A DSL for Fluorescence Microscopy

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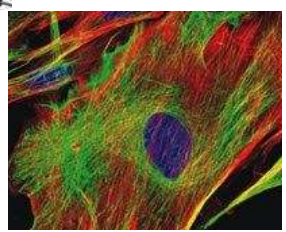
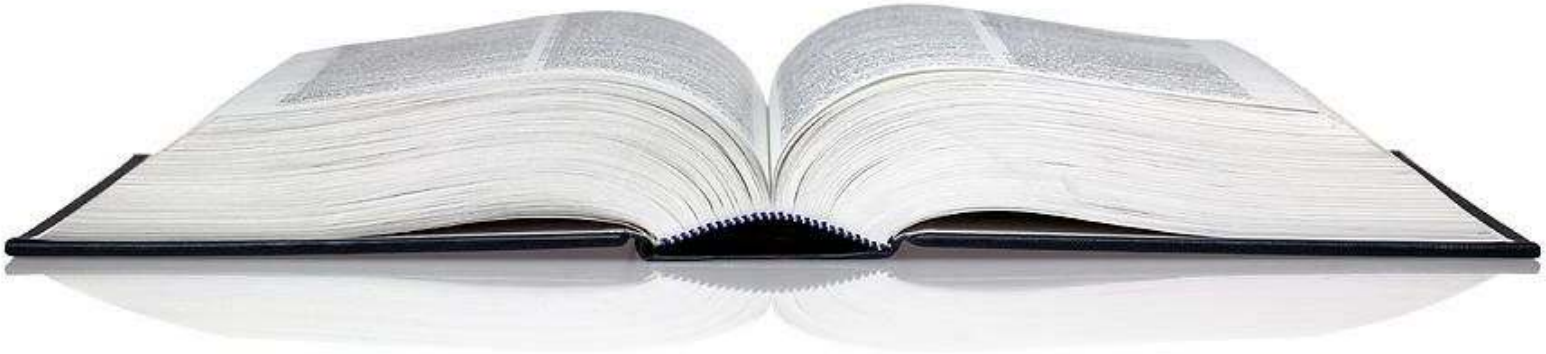
KU LEUVEN

Introduction

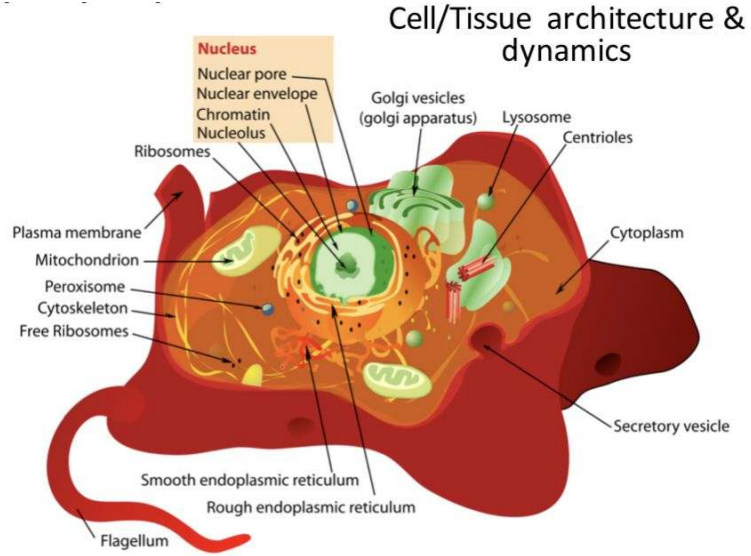
NanoBiology

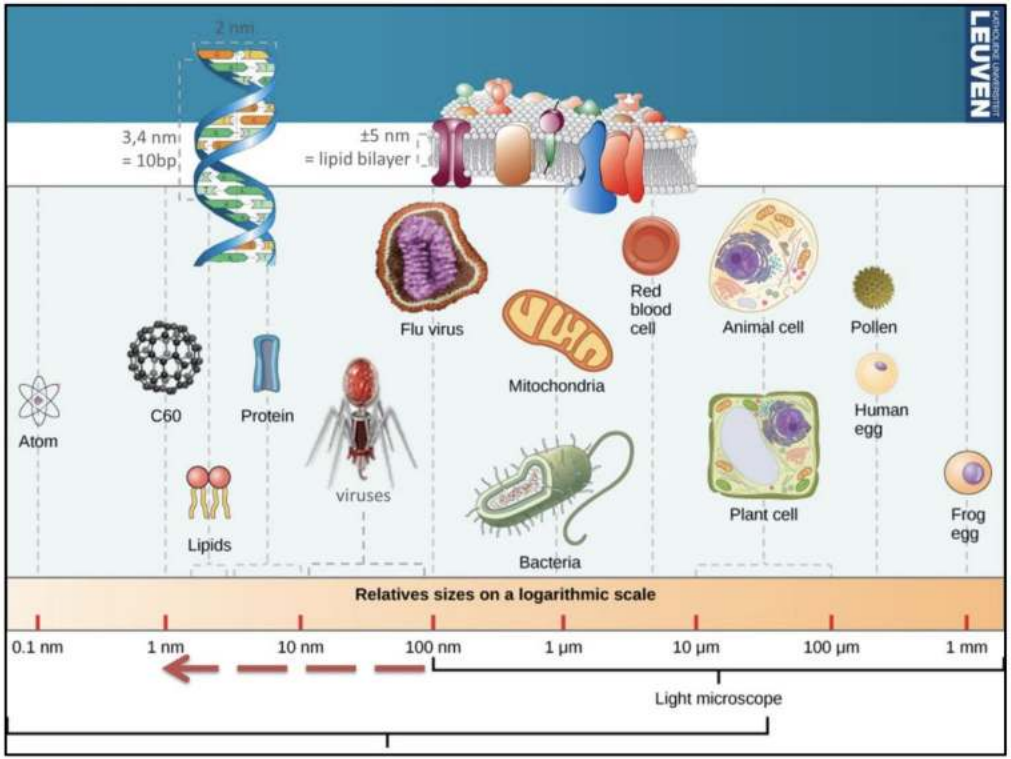


DSL



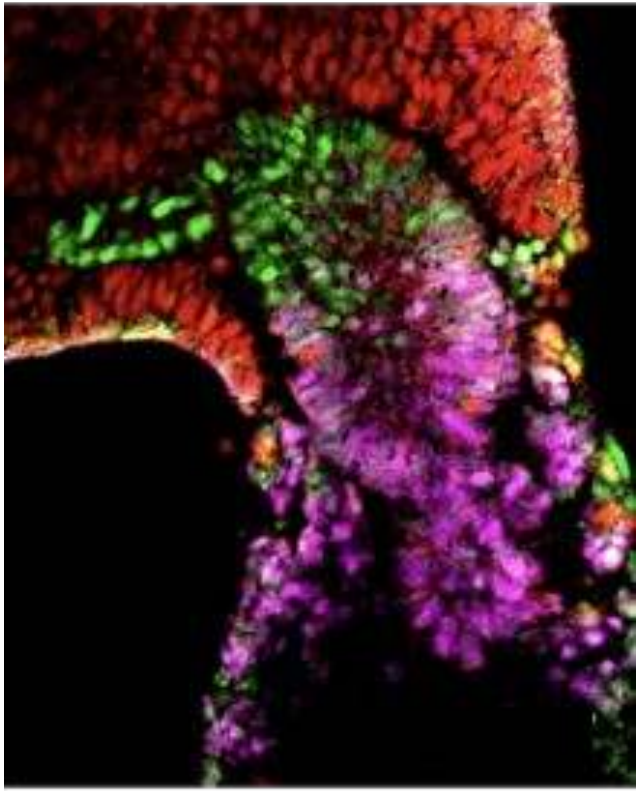
Why fluorescence?

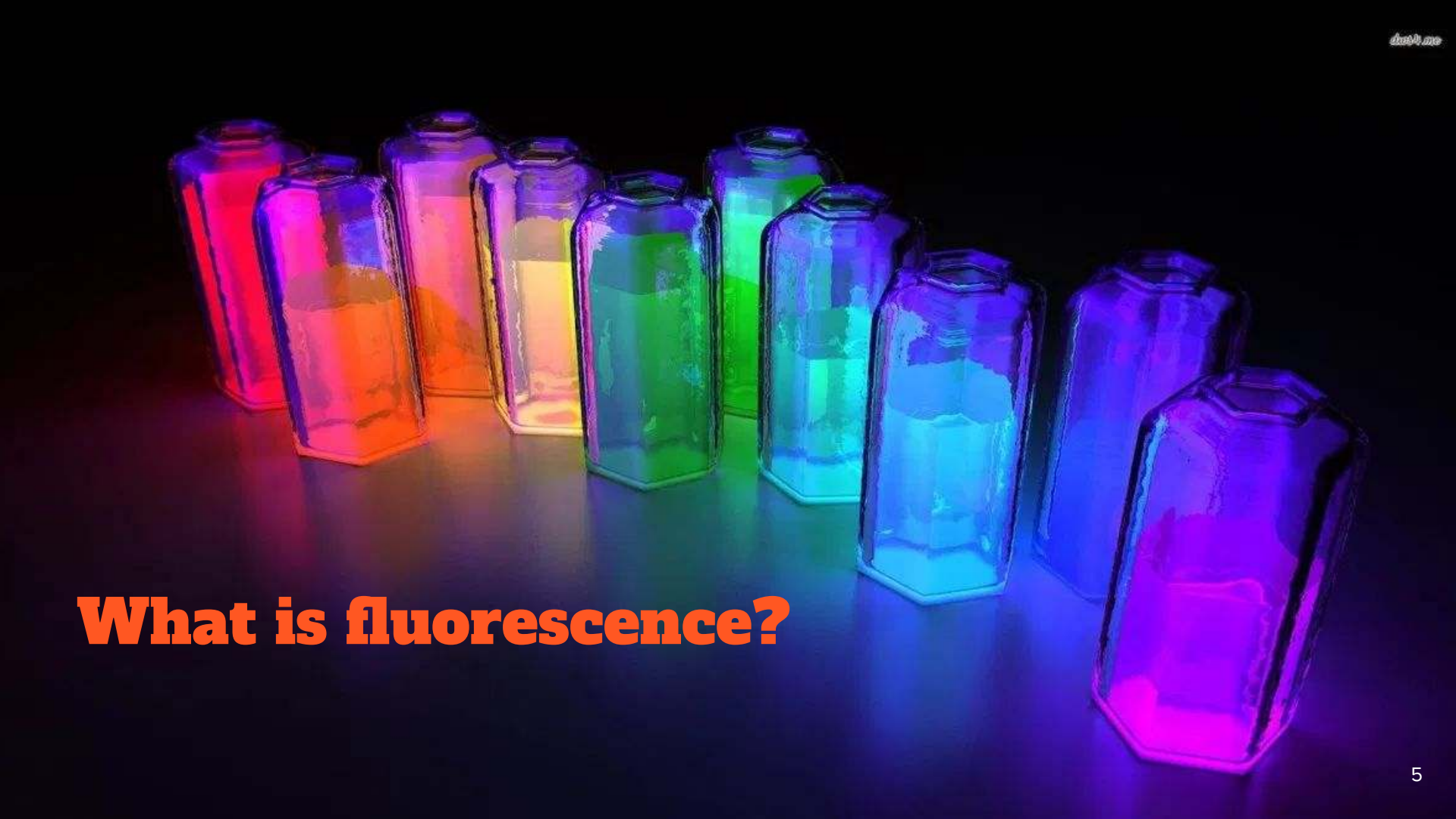




Why fluorescence?

- **non-invasive**
  - in situ
  - in vivo
- **selective**
- sample preparation
  - **simple**
  - **wide range** of fluorescent probes

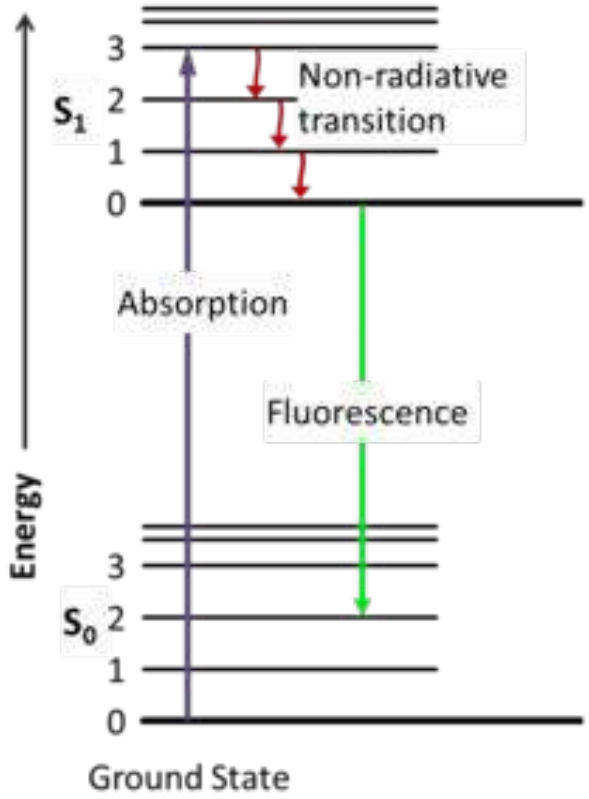




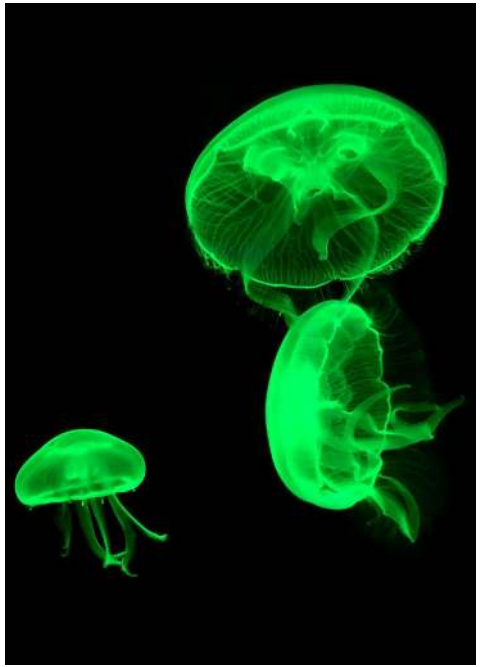
What is fluorescence?

Fluorescence

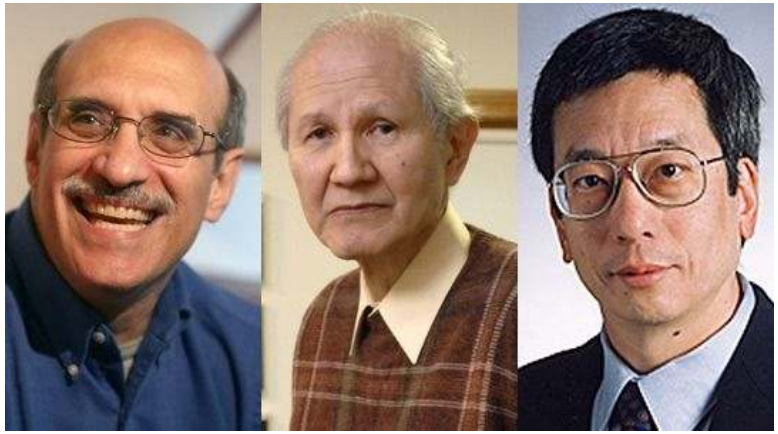
Jablonski diagram



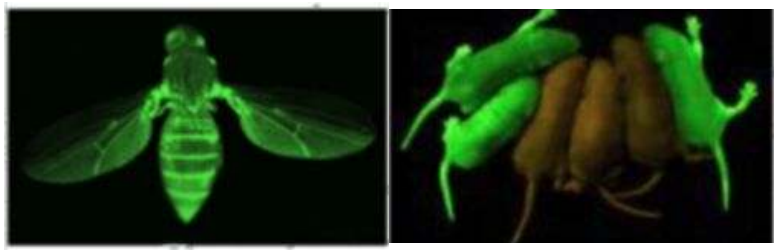
Fluorescence



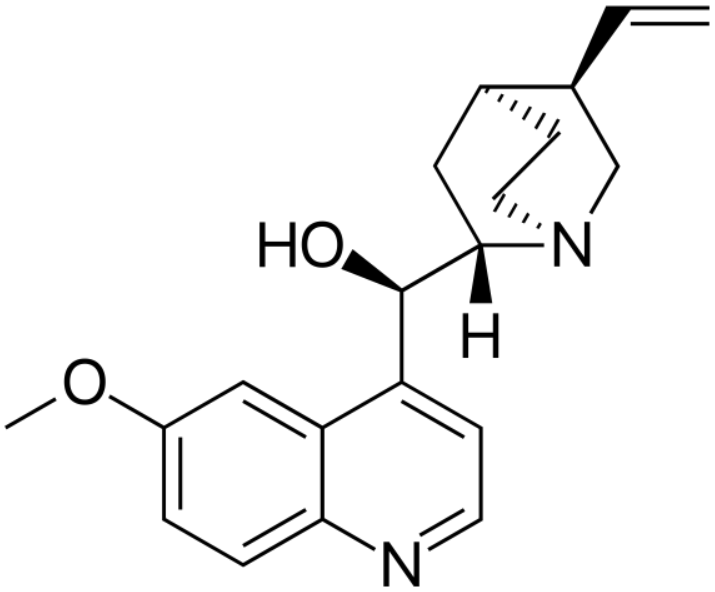
Green
Fluorescent
Protein



M.Chalfie - O.Shimomura - R. Tsien
Nobel Prize in Chemistry 2008

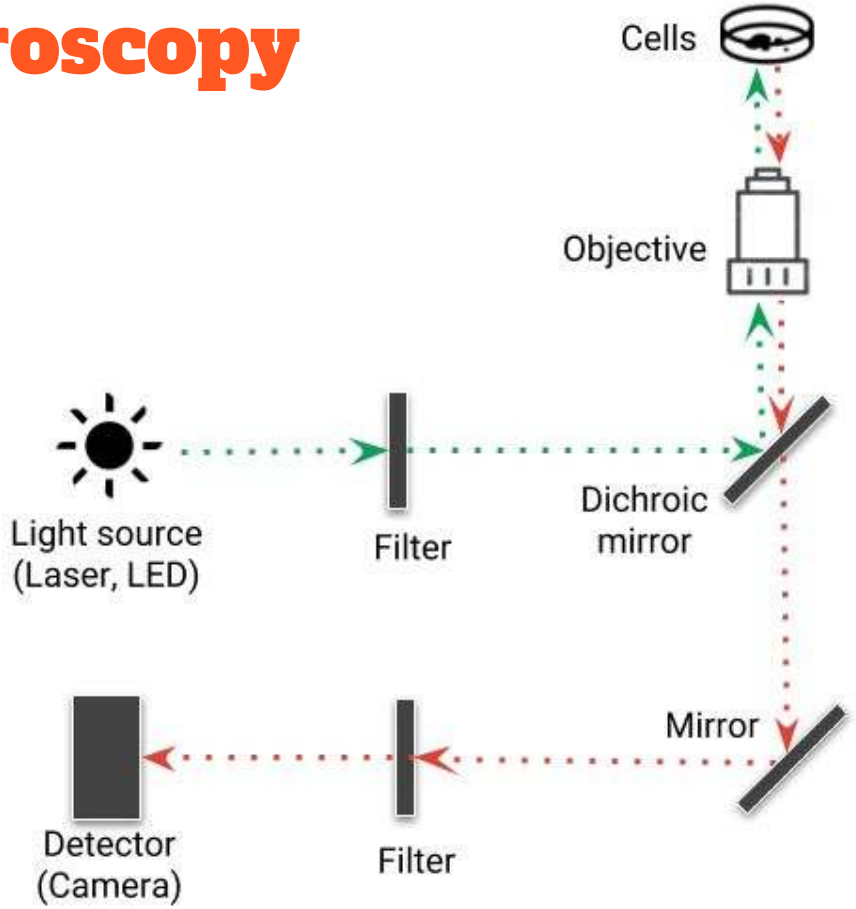


Fluorescence

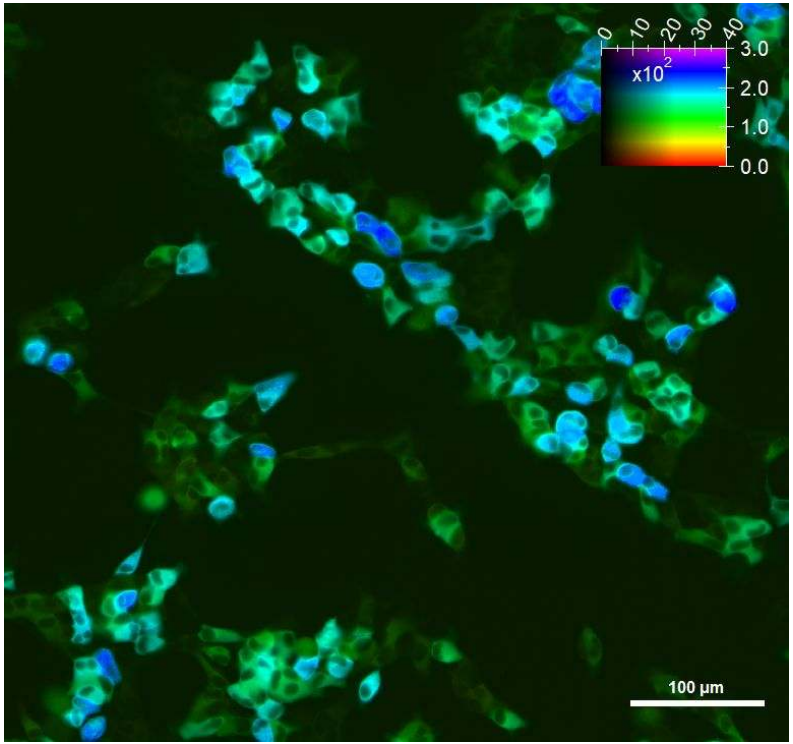


Quinine

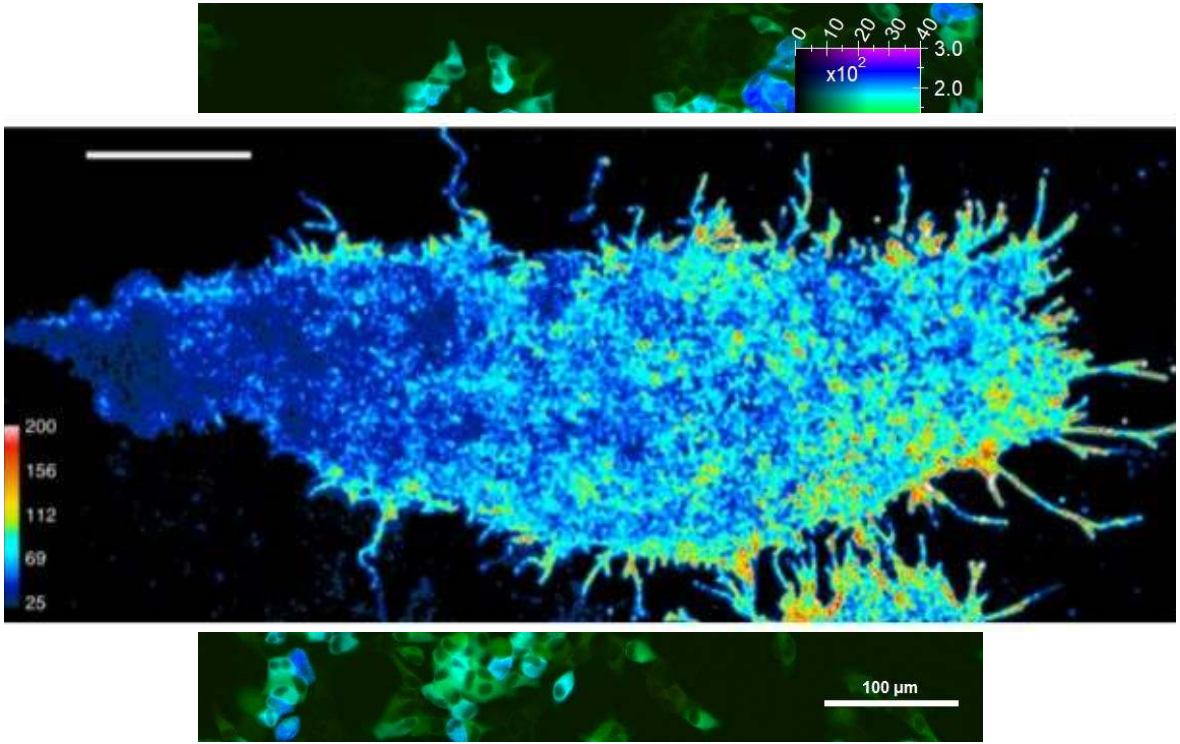
Fluorescence Microscopy



Fluorescence Microscopy



Fluorescence Microscopy



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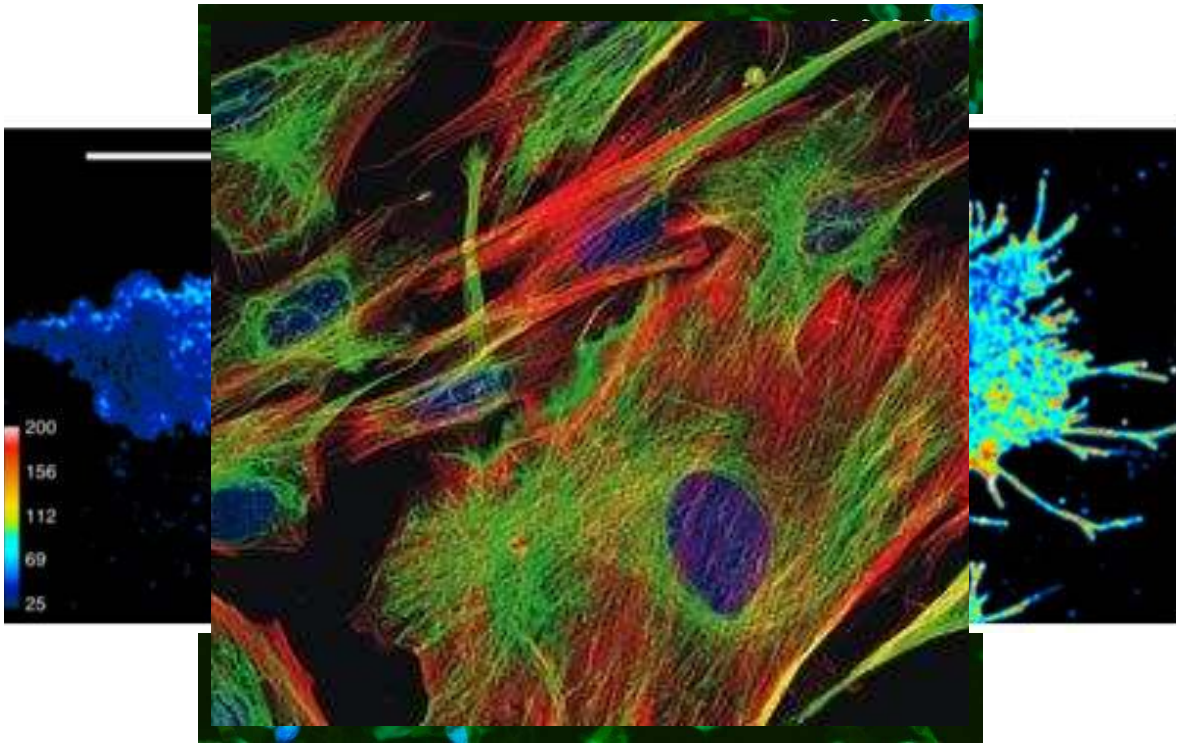
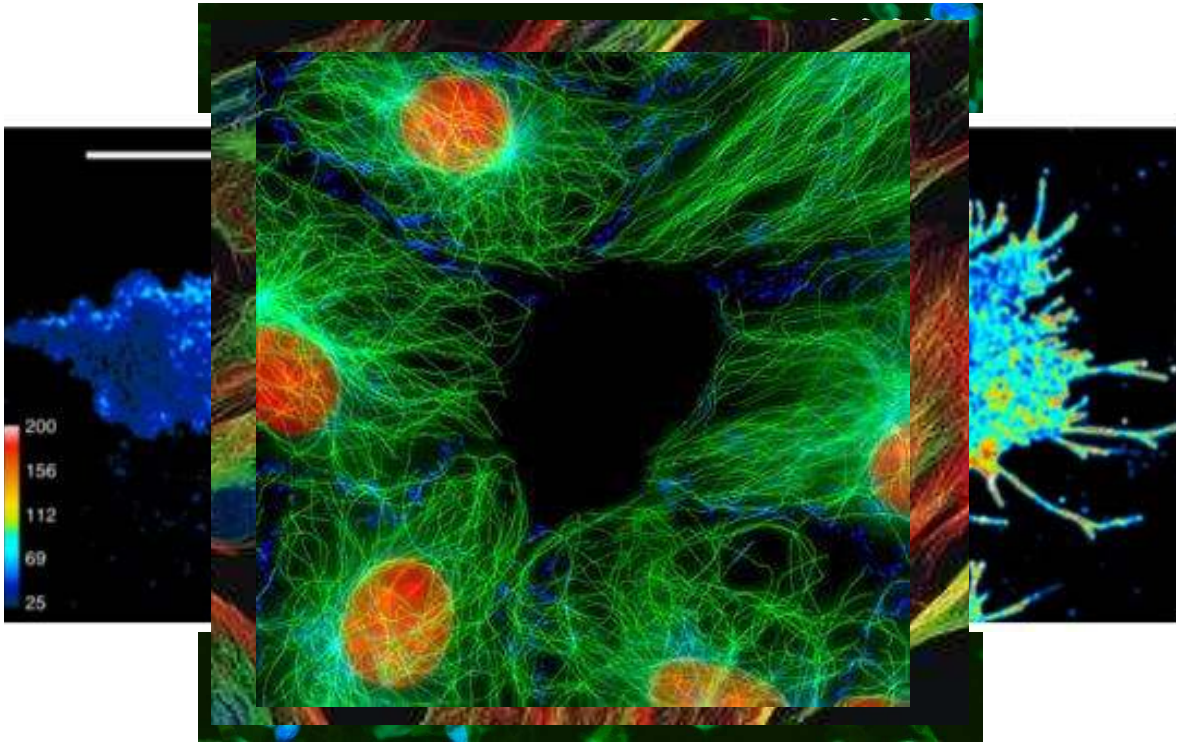


Fluorescence Microscopy



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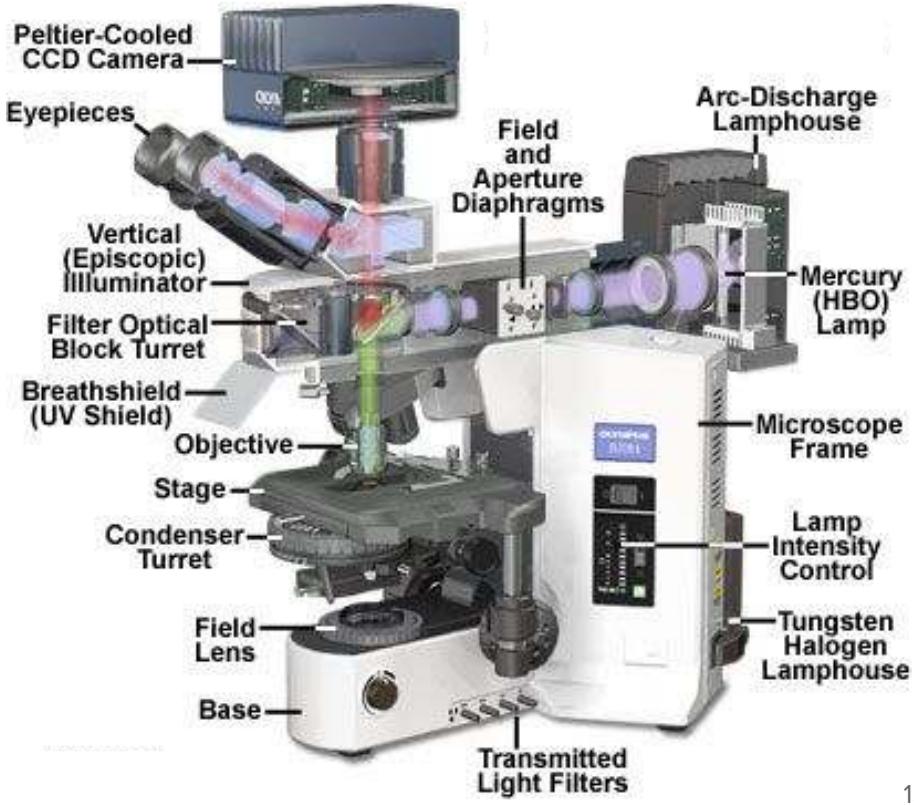
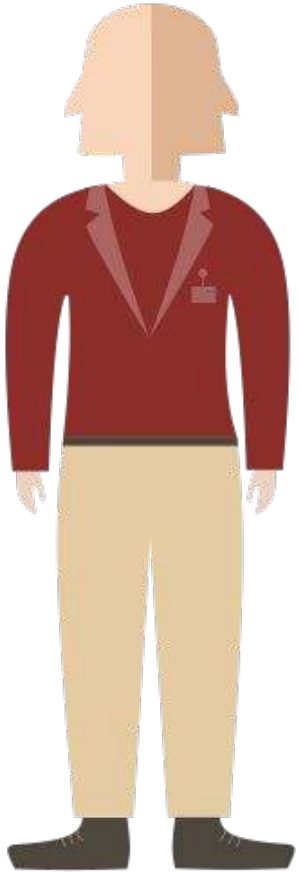
- Growing **technical complexity**
- **Expensive** instrumentation



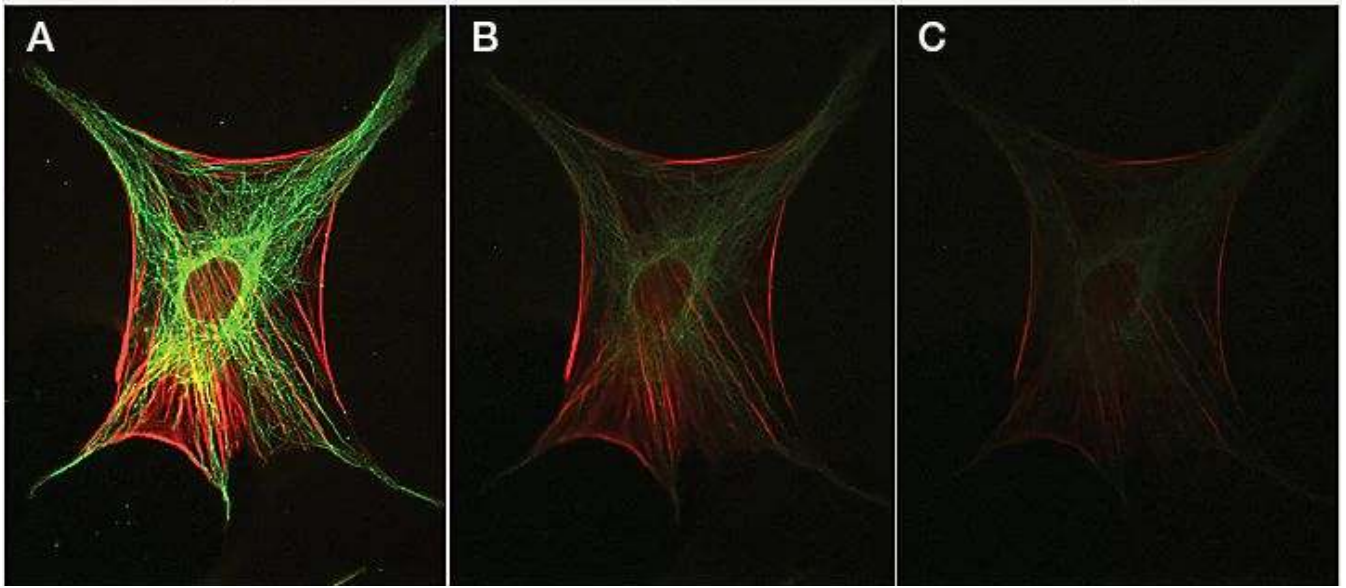
So, what's the problem?

- Growing **technical complexity**
- **Expensive** instrumentation
- **Dedicated staff members** (researchers + technicians)



So, what's the problem?

- Adapting the **experimental strategy**, setting **many parameters**
- No or little **safety** controls



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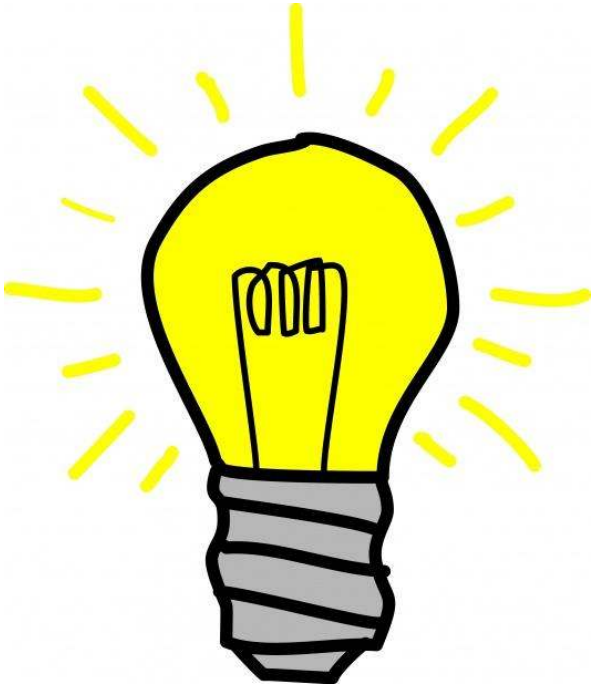

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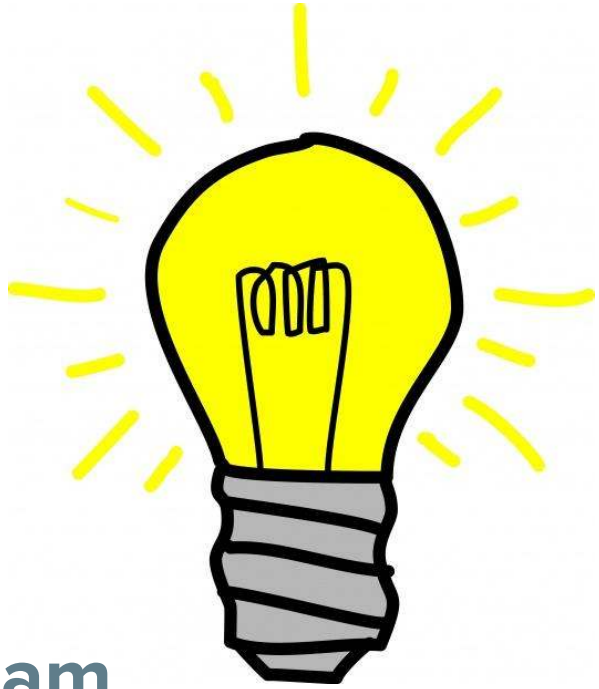
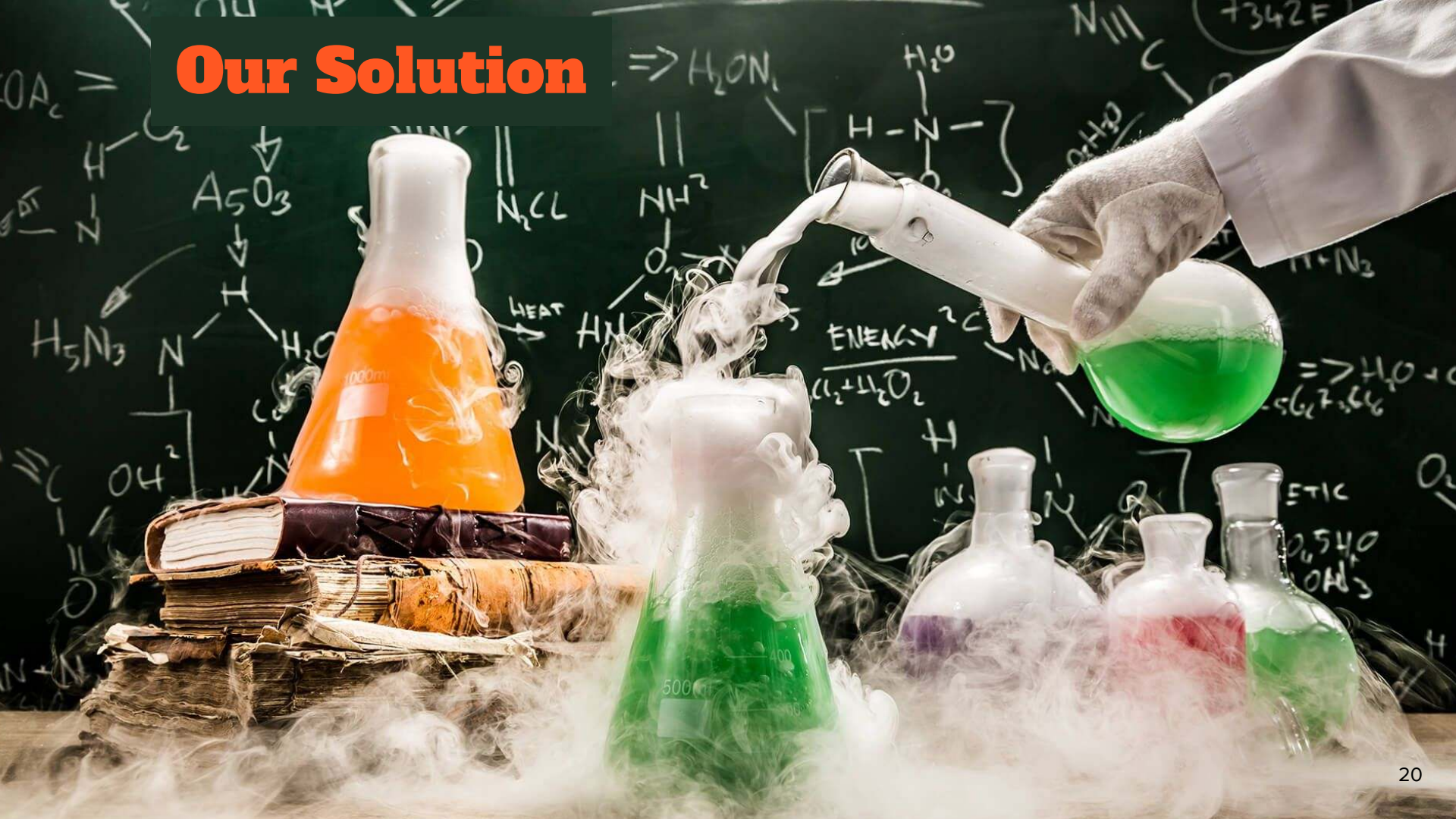


Setting up an experiment

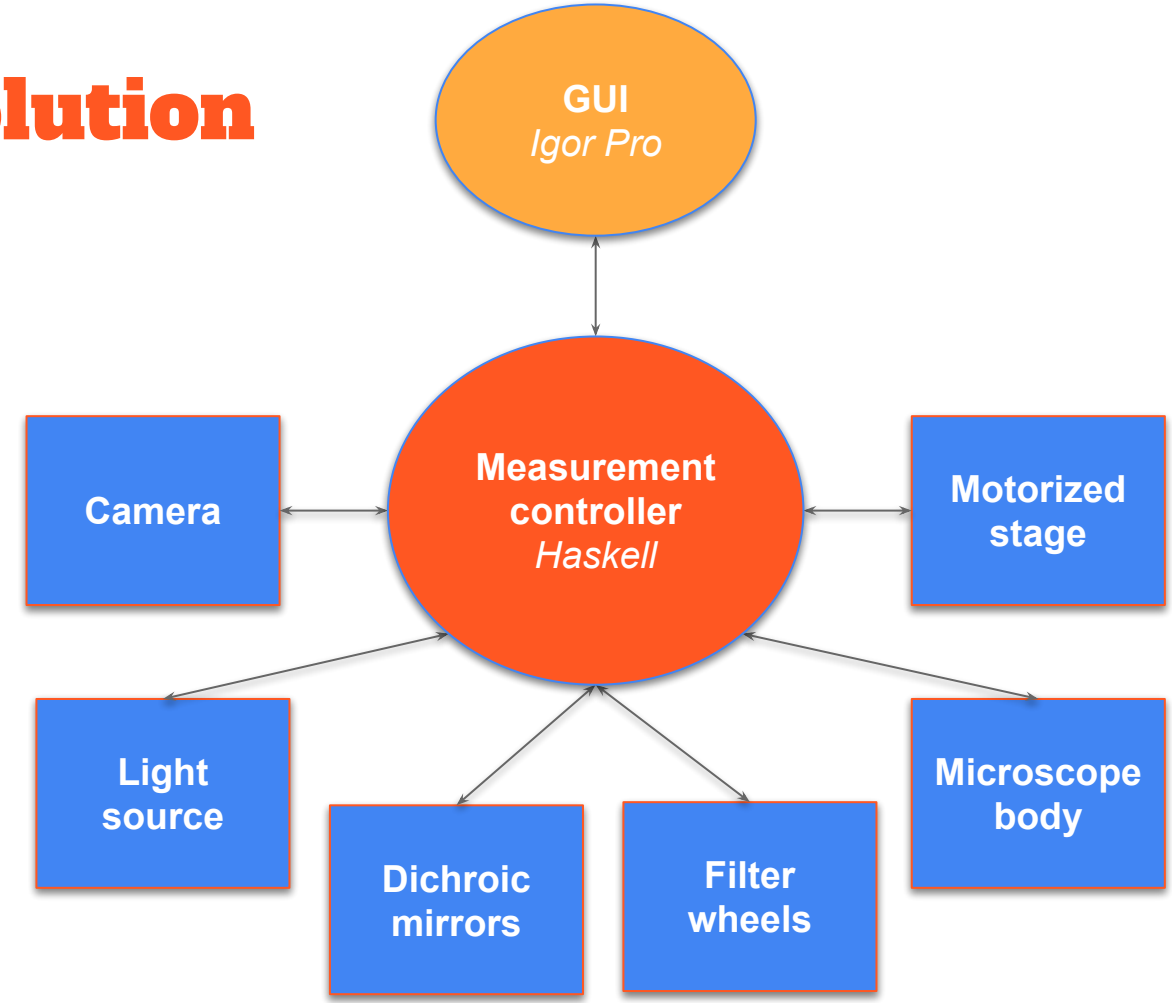
=

Constructing a computer program

Our Solution

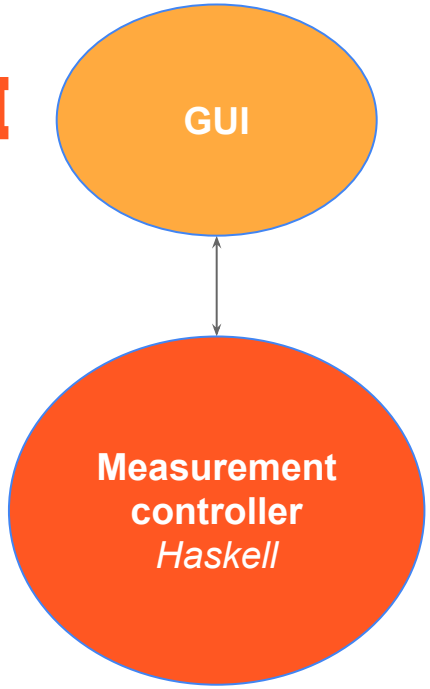


Our Solution



Solution: Controller vs GUI

- Communication with **GUI**

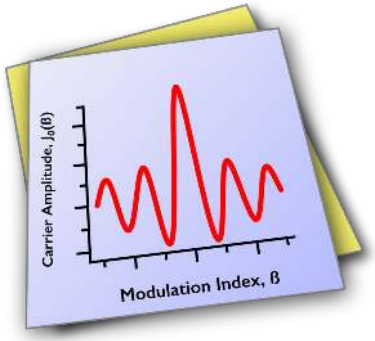


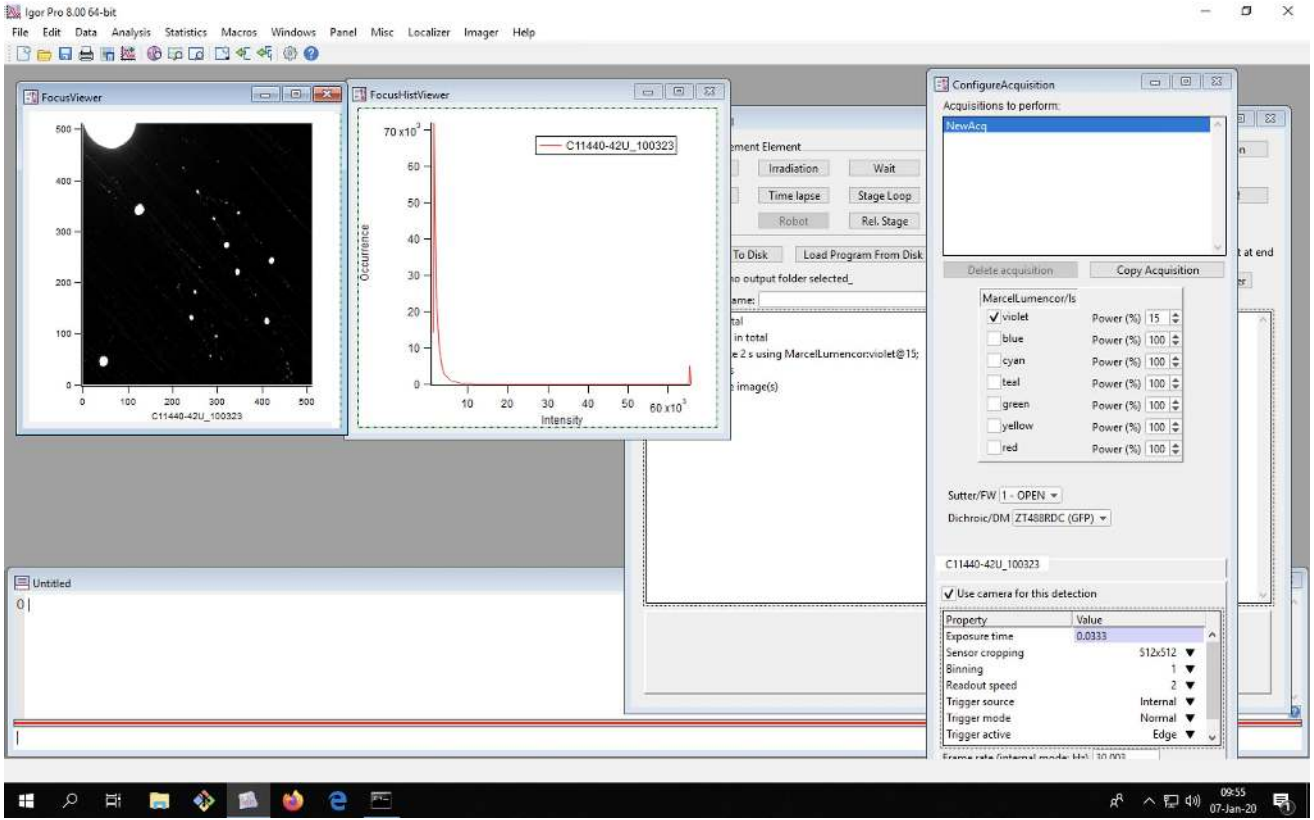
GUI

Igor Pro

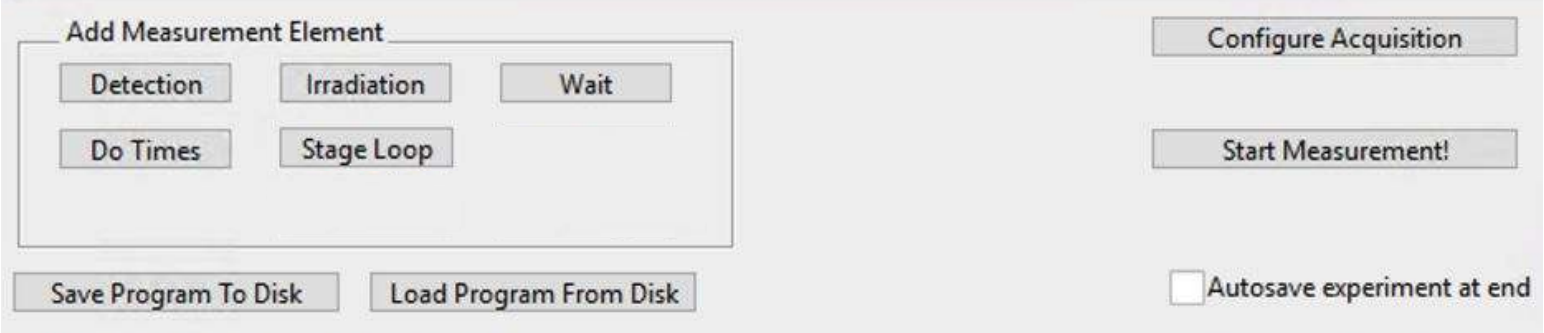
Technical Computing for Scientists and Engineers

WaveMetrics, Inc.





GUI: Example



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Technical Computing for Scientists and Engineers

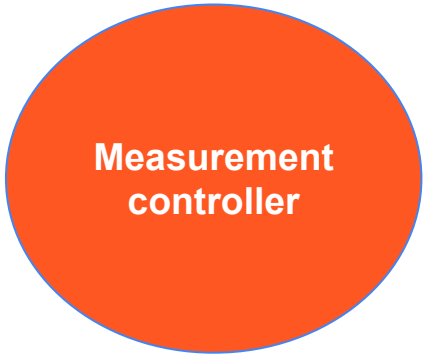
WaveMetrics, Inc.

```
do 5 time(s) in total
    irradiate 2 s using MarcelLumencor:violet@15;
    wait 3 s
    acquire image(s)
wait 10 s
acquire image(s)
```

Solution: Controller DSL

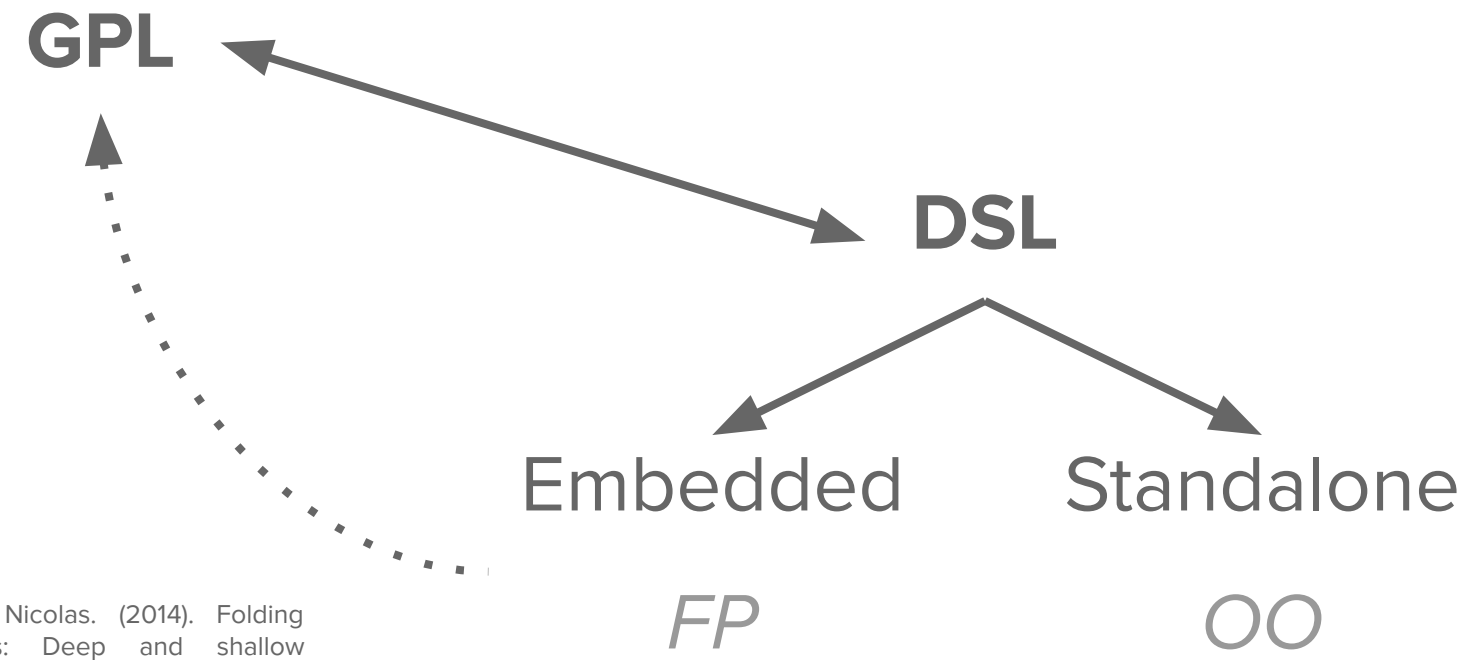
- Representing and reasoning over **domain-specific knowledge**

DSL



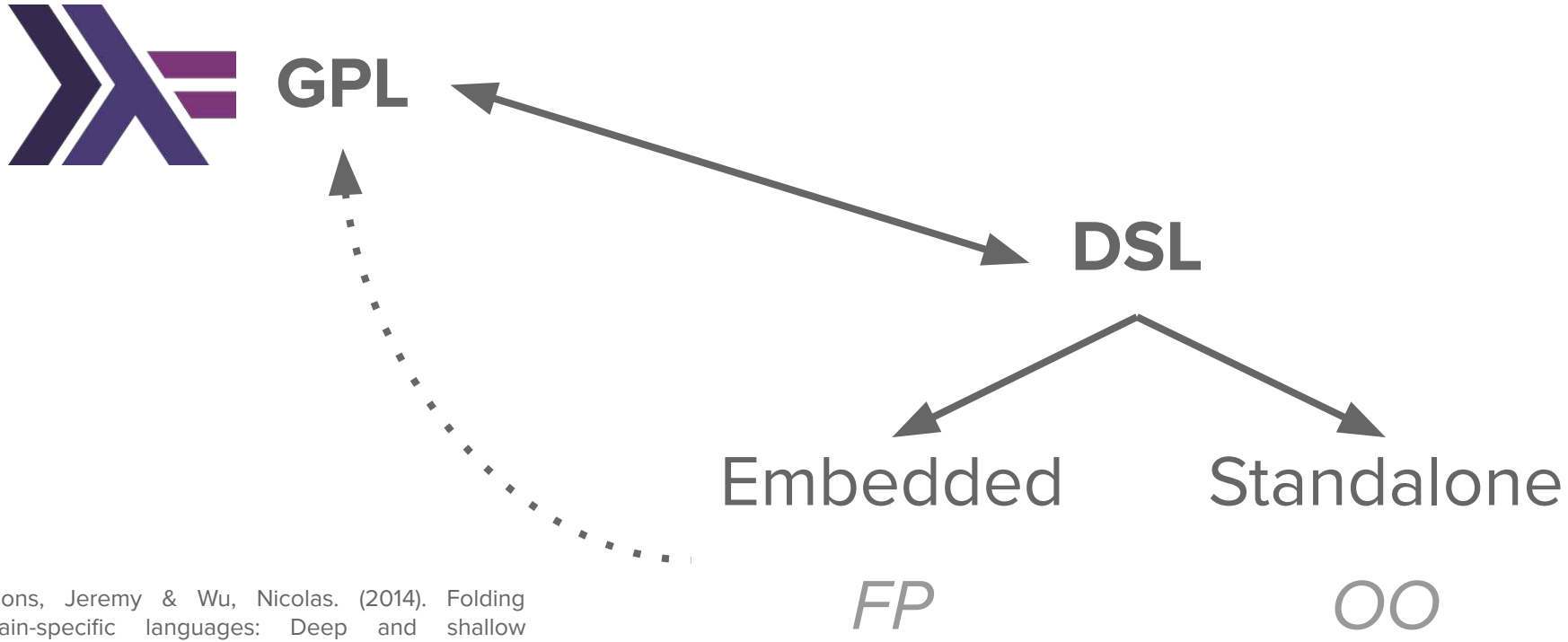
Haskell

Why DSL? Why Haskell?



Gibbons, Jeremy & Wu, Nicolas. (2014). Folding domain-specific languages: Deep and shallow embeddings (functional Pearl). Proceedings of the ACM SIGPLAN International Conference on Functional Programming, ICFP. 49. 10.1145/2628136.2628138.

Why DSL? Why Haskell?



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DSL Fragment

```
data StagePosition          =  StagePosition {  x :: Double
                                              , y :: Double
                                              , z :: Double  }

data MeasurementElement  = MEDetect
                         | MEWait  Double
                         | MEIrradiate  Double ( String,  Double )
                                        -- duration ( light source , power )
                         | MEDoTimes  Int  Prog
                         | MEStageLoop  [ StagePosition ]  Prog
                         | ...

type Prog                =  [ MeasurementElement ]
```

DSL: Example

```
do 5 time(s) in total
    irradiate 2 s using MarcelLumencor:violet@15;
    wait 3 s
    acquire image(s)
wait 10 s
acquire image(s)
```

```
[ MEDoTimes 5 [ MEIrradiate 2 ( MarcelLumencor:violet , 15 )
              , MEWait 3
              , MEDetect ]
, MEWait 10
, MEDetect ]
```

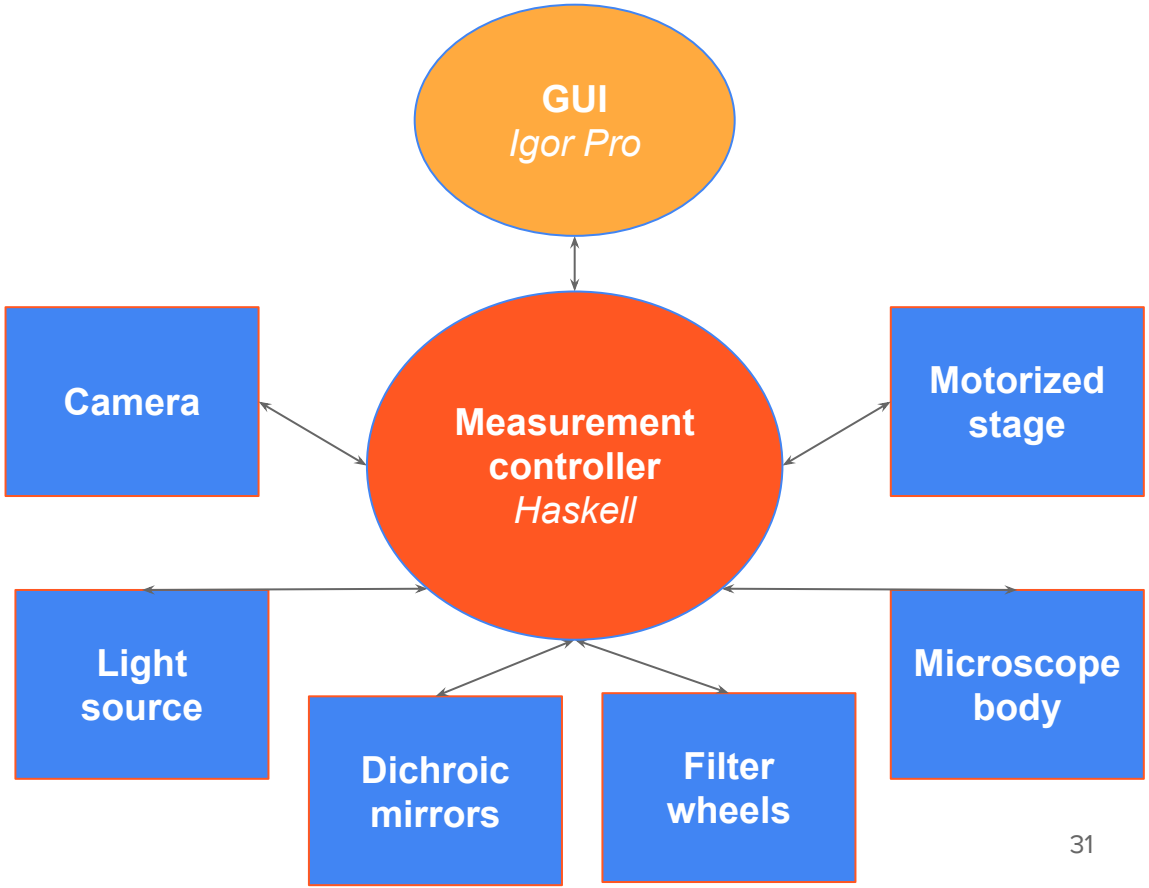
Deep embedding

```
executeProg :: Prog → IO ()
executeProg prog = foldMap executeME prog

executeME :: MeasurementElement → IO ()
executeME  MEDetect                    = executeDetection >> putStrLn (“detecting...”)
executeME (MEWait dur)                 = threadDelay (round $ dur * 1e6)
                                         >> putStrLn (“waiting...”)
executeME (MEIrradiate dur params) = executeIrradiation dur params
                                         >> putStrLn (“irradiating...”)
executeME (MEDoTimes n pr)             =
        mapM_ (\prs → executeProg prs) (take n . repeat $ pr)
                                          >> putStrLn (“times...”)
executeME (MEStageLoop poss pr)    =
        mapM_ (\pos → setStagePosition pos >> executeProg pr) poss
                                          >> putStrLn (“stage looping...”)
```

Solution: Controller vs Hardware

- Controlling **hardware**



Hardware

Camera

Light source

Dichroic mirrors

Motorized stage

Filter wheels

Microscope body

Hardware: Example

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do 5 time(s) in total
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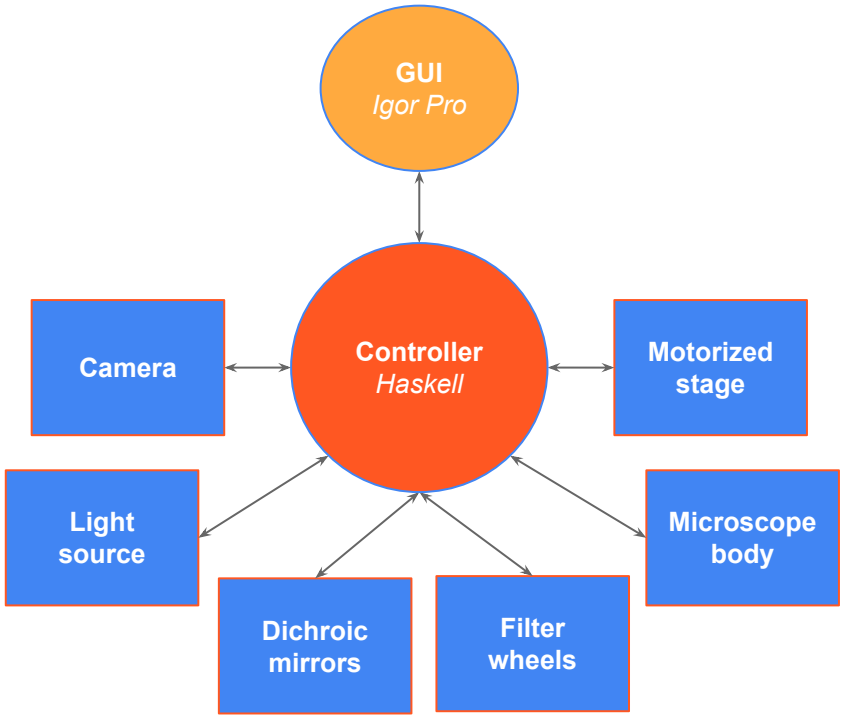
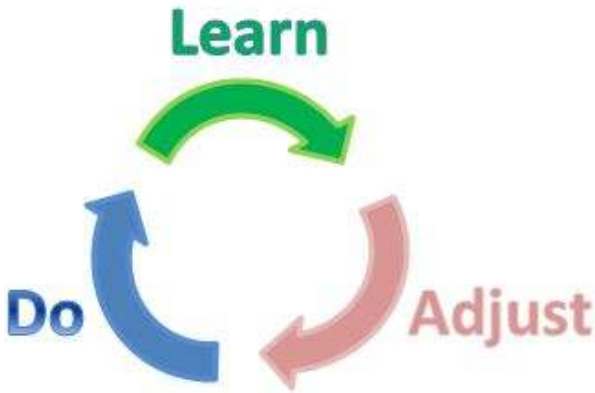
Results

Results



usable software

feedback loop

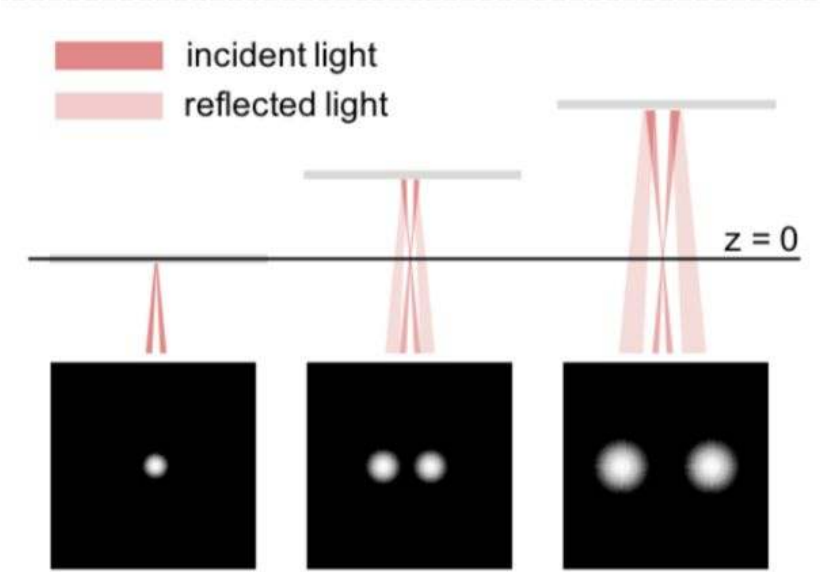


Compared to already existing SW

- **Modularity**
  - easily extendible for new hardware
  - works with several hardware setups
- Arbitrary long, **complex** programs

Compared to already existing SW

- **Modularity**
  - easily extendible for new hardware
  - works with several hardware setups
- Arbitrary long, **complex** programs
- Also non-trivial, more complex tasks
  - E.g. **autofocus** system



Future Work

- GUI
- DSL for knowledge representation
- Operational DSL for controlling HW/SW
- Fluorescence Microscopy Applications

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GUI

DSL for knowledge representation

Operational DSL for controlling HW/SW

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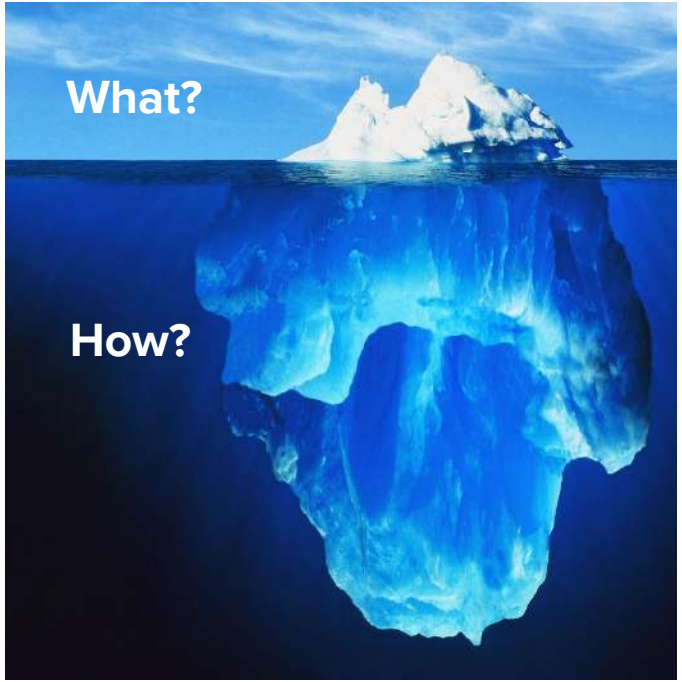

Future Work

GUI

DSL for knowledge representation

Operational DSL for controlling HW/SW

Fluorescence Microscopy Applications

- Increase **performance**
  - optimal rescheduling
  - parallelizing
- **Safety** and **sanity checks**

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Future Work

“A system that can learn from scientists and operators, and vice versa.”

Thanks!