# Mobile Phone and Handheld Microscopy for Helminth Diagnoses

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# Outline

1. Why use **mobile phone** and handheld microscopes?
2. What **devices** have been used to date?
3. What are some of the **limitations**?
4. What are the **future** directions to overcome limitations?

# Thank you


- **Dr. Jean Coulibaly** – Université Félix Houphouët-Boigny, Ivory Coast
- **Mr. Shaali Ame** – Public Health Laboratory, Pemba, Tanzania
- **Prof. Juerg Utzinger** – Swiss Tropical and Public Health Institute
- **Prof. Jennifer Keizer** – Swiss Tropical and Public Health Institute
- **Prof. Aydogan Ozcan** – University of California, Los Angeles
- **Prof. Dan Fletcher** – University of California, Berkeley
- **Dr. Richard Kobina Dadze** – University of Cape Coast, Ghana
- **Dr. Jason Andrews** – Stanford University

- **Funding**: Grand Challenges Canada

Princeton, ~2003

# Laos, 2014

***“Praziquantel Cheers”***

# 1. Why use mobile phone and handheld microscopes?

# The Issues

- Lack of **diagnostic support** at clinical and public health levels in resource-constrained settings
  - Especially in rural areas
- Some facilities can check **basic** blood tests
- Smaller places and more rural clinics have **few or no** diagnostic tests
  - Send out specimens vs. transfer people to larger clinics

# So what happens?

- Transferring people and/or specimens:
  - Time
  - Money
  - Sick people
    - No time - too sick, or have to be home to help support family
    - No money

- We attempt to deliver **equitable healthcare** and **public health** by bringing **quality laboratory diagnostics** to low-resource settings

- ***Bring the lab to the people rather than moving patients or specimens***
- Goal: develop, validate, and implement **portable**, **easy-to-use** microscopes to areas most in need
- Converting **mobile phones** into microscopes and using other **handheld microscope devices**

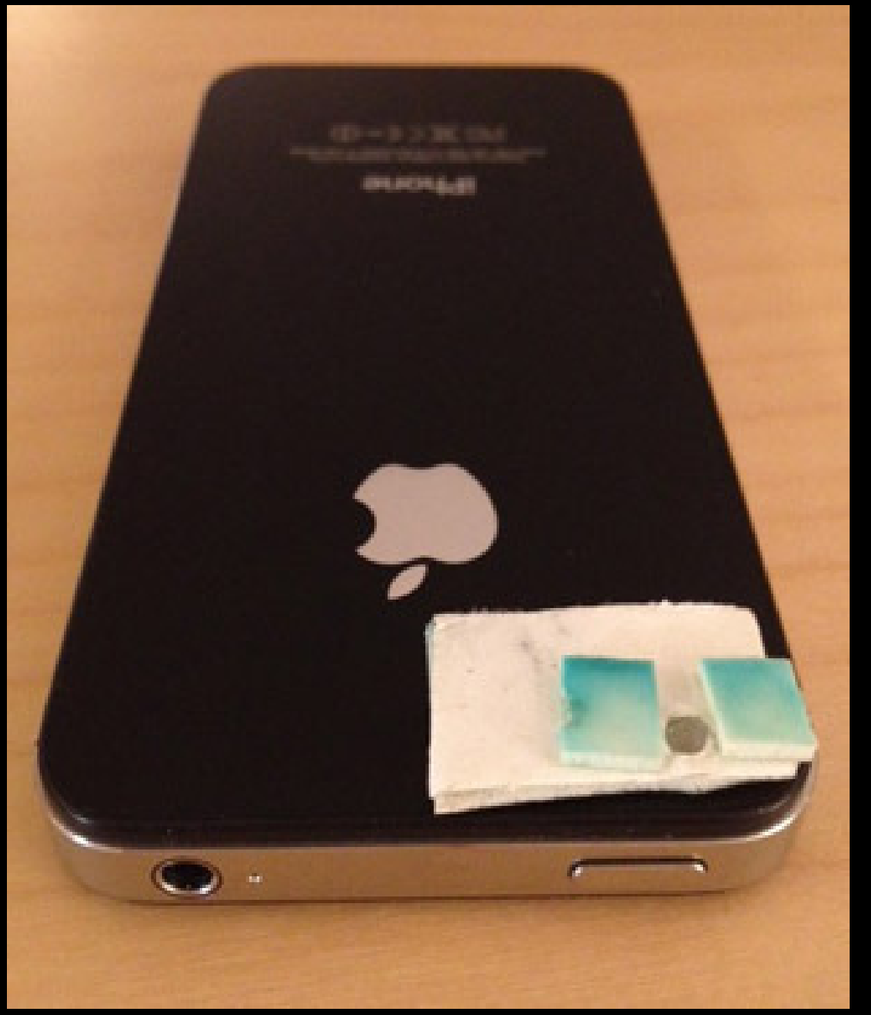
# Why do you want a mobile phone?

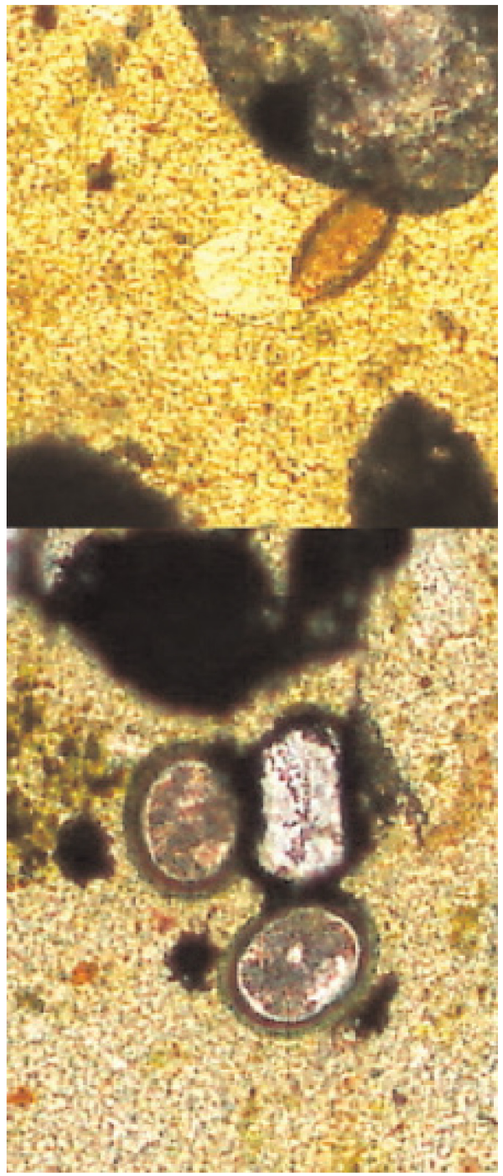
- Portable, **easy** to use, **battery** powered
- Digitize an image
  - Send to to others via **text** or **email**
  - Automated diagnoses with **computer vision** and **machine learning**
- Record other **health information**/data with image
- Mark the **GPS** coordinates

**Such technology could be used for rapid, portable, point-of-contact diagnoses for clinical or public health applications in resource-constrained settings**

# 2. What devices have been used to date?

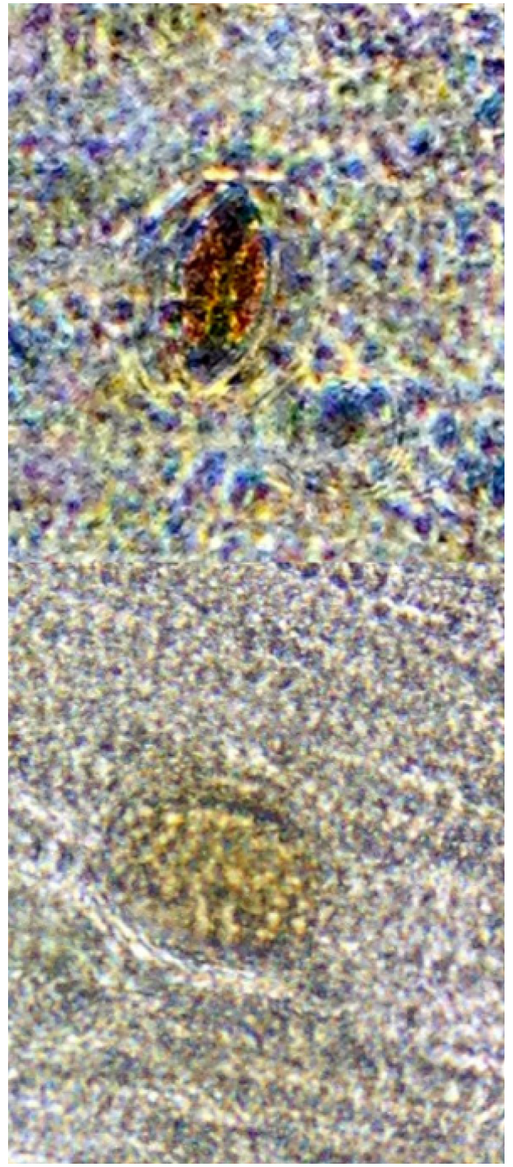
A long time ago in a galaxy far, far away....

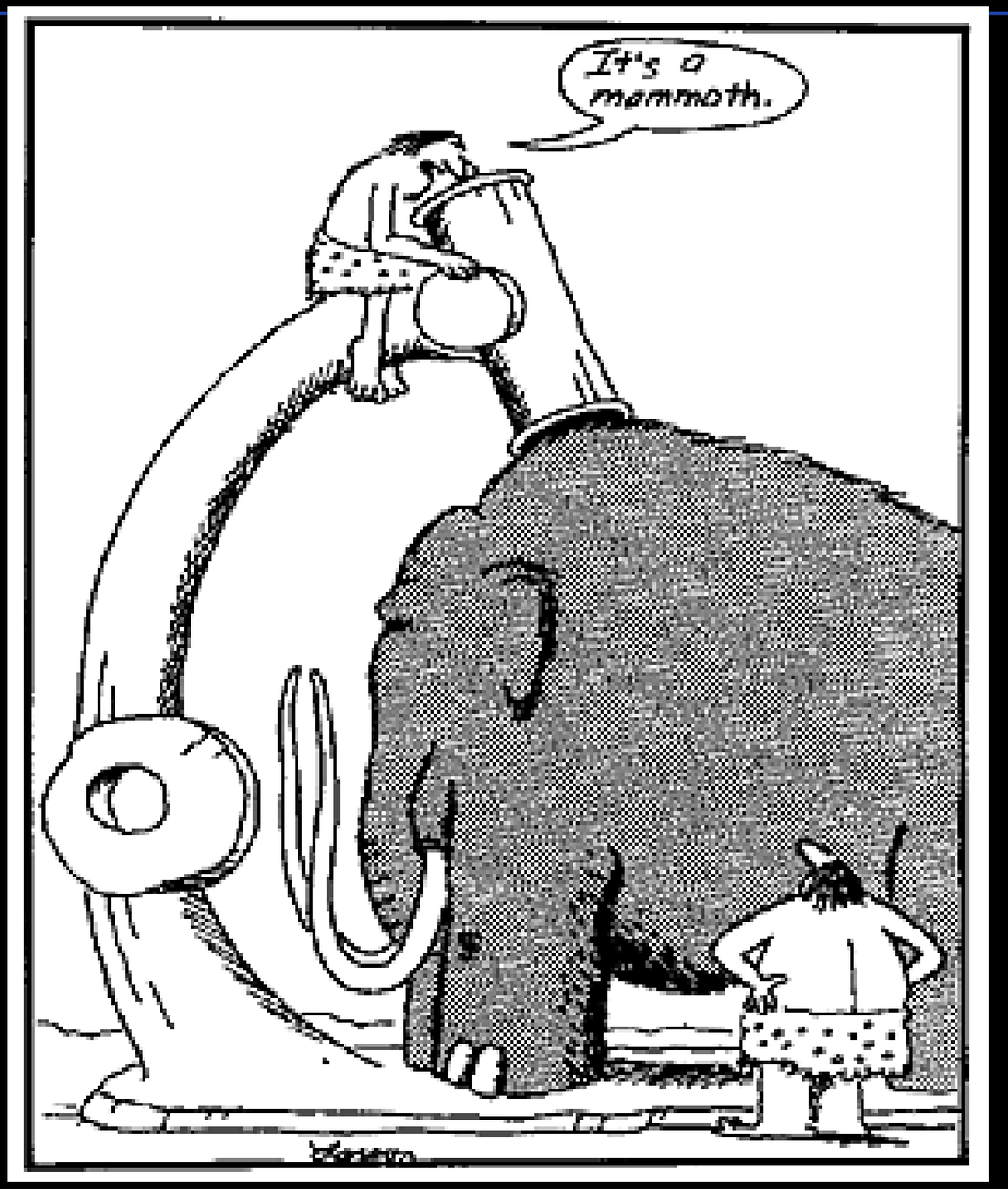




*T. trichiura*

*A. lumbricoides*




It's a mammoth.

Terrible!

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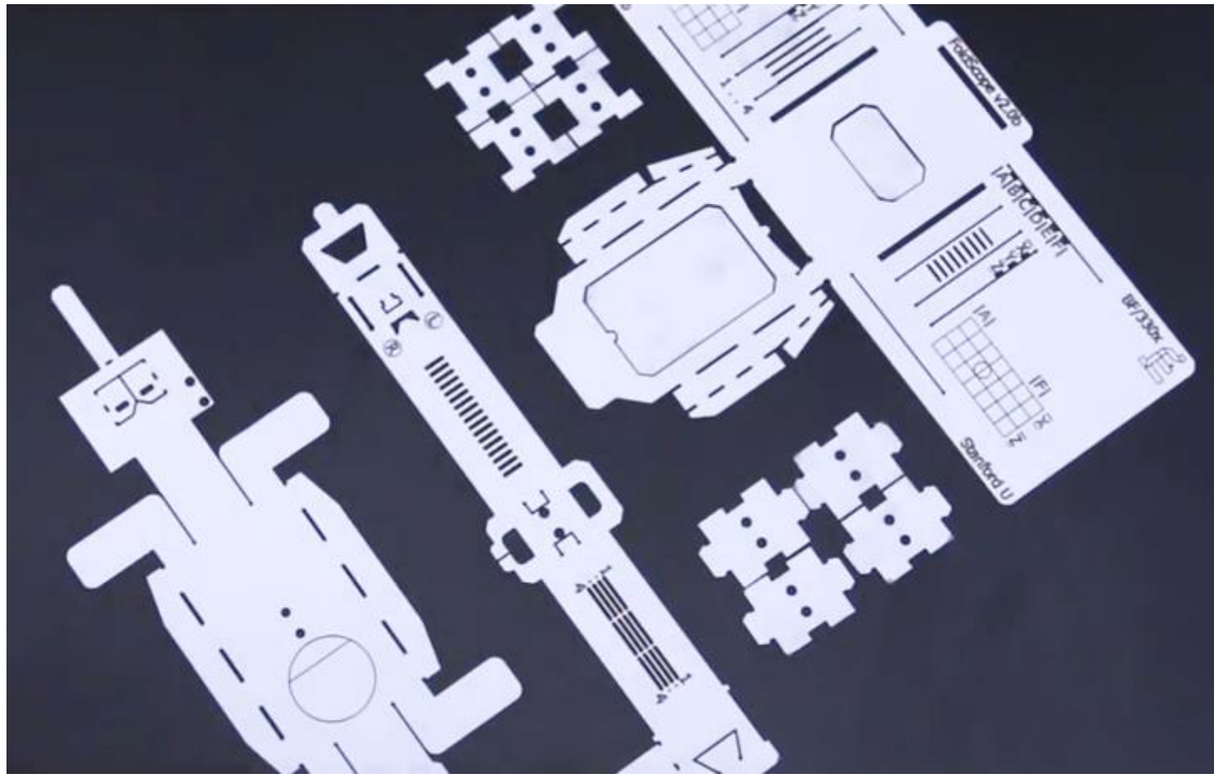
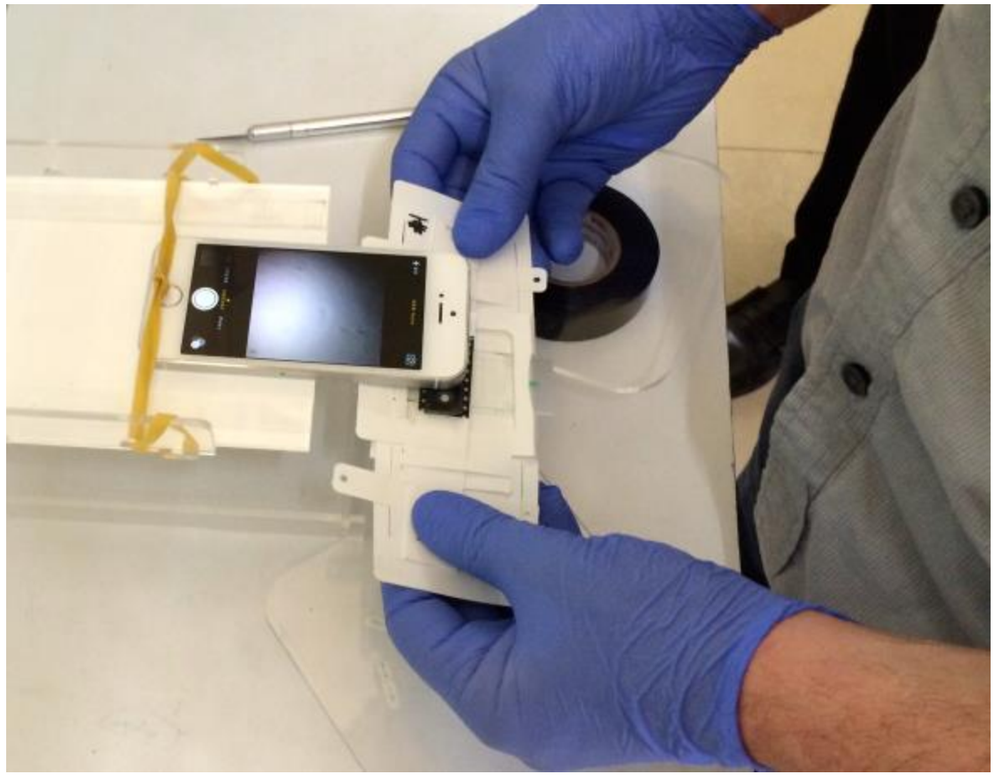
Anton van Leeuwenhoek, 1600s

# Foldscope

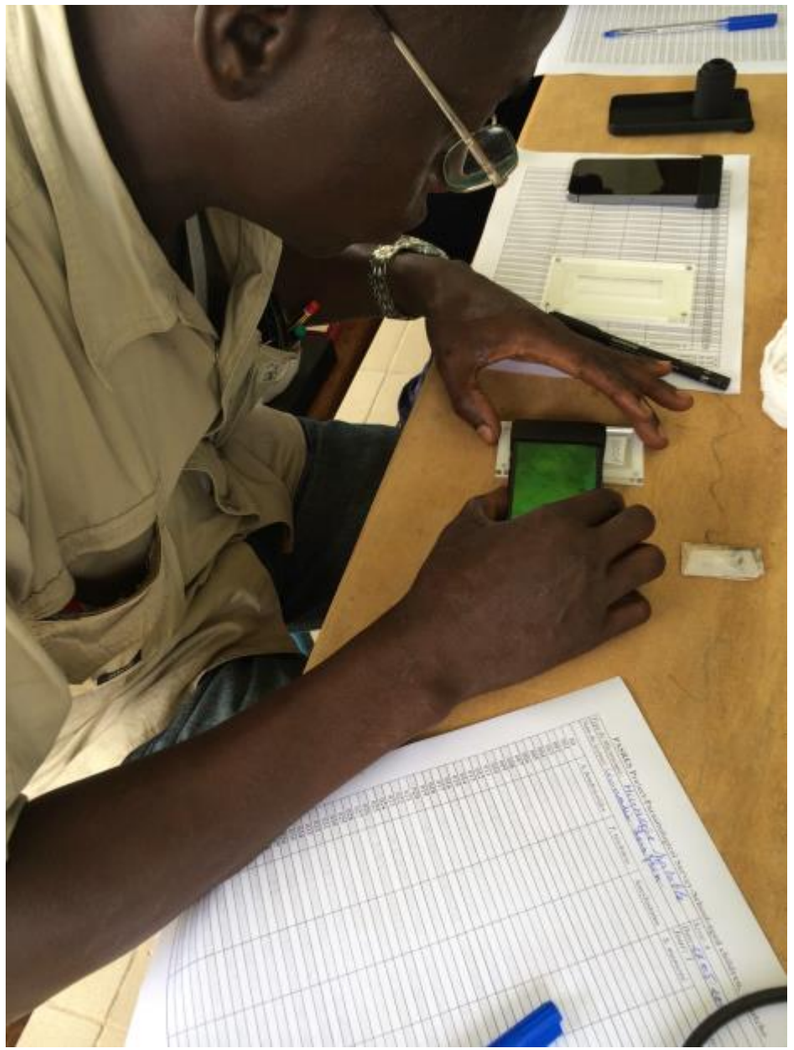




Cybulski, 2014

# Reversed Lens Microscope



| Device | Organism Detected | Sample Size | Sn/Sp (%) | NPV/PPV (%) |
|---|---|---|---|---|
| **Ball lens mounted to mobile phone** | *A. lumbricoides*, *T. trichiura*, hookworm | 199 | 69.4/61.5 | 92.3/23.2 |
| **Foldscope** | *S. haematobium* | 49 | 55.9/93.3 | 95.0/48.3 |
| **Reversed-lens Cellscope** | *S. haematobium* | 49 | 67.6/100.0 | 100.0/57.7 |

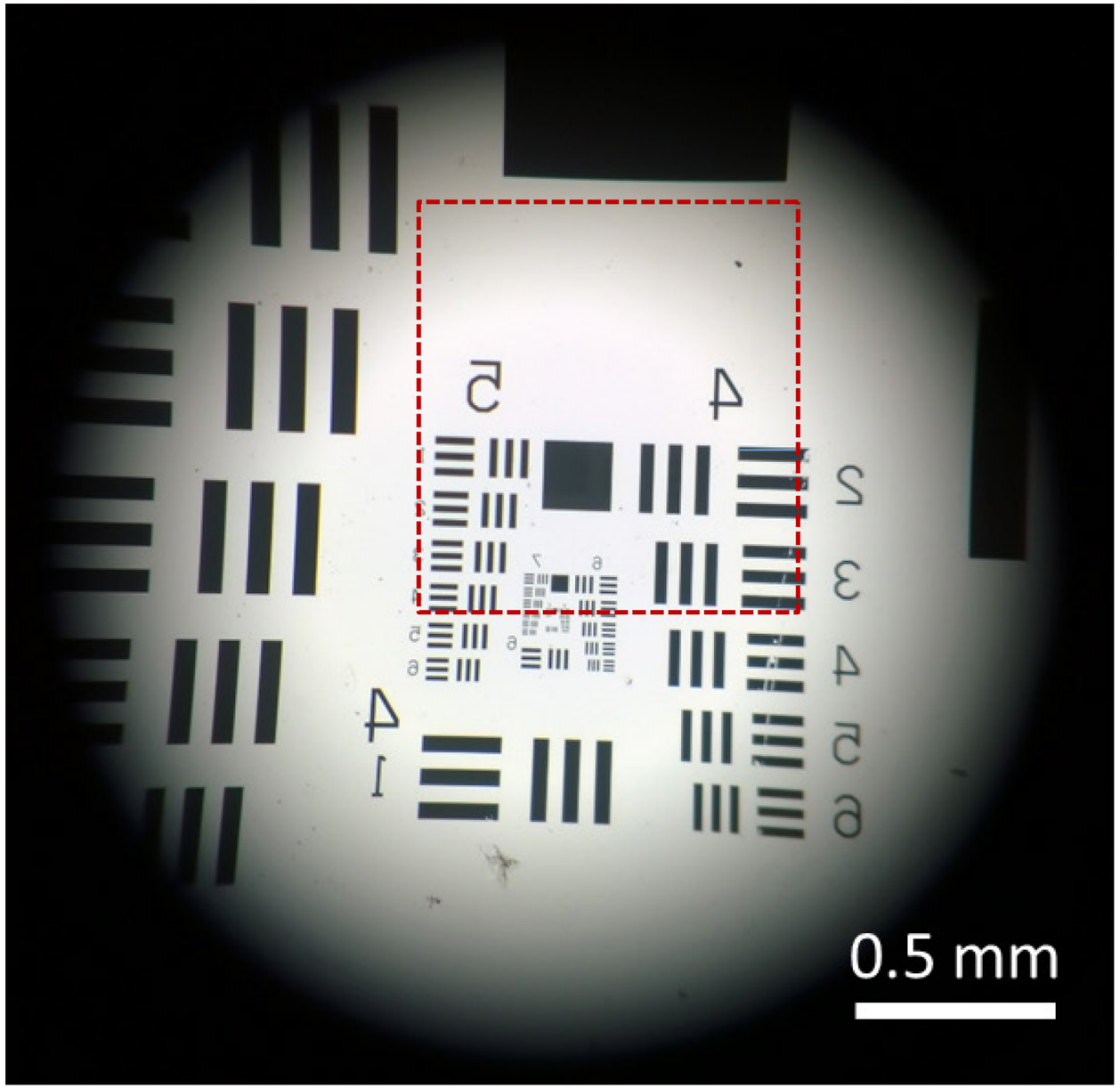
# Handheld and Mobile Phone Microscopes

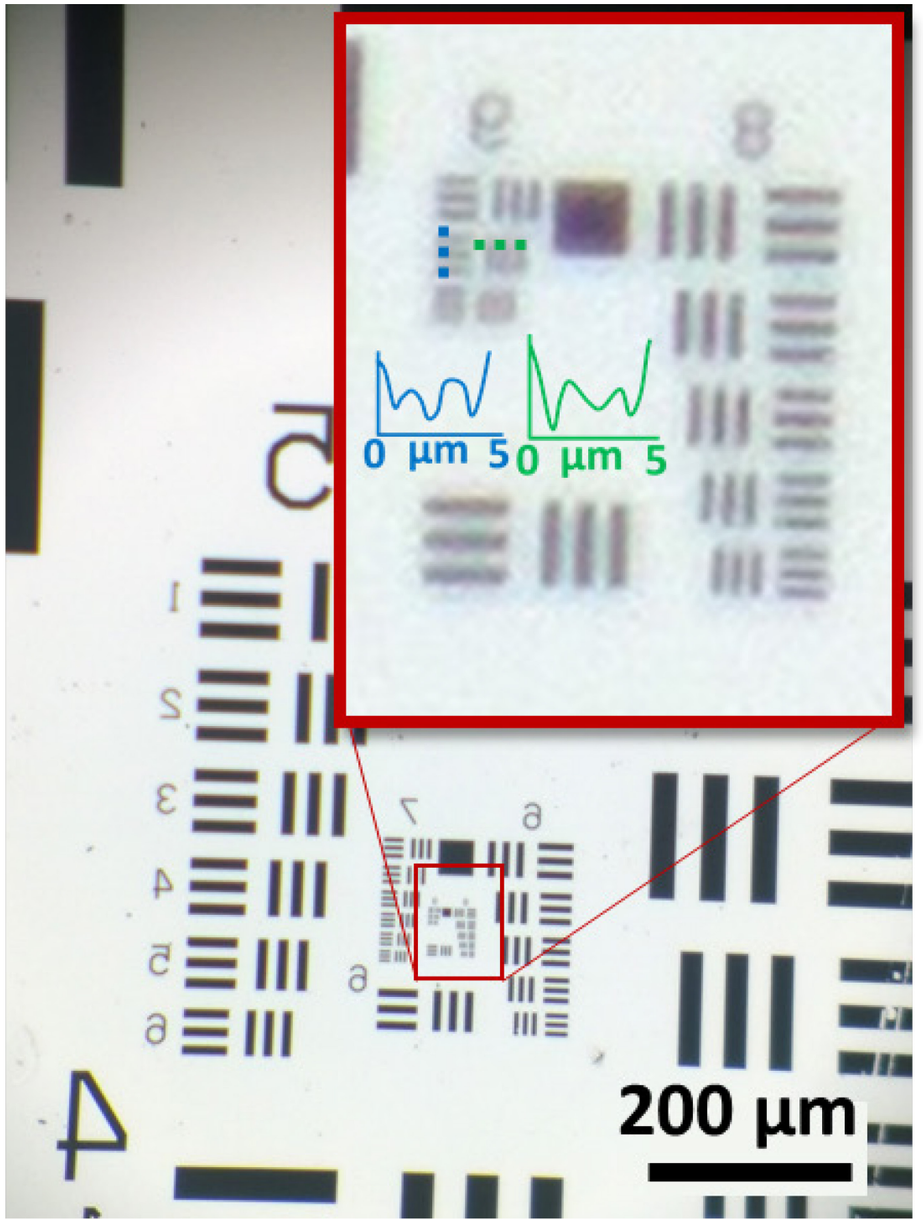
- Handheld microscope with mobile phone attachment
- Weighs 0.5 kg
- Good success field studies on STH and schistosomiasis

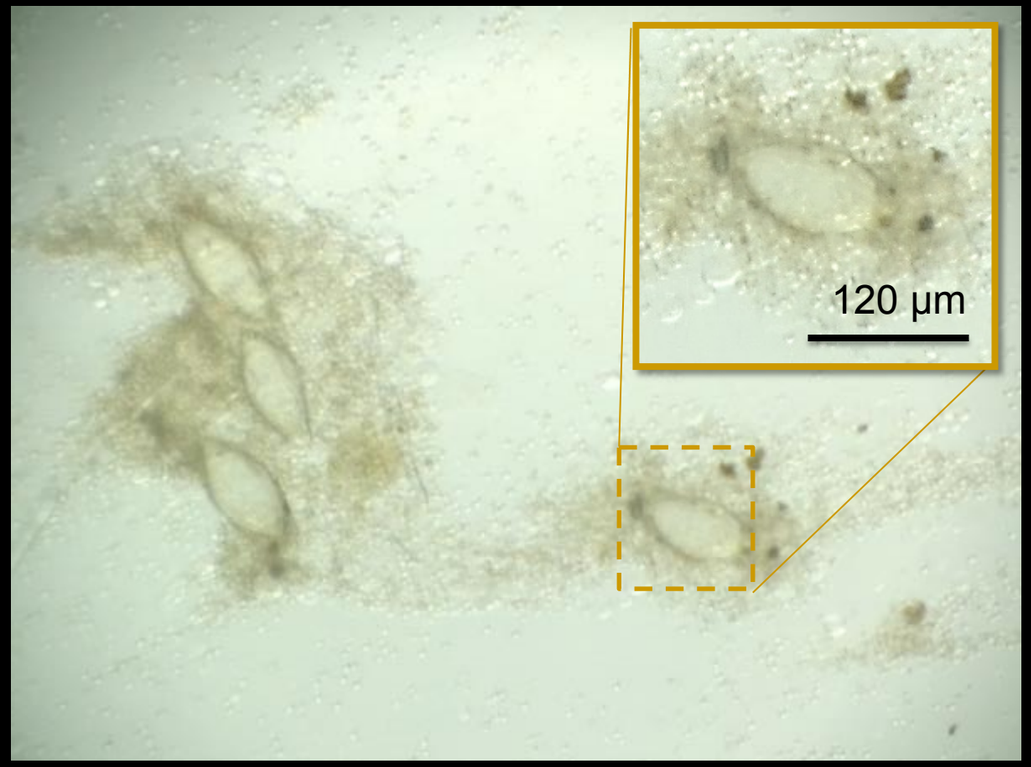

*Newton Nm¹*


NOKIA


UCLA
Nano | Bio
Photonics


0.5 mm


0 µm 5
0 µm 5
200 µm


120 µm

| Device | Organism Detected | Sample Size | Sn/Sp (%) | NPV/PPV (%) |
|---|---|---|---|---|
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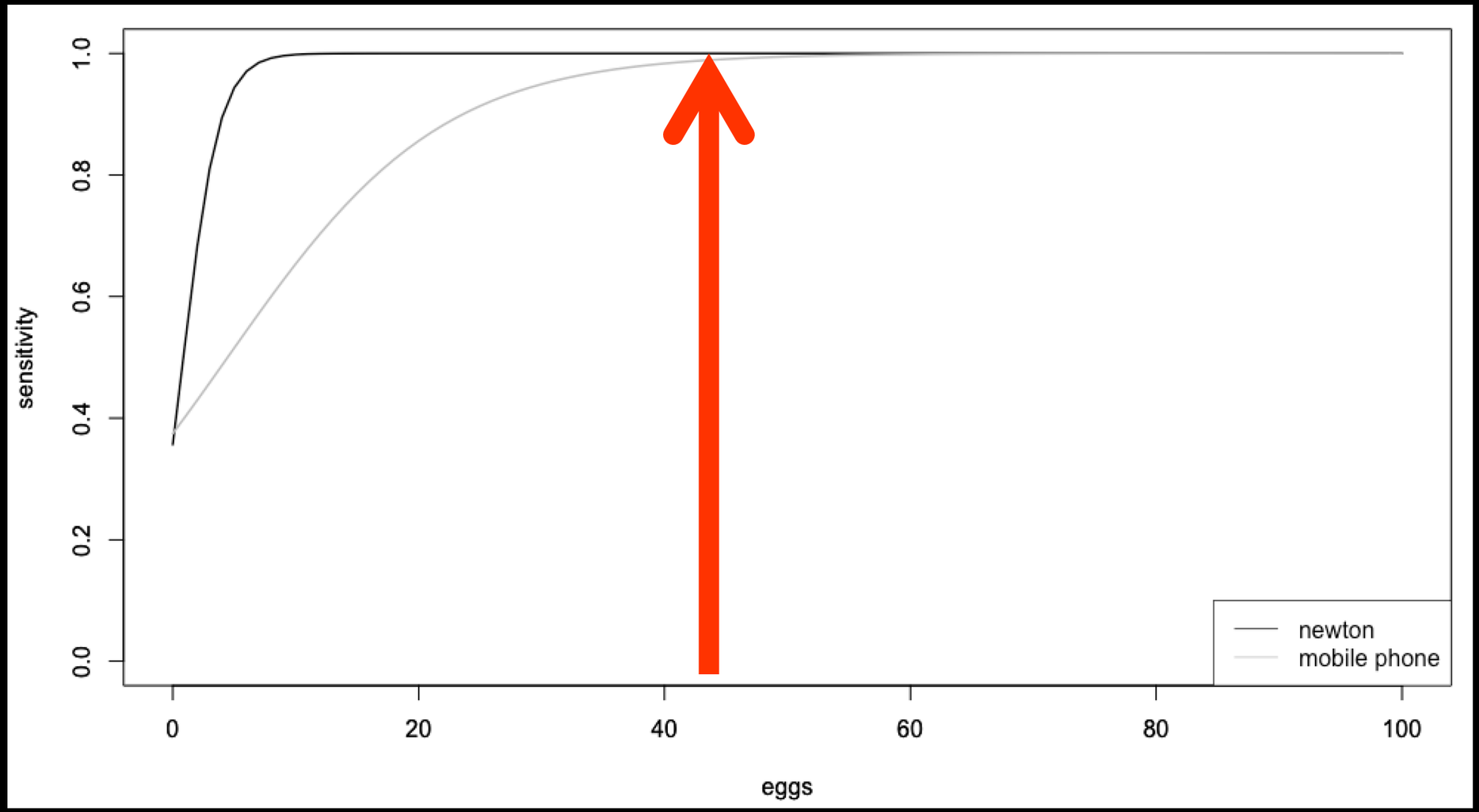
| **Newton Nm1 with mobile phone attached** | *S. mansoni* | 226 | 91.7/99.5 | 91.7/99.5 |
| **Newton Nm1 with mobile phone attached** | *S. haematobium* | 226 | 81.1/97.1 | 94.8/88.6 |
| **3D printed mobile phone microscope** | *S. haematobium* | 59 | 72.1/100.0 | 100.0/57.1 |

# *S. haematobium*: sensitivity by egg count




*S. haematobium*
<50 low intensity
≥50 high intensity

- ***How do these devices work in real-world setting by people who actually use them in their day-to-day clinical or public health work?***

- We have evaluated the performance of devices, used by local microscopists, integrated in community-based screening and treatment programs for malaria, schistosomiasis and soil-transmitted helminth infection

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LAKERS

# The unintended “selfie”

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# 3. What are some of the limitations?

# What are some of the limitations?

- Design of devices:
  - **Optics** are good in most devices
  - Better design devices for **high-throughput** of samples
    - may need to re-think sample preparation

- Implementation of devices:
  - Need validation in **real-world** settings
  - Issues with scale-up when devices are "*good enough*"

# 4. What are the future directions to overcome limitations?

# Capabilities prototype devices?

- Quality imaging at the sub-micron level
- Computer vision and machine learning
  - Automated identification and quantification of organisms
- Tracking GPS coordinates to map diagnoses
- Ability to input other meaningful clinical data
- Endless possibility for other applications

# *A word on cost-effectiveness

***The cost of the device is trivial as long as it is robust, has sufficient optics, and is designed for efficient throughput***

# Summary

- Mobile Phone microscopy has incredible **potential** to improve the **quality of care** in ***clinical*** and ***public health*** settings

- Validate new devices in **real-world** settings

- **Scale up** training and usage in appropriate settings

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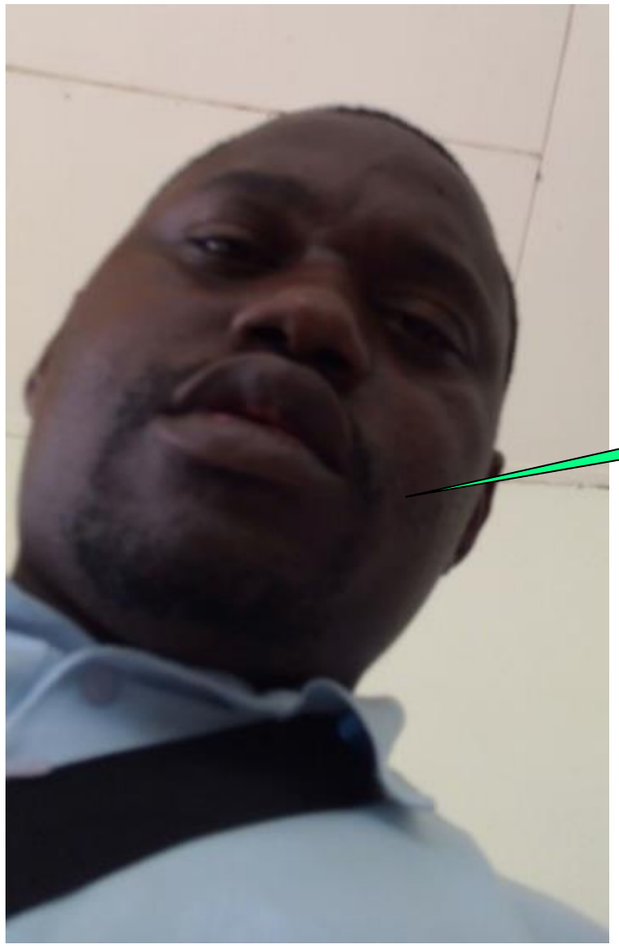

Thank you

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# Costs

- Build robust microscopes that **function** well
- **Resist** the urge to build the **cheapest** microscopes that sacrifice image quality
- We have seen costs for typical components drop and many of these items are available in developing countries
  - Smart phones
  - Webcams

# Costs – an exercise

- Lifespan of microscope = 10 years
- Cost of laboratory technician
  - $4000/year
  - x10 years
  - **= $40,000**
- Works
  - 48 weeks per year
  - 5 days per week

# Costs – an exercise

- **$1 device**
  - Processes **30** samples per day
  - 7,200 samples per year
  - 72,000 over 10 years
  - Total cost over 10 years$40,000 + $1 = **$40,001**
  - **Cost per sample: $0.56**

- **$500 device**
  - Process **40** samples per day
  - 9,600 samples per year
  - 96,000 samples over 10 years
  - Total cost over 10 years
    $40,000 + $500 = **$40,500**
  - **Total cost per sample: $0.42**

# Costs – an exercise

- Image quality with $500 device likely better than $1 device
- Added ‘soft’ costs with cheaper device - lowered sensitivity and specificity
  - Missed diagnoses, greater healthcare expenses
    - Time off of work, morbidity, etc.
- ***The cost of the device is trivial, throughput and proper diagnosis is everything***