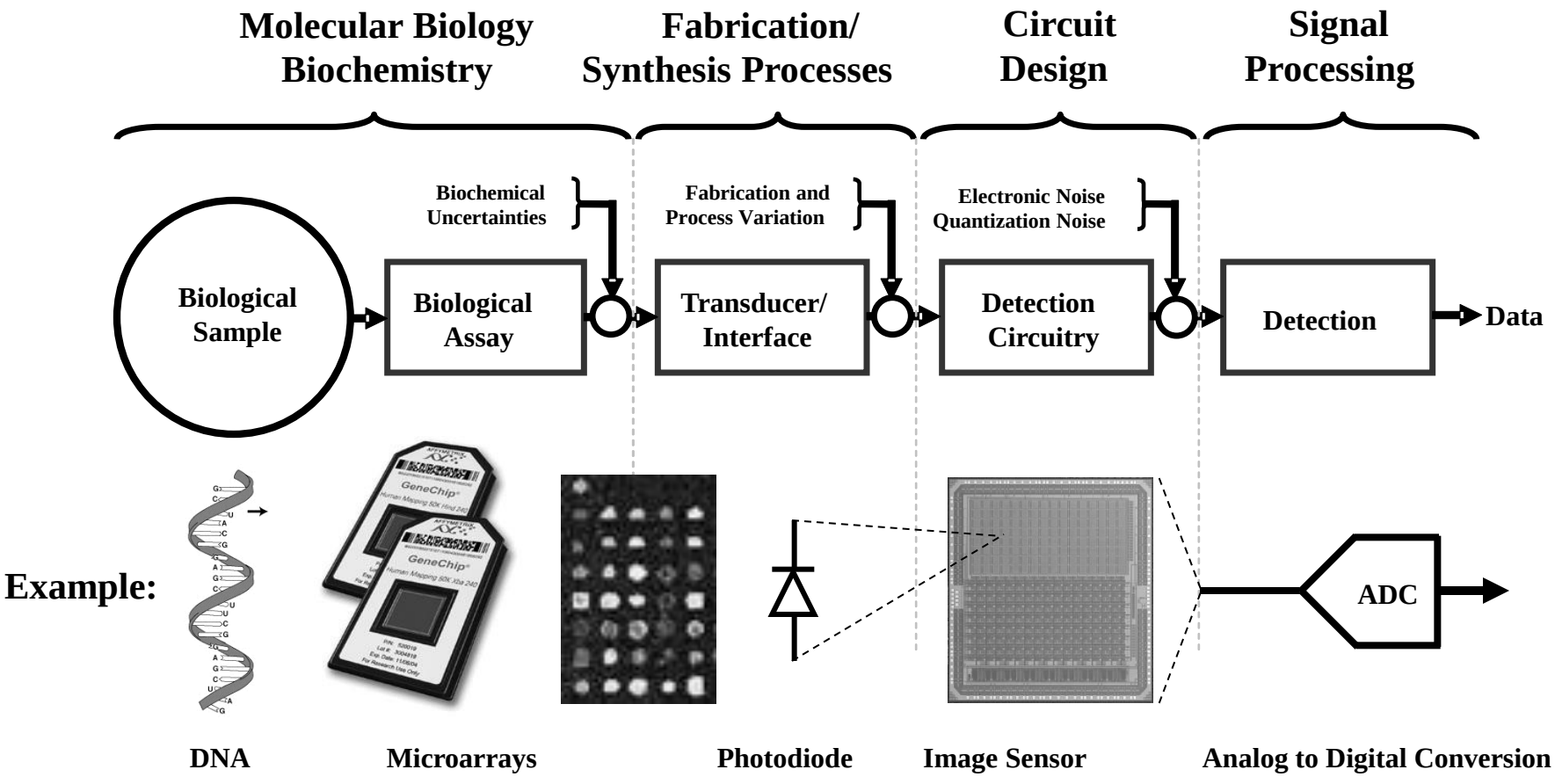
- Membrane Biophysics and Model Membranes
- Biological and Synthetic Nanopores for Sensing and Single Molecule Characterization
- Cell and Biomolecular Microarrays for Sensing and Cell Studies
- Hydrogel Micro/Nano Structures for Biological Studies
- Lipid-Enveloped Particles for Gene and Drug Delivery

Publications

- Many publication of Dr. Sheereen Majd can be viewed at **Sciencedirect** & **Google Scholar** (Hyperlinked)

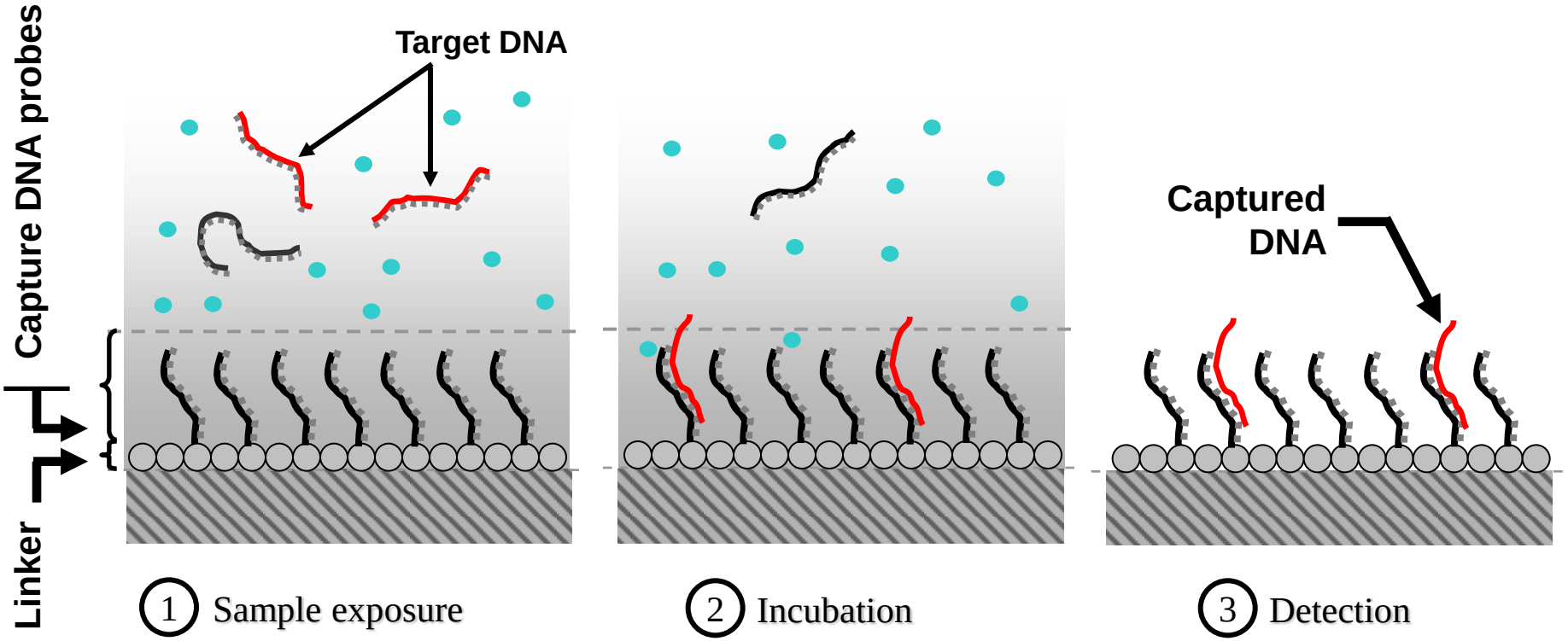
Biomolecular Detection Systems

- Bio-molecular detection systems, in general, have the following sub-blocks:



Affinity-Based Biosensors

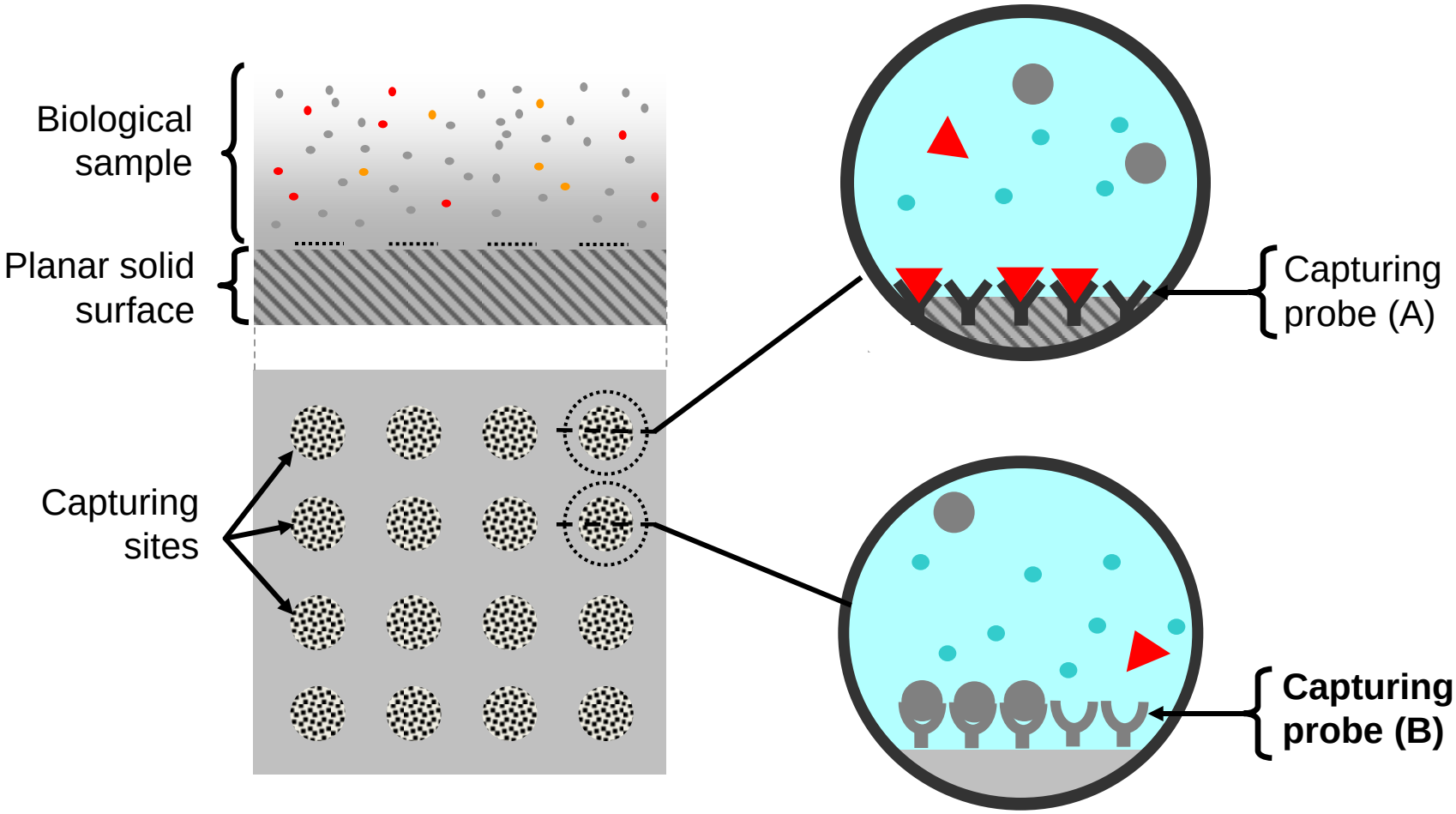
- Exploit the affinity of certain biomolecules for each other to capture and detect:



* There are different transduction methods for “counting” the binding events, e.g., fluorescence, electrochemical, chemi-luminescence …

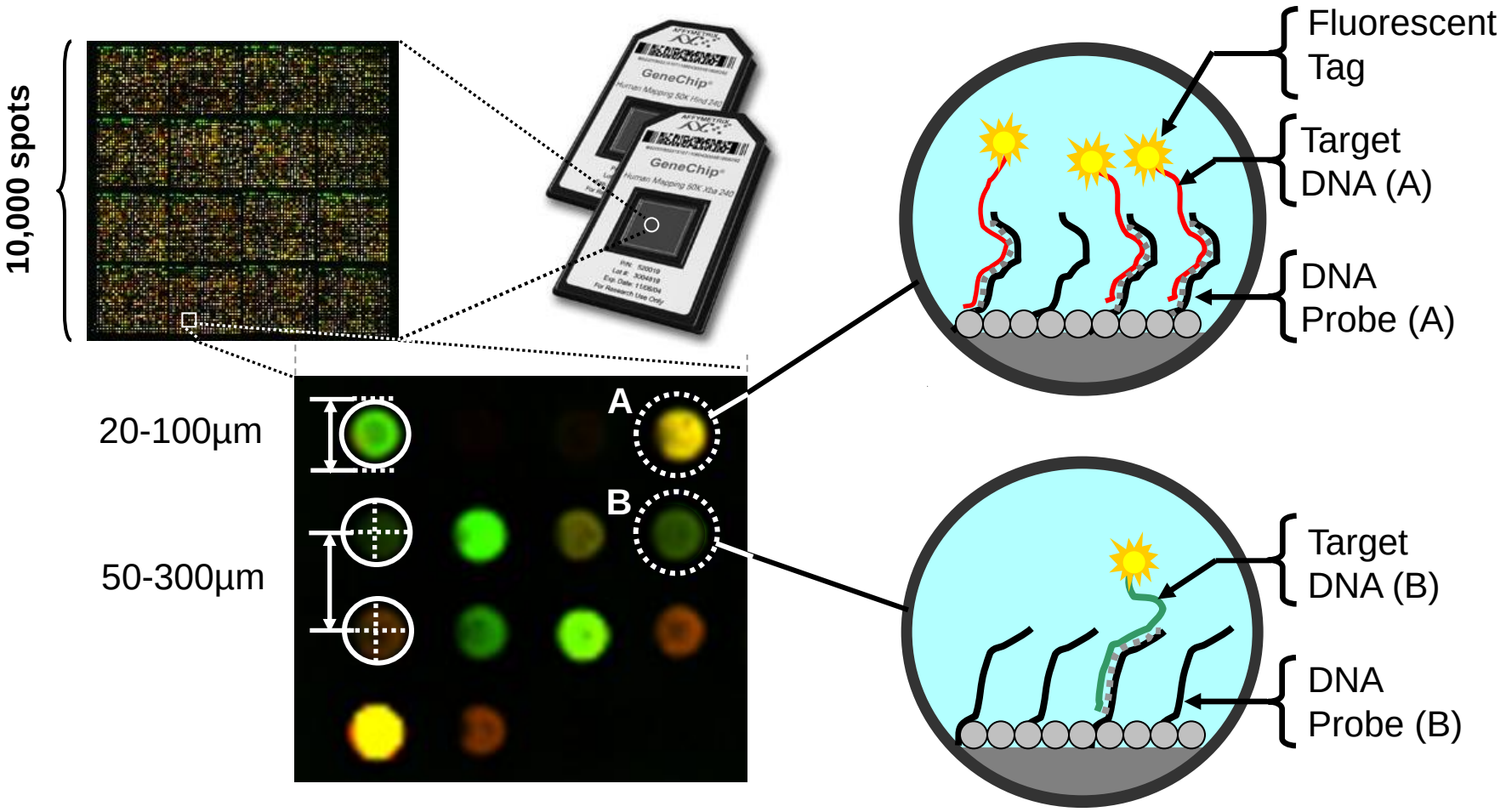
Parallel Affinity-Based Sensing

- For simultaneous detection of multiple targets, use affinity-based sensors in parallel:



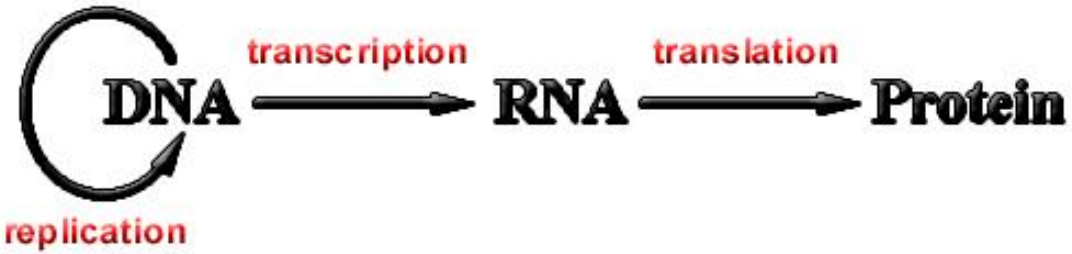
DNA Microarrays

- DNA microarrays are massively parallel affinity-based biosensor arrays:



Applications of DNA Microarrays

- Recall central dogma:

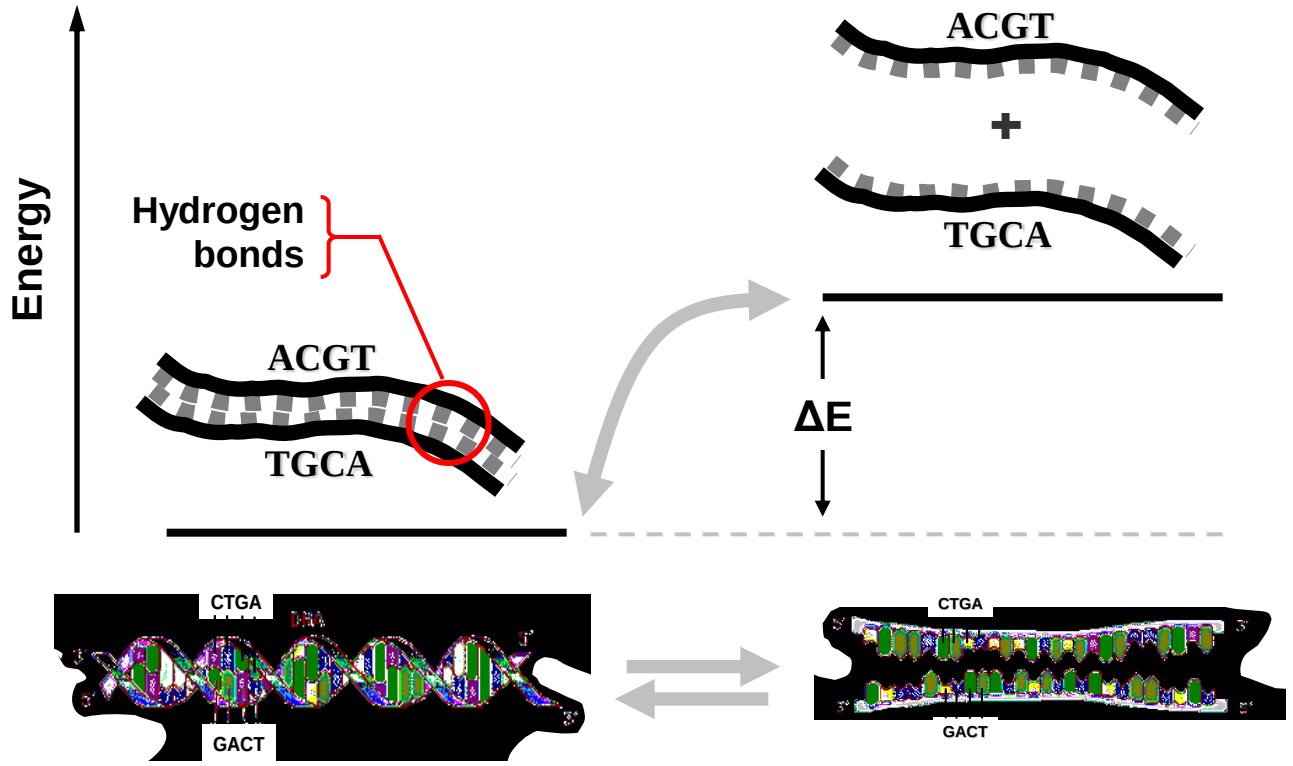


- DNA microarrays interrupt the information flow and measure gene expression levels
  - frequently, the task is to measure relative changes in mRNA levels
  - this gives information about the cell from which the mRNA is sampled (e.g., cancer studies)

- Other applications:
  - single nucleotide polymorphism (SNP) detection
  - simultaneous detection of multiple viruses, biohazard / water testing

Sensing in DNA Microarrays

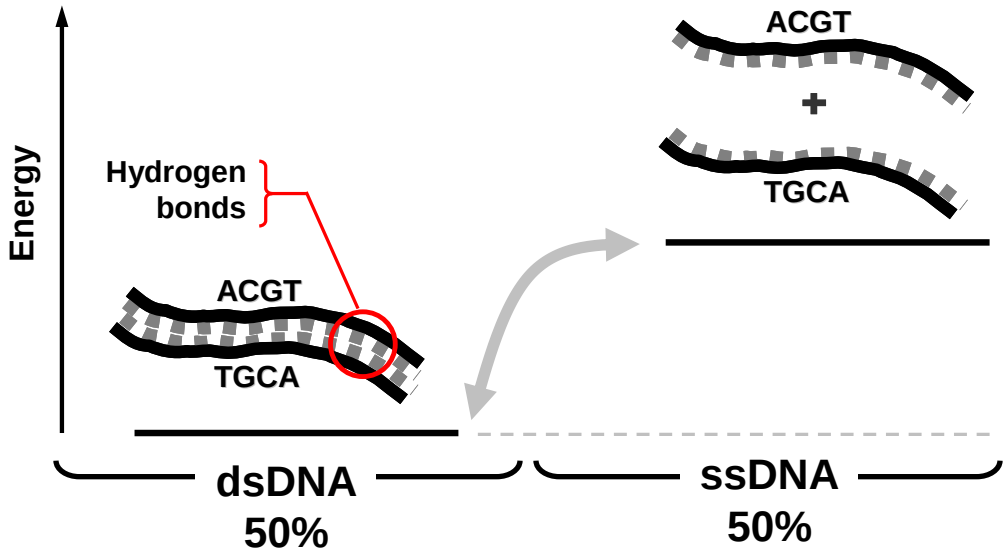
- When complementary ssDNA molecules get close to each other, electrostatic interactions (in form of hybridization bonds) may create dsDNA



- Because of thermal energy, the binding is a reversible stochastic process
- Relative stability of the dsDNA structures depend on the sequences

Stability of dsDNA: Melting Temperature

- The melting temperature (T_m) of a DNA fragment: the temperature at which 50% of the molecules form a stable double helix while the other 50% are separated into single strand molecules

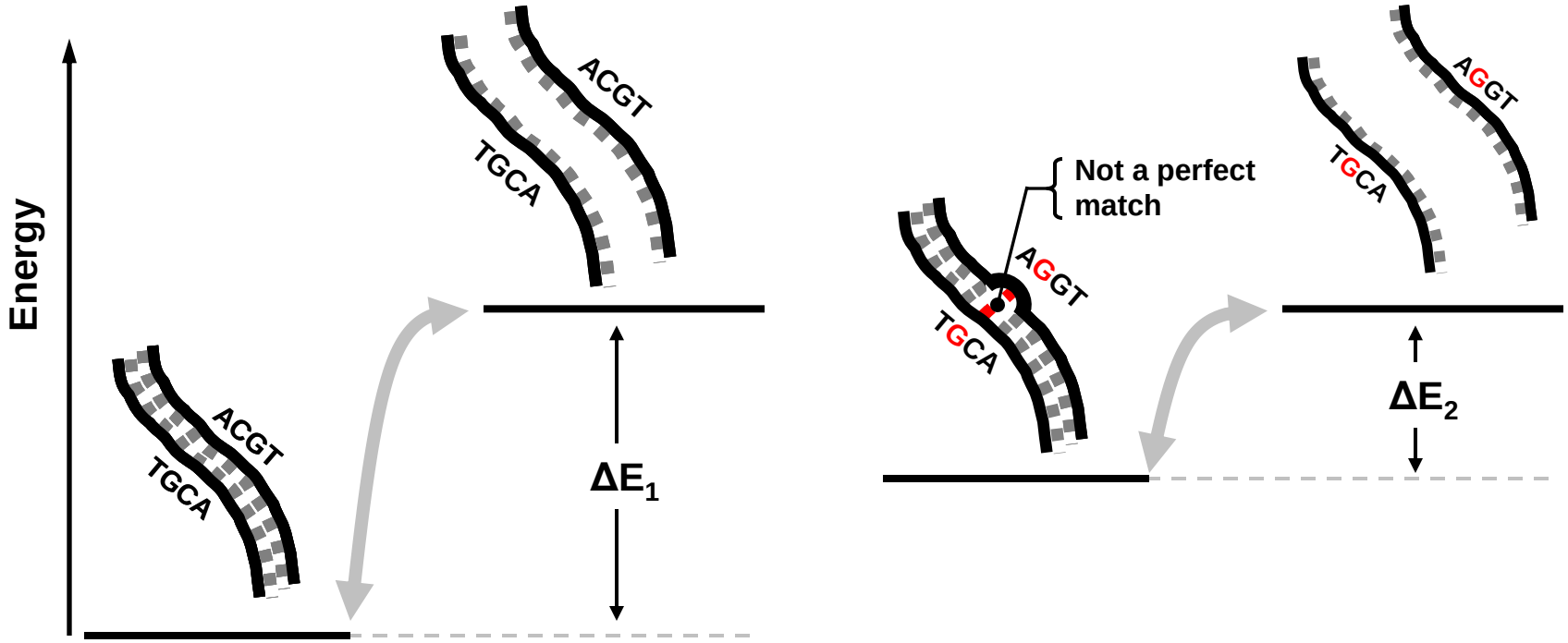


- Melting temperature is a function of DNA length, sequence content, salt concentration, and DNA concentration
- For sequences shorter than 18 ntds, there is a simple (Wallace) heuristic:

$$T_m = 2(A+T) + 4(G+C)$$

Nonspecific Binding (Cross-hybridization)

- Depending on sequences, non-specific binding may also happen:



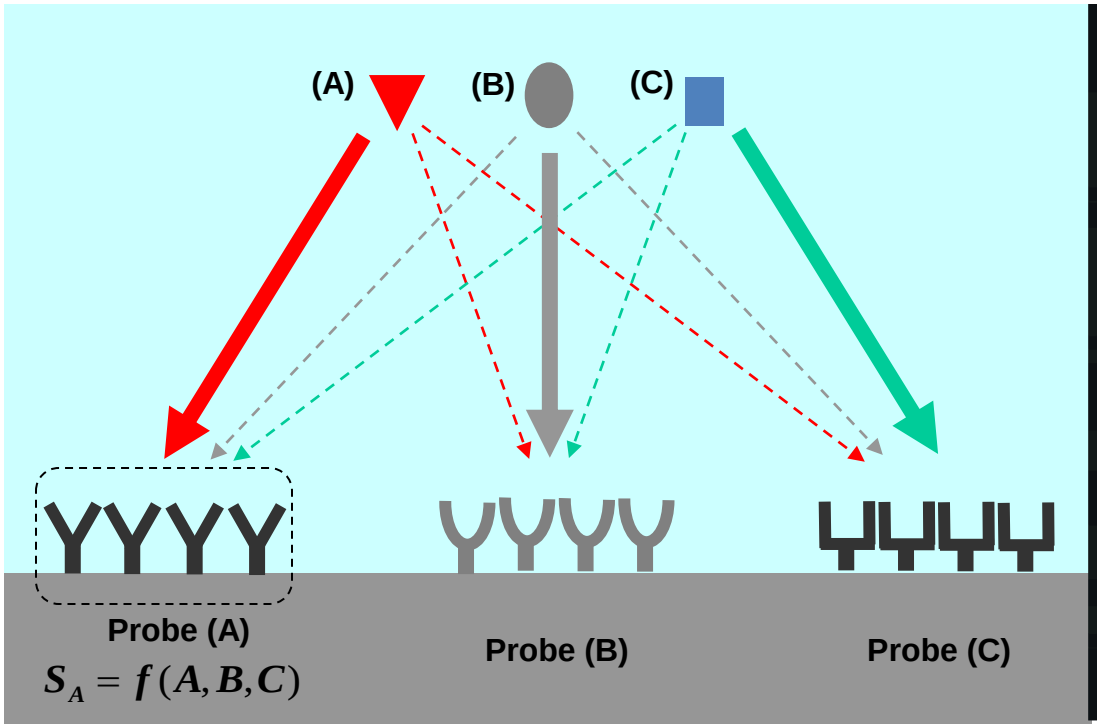
$$\Delta E_1 > \Delta E_2$$

$$(\text{Bond stability})_1 > (\text{Bond stability})_2$$

- So, non-specific binding is not as stable as specific binding

Non-specific binding in microarrays

- Non-specific binding (cross-hybridization) manifests as interference:

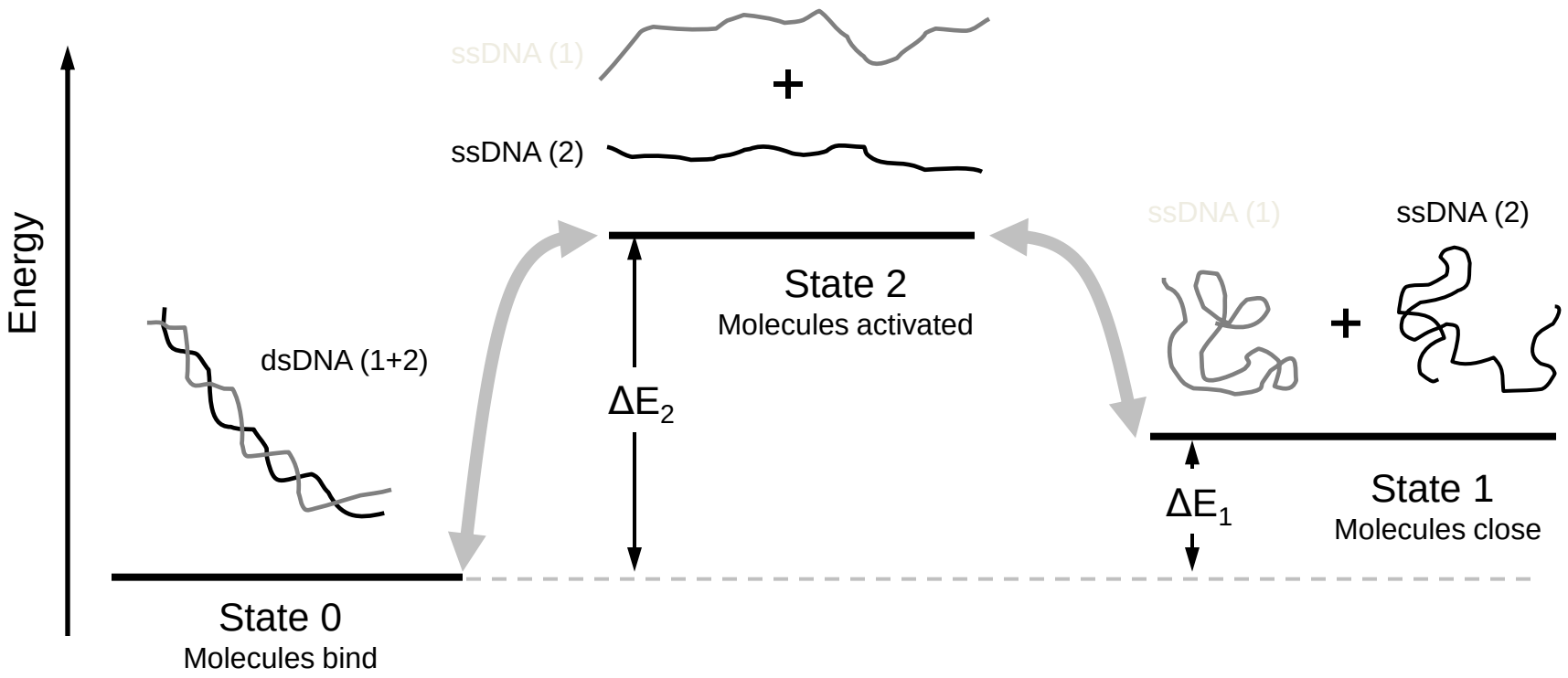


- Interference may lead to erroneous conclusions
- Useful signal is affected by the interfering molecules, false positives possible

Road to a Model: Underlying Physics

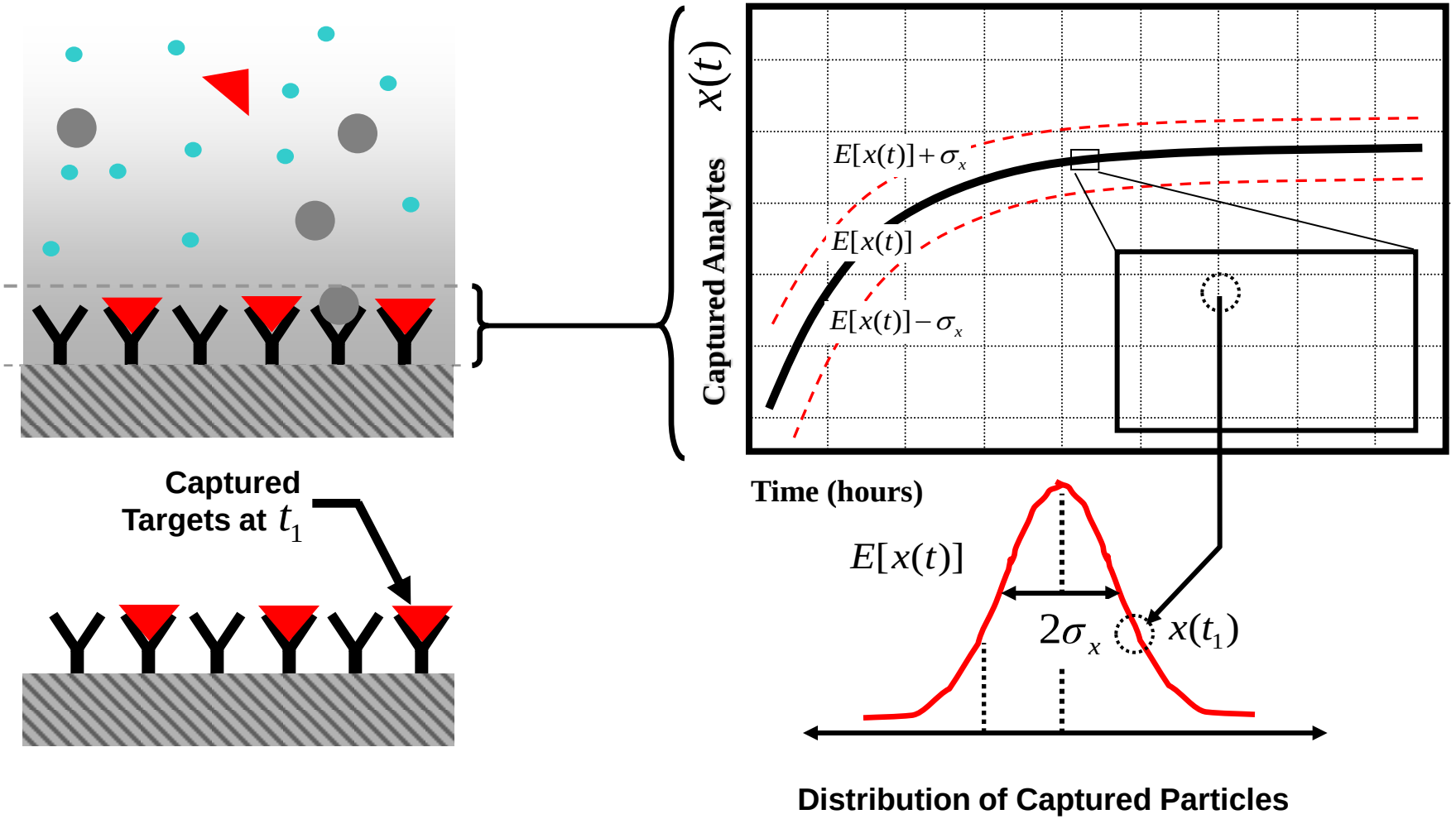
The kinetics of reactions depends on:

1. The frequency that the reactive species (e.g., molecules) get close to each other
2. If in close proximity, can thermal energy "facilitate" microscopic interactions



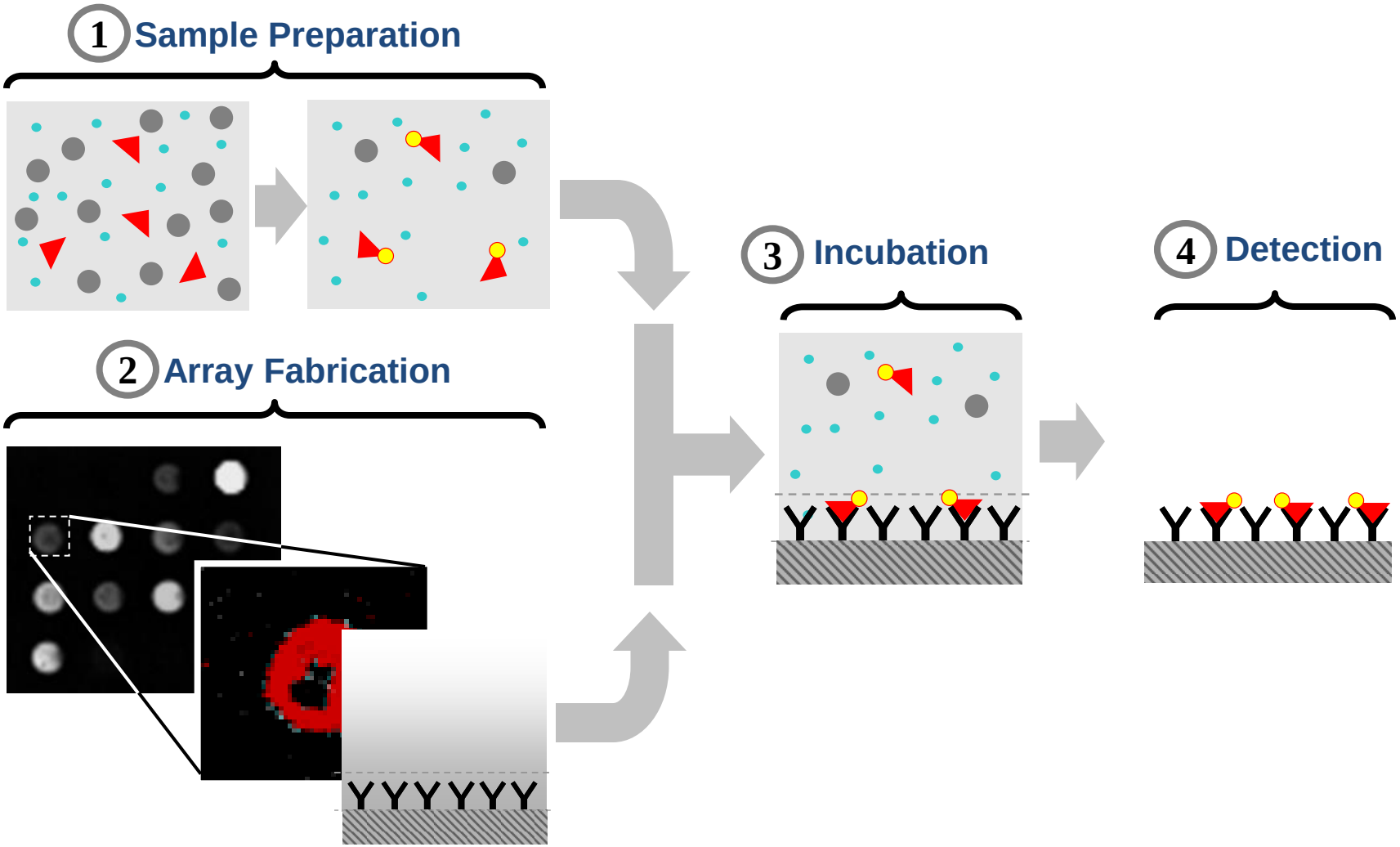
The Number of Captured Targets: A Random Process

The number of captured molecules forms a continuous-time Markov process



Microarrays

The steps involved in an experiment:

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