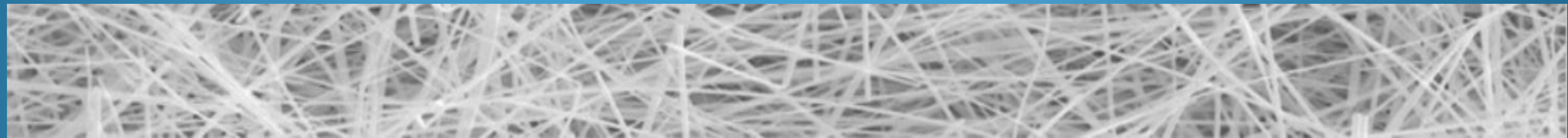


# Impact of Silver Nanowire Length and Diameter on the rainbow trout RTgillW1 cell line

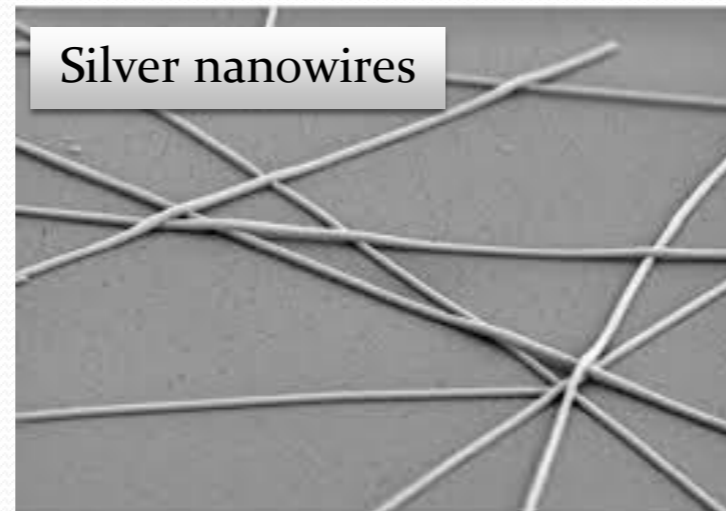
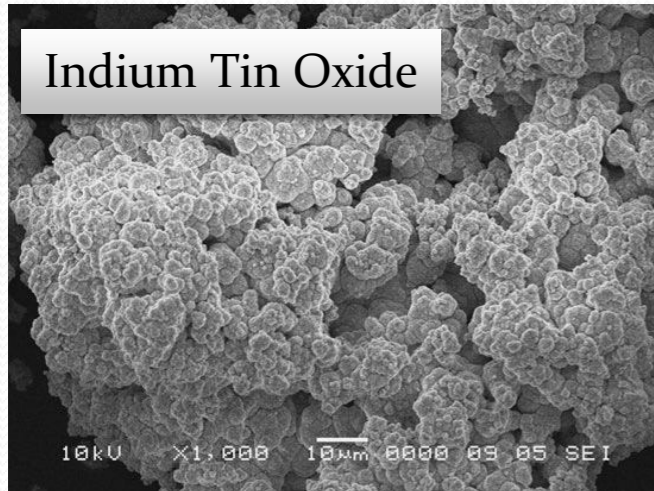


Devrah Arndt, Abderrahmane Tagmout, Christopher Vulpe  
Department of Physiological Sciences  
University of Florida, USA

Djadidi Toybou, Laurent Charlet  
University of Grenoble Alps, Grenoble, France



# Silver Nanowire Applications



## Touchscreen Displays

100x more conductive than ITO; higher transmission and lower resistance

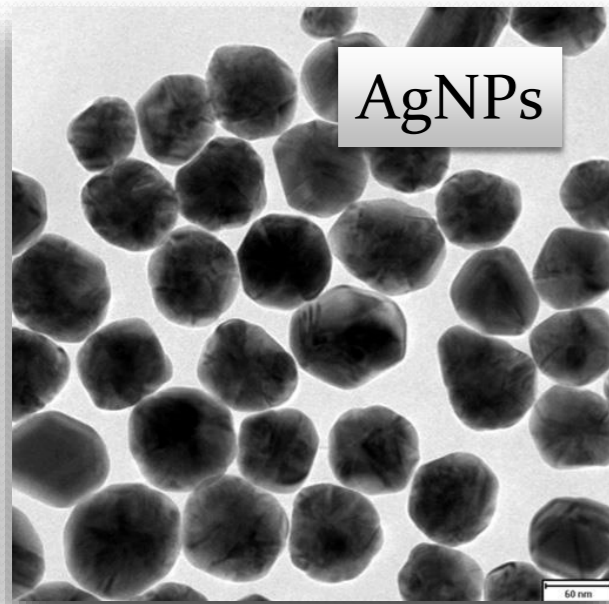
Can be deposited on plastic, making for more lightweight and aesthetically pleasing products

Apple iWatch

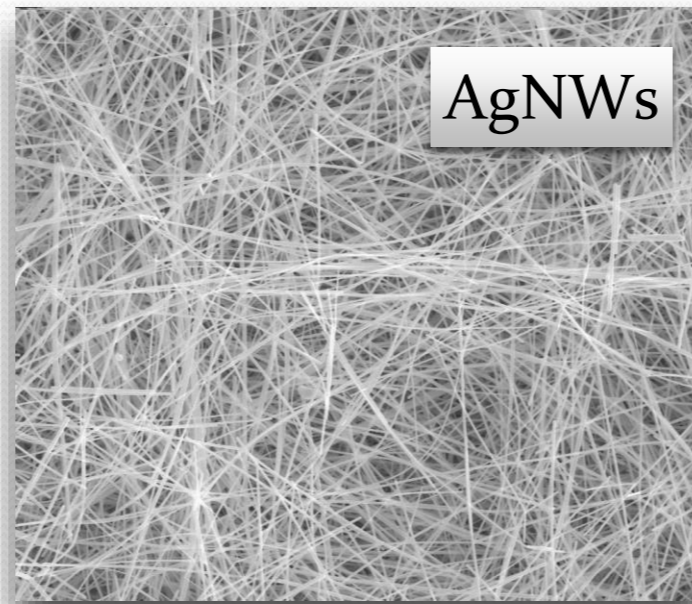
Flexible touchscreens



# Silver nanowire toxicity



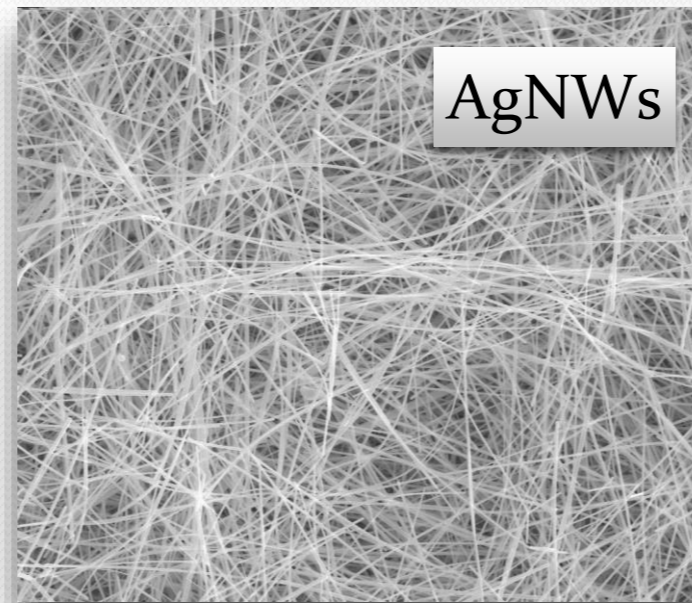
VS.



- Altered patterns of transport in the environment and within organisms
- Distinct modes of cellular uptake and injury



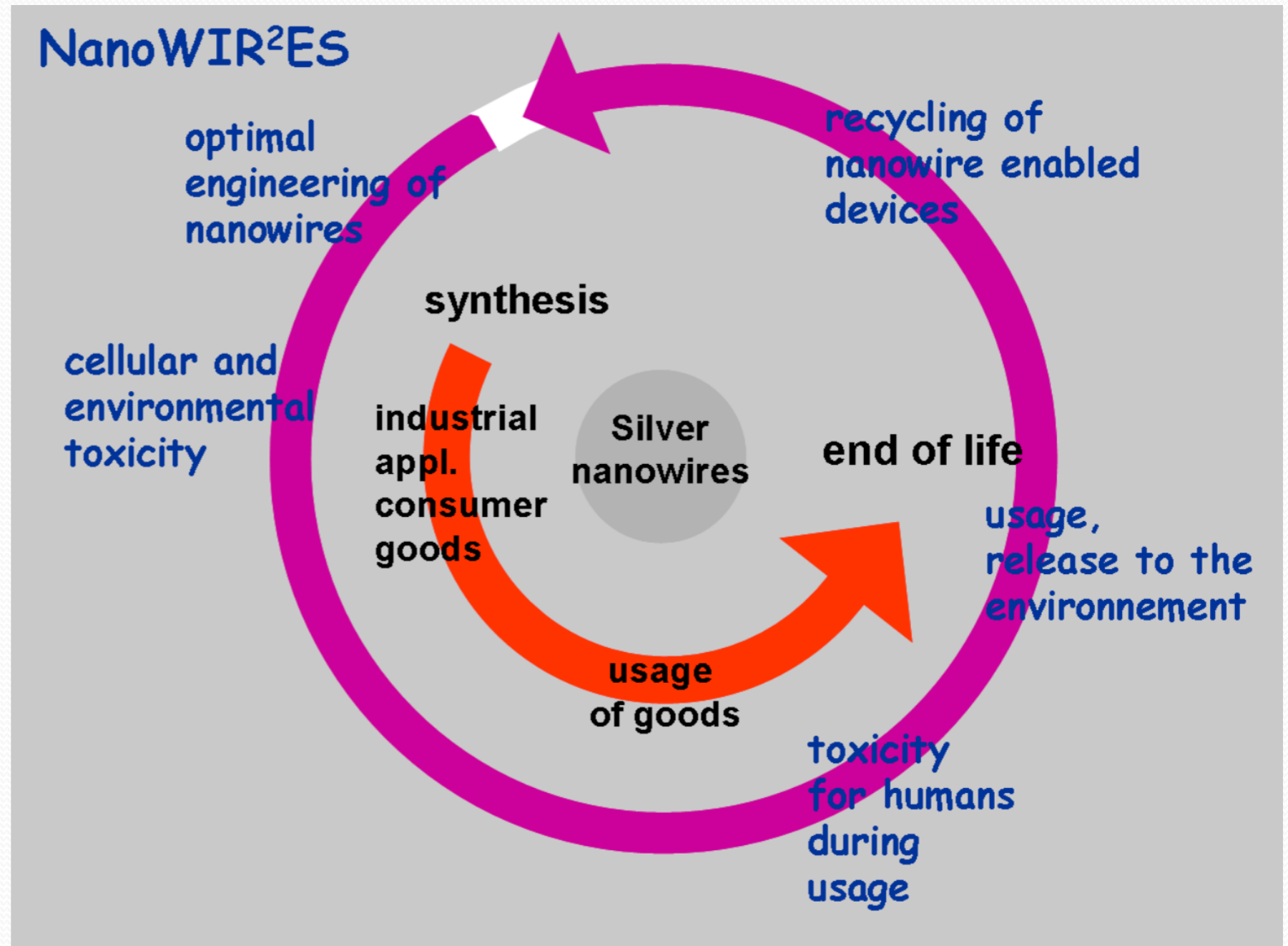
VS.



- Asbestos-like toxicity due to high aspect ratio
- Damage to biological clearance mechanisms

# SIINN Nanowir2es Project

- **Synthesis and Characterization** (Benjamin Gilbert, U of Berkely; Vincent Jamier; Leitat Technology Center, Spain)
- **Toxicity testing; human** (Laurent Charlet at U of Grenoble Alps, France) and **environmental** (Chris Vulpe at U Florida)
- **Waste removal and recycling** (Annette Hofmann at U of Lille, France)





# Cell and organism ecotoxicity



**Part I:** Cellular and larval toxicity and changes in bioenergetics.



RTgill-W<sub>1</sub>  
RTgutCC

**Part II:** Uptake, bioaccumulation, and trophic transfer of Ag NWs.



**Part III:** Mechanism of action by genomic analysis.



# Cell and organism ecotoxicity



**Part I:** Cellular and larval toxicity and changes in bioenergetics.



RTgill-W<sub>1</sub>  
RTgutCC



**Part II:** Uptake, bioaccumulation, and trophic transfer of Ag NWs.

**Part III:** Mechanism of action by genomic analysis.



# AgNW Characterization

AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$
Short and thin	$7 \pm 3$	$38 \pm 4$
Long and thin	$26 \pm 8$	$38 \pm 5$



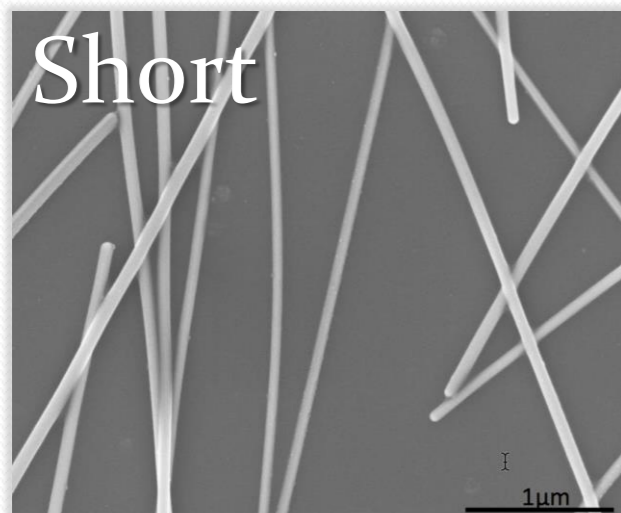
# AgNW Characterization

AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$
<del>Short and skinny</del>	<del><math>7 \pm 3</math></del>	<del><math>38 \pm 4</math></del>
<del>Long and skinny</del>	<del><math>26 \pm 8</math></del>	<del><math>38 \pm 5</math></del>

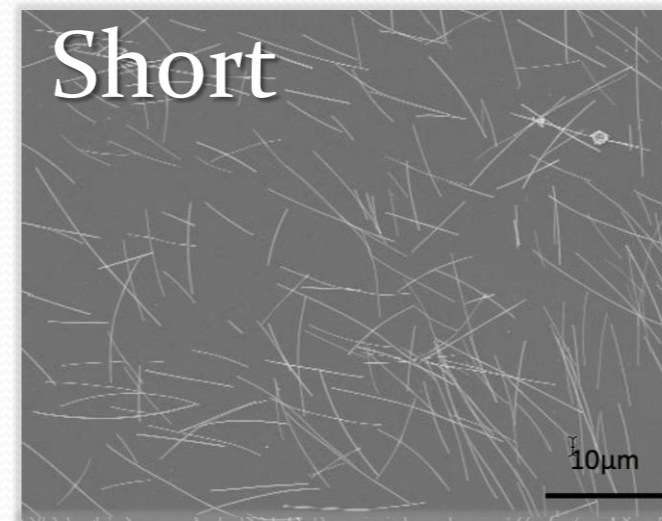
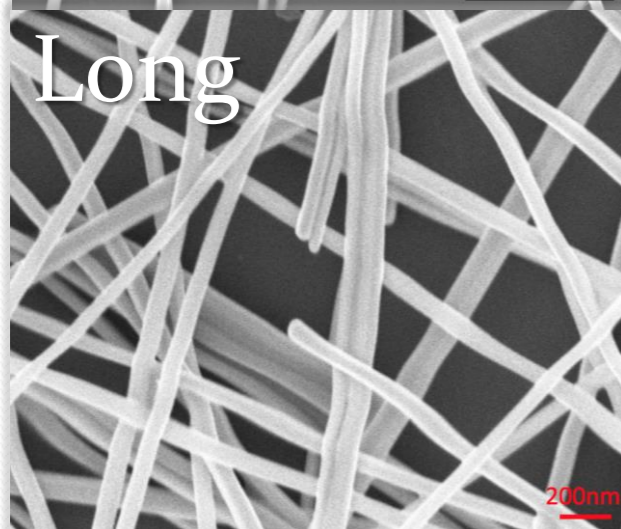


# AgNW Characterization

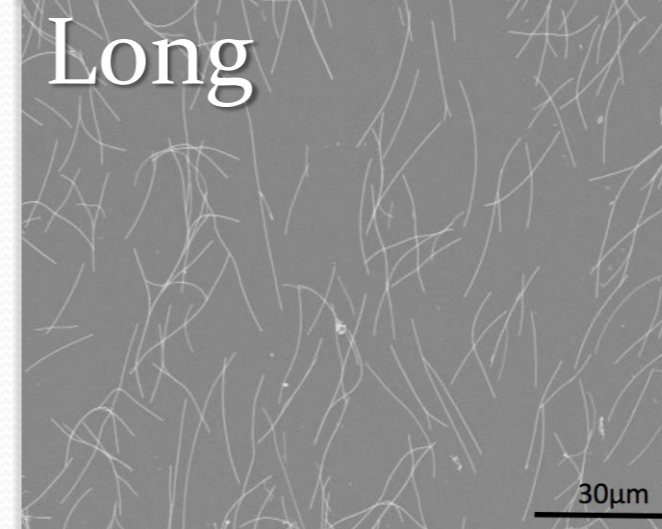
AgNW type	Diameter (nm)	Length ( $\mu\text{m}$ )	Aspect Ratio (L/D)
Wide and short	$93 \pm 11$	$9 \pm 3$	96.77
Wide and Long	$90 \pm 11$	$25 \pm 7$	277



- Diameters are nearly equivalent

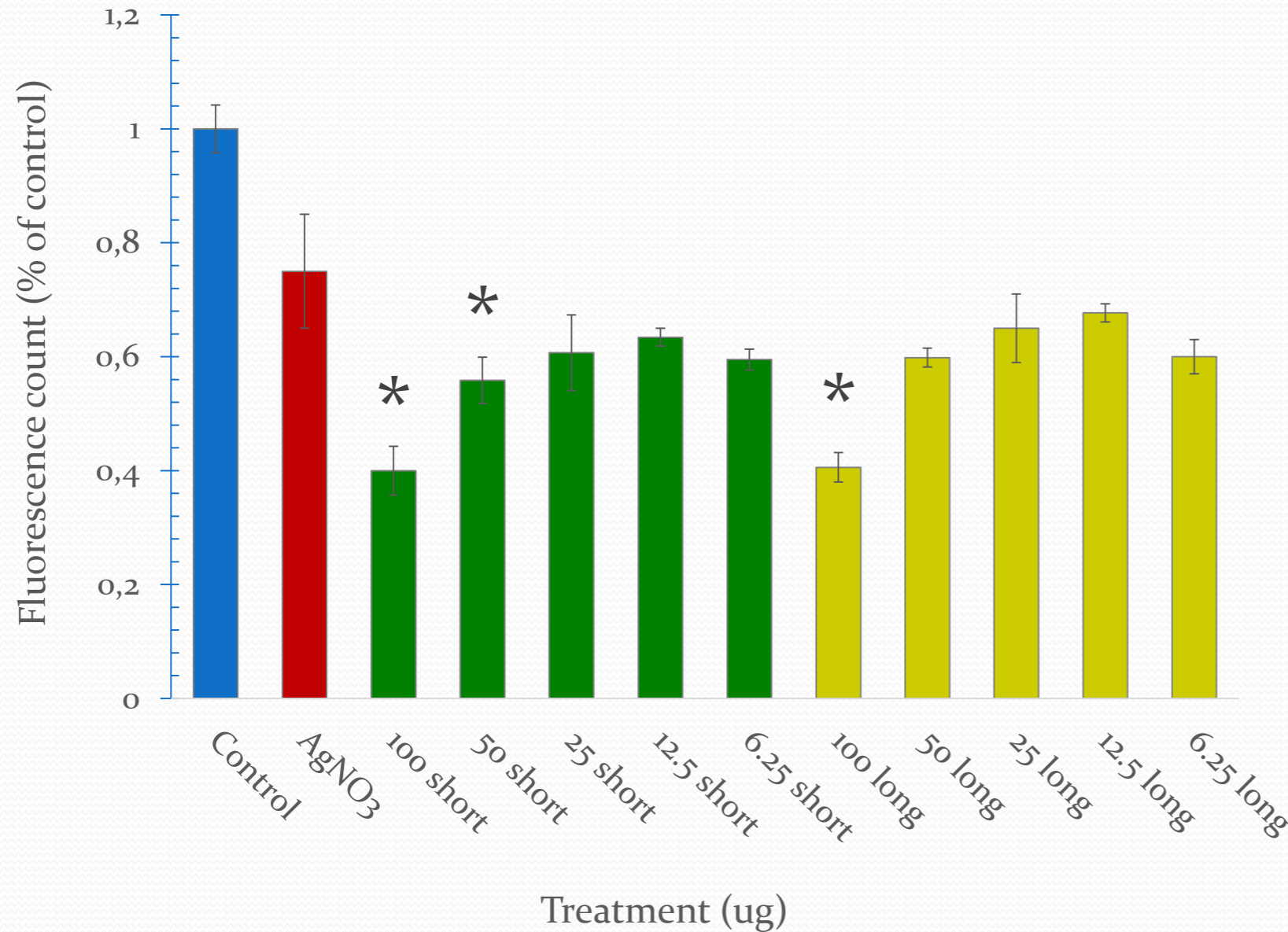


- Length varies



# AgNW toxicity in RTgillW1

AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$



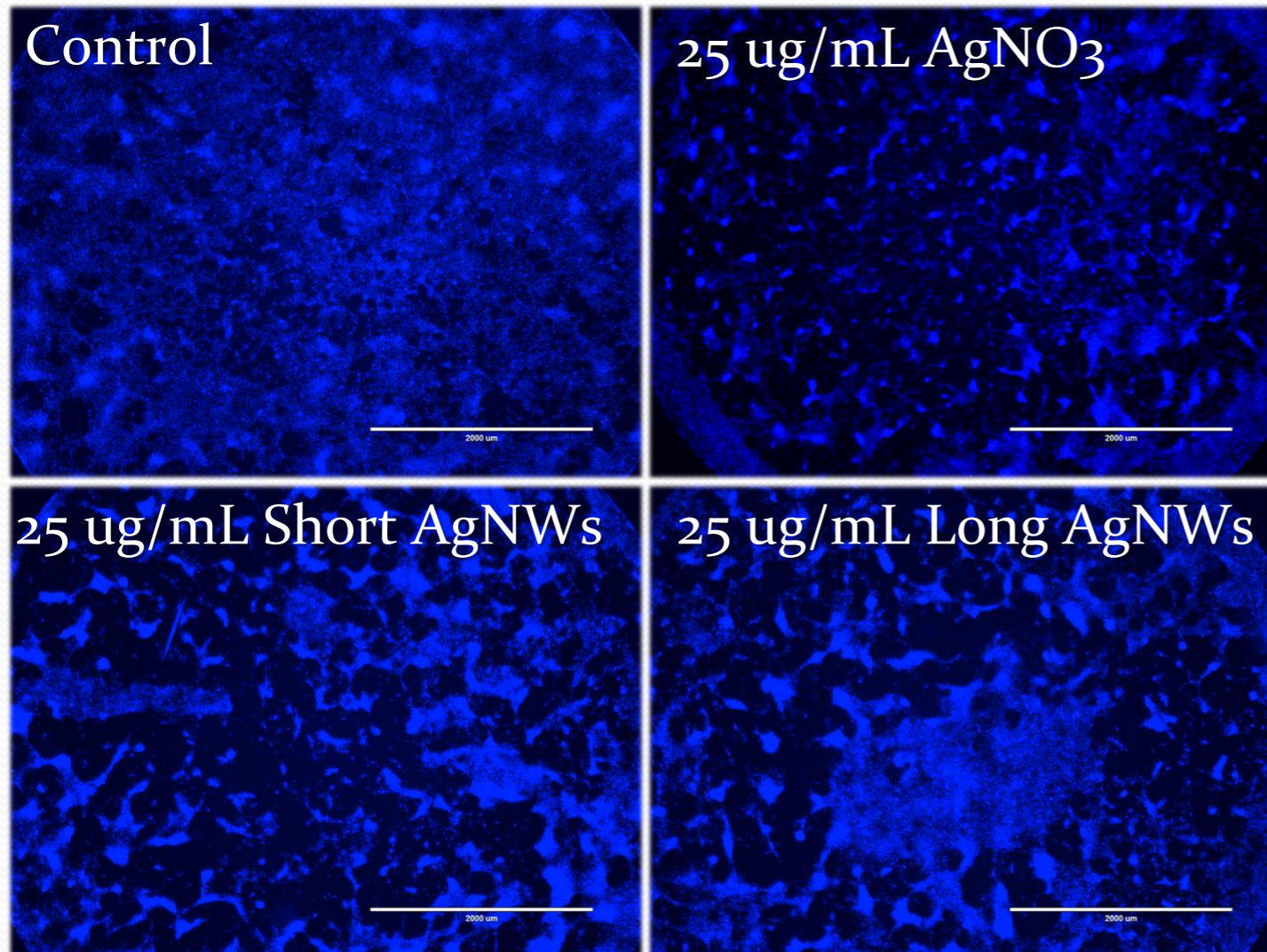
- All treatments toxic compared to control
- Toxicity due to ionic silver
- Short AgNWs > Long AgNWs

Cell titer glo assay, 48 hour exposure



AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$

# AgNW toxicity in RTgillW1



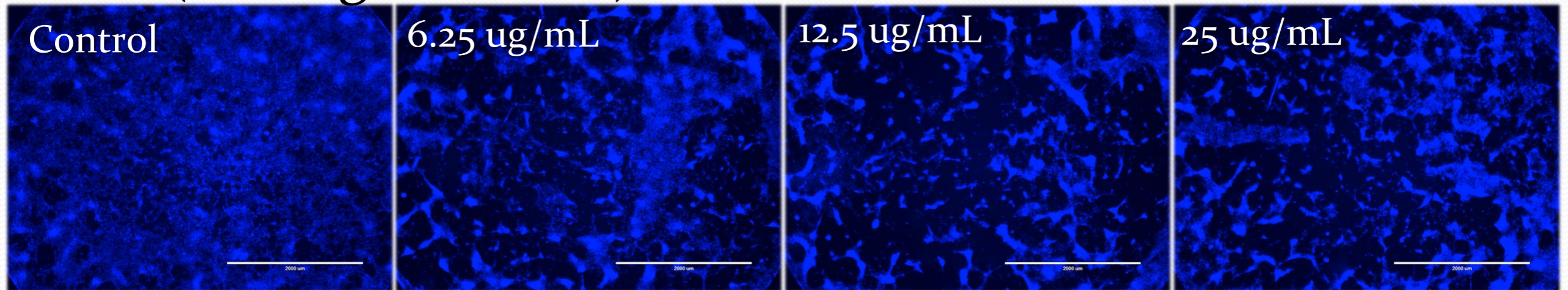
- Cells evenly dispersed in control
- Clumping/dissociation of cells in AgNO<sub>3</sub> and AgNW treatments
- Short AgNWs > Long AgNWs



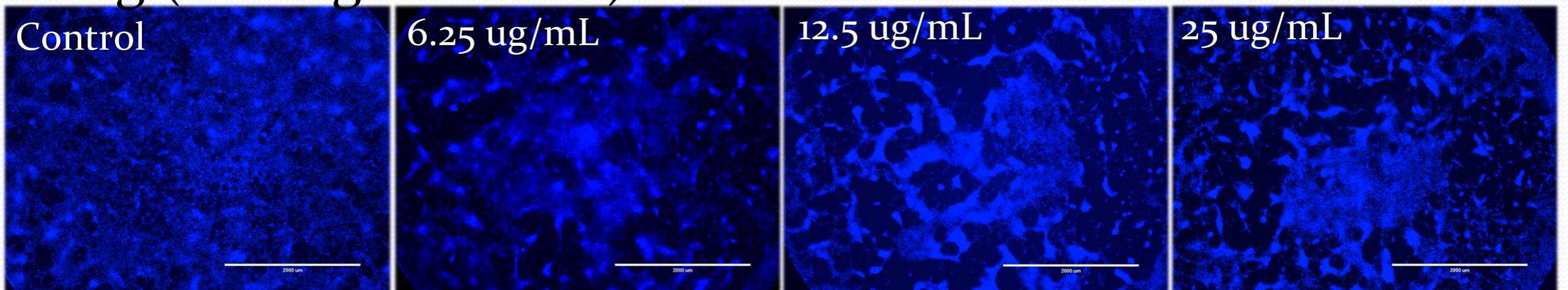
# AgNW toxicity in RTgillW1

AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$

## Short (2x magnification)



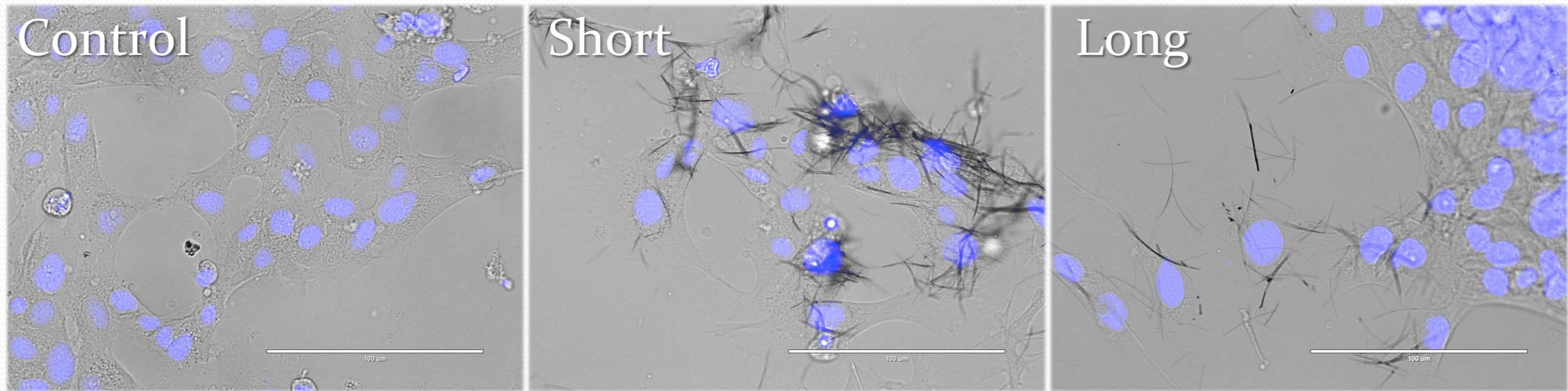
## Long (2x magnification)



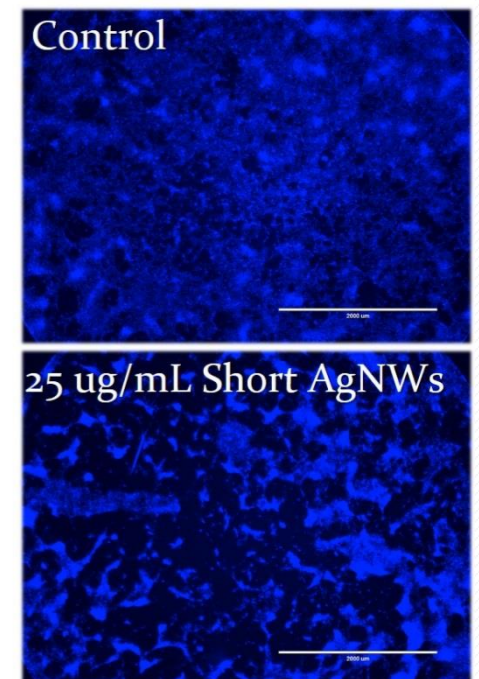


AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$

# AgNW toxicity in RTgillW1

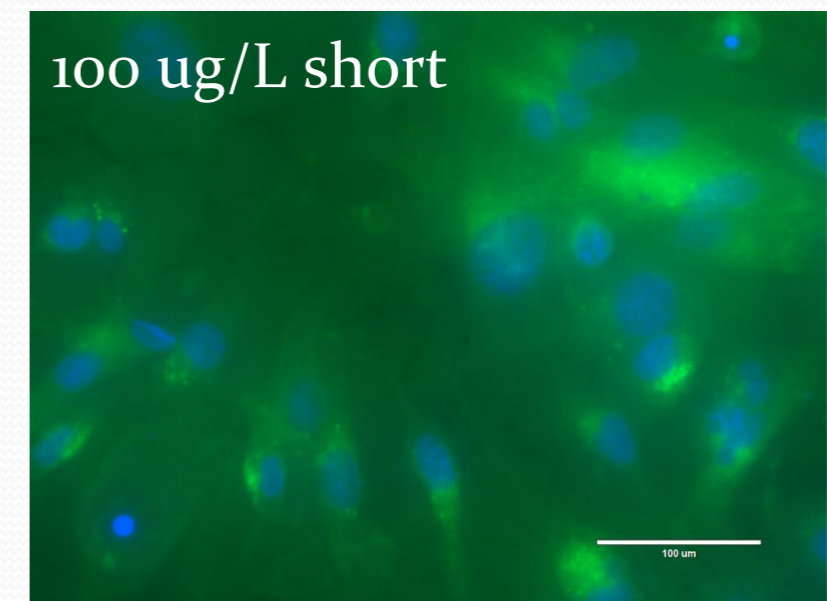
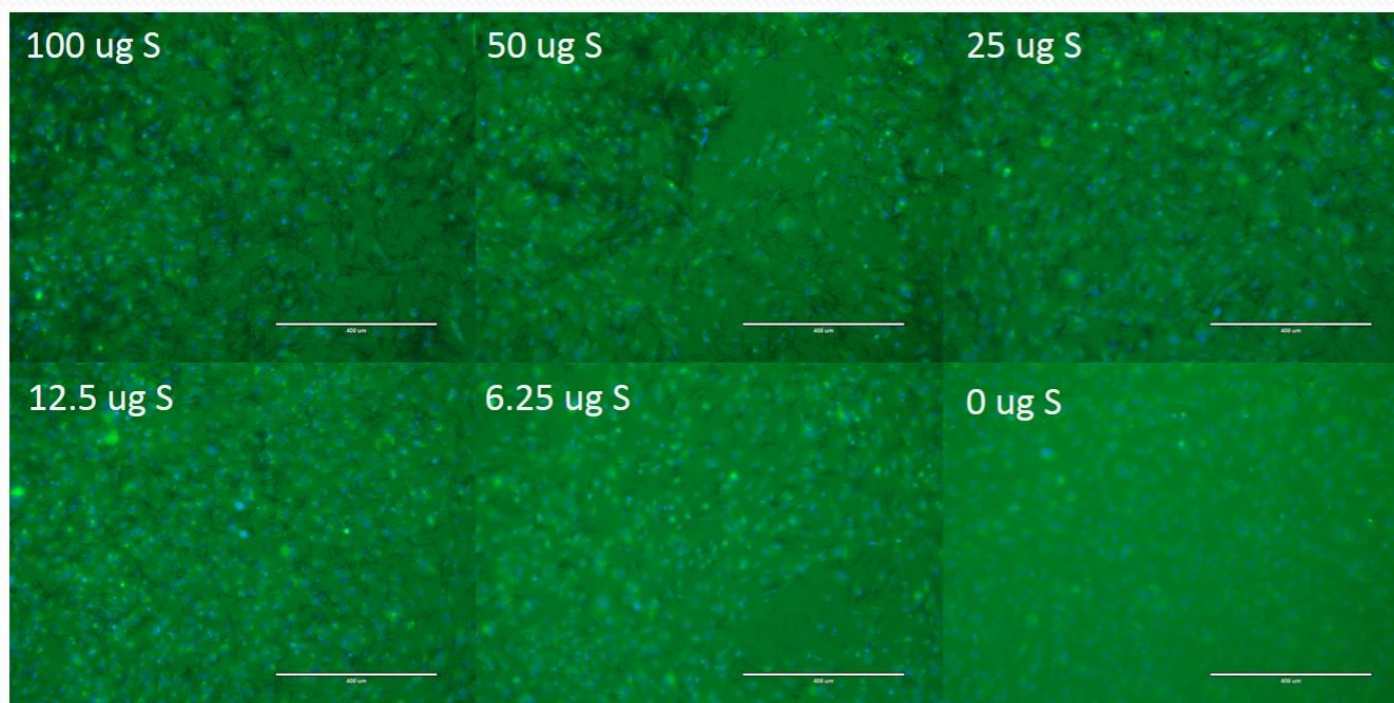
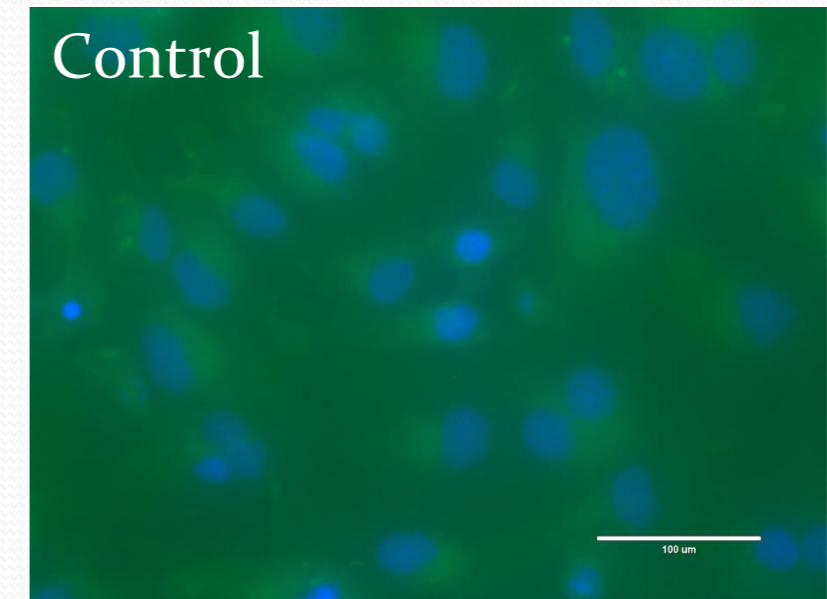
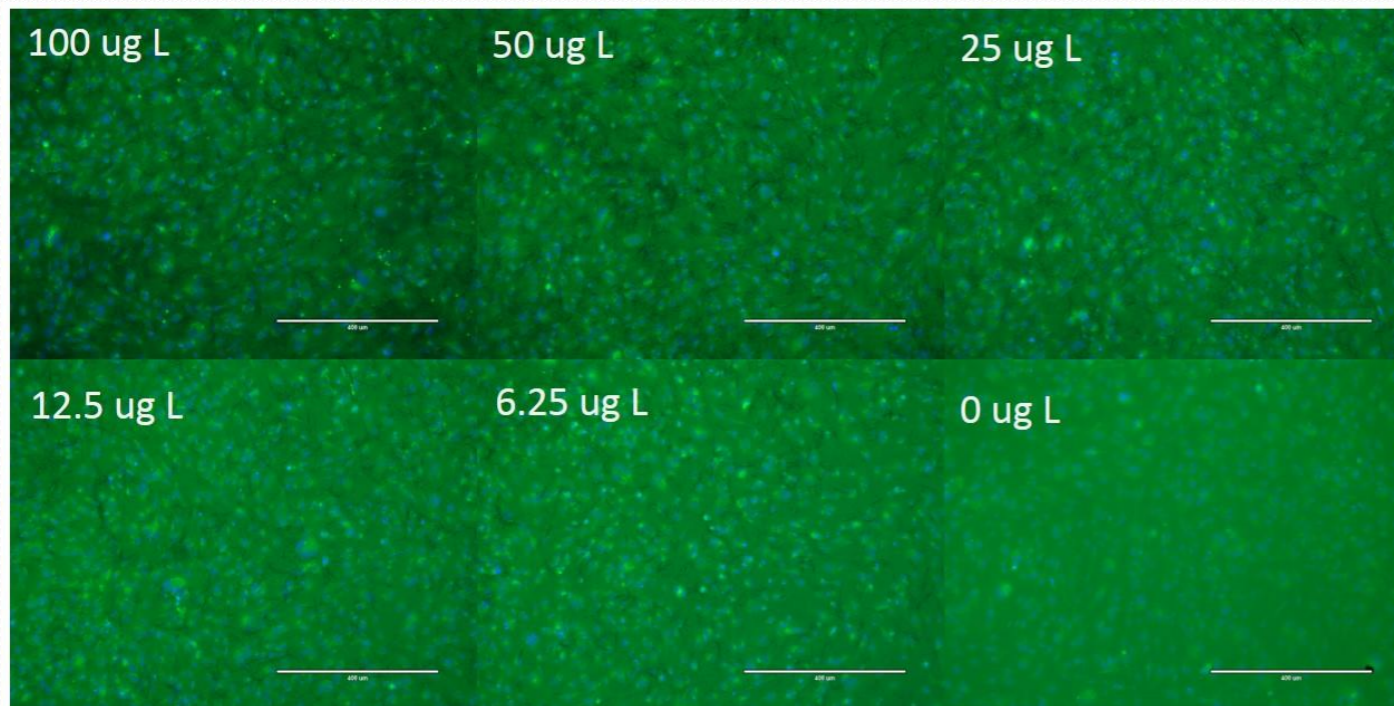


- AgNWs coming into contact with cells
- Nuclei and cells in photos appear okay
- Clumps of missing cells in 2x photos indicates toxicity





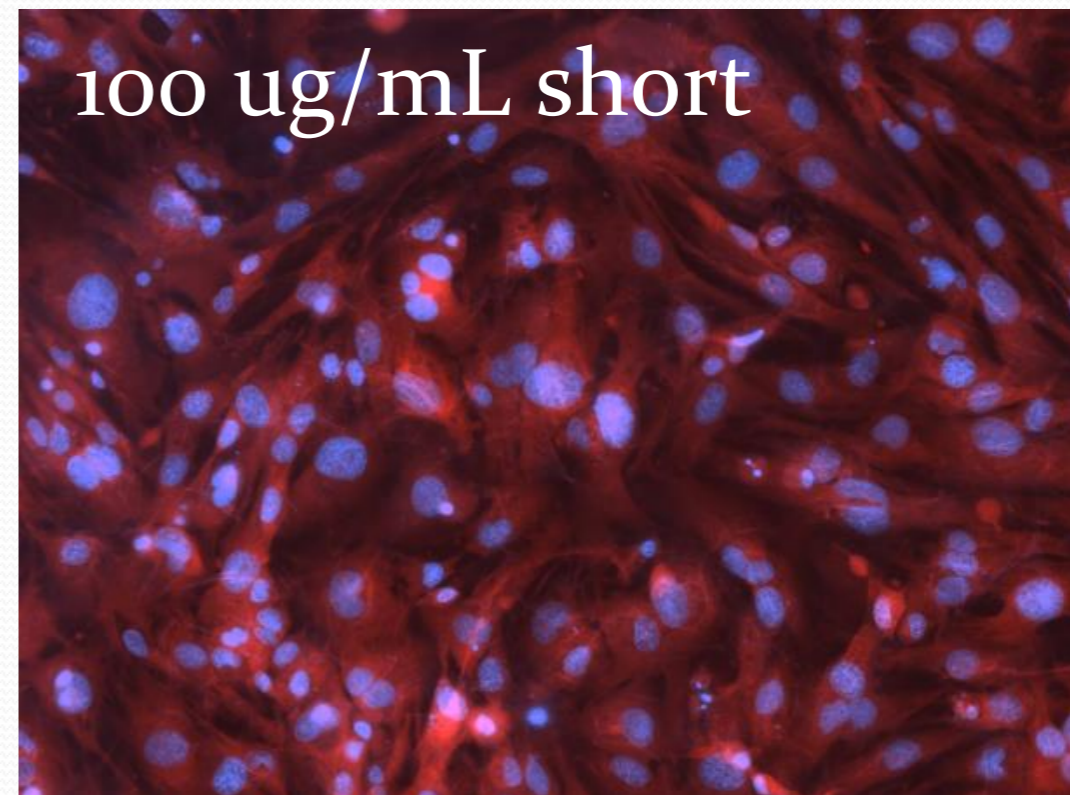
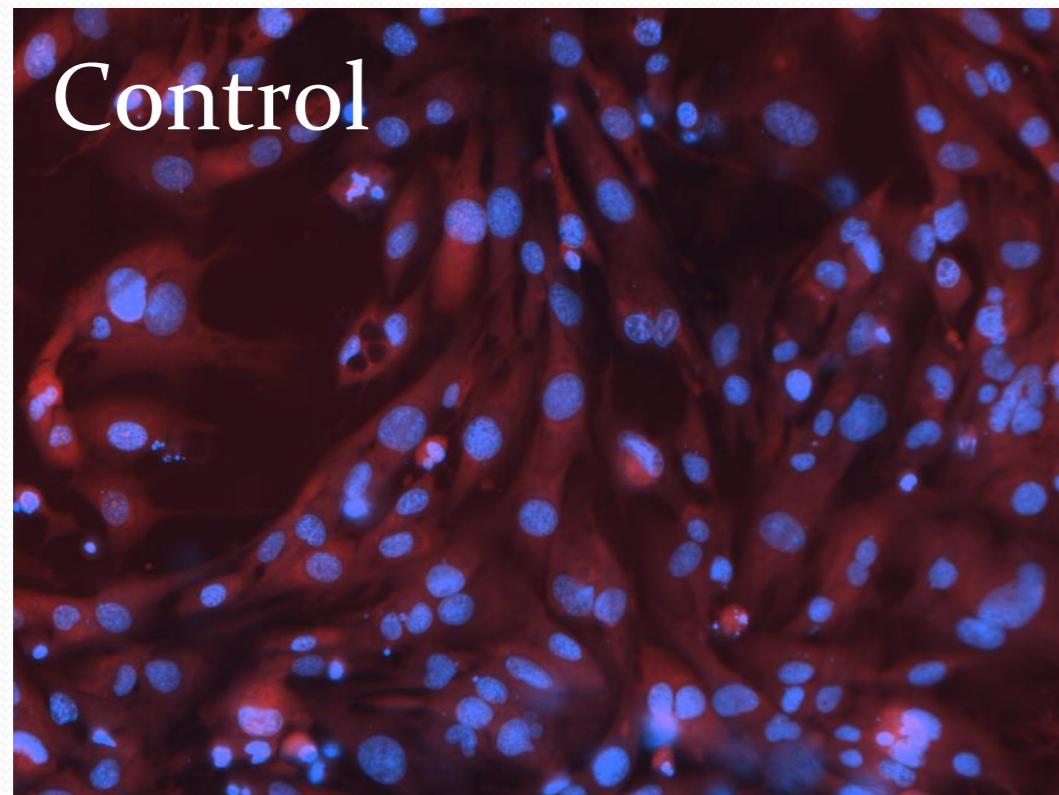
# Increased Lysosome acidity



- Lysosensor dye, GFP filter
- Hoescht 33342, DAPI filter



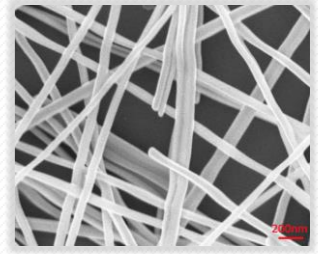
# Increased MMP



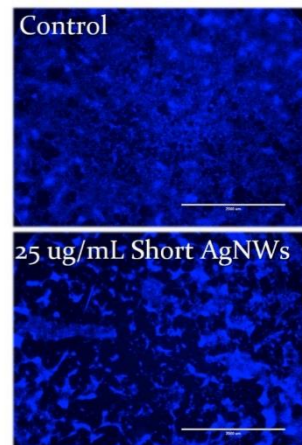
- Mitotracker dye; Cy5 filter
- Increased signal indicates hyperpolarization of mitochondrial membrane

AgNW type	Length ( $\mu\text{m}$ )	Diameter (nm)
Short and Wide	$9 \pm 3$	$93 \pm 11$
Long and Wide	$25 \pm 7$	$90 \pm 11$

# Conclusions



- Preliminary data indicates AgNW length plays an important role in cytotoxicity
  - Even between AgNWs that only differ in aspect ratio by a factor of 180
  - Short AgNWs are more toxic than long AgNWs
- Future work will investigate additional cellular endpoint, whole organism toxicity, and the mechanism of toxicity.
- Endosomal toxicity





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France*

*Laurent Charlet  
France*

*Chris Vulpe  
USA*

*Vincent Jamier  
Spain*

Questions