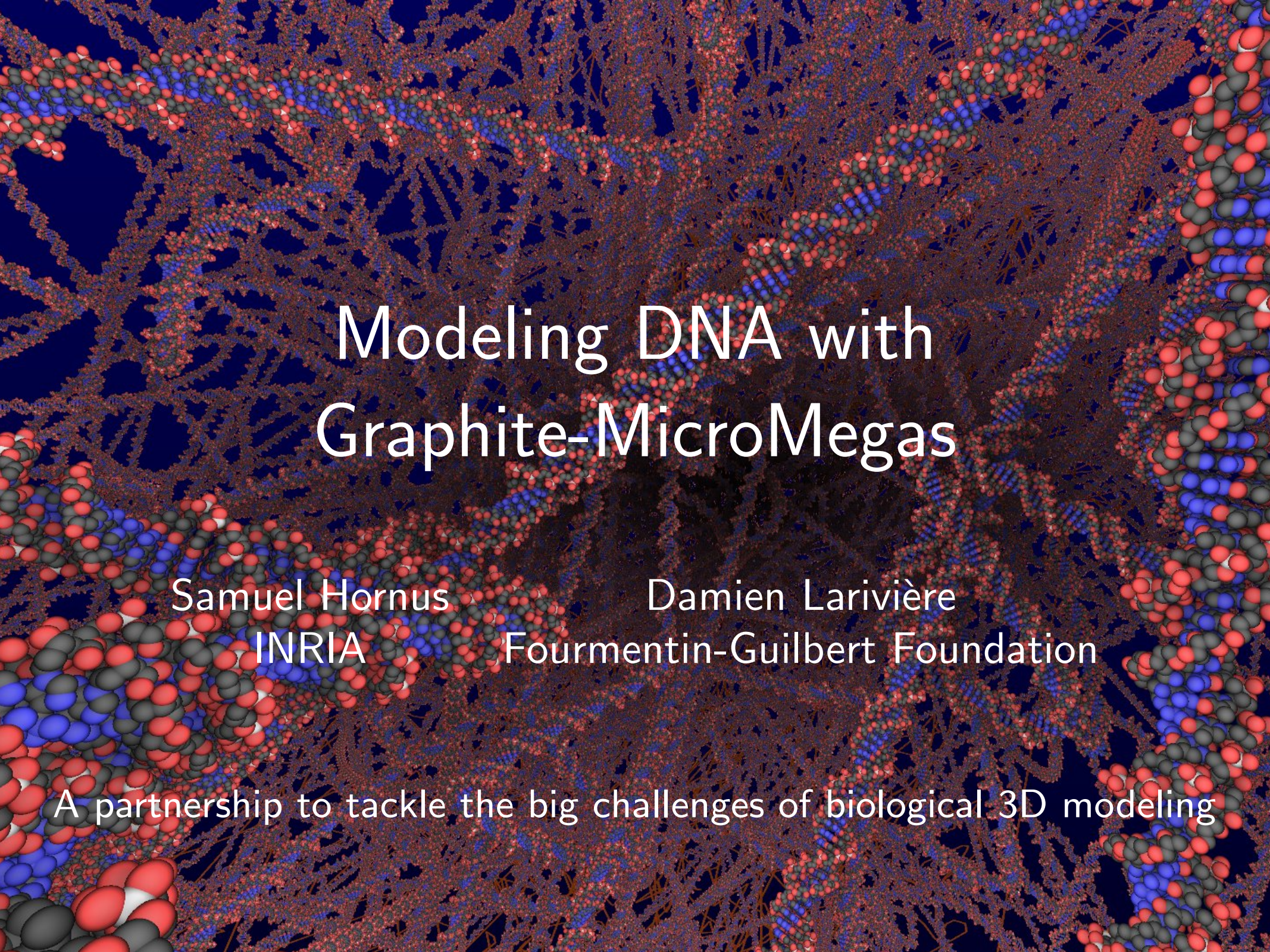


Modeling DNA with Graphite-MicroMegas

Samuel Hornus
INRIA

Damien Larivière
Fourmentin-Guilbert Foundation

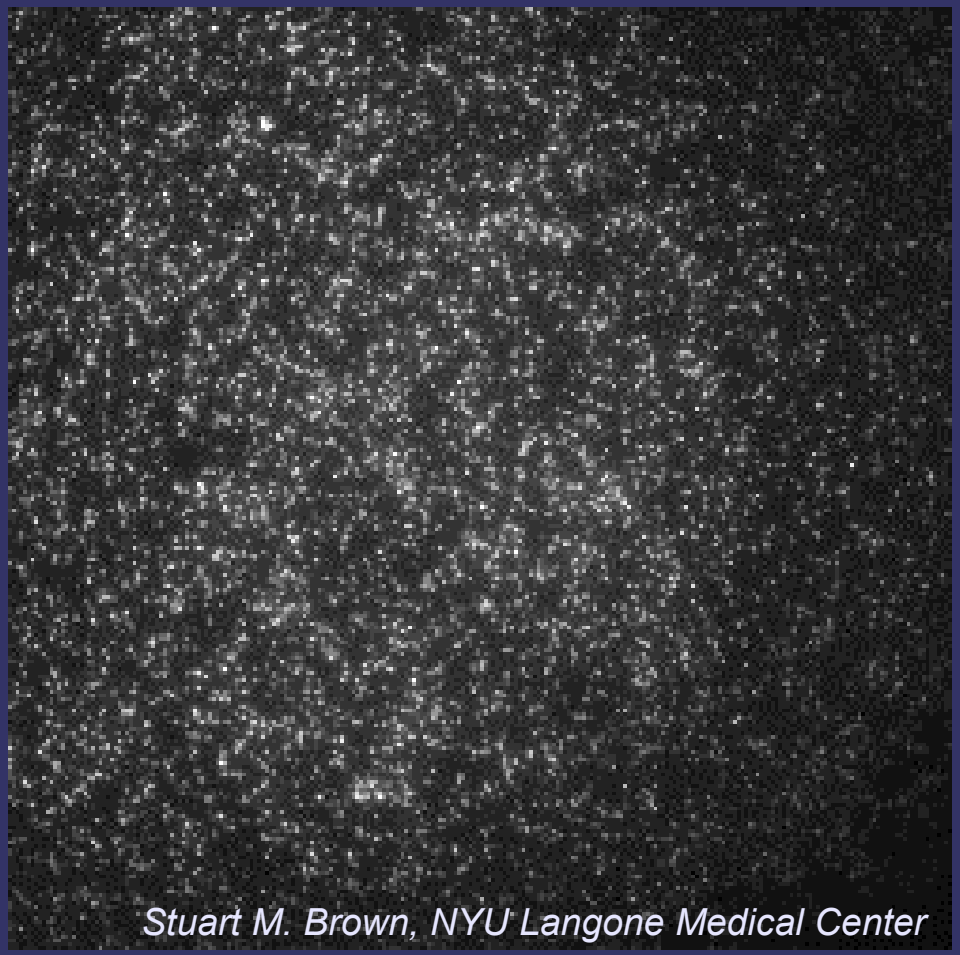
A partnership to tackle the big challenges of biological 3D modeling

Agenda

- Biological data deluge
- Data mass and comprehension
- Comprehension by 3D modeling
- Modeling DNA is required
- MicroMégas is of great help

Biological data deluge

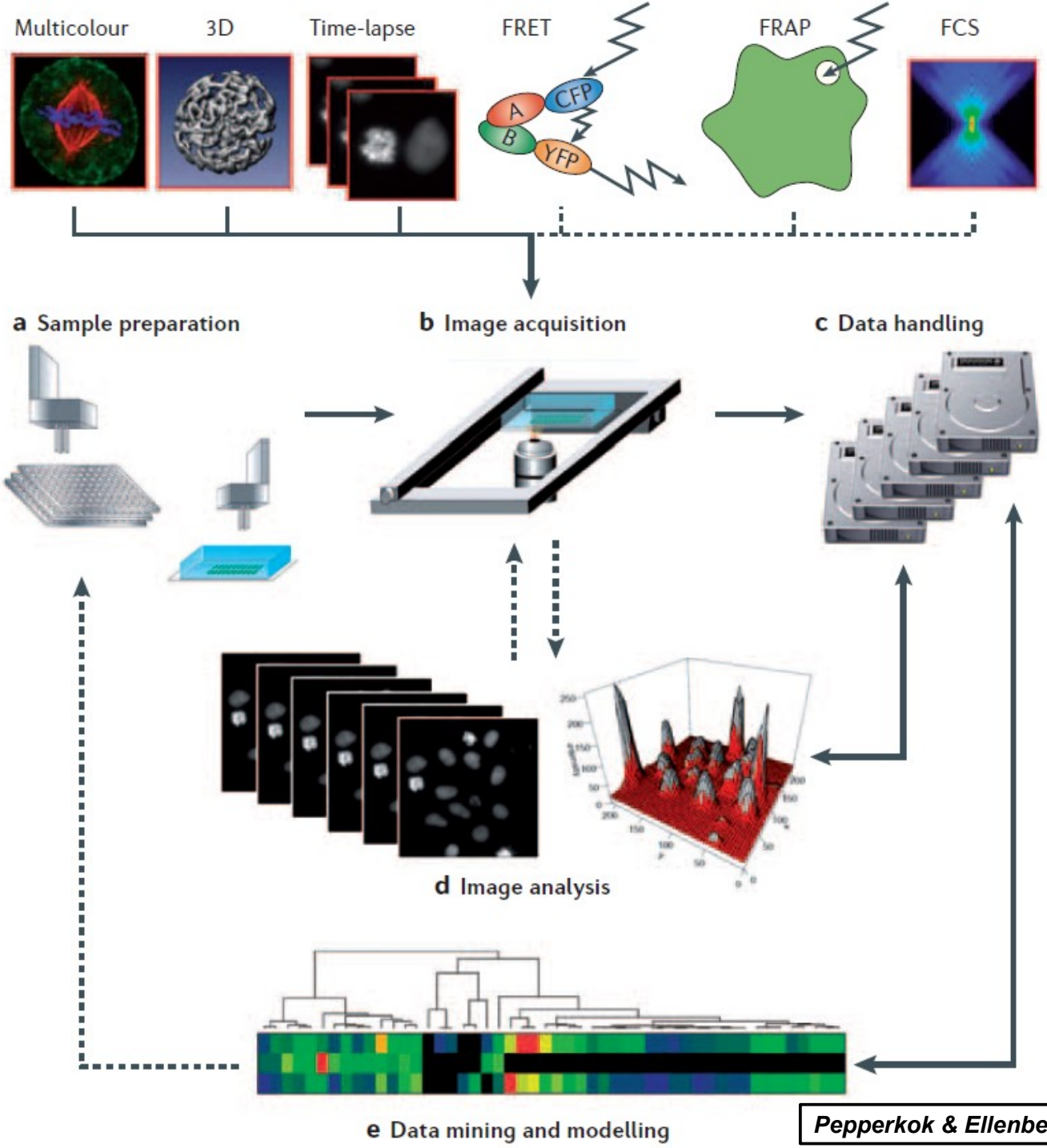
- Modern sequencers: One human genome every 14 minutes, 1-2 TB of raw data



Stuart M. Brown, NYU Langone Medical Center

A, T, G, C,...

Biological data deluge

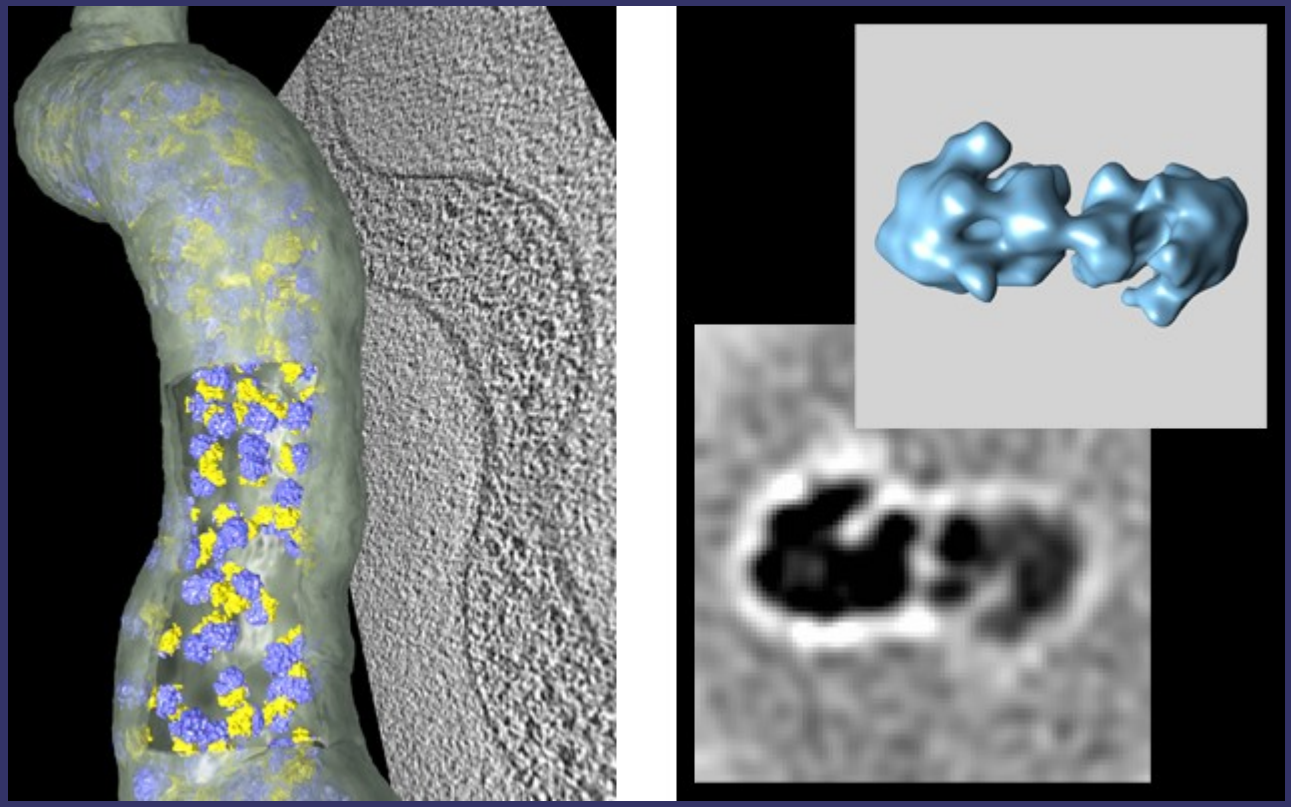


- Fluorescence microscopy:
  - Basis of numerous experiments
  - Acquisition of millions images per run
  - Generates several tens of terabytes

Pepperkok & Ellenberg, Nature, 2006

Biological data deluge

Electron microscopy

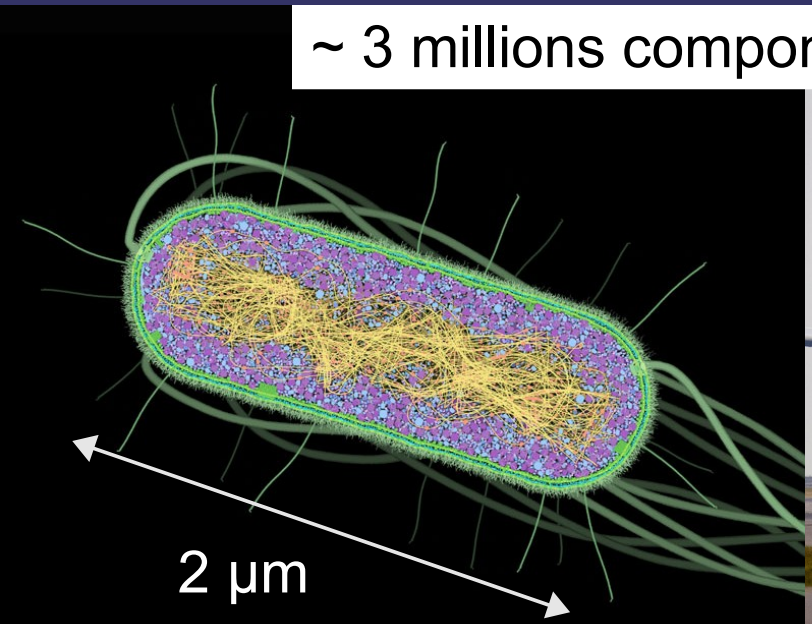


Julio.Ortiz, Max Planck Institute of Biochemistry

Data mass and comprehension

- 50 years used to dissect cells
- Time is come to re-assemble the disconnected parts

~ 3 millions components at the right place

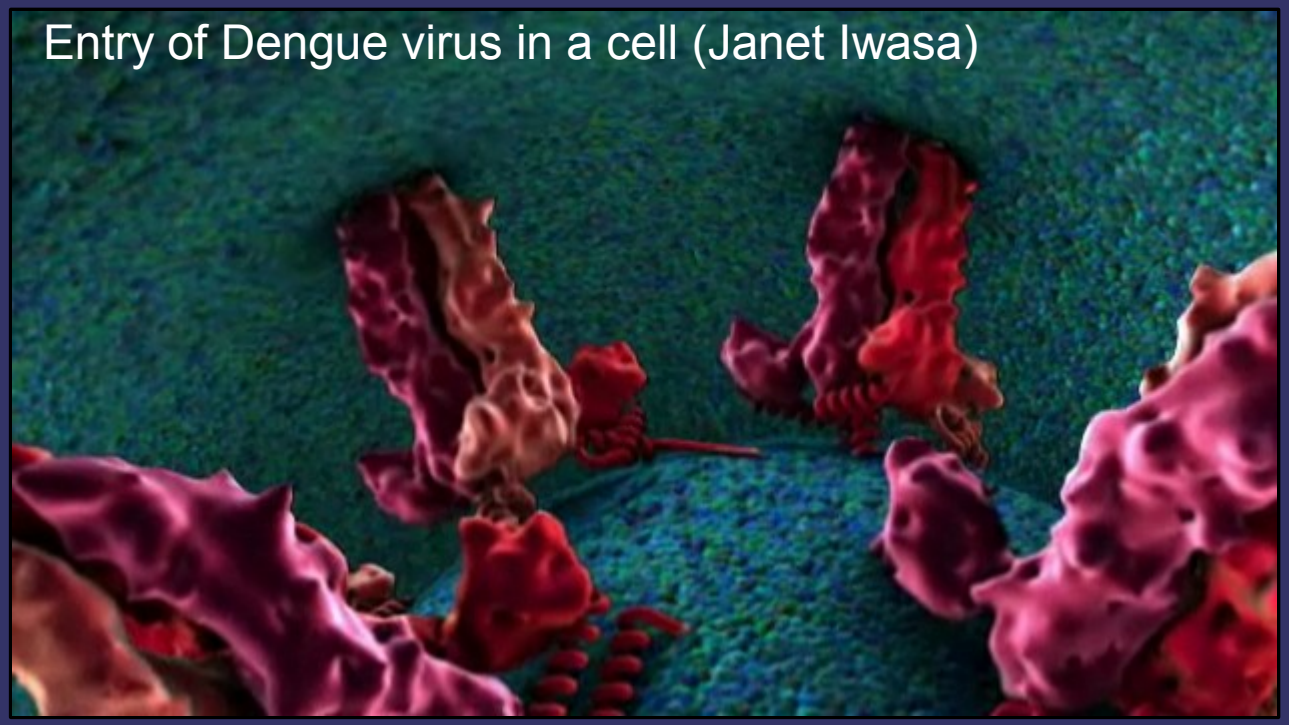


David Goodsell, TSRI

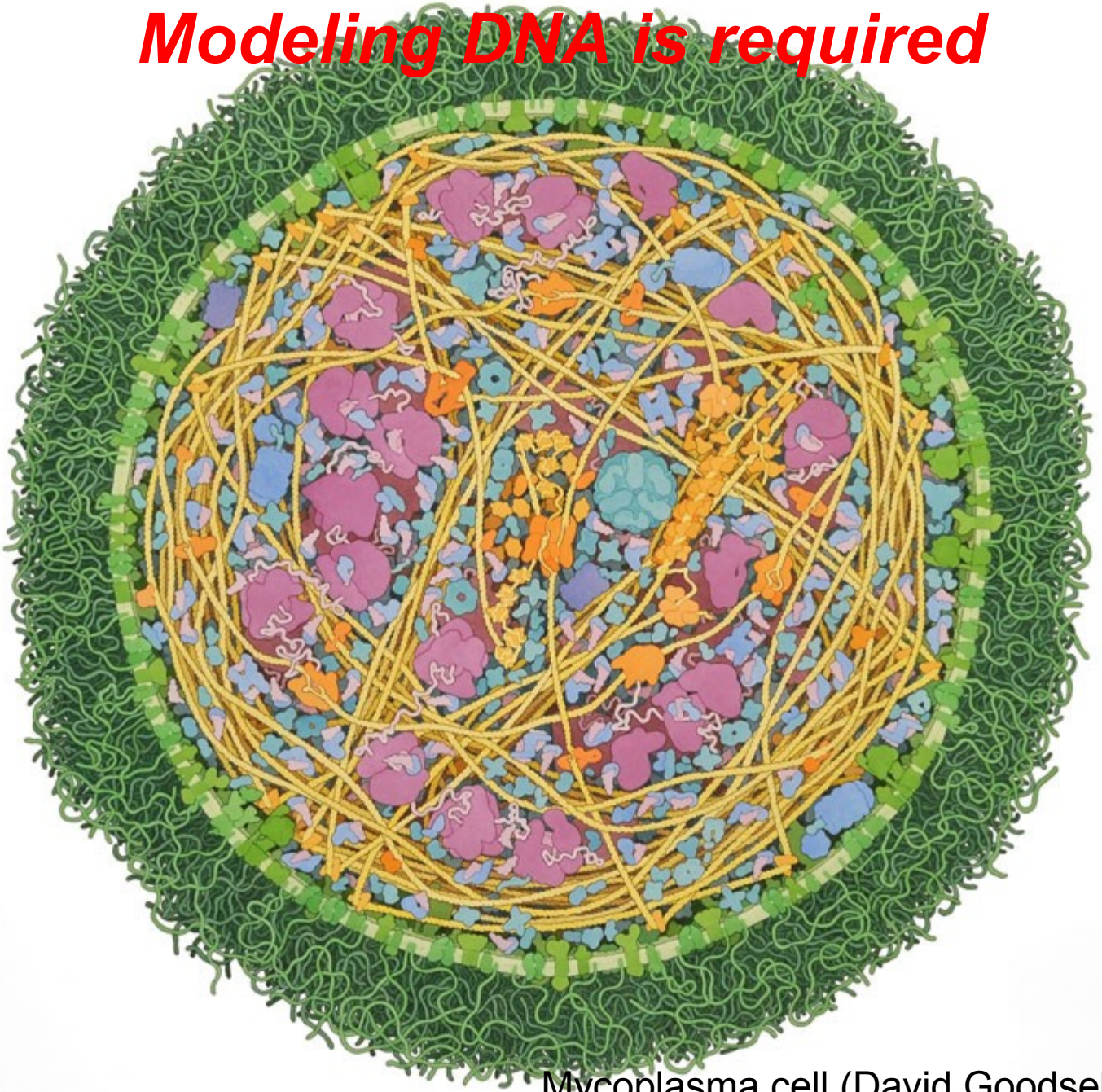
http://www.asiatraveltips.com/newspics/0611/AirbusA380inHK2.jpg

Comprehension by 3D modeling

- 3D modeling is being adopted
- 3D software borrowed from “Hollywood”
- Need a career time to be learned



Modeling DNA is required



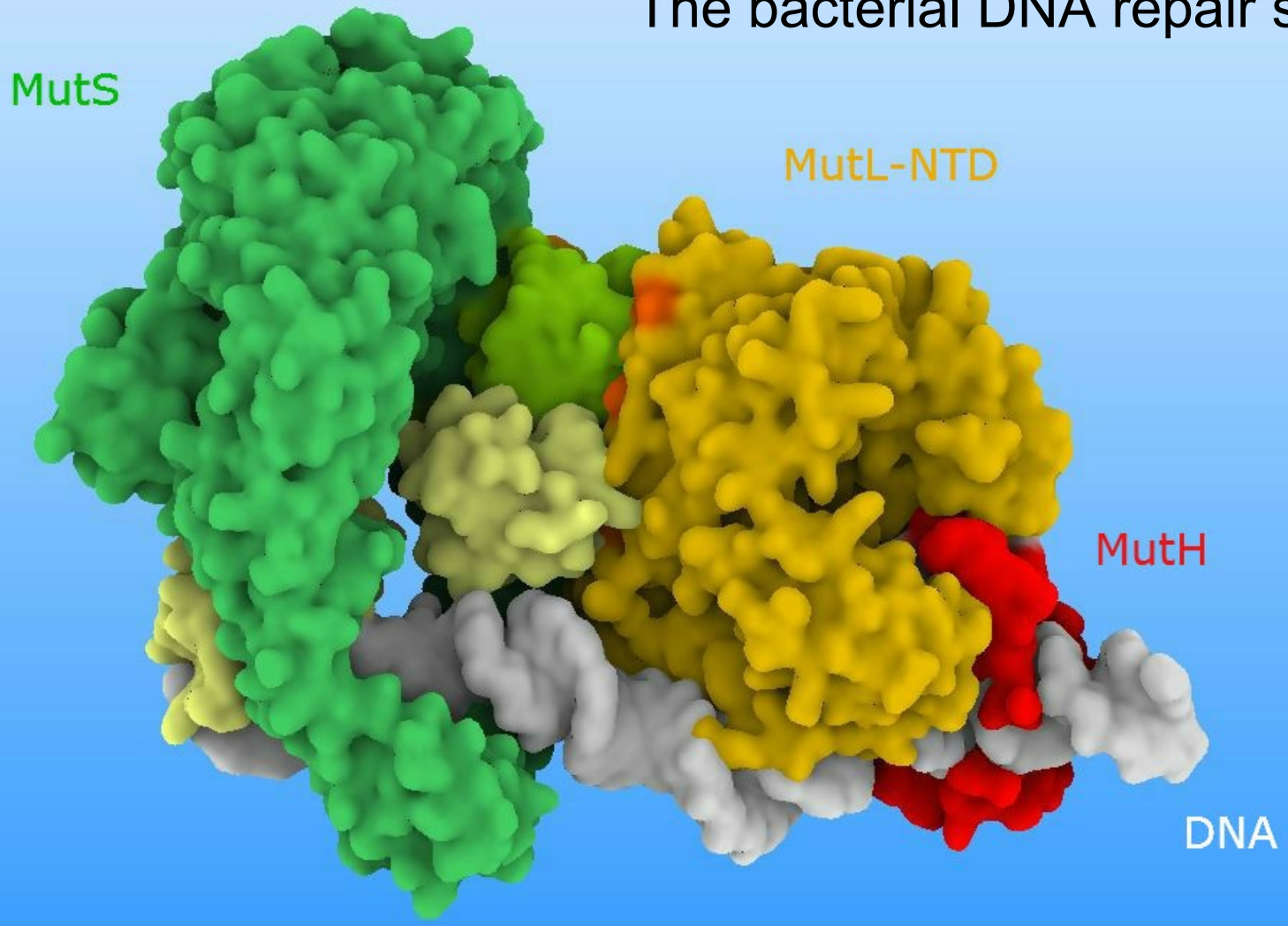
Mycoplasma cell (David Goodsell)

Modeling DNA is required

- Standard molecular tools and webservices:
  - Lack of intuitivity
  - Very basic modeling functions
- The opensource and intuitive *MicroMégas* plugin overcomes this situation

MicroMégas is of great help

The bacterial DNA repair system

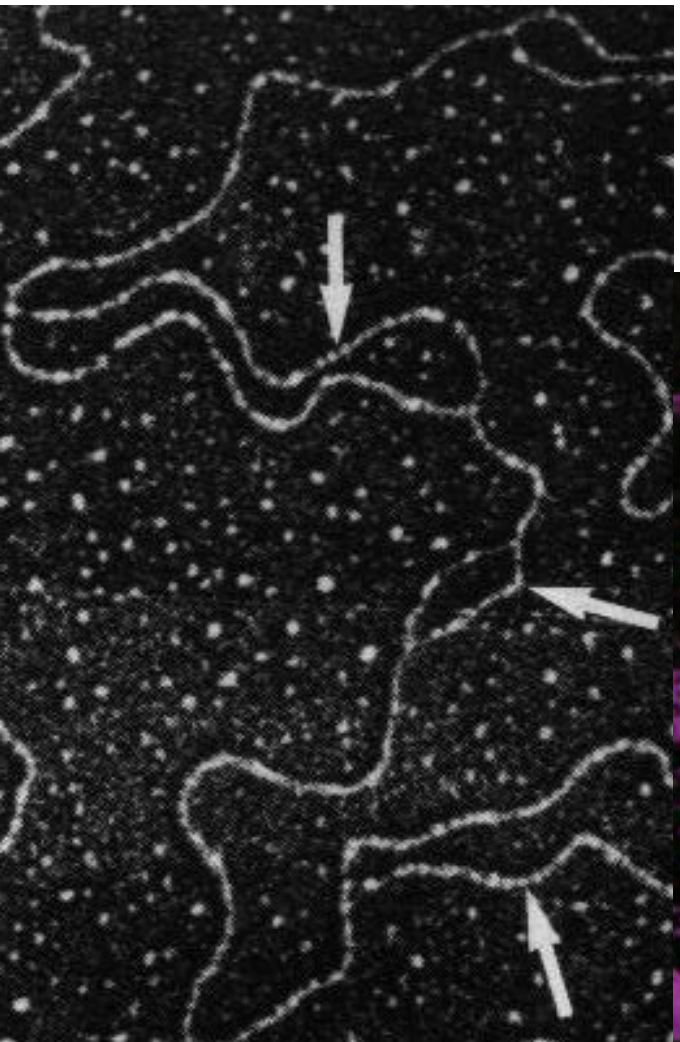


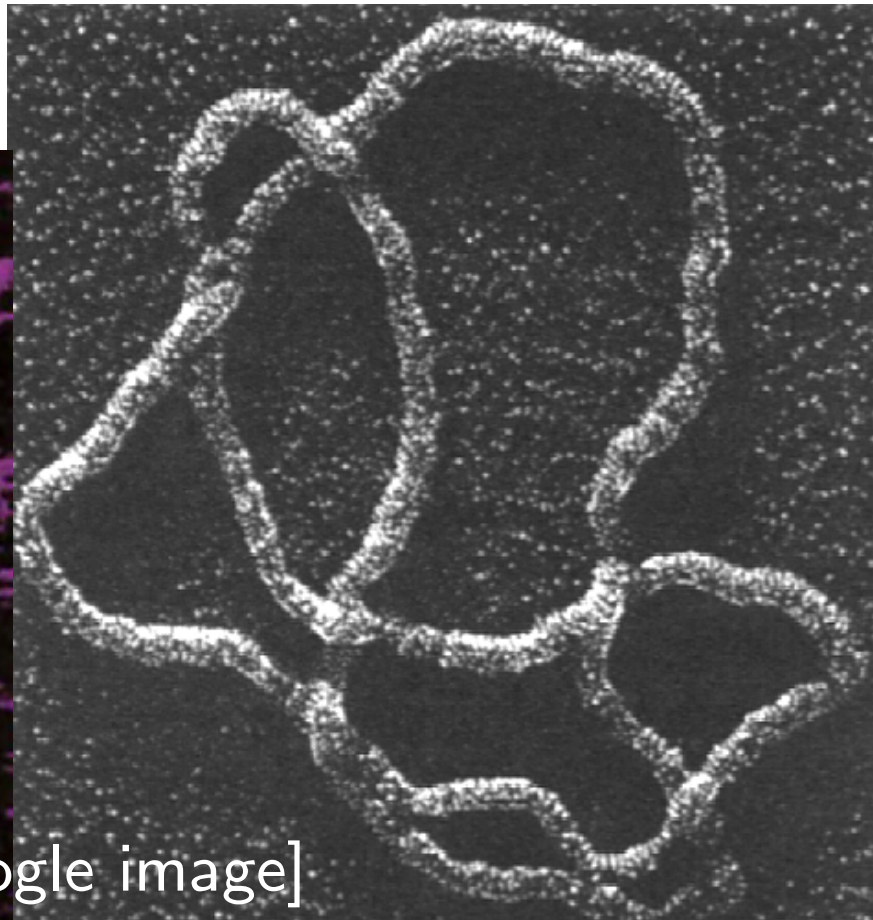
Winkler *et al*, J. Biological Chemistry, March 2011

Geometry of DNA

Naive view of DNA is good for low-level modeling:

- string-like structure
- helical shape
- long sequence of very similar "base pairs" (`ACGT`)



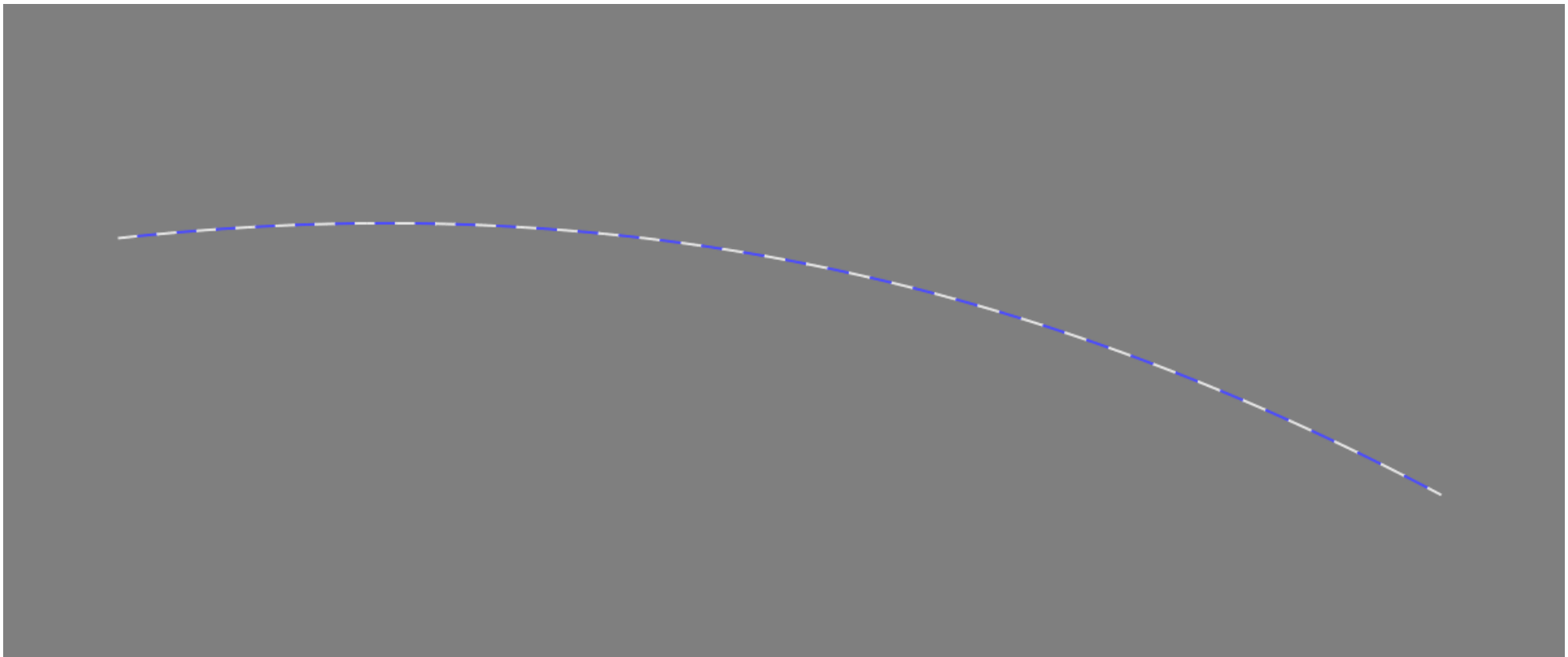


[google image]

Geometry of DNA

Computer graphicists translate this structure to:

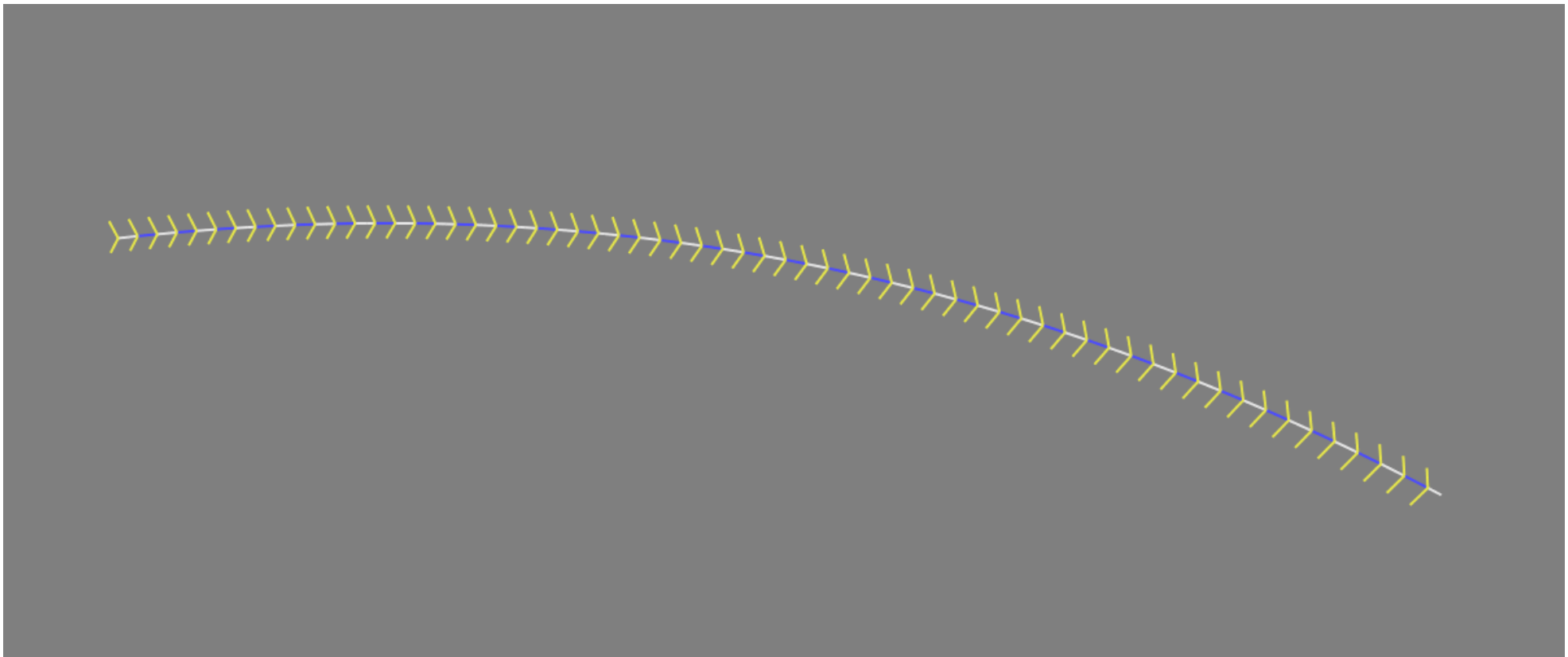
- a curve



Geometry of DNA

Computer graphicists translate this structure to:

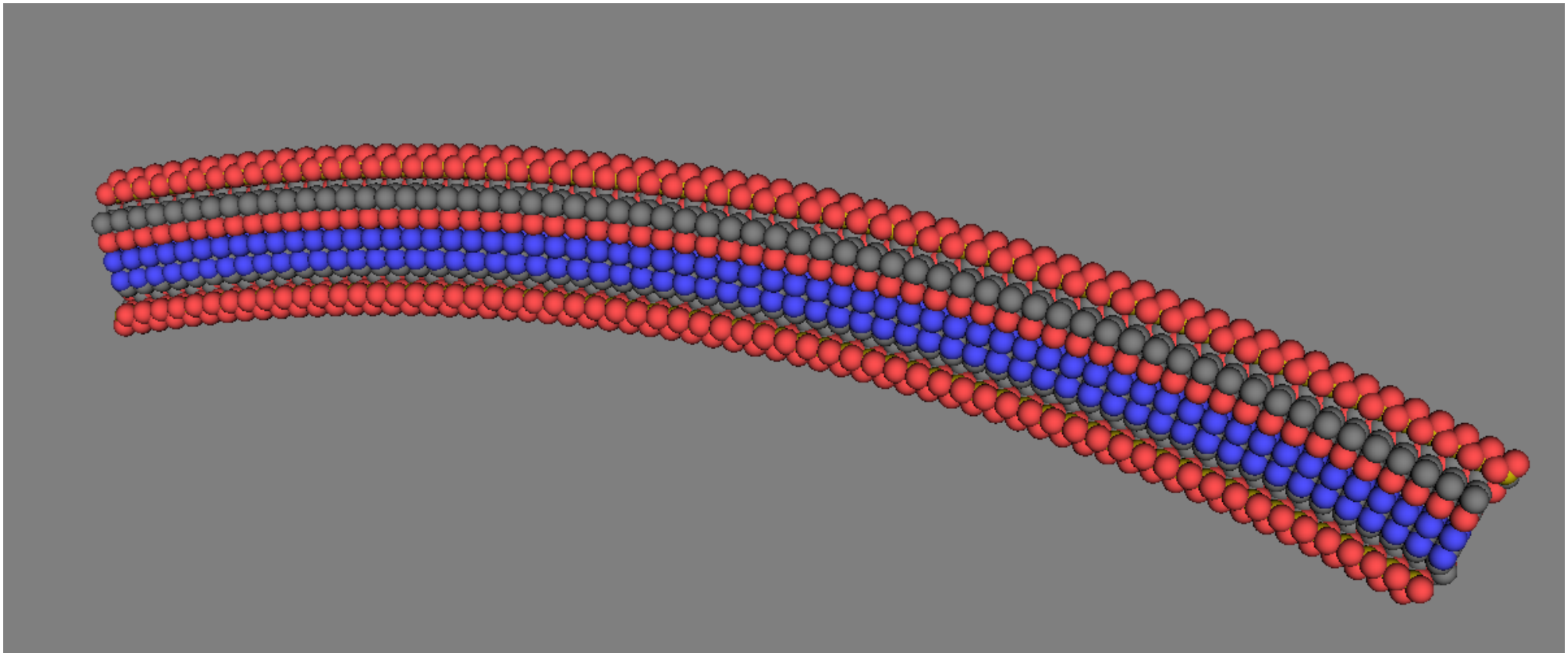
- a curve
- a uniform sampling of orthonormal frames



Geometry of DNA

Computer graphicists translate this structure to:

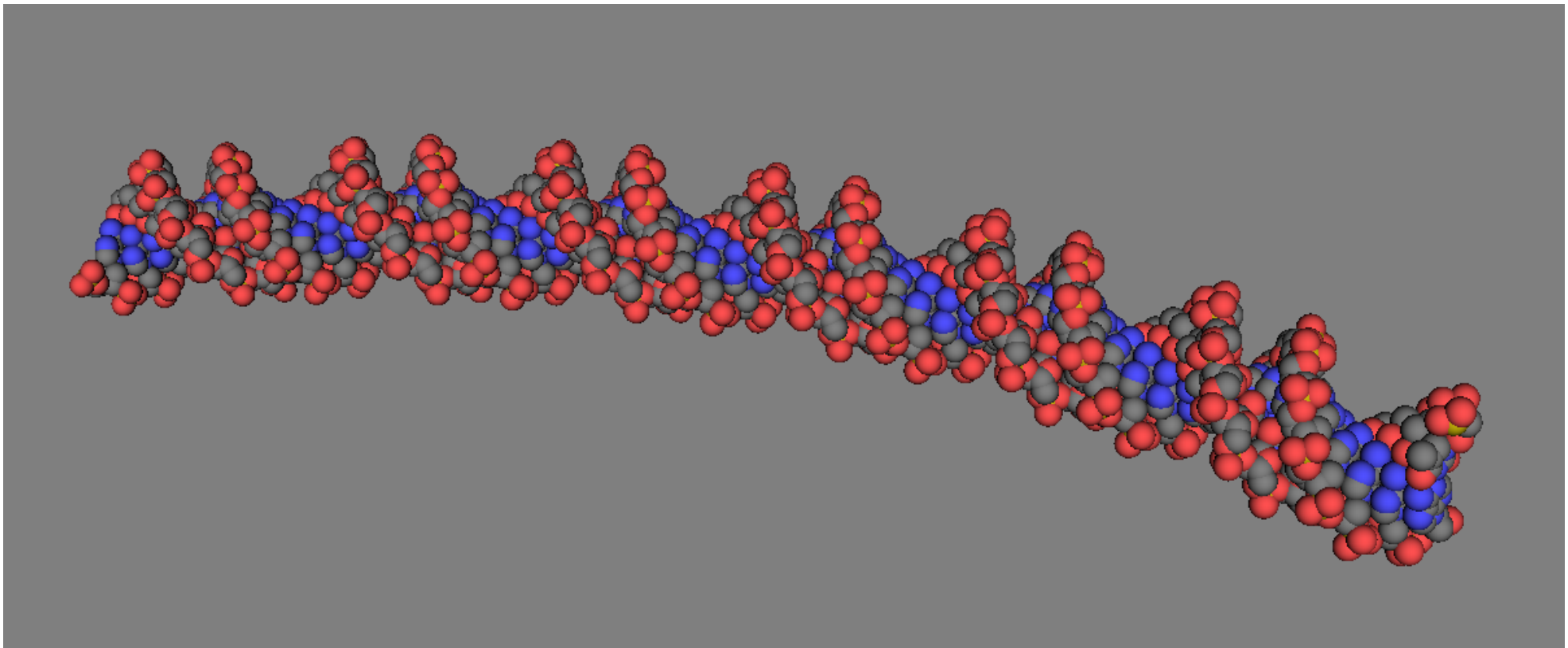
- a curve
- a uniform sampling of orthonormal frames
- instancing of base pairs



Geometry of DNA

Computer graphicists translate this structure to:

- a curve
- a uniform sampling of orthonormal frames
- instancing of base pairs
- with twisting: rotation around the tangent vector



Modeling a curve

Standard curve models:

- Quadratic Bézier curve
- Cubic Bézier curve
- Special case when input is a bare sequence of points
  $\Longrightarrow$ interpolatory subdivision scheme
  [Dyn, Floater and Hormann 2009]

Uniform sampling

Generating a uniform sampling with tangent is easy

Generating a normal at each sample point is difficult

Uniform sampling

Generating a uniform sampling with tangent is easy
Generating a normal at each sample point is difficult

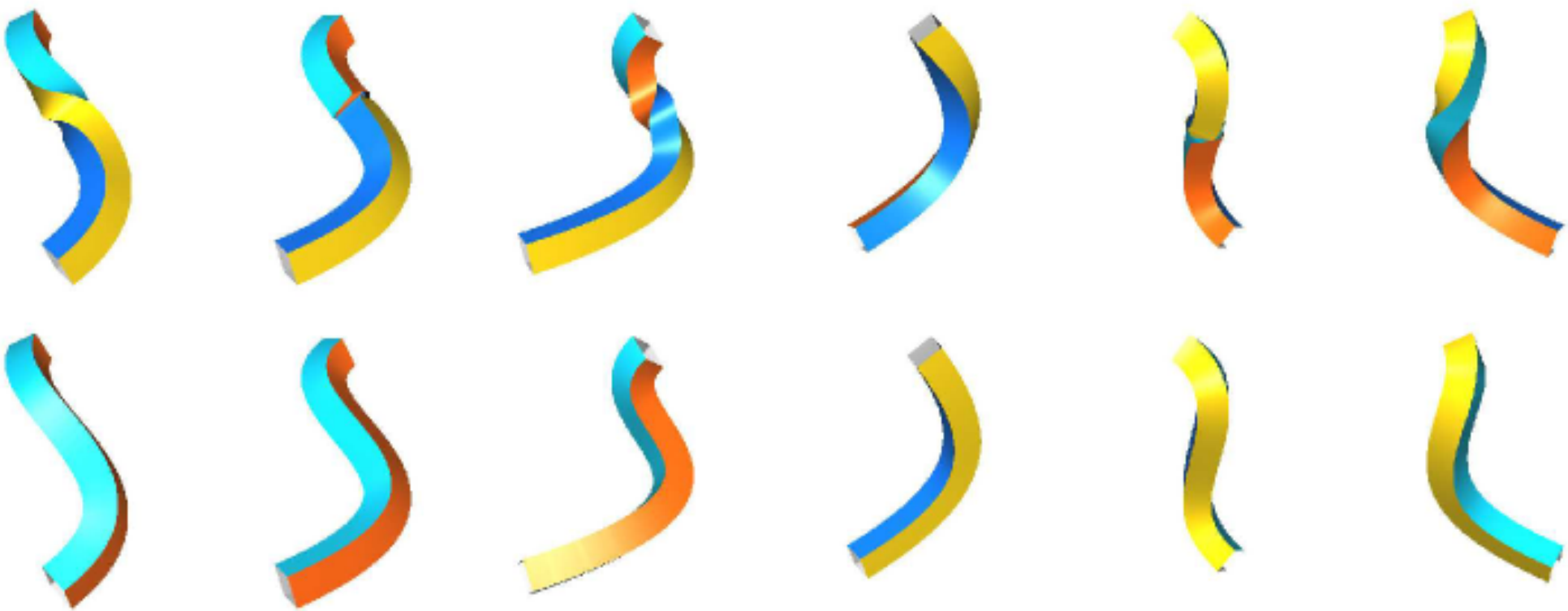
We want a continuous frame that minimizes torsion
E.g. the Frénet-Serret frame is not continuous

Uniform sampling

Generating a uniform sampling with tangent is easy
Generating a normal at each sample point is difficult

We want a continuous frame that minimizes torsion
E.g. the Frénet-Serret frame is not continuous

Recent technique: very fast and very good approximation:
[Rotation Minimizing Frames, ACM ToG 27(1):2, 2008]



Visualization with instancing and "ray-casting"

Use OpenGL to instantiate a 3D model of a base-pair in each frame along the curve:

- Setup GL transform matrix
- One call to `glDrawArrays` to draw one base pair

Visualization with instancing and "ray-casting"

Use OpenGL to instantiate a 3D model of a base-pair in each frame along the curve:

- Setup GL transform matrix
- One call to `glDrawArrays` to draw one base pair

A base-pair has ≈ 40 atoms. We setup GLSL programs so that:

- input $=$ array of atoms $\{$center, radius, color$\}$
- geometry shader builds a quad in front of the atom
- pixel shader compute intersection of ray & atom (a sphere)

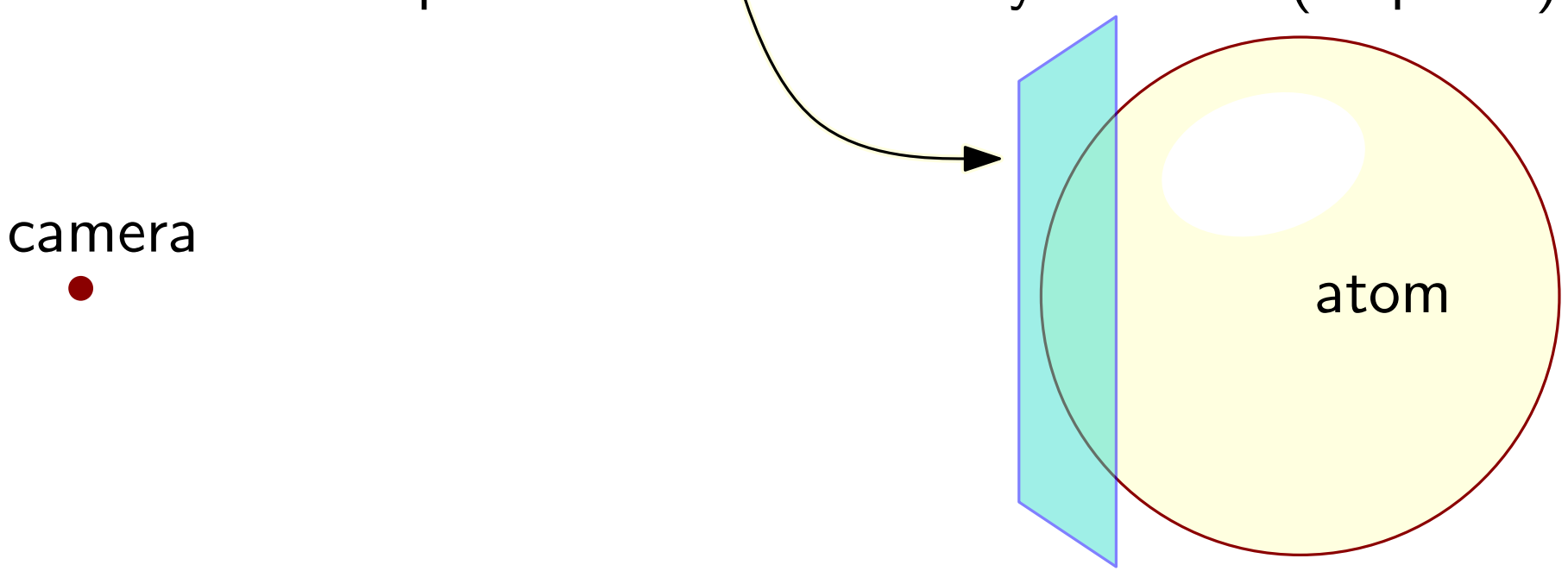
Visualization with instancing and "ray-casting"

Use OpenGL to instantiate a 3D model of a base-pair in each frame along the curve:

- Setup GL transform matrix
- One call to `glDrawArrays` to draw one base pair

A base-pair has ≈ 40 atoms. We setup GLSL programs so that:

- input = array of atoms {center, radius, color}
- geometry shader builds a quad in front of the atom
- pixel shader compute intersection of ray & atom (a sphere)



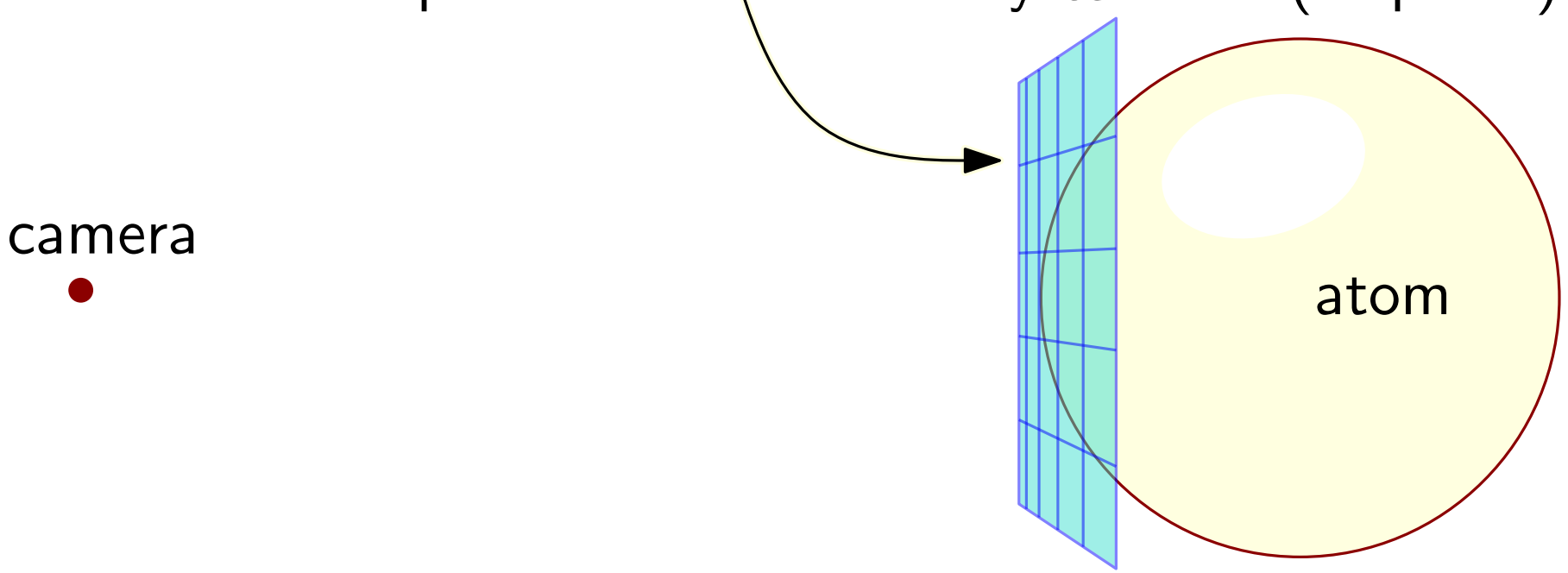
Visualization with instancing and "ray-casting"

Use OpenGL to instantiate a 3D model of a base-pair in each frame along the curve:

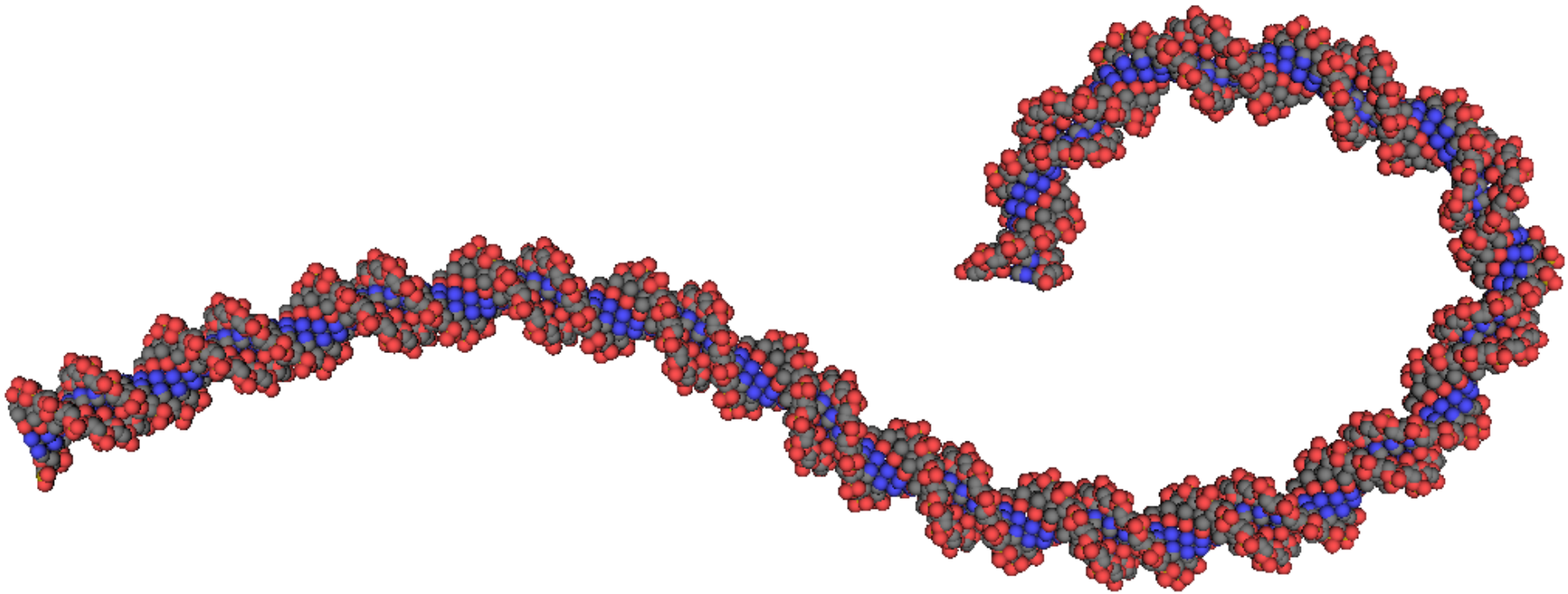
- Setup GL transform matrix
- One call to `glDrawArrays` to draw one base pair

A base-pair has ≈ 40 atoms. We setup GLSL programs so that:

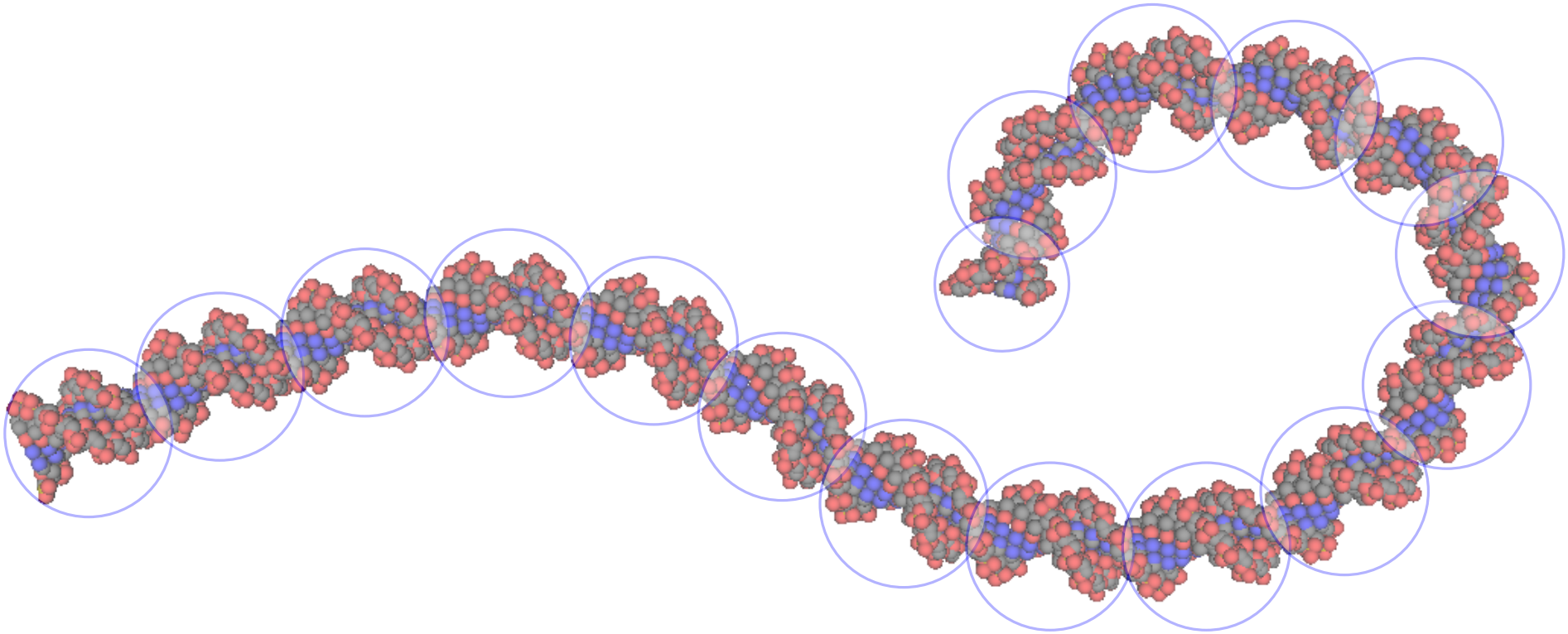
- input = array of atoms {center, radius, color}
- geometry shader builds a quad in front of the atom
- pixel shader compute intersection of ray & atom (a sphere)



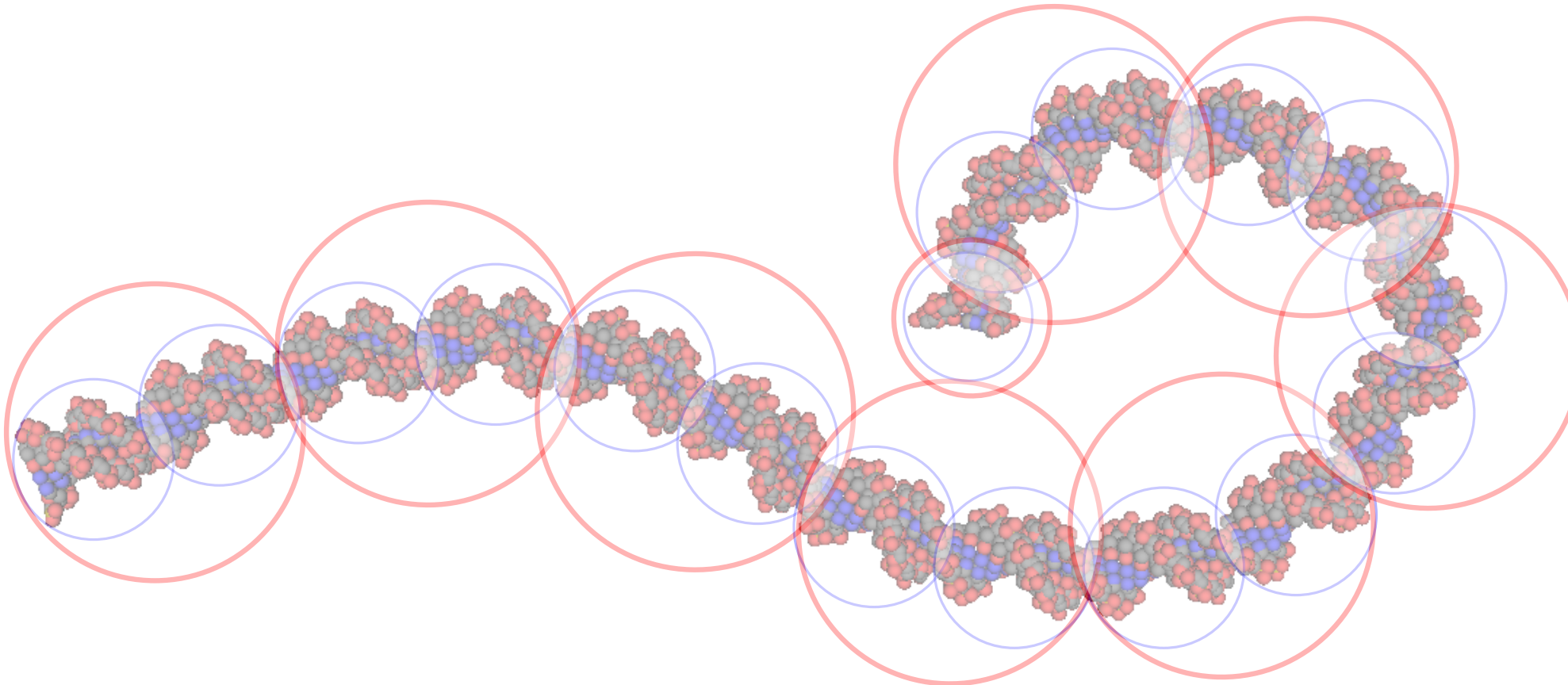
Level of Details



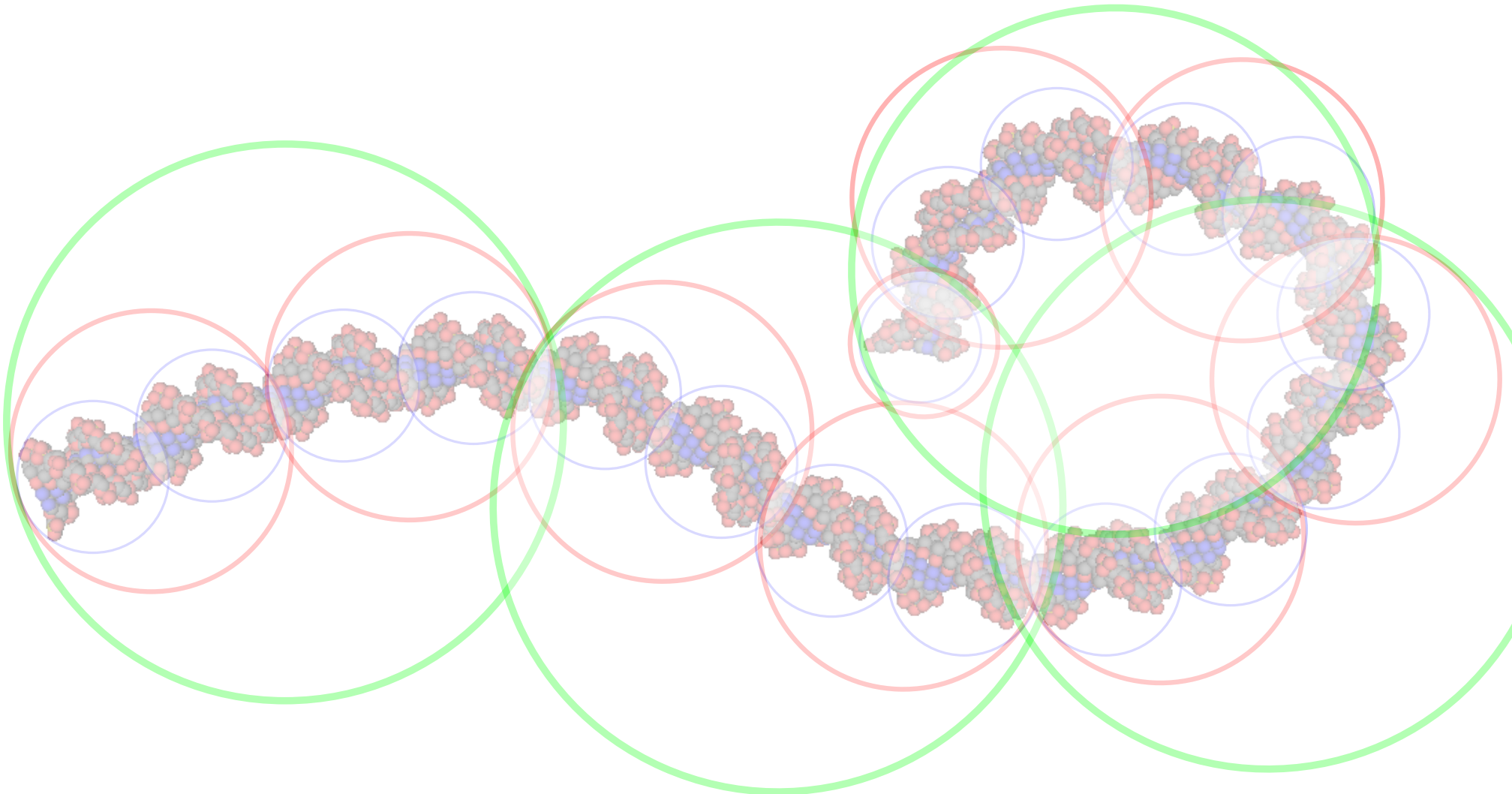
Level of Details



Level of Details



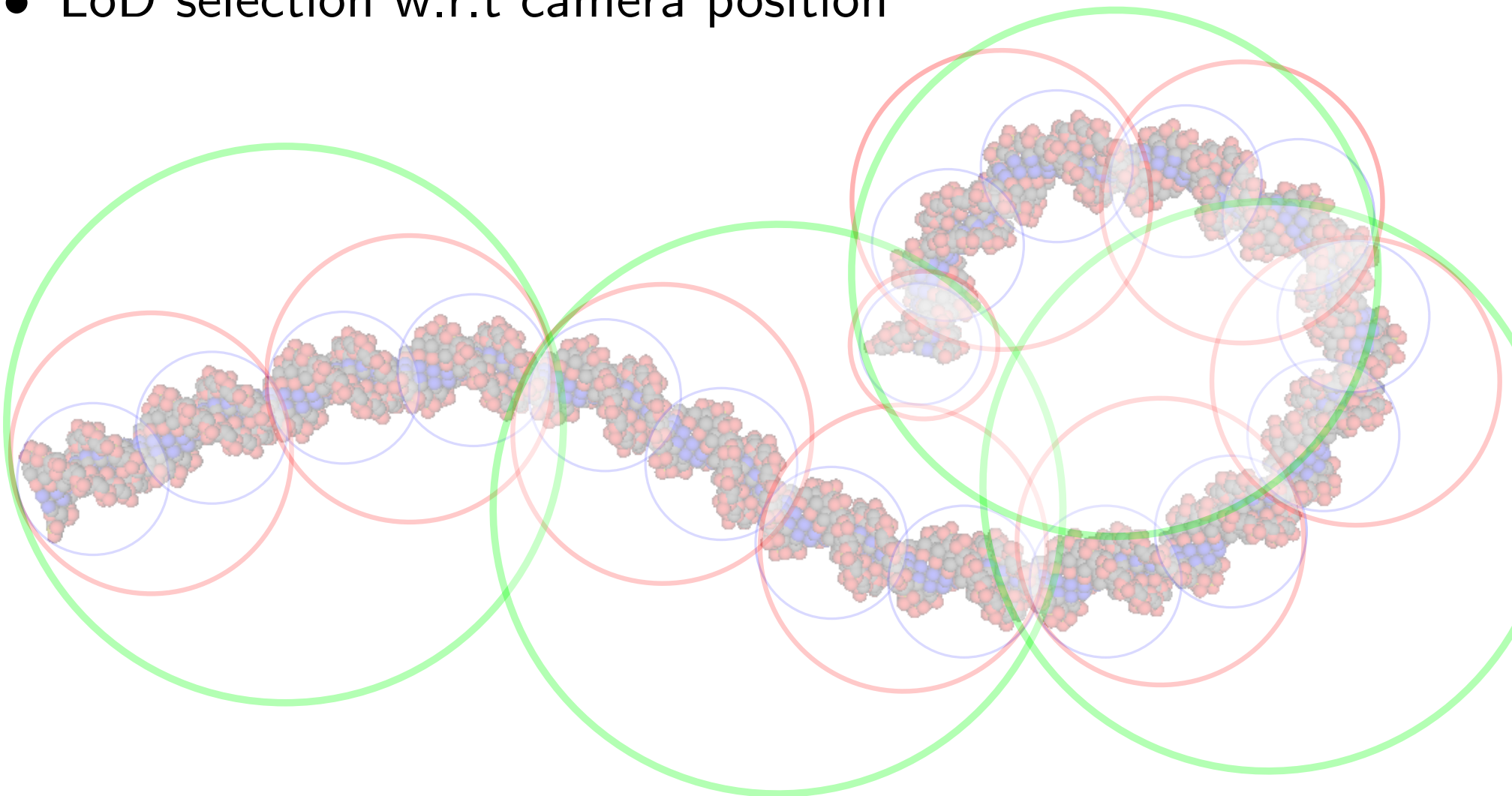
Level of Details



Level of Details

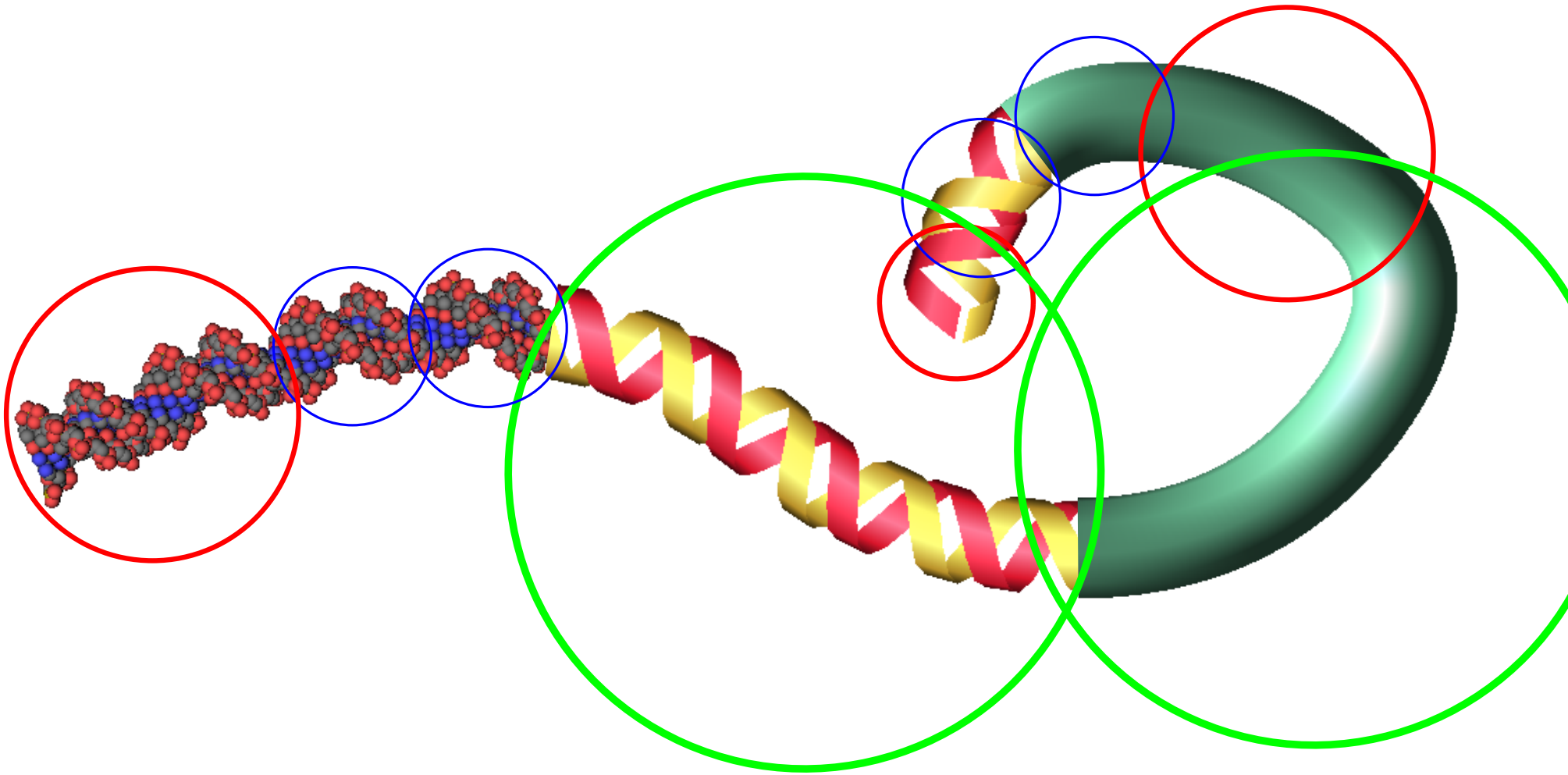
Hierarchy used for

- base-pair picking (on mouseclick)
- LoD selection w.r.t camera position



Level of Details

$\longleftarrow$ Camera is left of screen

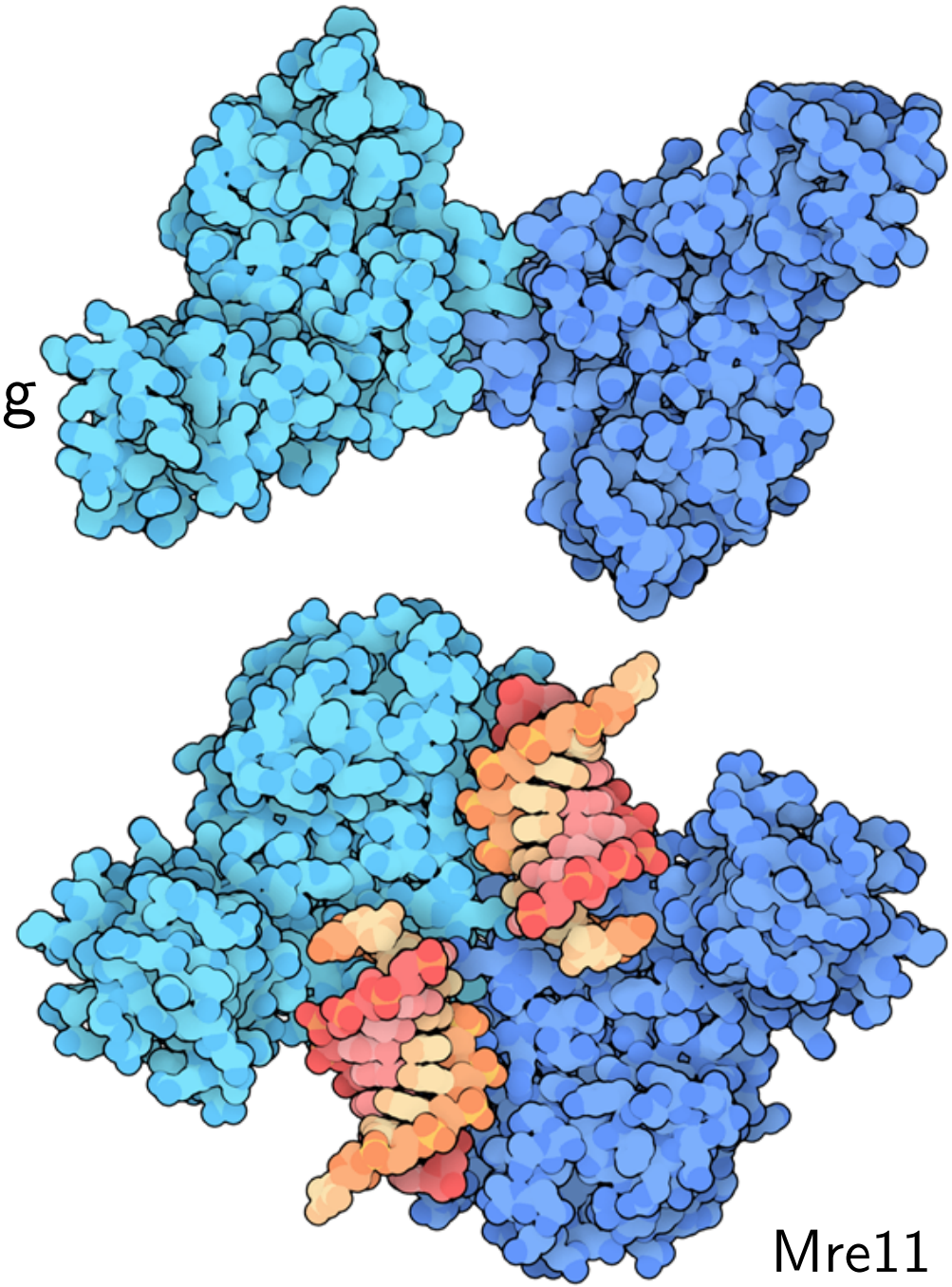



Thank you
[demo?]

Why modeling biological scenes spatially?

Medical illustration

- Popularizing knowledge
- Help scientists' understanding
- Dynamic simulation



Mre11

David Goodsell © 2010

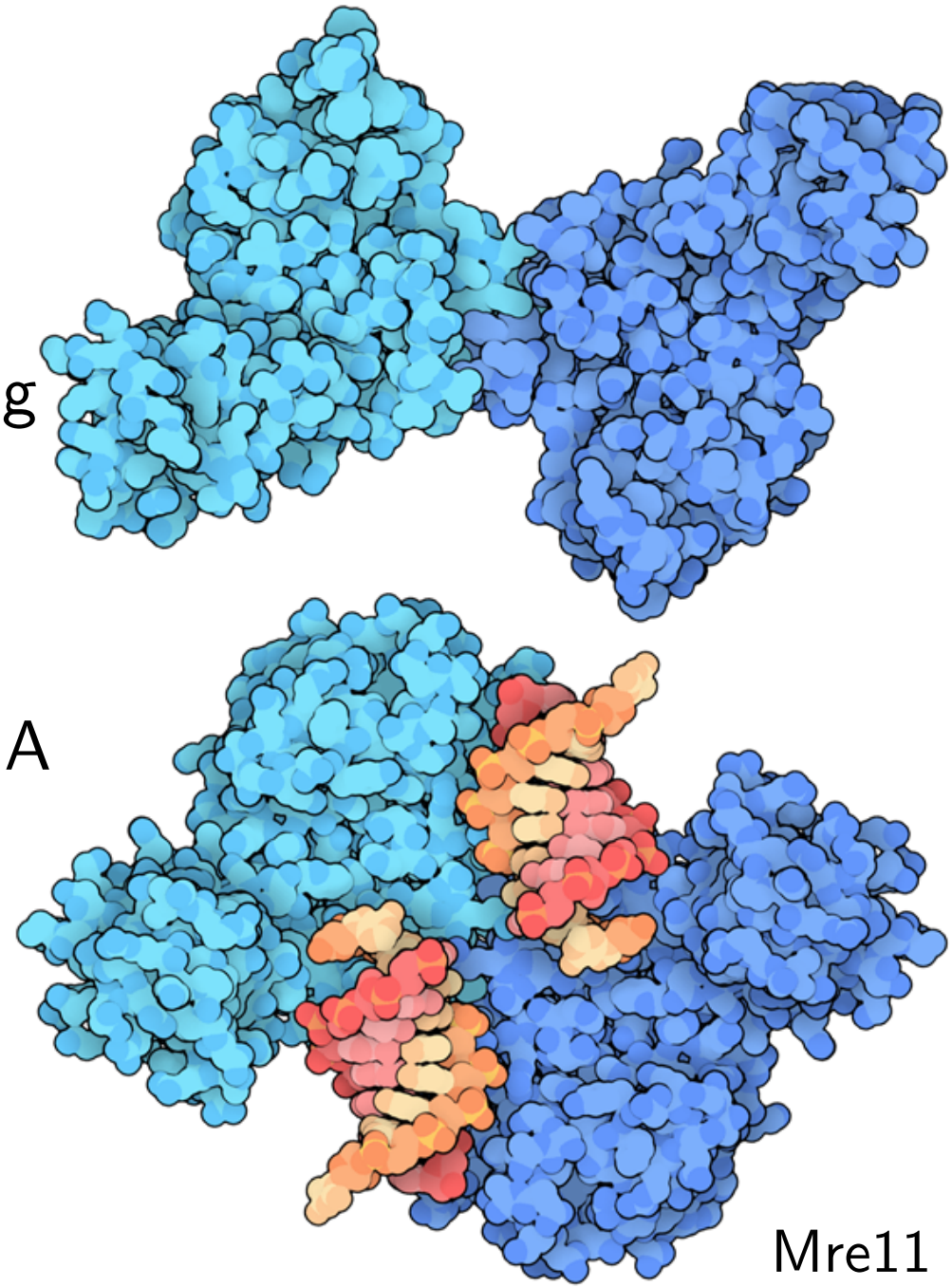
Why modeling biological scenes spatially?

Medical illustration

- Popularizing knowledge
- Help scientists' understanding
- Dynamic simulation

Scientific reasons specific to DNA

- Later in this talk...



Mre11
David Goodsell © 2010

Modeling DNA

Growing importance of modeling and simulation for experiments

$\Longrightarrow$ need for specialized spatial modeling tools for biologists

$\Longrightarrow$ DNA is an important target

Modeling DNA

"Modeling DNA in space is such a tedious job!"

— *microbiologists and illustrators*

Modeling DNA

"Modeling DNA in space is such a tedious job!"

— *microbiologists and illustrators*

Use advanced 3D modeling software

- Maya
- 3D Studio
- Blender

Or command-line tool and web services with form-based input

- 3DNA
- 3D-DART
- DNA Maker

And some with "UI"

- VDNA (VMD plugin)

Modeling DNA

"Modeling DNA in space is such a tedious job!"

— *microbiologists and illustrators*

Use ad

Blender

Or con

service

A Maker

And sc

plugin)