# Point-of-Care Medical Diagnostic Using Smart Phone

A cost effective and mobile platform to analyze blood samples.

Smartphone Microscopy
SMARTSCOPE

**PIII Presentation**

By,
**O**mkar **J**ambovane
Sr.PD **I** 136130011

Guide
**P**rof. **N S**adhu

IDC, IIT Bombay

SMARTSCOPE

Smartphone Microscopy

Image reference as seen on : 30/02/2015 : http://www.clipartlord.com/category/home-clip-art/appliances-clip-art/mobile-phones-clip-art/smartphone-clip-art/

# Need

Smartphone Microscopy

Rural India

Over 70% of India's population

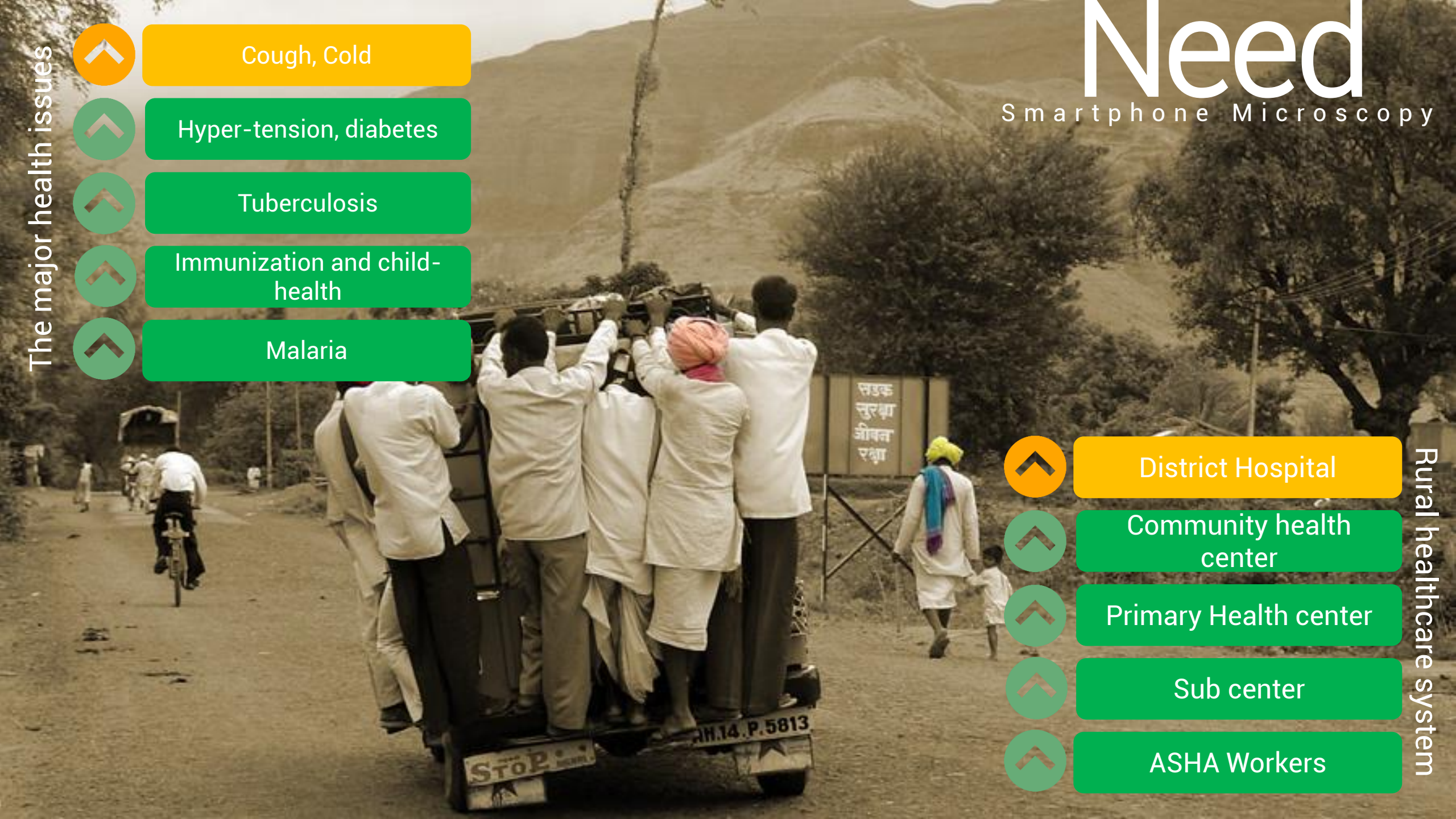
Health care and services.

# Need

Smartphone Microscopy

The major health issues

- Cough, Cold
- Hyper-tension, diabetes
- Tuberculosis
- Immunization and child-health
- Malaria




Rural healthcare system

- District Hospital
- Community health center
- Primary Health center
- Sub center
- ASHA Workers

Need

Smartphone Microscopy

# Smartphone Use

SMARTPHONE PENETRATION AS A PERCENTAGE OF THE TOTAL POPULATION

13%

SMARTPHONE USERS SEARCHING FOR LOCAL INFORMATION VIA THEIR PHONE

95%

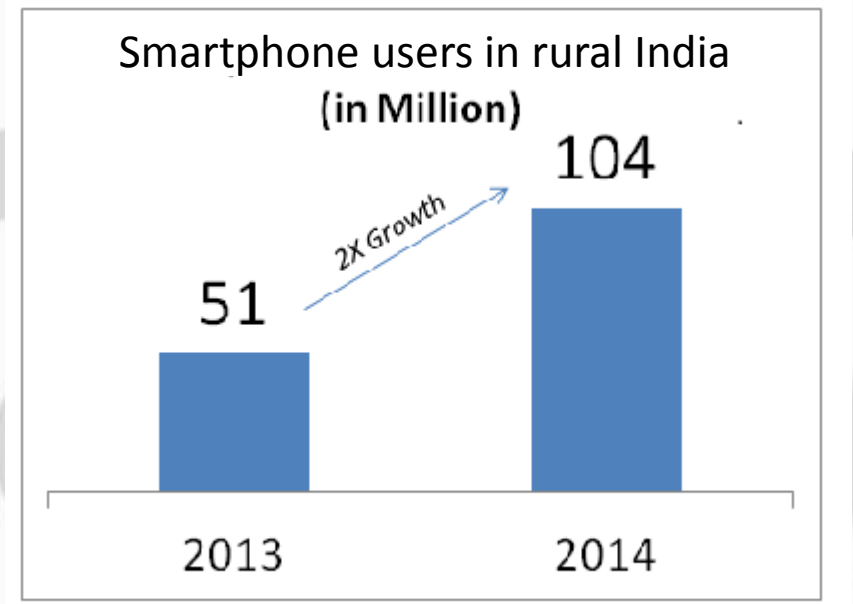
SMARTPHONE USERS RESEARCHING PRODUCTS VIA THEIR PHONE

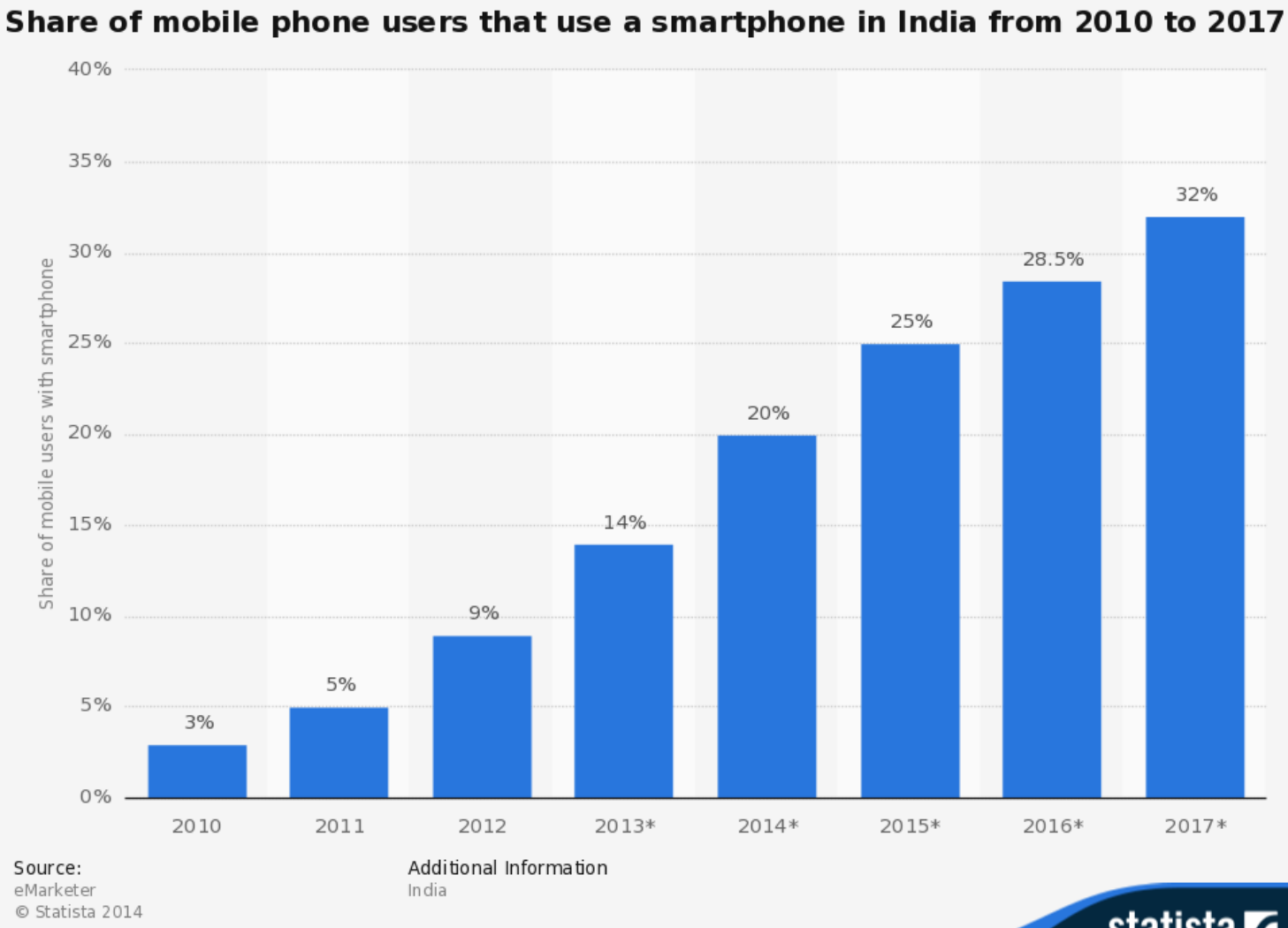
91%

SMARTPHONE USERS WHO HAVE MADE A PURCHASE VIA THEIR PHONE

54%

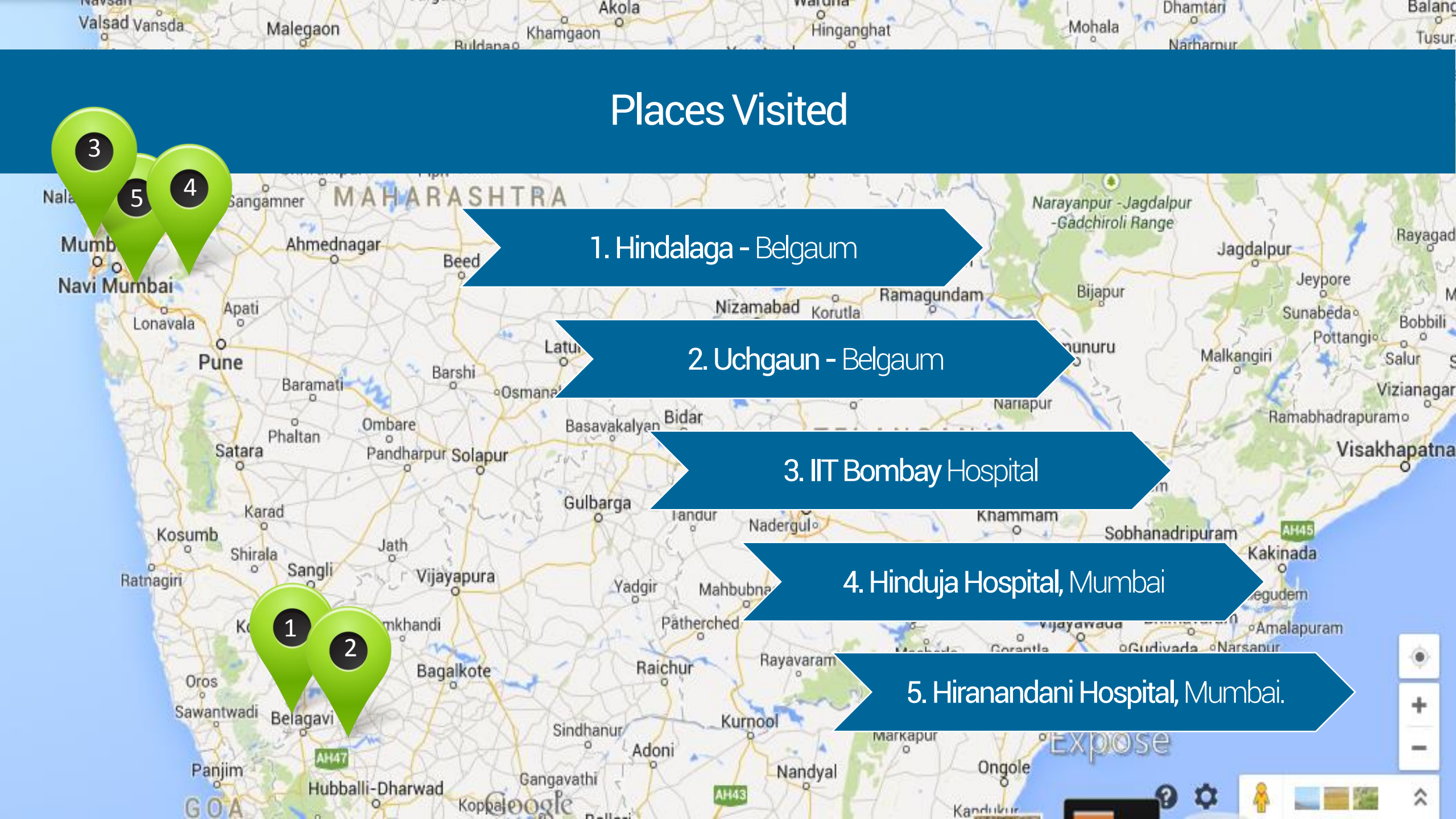
# Smartphone user penetration rate in India



# User Study


# Places Visited




1. **Hindalaga** - Belgaum

2. **Uchgaun** - Belgaum

3. **IIT Bombay** Hospital

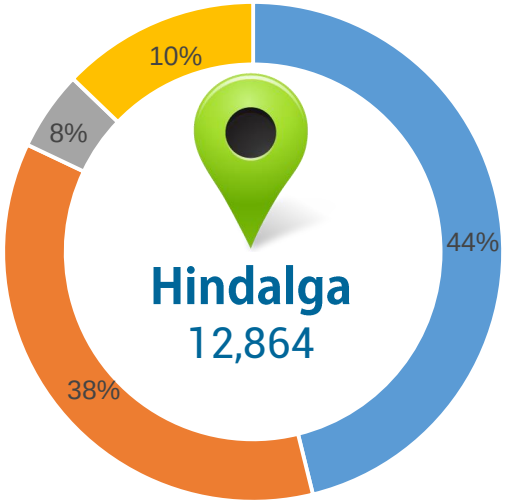
4. **Hinduja Hospital,** Mumbai

5. **Hiranandani Hospital,** Mumbai.

# Statistics of blood and sputum tests

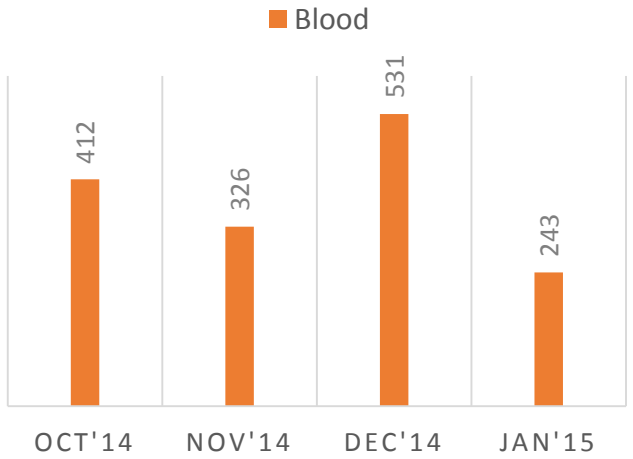
## Hindalga

Population




Male Female Under 6yr Above 60

SAMPLES SENT OUTSIDE

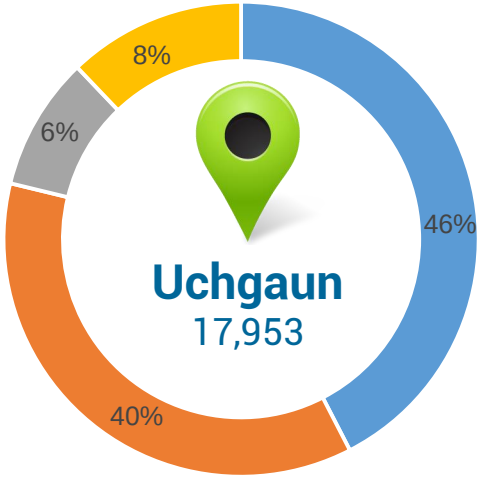



Average

Blood tests/day= ~12

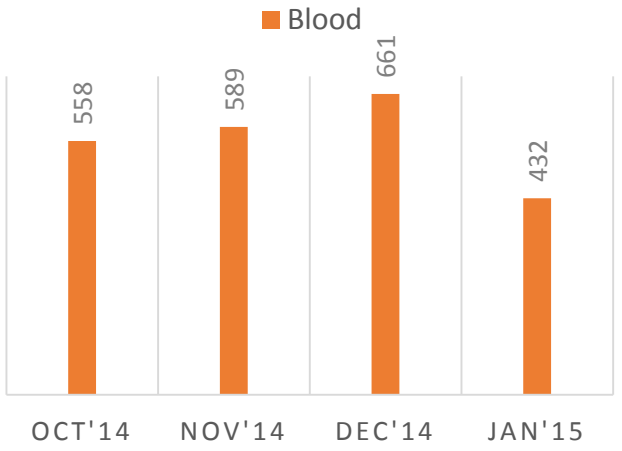
## Uchgaun

Population




Male Female Under 6 yr Above 60 yr

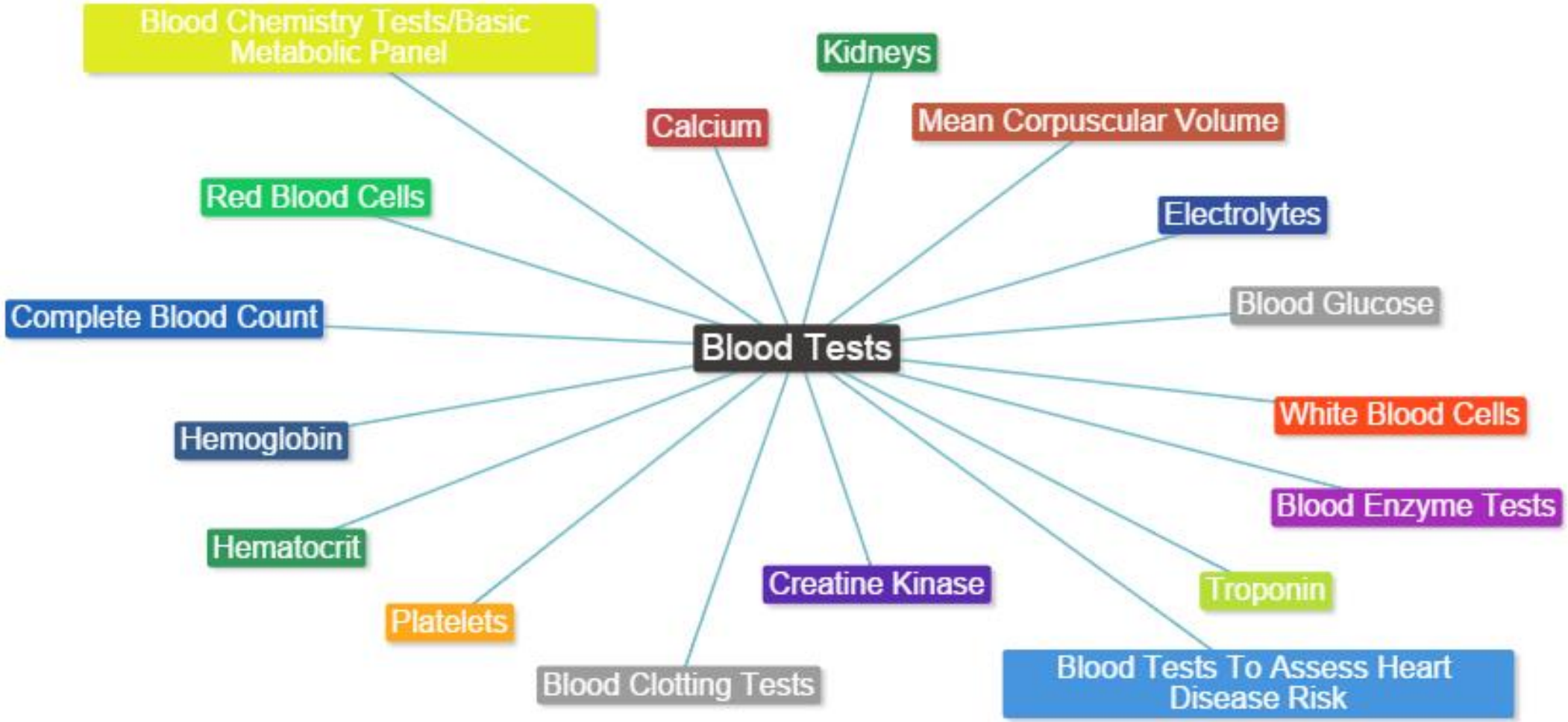
SAMPLES SENT OUTSIDE



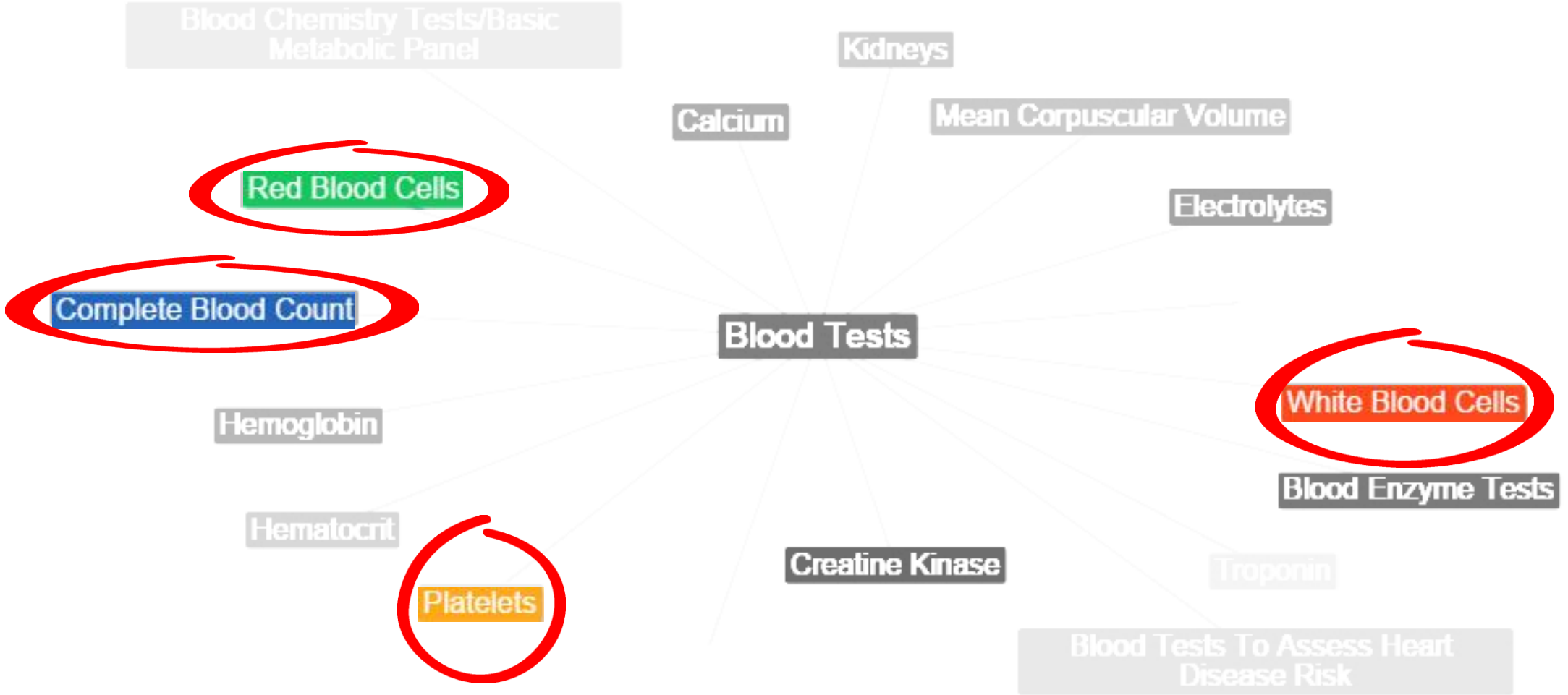

Average

Blood tests/day= ~16

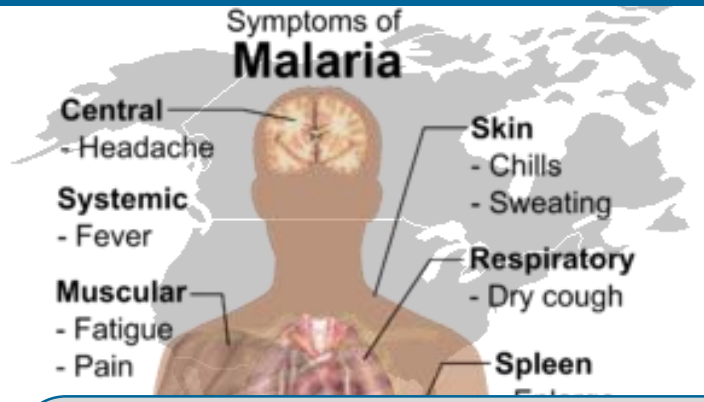
# Some basic blood tests



# Blood tests under 100x magnification

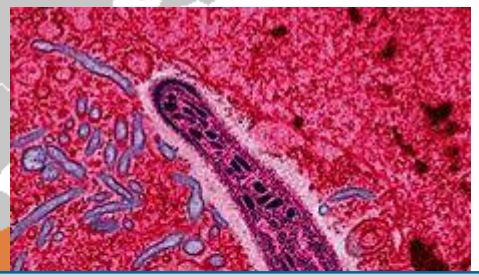


# Malaria test




219 million cases of malaria

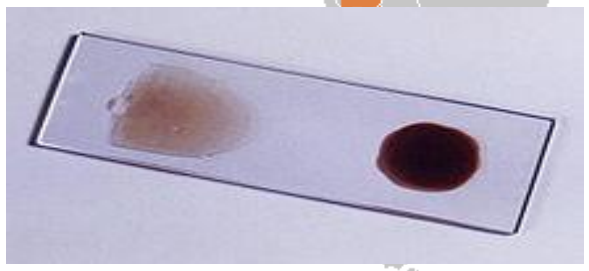
1.31 million cases In India

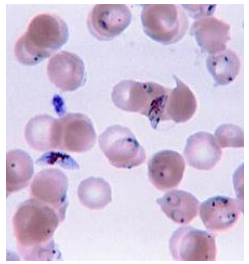


The RDT tests are still regarded as complements to conventional microscopy but with some improvements it may well replace the microscope.

- http://en.wikipedia.org/wiki/Malaria_antigen_detection_tests..(As seen on 24/01/2015)

Diagnosis





The disease is transmitted most commonly by an infected female *Anopheles* mosquito.

Reference as seen on 02/01/2015: http://en.wikipedia.org/wiki/Tuberculosis

# Activity analysis

1. Patient comes to the pathology

2. Patient data is recorded

3. Blood smear is taken

4. A receipt of the test is given to the patient

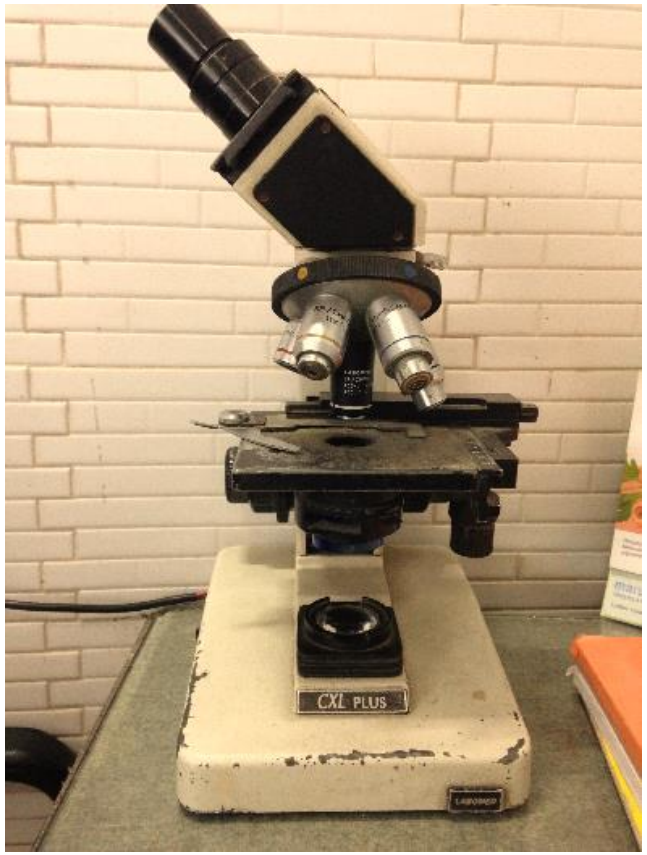
5. The staining is done

6. The diagnosis is done on the same day if possible

# Components required for blood film test


**Blood strainer A**


**Blood strainer B**

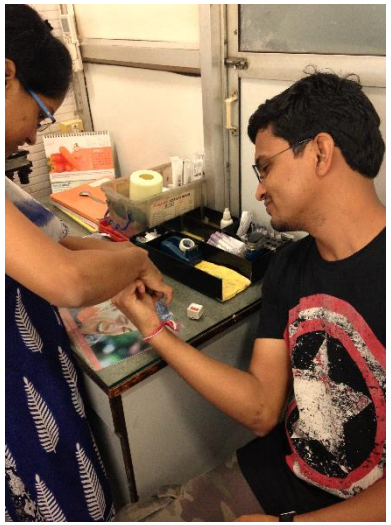



**Microscope**

- Stains: Stain A and stain B
- Water
- Methanol
- Slides.
- Blood smears
- 6.Microscope

# Staining process activity analysis

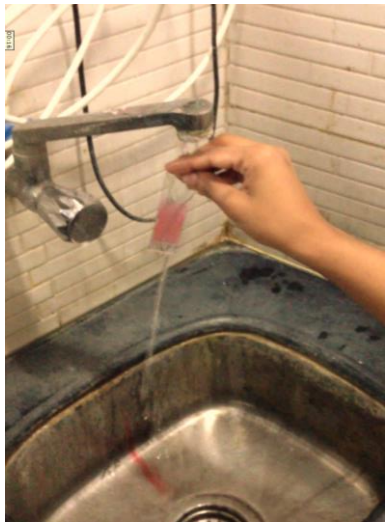
Finger stick puncture by using a sterile safety lancet



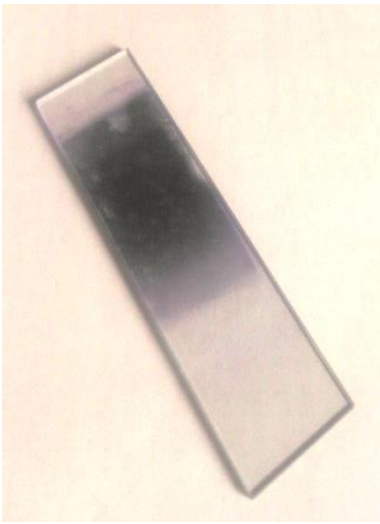
Blood drop collection on a slide and spread over it.

Dip that slide in strainer B first

After washing the slide under running water dip it in a strainer A



Again wash it under running water and let the slide dry.



Stained slide is ready for diagnosis under the microscope.

# Observations

- ASHA workers walk almost 15km
- Collected slides are sent to the city hospital for diagnosis
- Report is then personally collected from city hospital which takes almost 2 days.
- Blood film test is the most feasible and reliable in city.
- Coverage by govt. workers is much more lower than the targets
- Redundant data entry
- Overload of work on lab technicians
- Lack of incentive for surveillance investigators

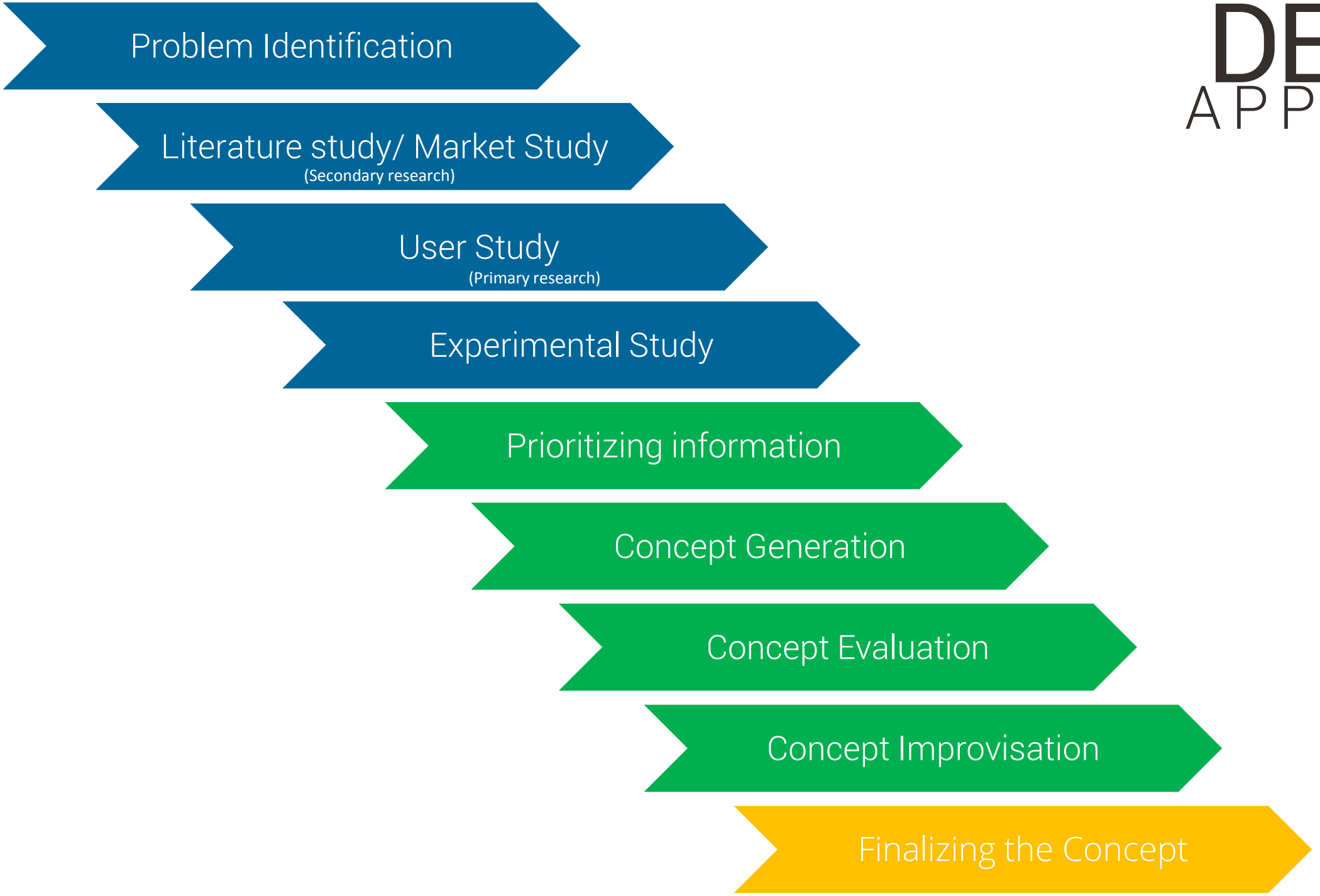
# Insights

- An easy to use diagnostic system required.
- Need a light weight, compact and precise tool.
- A need to streamline the communication among patients, investigators, doctors and labs.
- Making blood film test most economical and most feasible for mass application
- Maintenance of data and its accessibility can be improved
- Should make provision for using lower skilled manpower in the diagnosis process
- Provision for motivation in the system itself is required
- Fast delivery of reports is required

# Design Brief

“Design and develop a lab on smart phone platform that aims to implement multiple telemedicine related functionalities on smart phone, which can potentially improve the diagnostic system, health care report delivery and help in reducing the cost of bio medical tests ,even at remote locations".

# DESIGN APPROACH



## Problem Identification

Blood and sputum tests are the most common test panels ordered, yet advance hematology analyzers and appropriate laboratory infrastructure are absent or limited in most of the locations in India

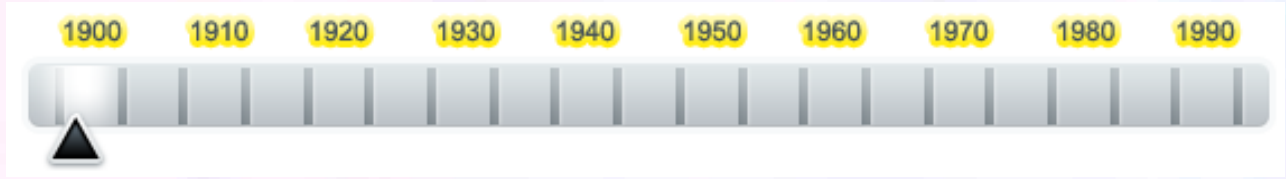

This smartphone based microscopy platform can used to measure some basic blood tests

# Literature study/ Market Study

- **MicroScope...** First Microscope
- **MicroScope -** History
- **MicroScope** Contributors
- **Parts of** MicroScope.
- **Smart** MicroScopes.

# Literature study/ Market Study

## MicroScope... First Microscope




**Nikon** is one of the world's largest manufacturers of microscopes and cameras, They made this microscope in the early 1900s. The compound monocular microscope is fashioned from brass and has a black-enameled horseshoe base.

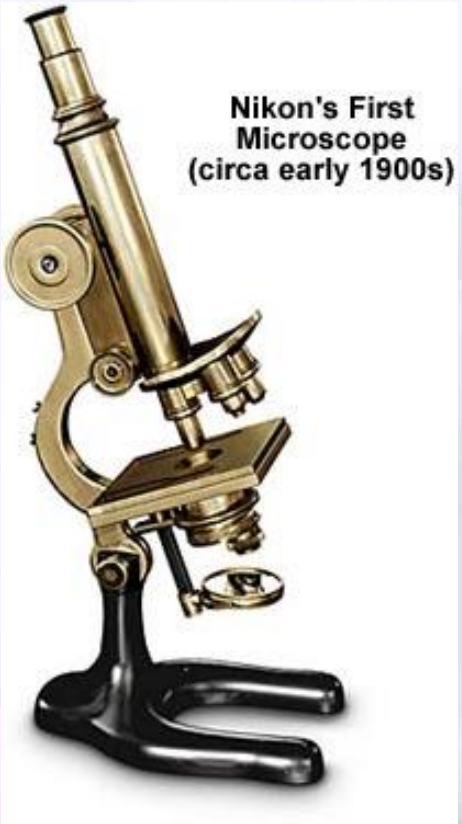


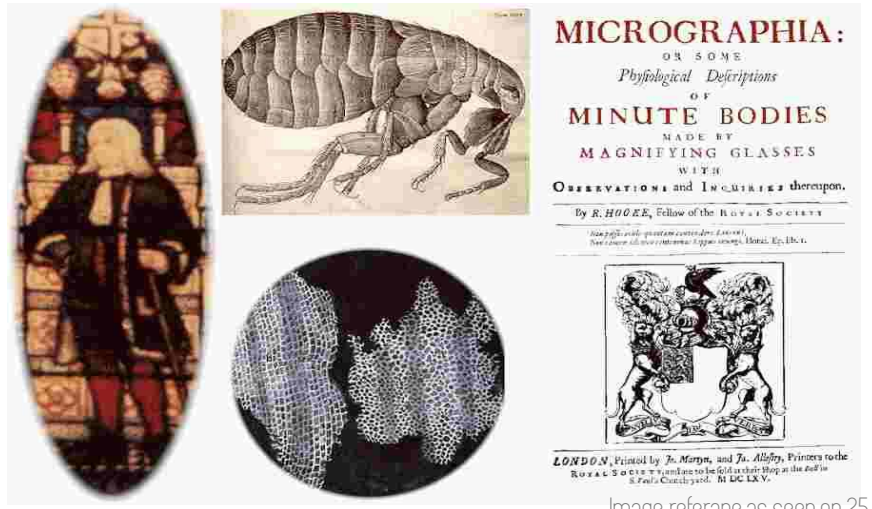

Image reference as seen on 22/01/2015 :
http://www.microscopyu.com/museum/firstnikon.html

Image reference as seen on 21/01/2015 : http://www.dreamstime.com/royalty-free-stock-images-green-microscope-image22544559

# MicroScope - History


Credit for the first microscope is given to **Zacharias Janssen**, pictured at the left, in Middleburg, Holland, around the year **1595**.

The magnification of these early scopes ranged from 3X to 9X, depending on the size of the diaphragm openings.




The First Compound Microscope (circa 1595)

Image referane as seen on 25/01/2015 : http://www.cas.miamioh.edu/mbiws/microscopes/fathers.html

# Literature study/ Market Study

## Parts of MicroScope

Interest Area

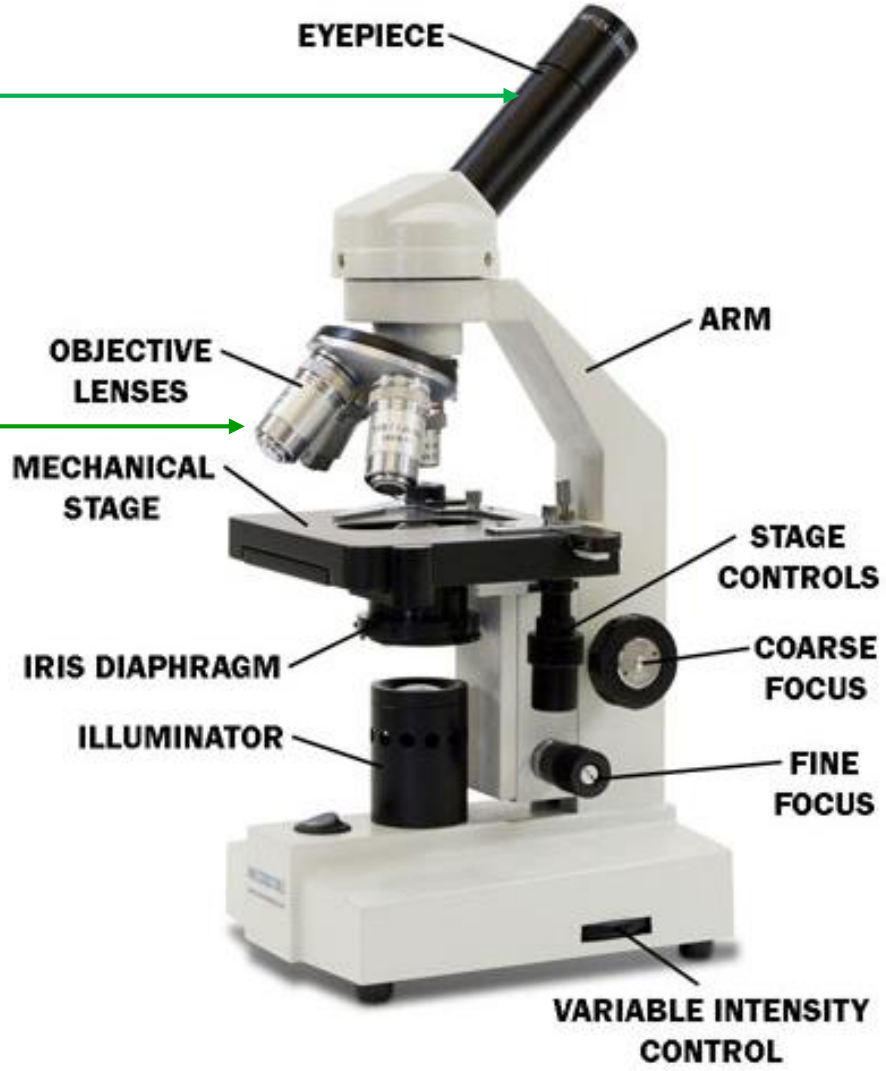
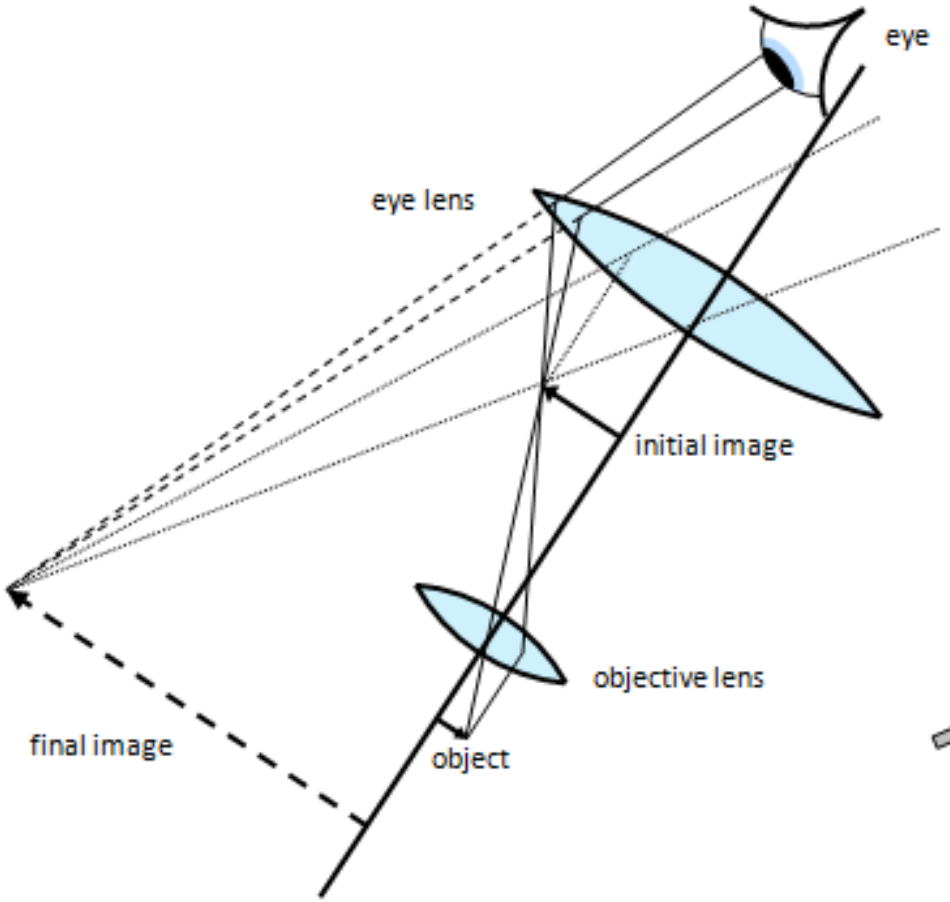
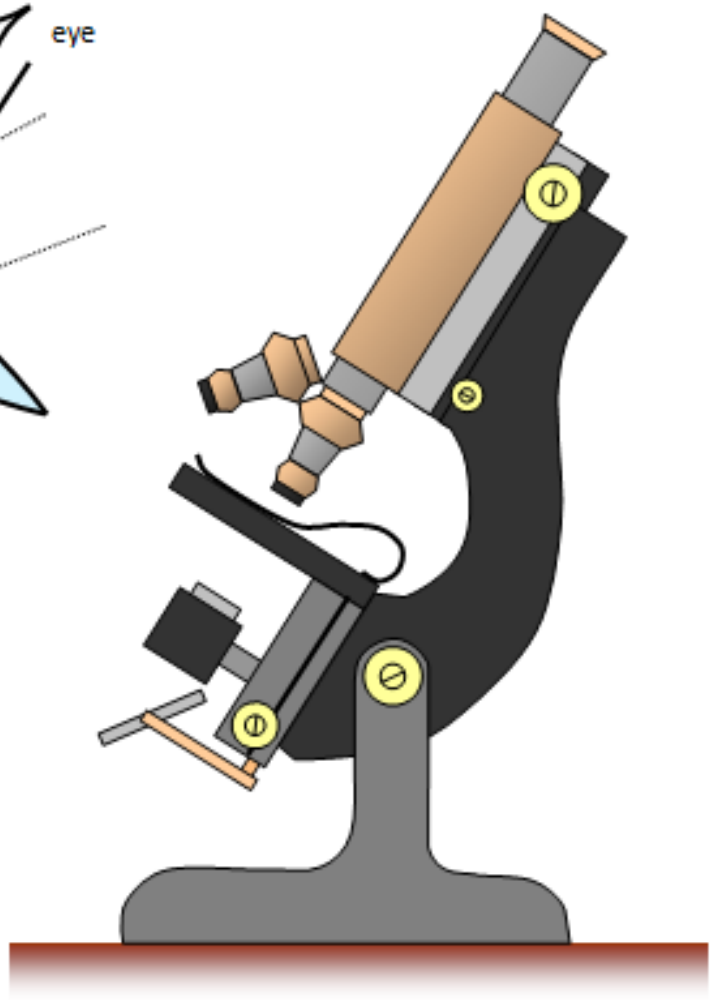



Image reference : as seen on 22/01/2015 http://woomyoung.co.kr/product_view.html

Literature study/ Market Study

# Simple and block Diagram of a MicroScope.



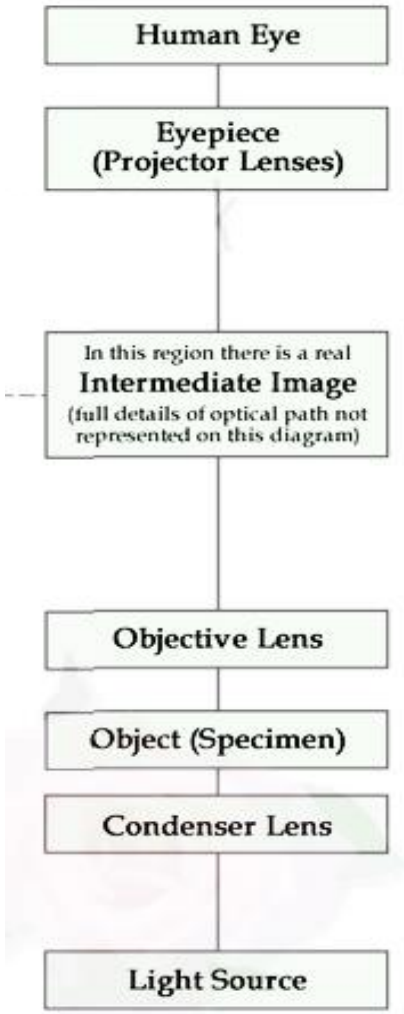



Image reference seen on 22/01/2015 : http://www.ivyroses.com/Biology/Techniques/Light-Microscope.php

# Literature study/ Market Study

## Optical physics of a MicroScope.

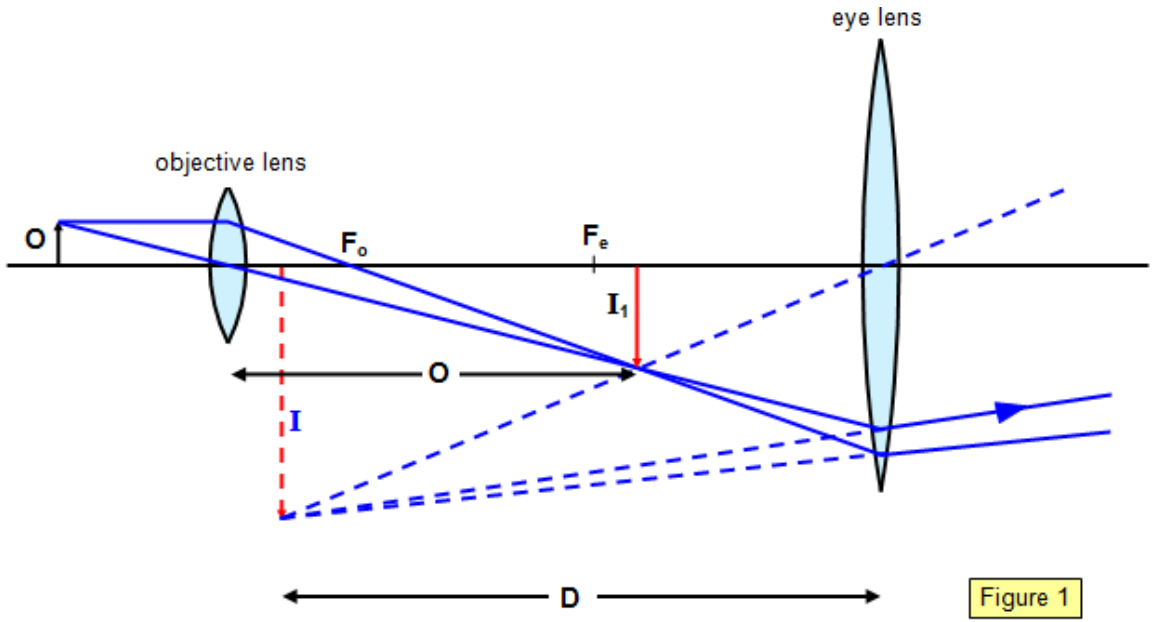
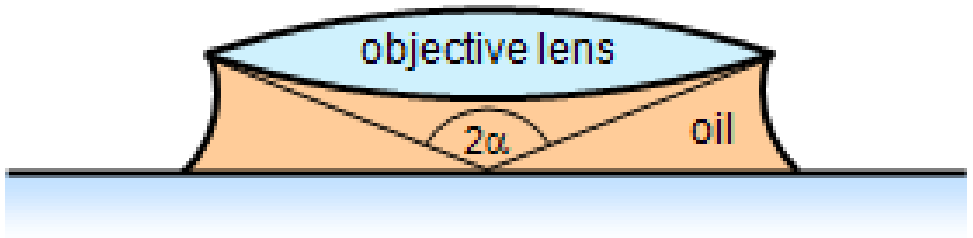



Figure 1




### Magnifying power (M) = $[D/f_e - 1][v/f_o - 1]$

Where $f_e$ is the focal length of the eye lens, $f_o$ that of the objective lens and v the distance of $I_1$ from the objective lens.

### Resolving power of microscope = $\lambda/[2n\sin(\alpha)]$

The resolving power of a microscope can be shown to depend on the wavelength of light used (λ), the refractive index of the medium above the slide (n) and the angle subtended at the objective (α)

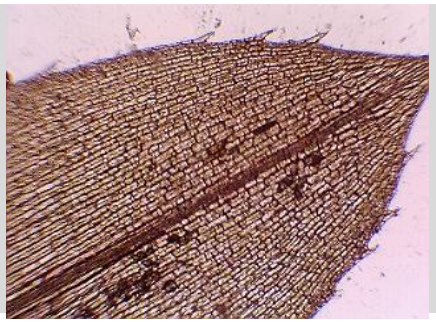
Image reference seen on 22/01/2015 : http://www.ivyroses.com/Biology/Techniques/Light-Microscope.php

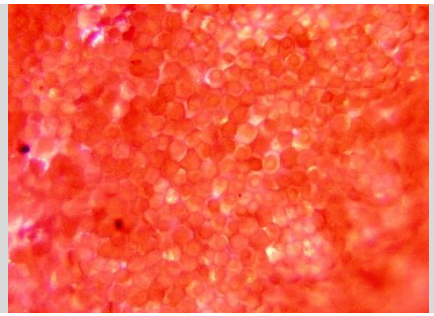
## Literature study/ Market Study

## Total Magnification.


×


= 10X

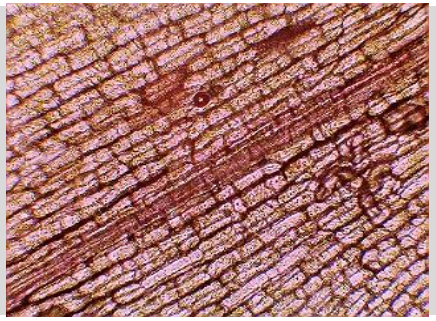




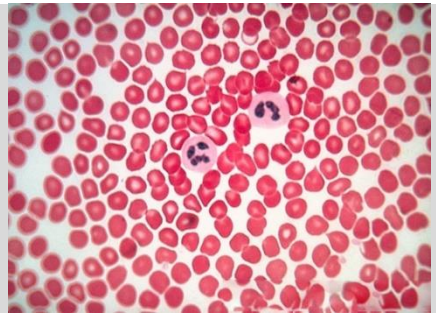

×


= 40X

Elodea

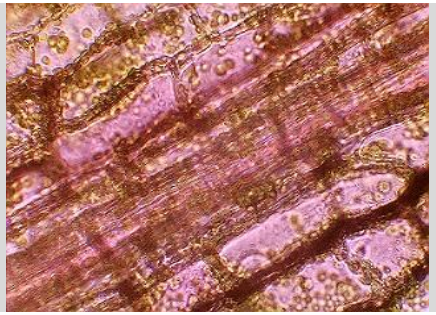


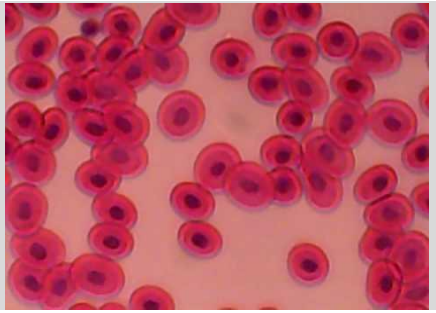
Blood




×


= 100X





# Literature study/ Market Study

Smartphone

- **SmartPhone...** History
- **SmartPhone -** Parts
- **MicroScope** Contributors
- **Parts of** MicroScope.
- **Smartphone market** study.

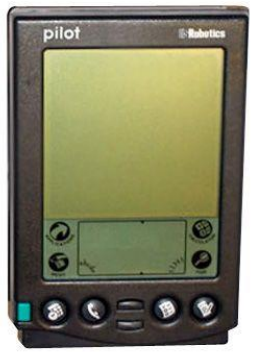
Image reference : as seen on 29/01/2015 :http://www.appia.com/blog/smartphone-usage-on-the-rise-globally

# Literature study/ Market Study

## A Brief History of SmartPhones.

**1993**
The IBM Simon

**1996**
The Palm Pilot




**1998**
The Nokia 9110 Communicator


**2002**
BlackBerry 5810


**2010**
The HTC EVO 4G


**2003**
The Palm Treo 600


**2007**
The Apple iPhone

**2007**
Google unveils Android


**2009**
The Motorola Droid


Image reference : As seen on 22/01/2015 : http://www.movdata.net/smartphone-png.html

# Literature study/ Market Study

## Parts of SmartPhone.

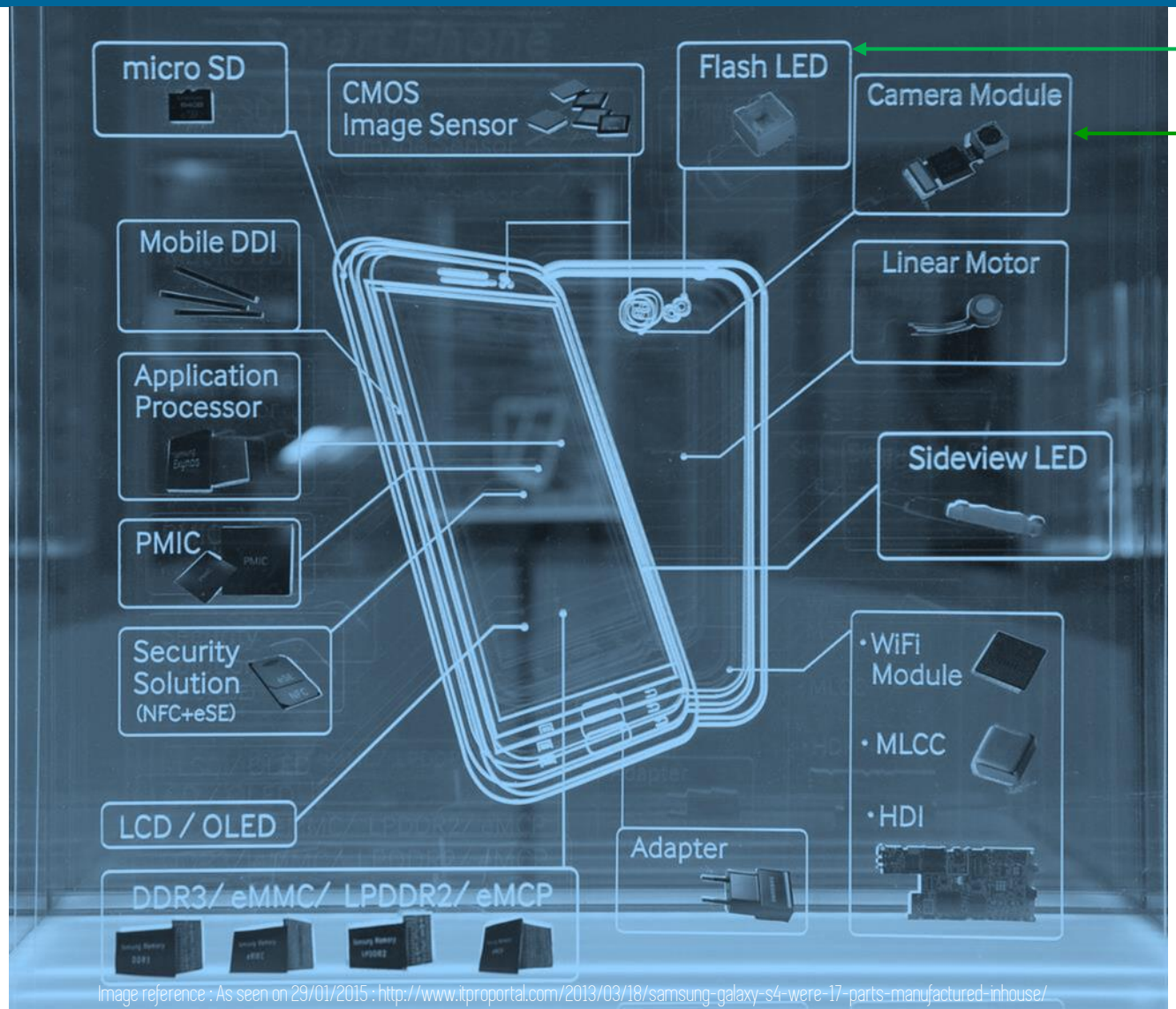
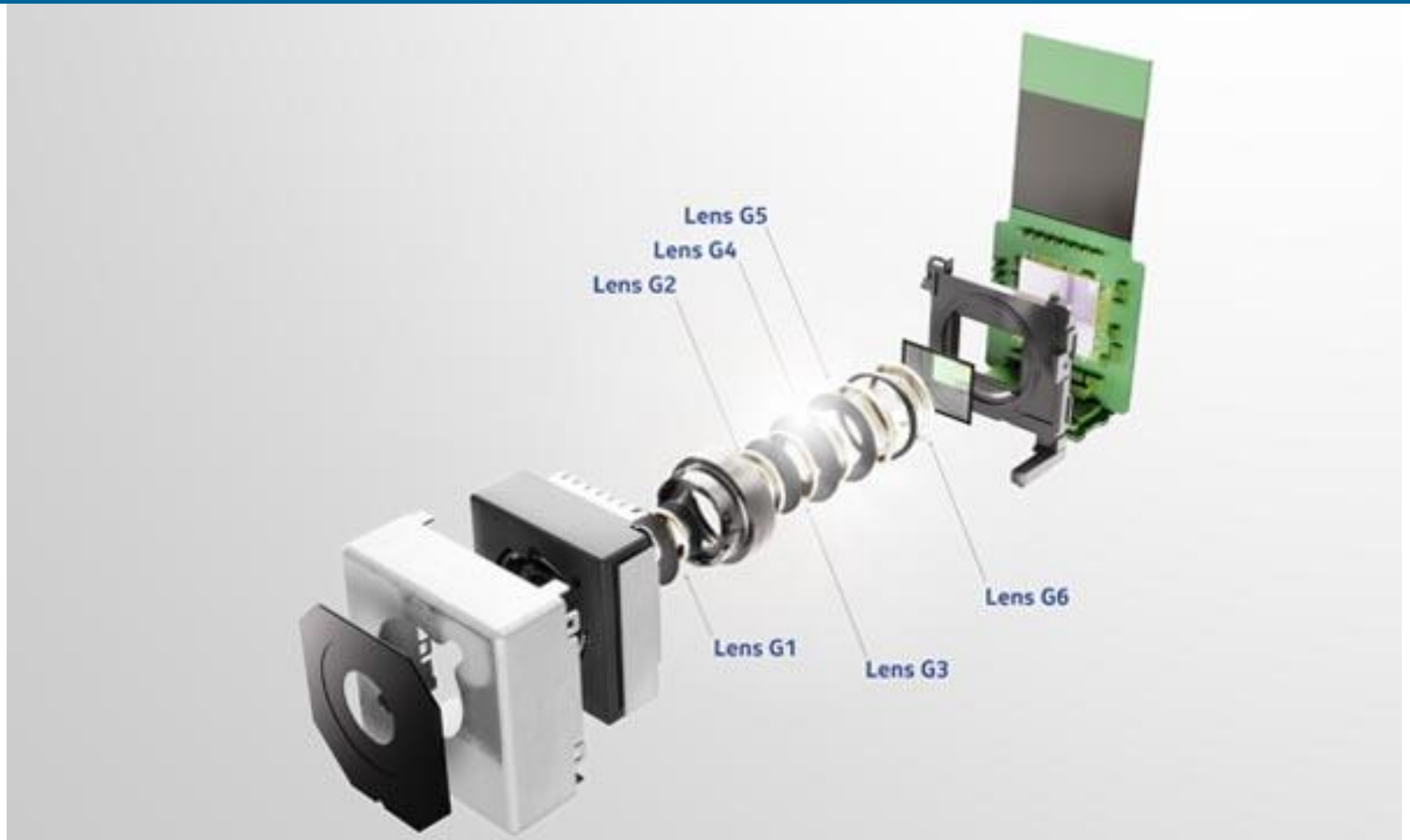



Image reference : As seen on 29/01/2015 : http://www.itproportal.com/2013/03/18/samsung-galaxy-s4-were-17-parts-manufactured-inhouse/

Interest Area


Lens G5
Lens G4
Lens G2
Lens G6
Lens G1
Lens G3

# Literature study/ Market Study

## Smartphone market study.

**Apple iPhone 4s**

115.2 x 58.66 x 9.3 mm
4.54 x 2.31 x 0.37 in
140 gr / 4.94 oz

3.5" screen
640x960px
~330 ppi

**Nokia Lumia 800**

116.5 x 61.2 x 12.1 mm
4.59 x 2.41 x 0.48 in
142 gr / 5.01 oz

3.7" screen
480x800px
~252 ppi

**Google Galaxy Nexus**

135.5 x 67.94 x 8.94 mm
5.33 x 2.67 x 0.35 in
135 gr / 4.76 oz

4.65" screen
720x1280px
~316 ppi

**Samsung Galaxy S II LTE**

130.9 x 69.9 x 9.4 mm
5.15 x 2.75 x 0.37 in
132 g / 4.66 oz

4.5" screen
480x800px
~207ppi

**HTC Evo 4G**

122 x 66 x 12.7 mm
4.8 x 2.6 x 0.5 in
170 g / 6 oz

4.3" screen
480x800px
~217ppi

**Samsung Galaxy S II HD LTE**

129.8 x 68.8 x 9.5 mm
5.11 x 2.71 x 0.37 in
130.5 g / 4.6 oz

4.65" screen
720x1280px
~316ppi

**Samsung Galaxy Note**

145.8 x 82.95 x 9.65 mm
5.74 x 3.27 x 0.38 in
178 g / 6.28 oz

5.3" screen
800x1280px
~285ppi

**Sony Ericsson Xperia X10**

119 x 63 x 13 mm
4.69 x 2.48 x 0.51 in
135 g / 4.76 oz

4" screen
480x854px
~245ppi

# Literature study/ Market Study

## Parallel Product Study.

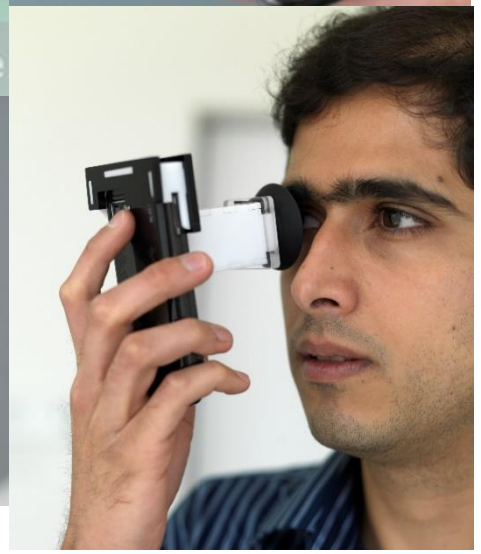



Images reference : As seen on: 29/01/2015 : http---kartrocket-mtp.s3.amazonaws.com-all-stores-image_gadgetstuff-data-ML_FishEyeLens_001

# Experimental Study

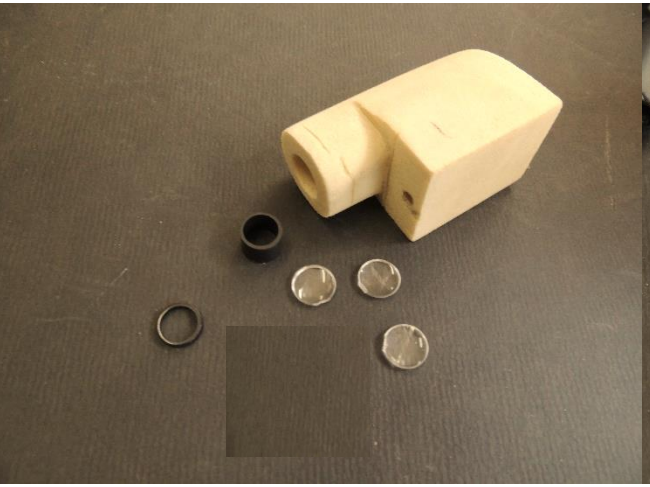
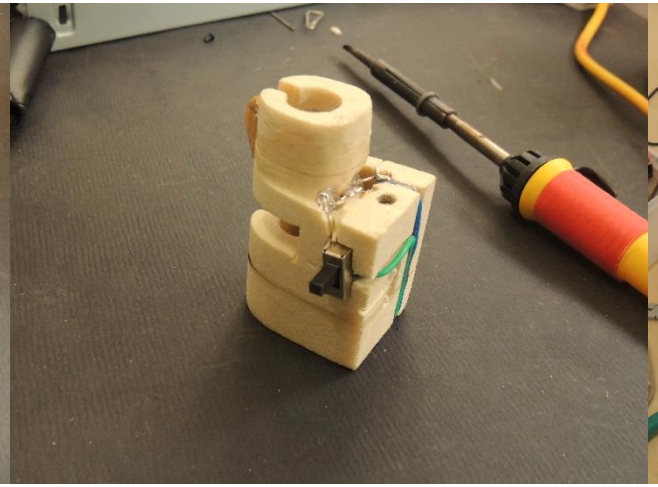
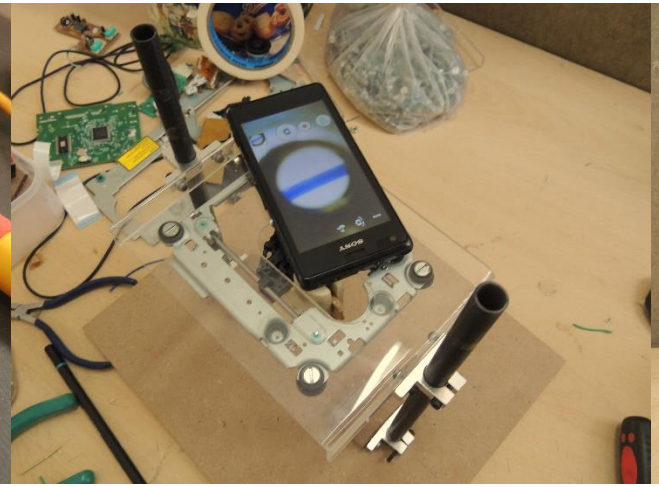
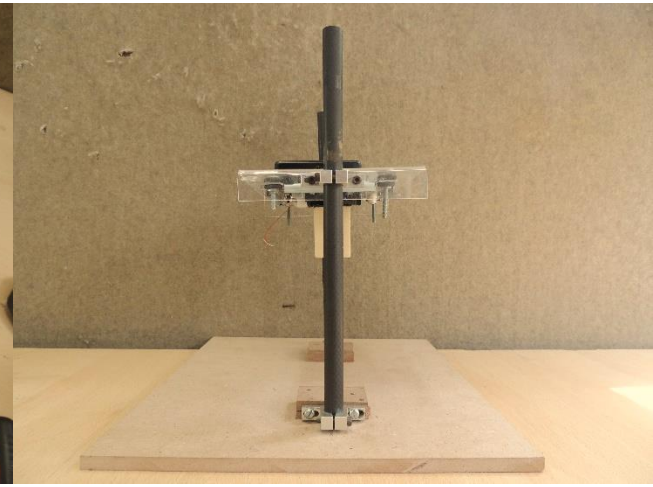
## Inspiring Product

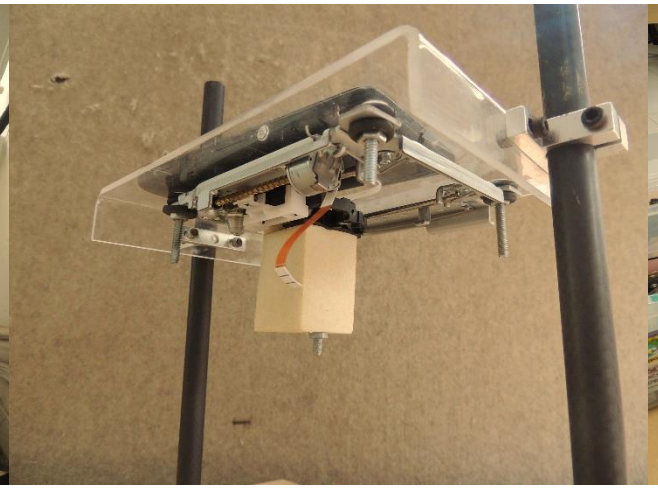
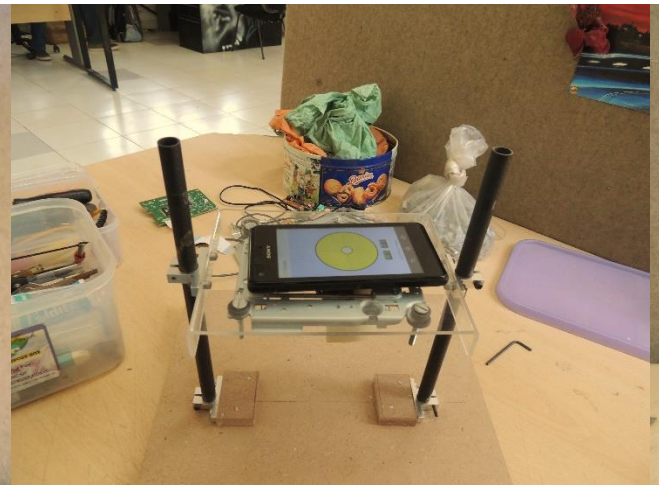
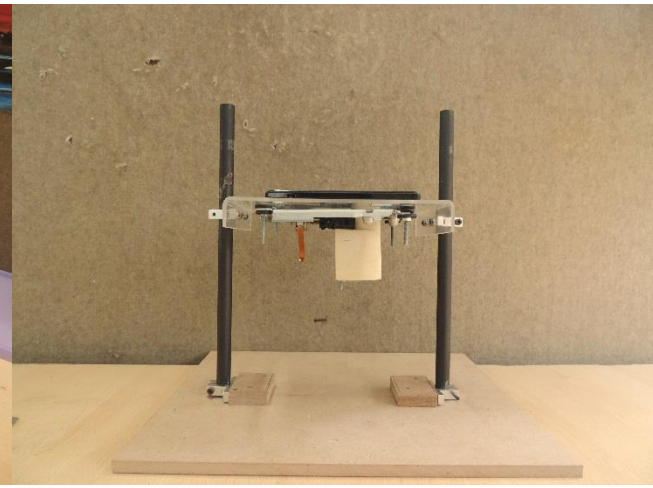




Experimental Study

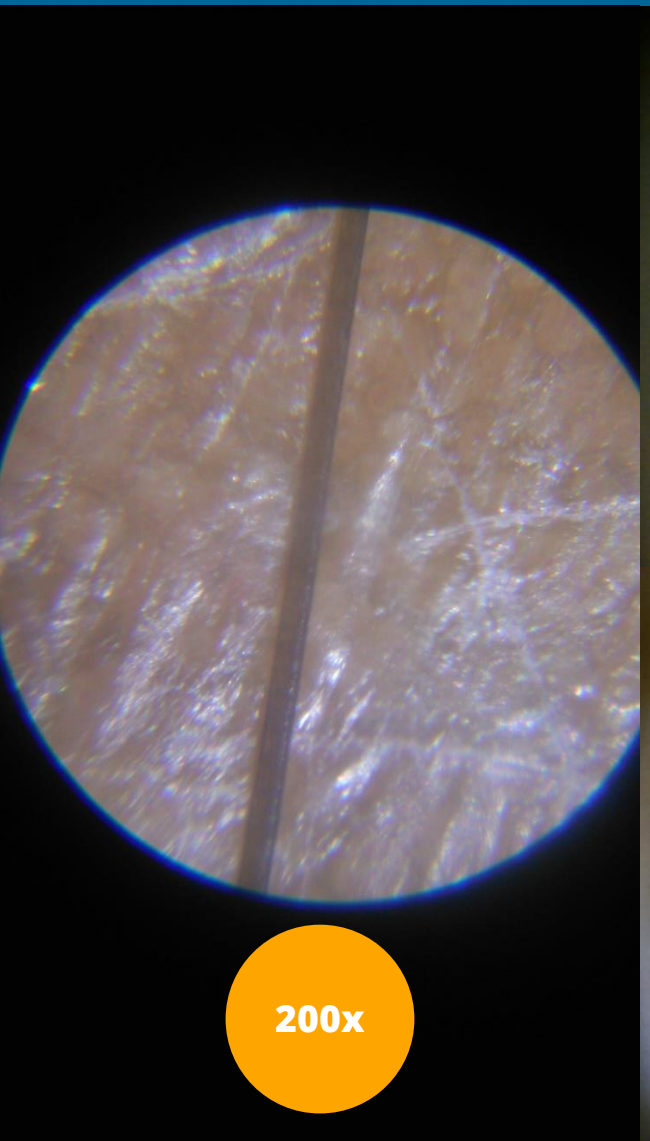
# Lens Study and test rig experimentation

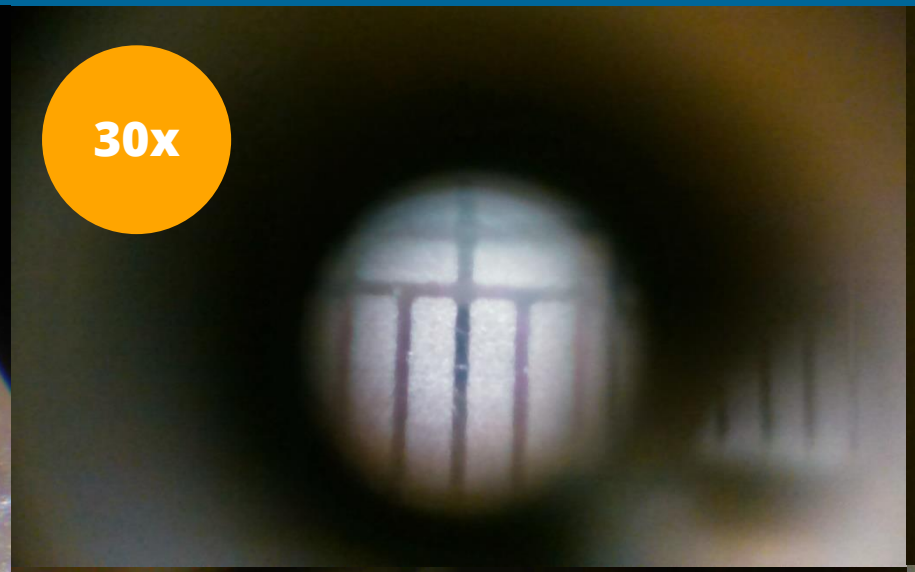





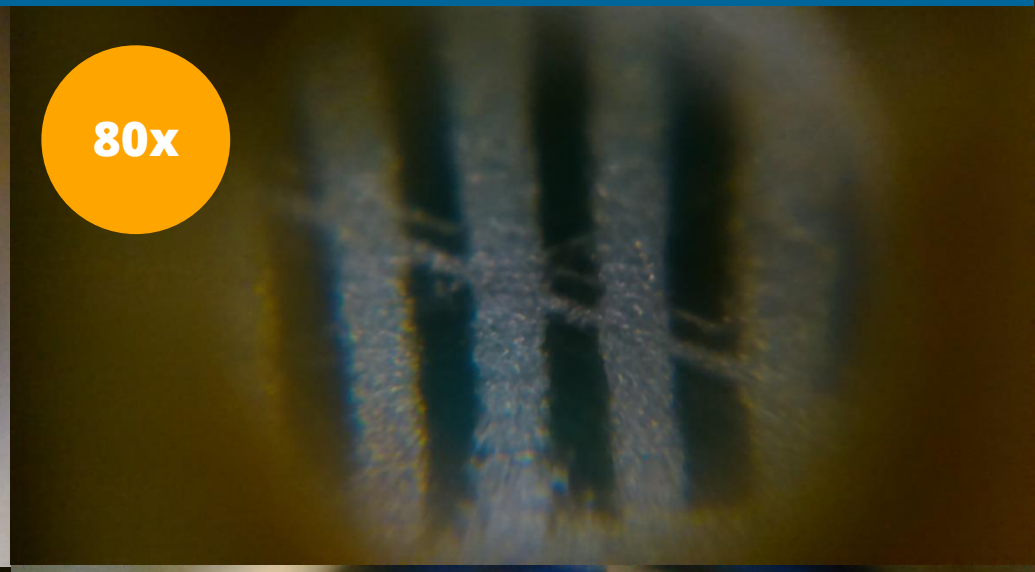




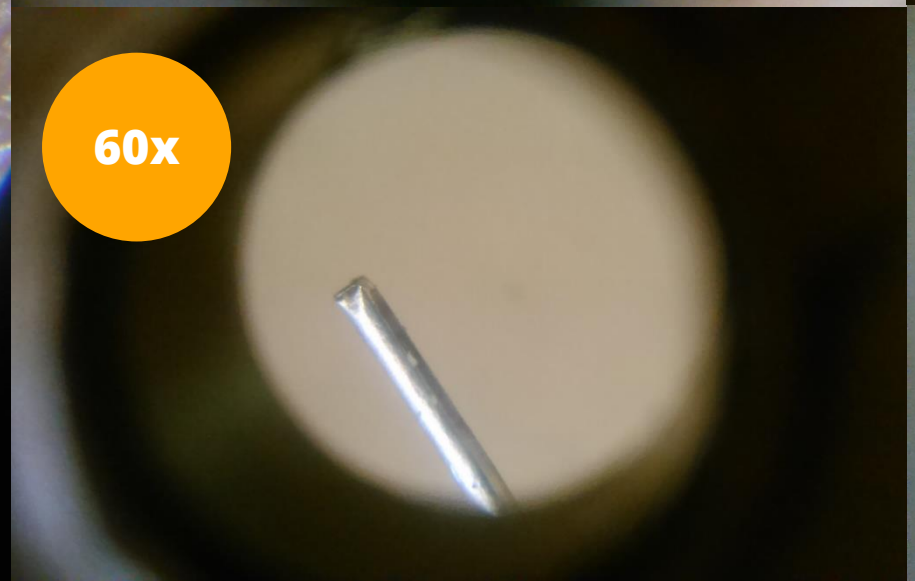
Experimental Study

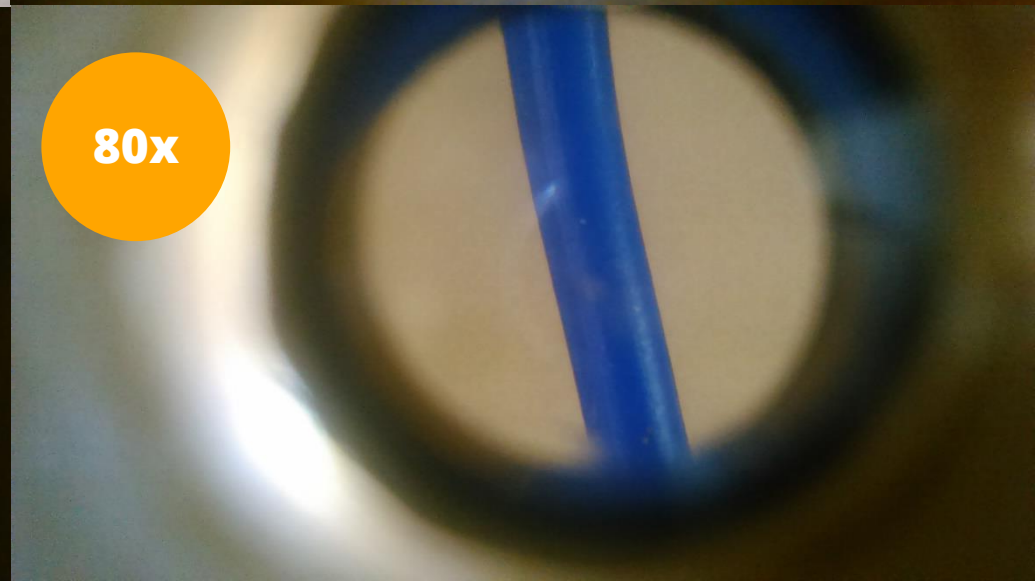
# Test rig experimentation output (1st to 6th Attempt)



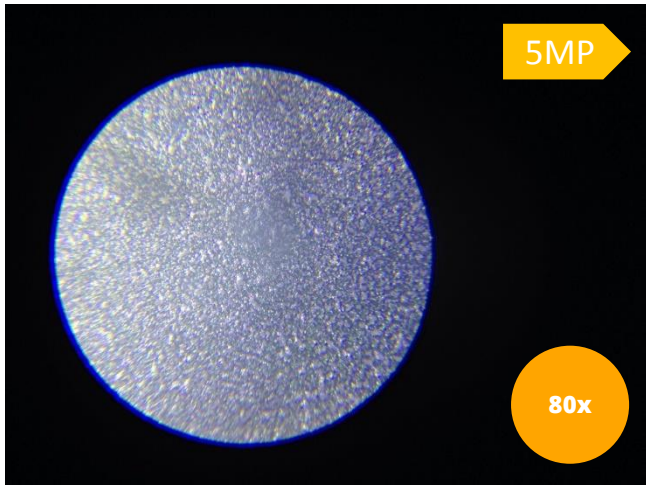



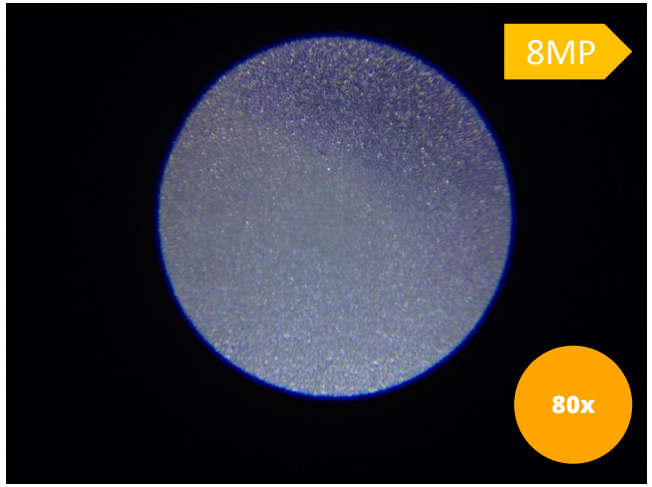



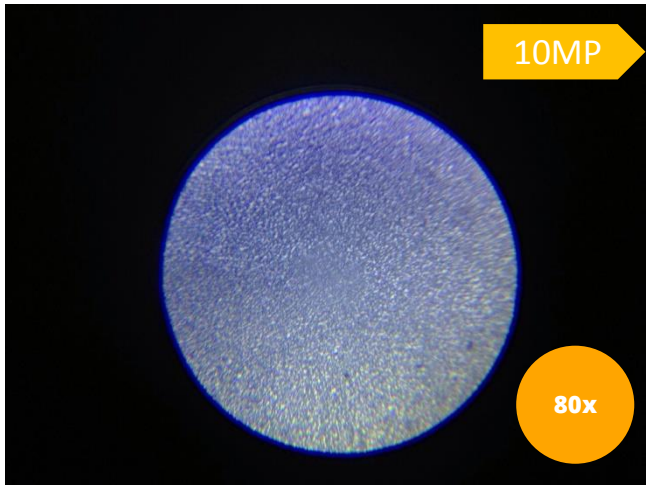



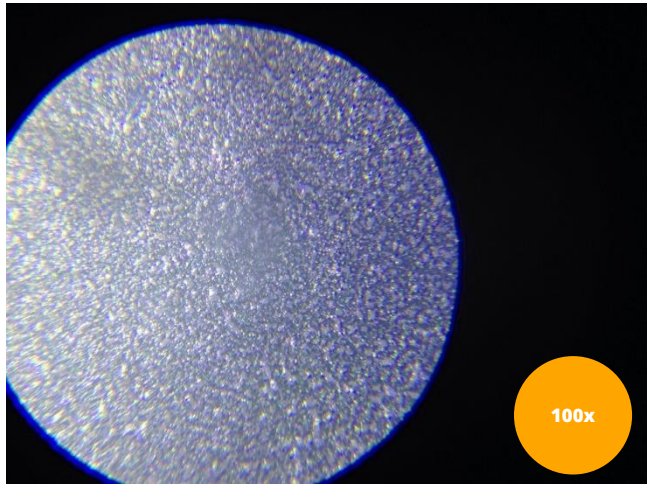
Experimental Study

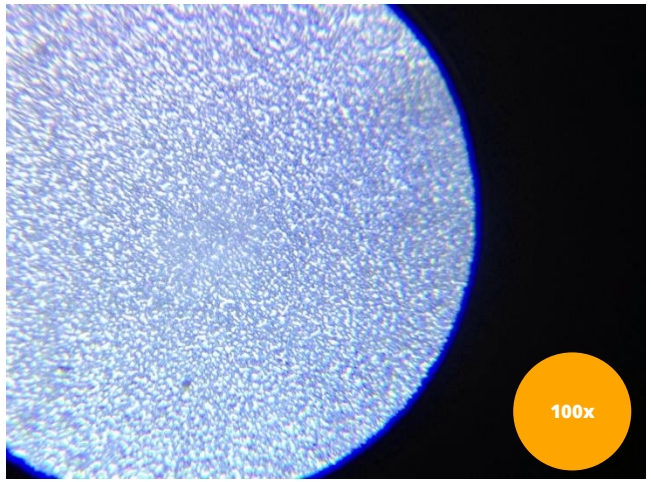
# Test rig experimentation output (6th to 18th Attempt)

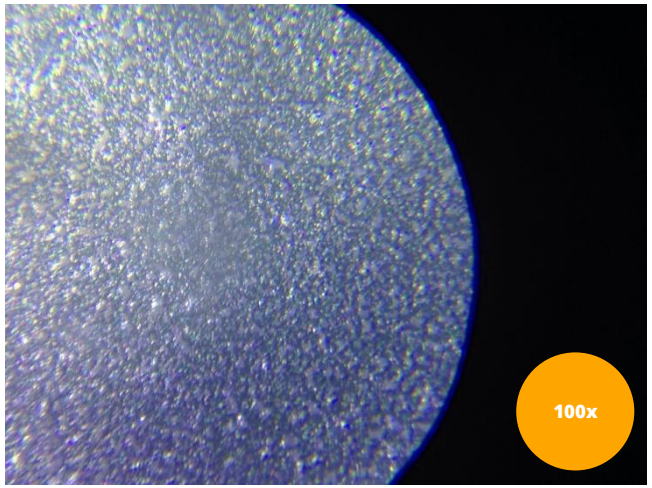


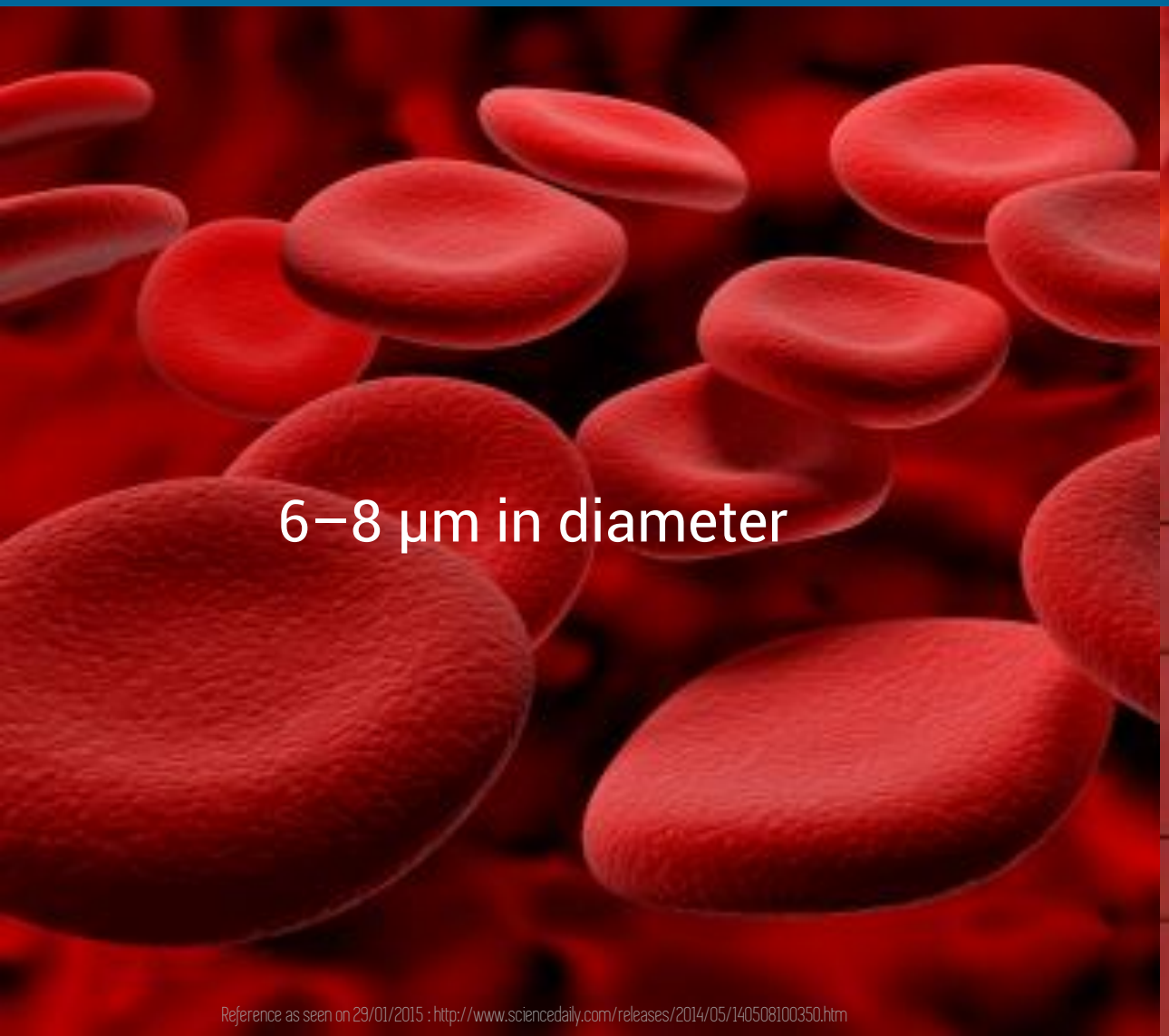



# Prioritization of information

Mobile user study

Prioritization of information

# Blood cell dimension and Pixel..

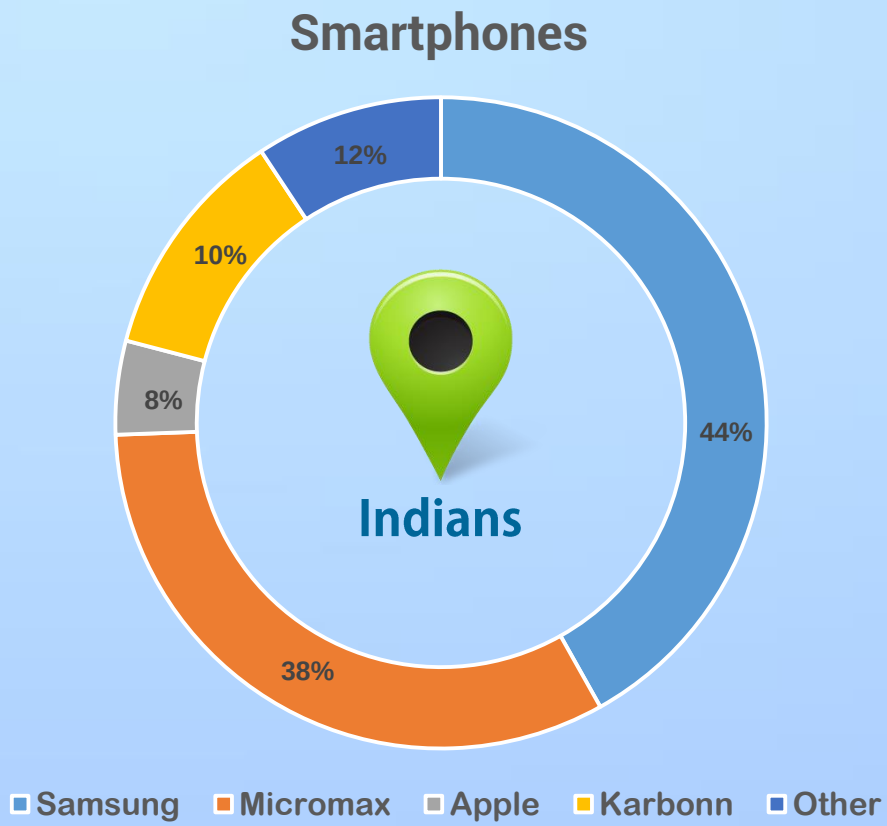



Reference as seen on 29/01/2015 : http://www.sciencedaily.com/releases/2014/05/140508100350.htm

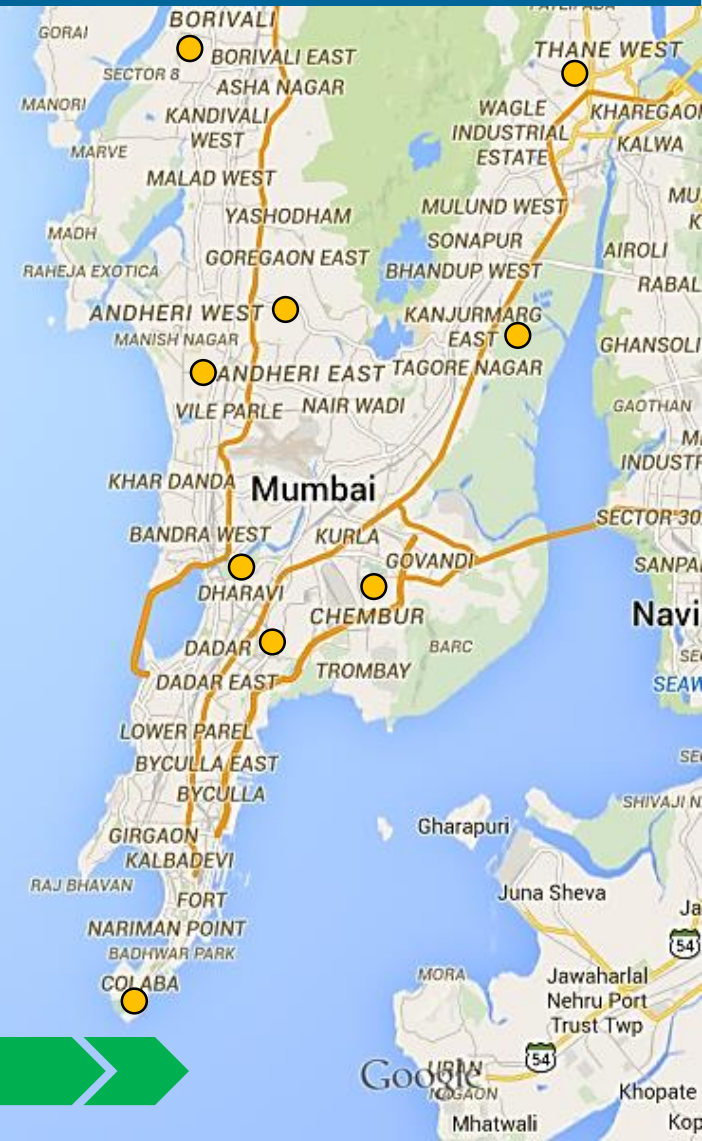

Reference as seen on 29/01/2015 : http://rhizome.org/editorial/2012/jun/25/sharits/

# Prioritization of information

## Insights from Mobile user study




- Bhandup
- Borivali West
- Thane
- Andheri West
- Andheri East
- Bandra
- Dadar
- Chembur
- Colaba
- Belgaum
- Pune
- Kolhapur
- Google Form



Prioritization of information

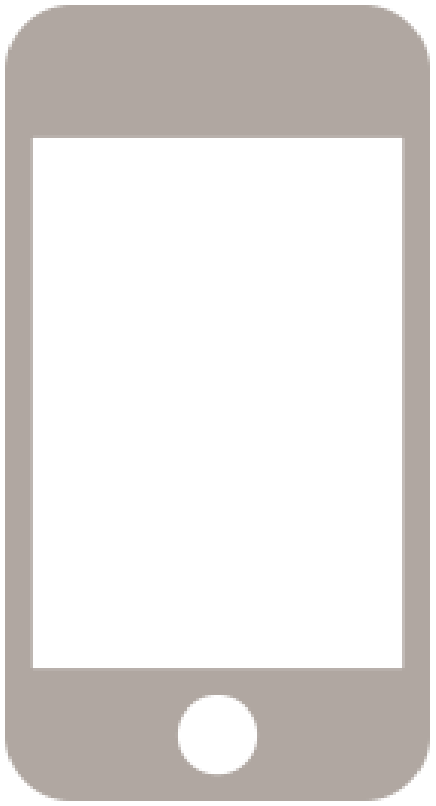
Insights from Mobile user study

Prioritization of information

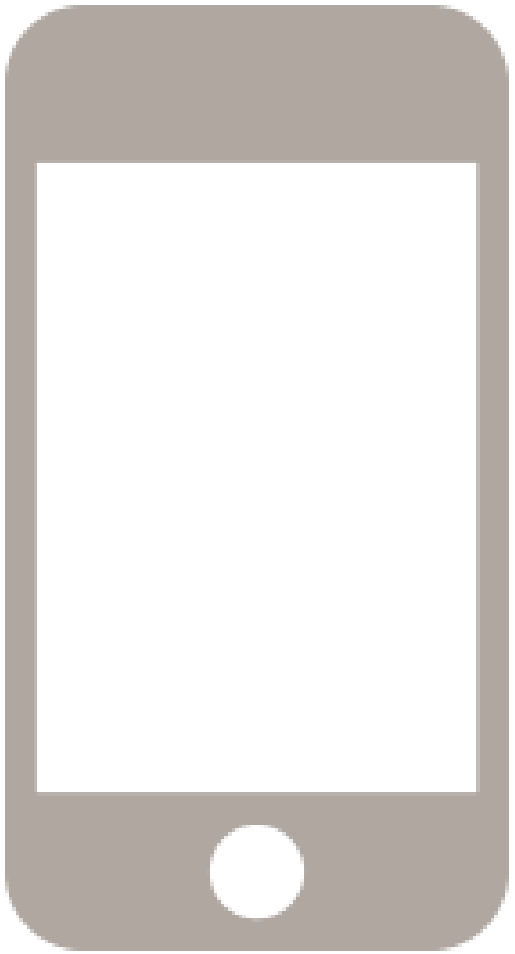
# Oil emersion microscope lens study

# Prioritization of information

## Smartphone Dimension Study

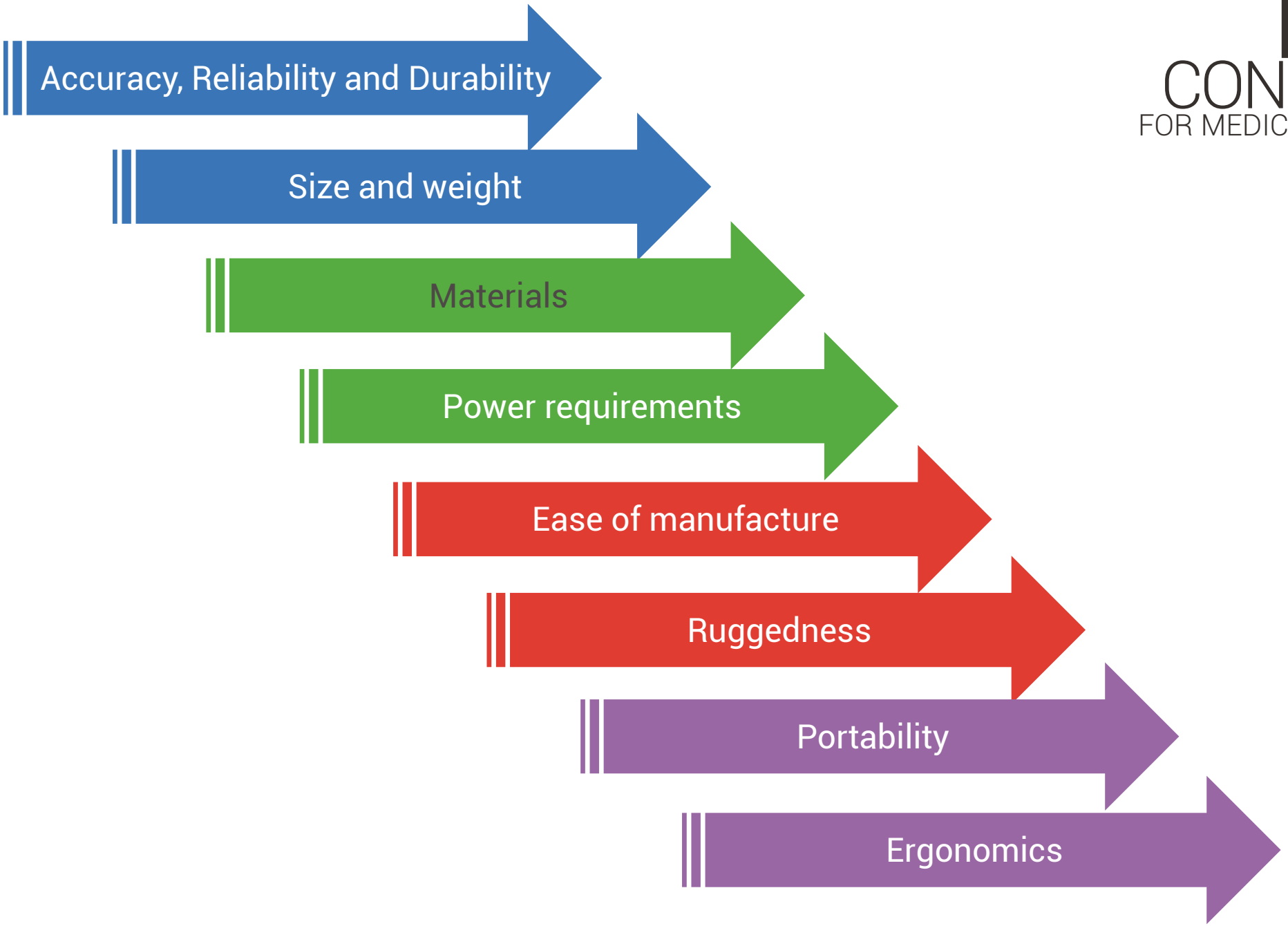


57 mm



95 mm

# DESIGN CONSIDERATIONS
FOR MEDICAL DEVICES IN RURAL INDIA



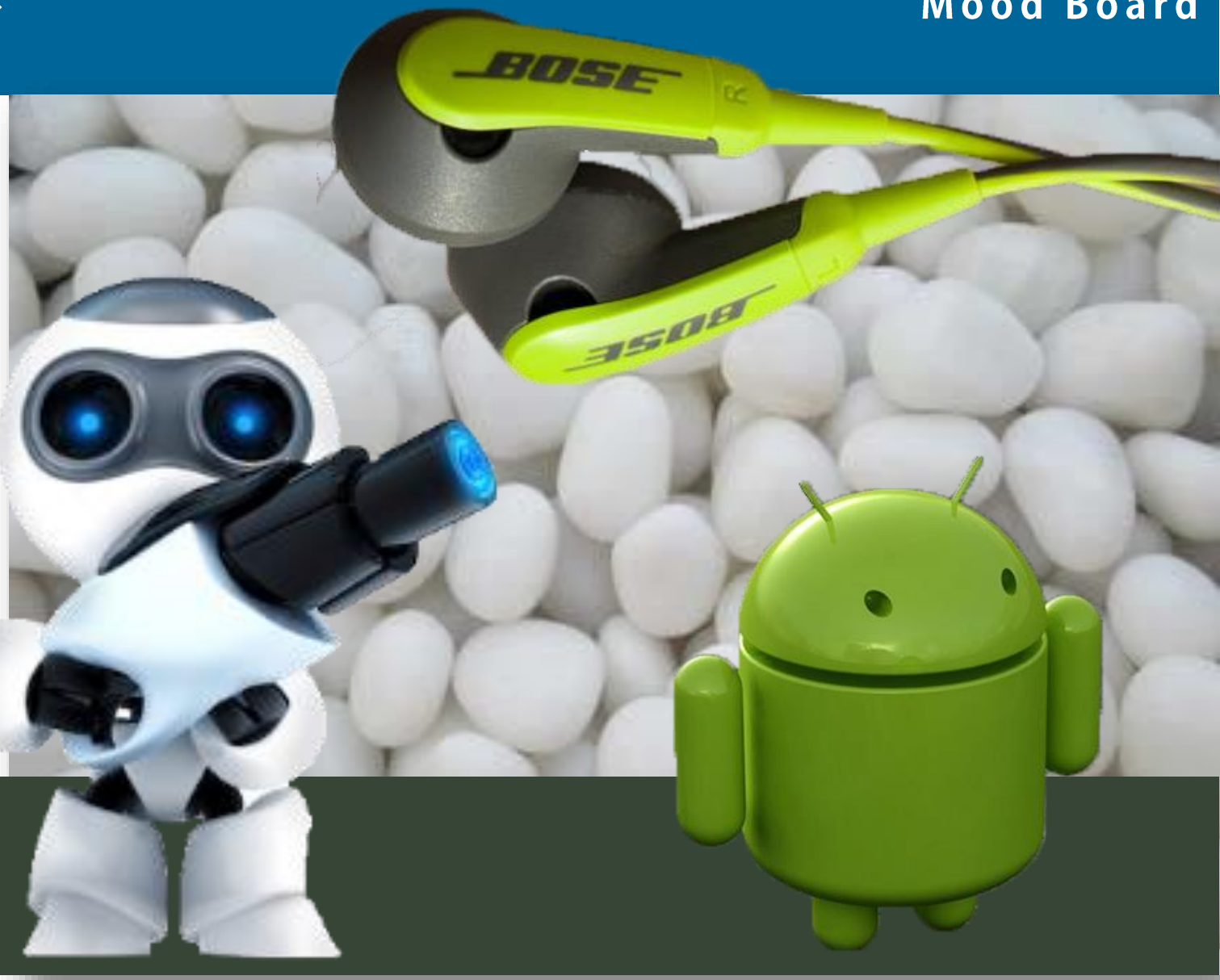
# Concept Generation

## Mood Board

Colors

Textures

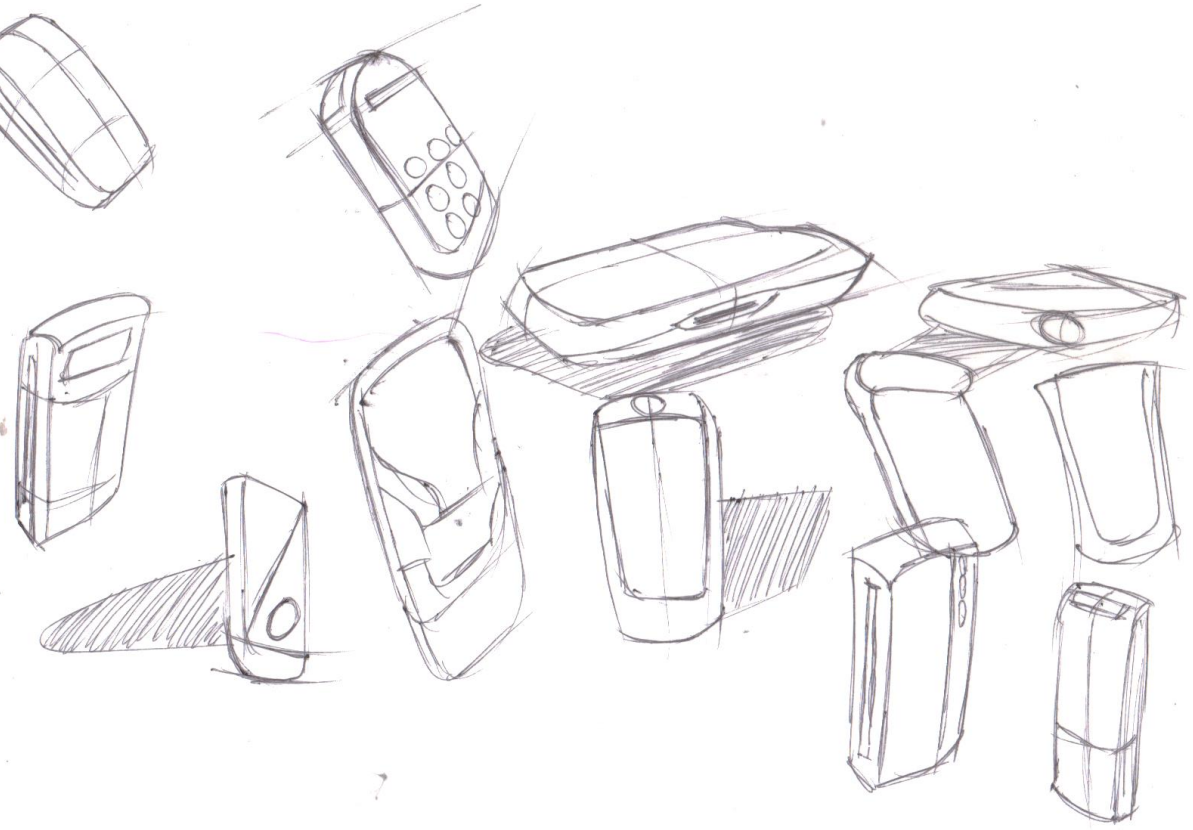
Shapes

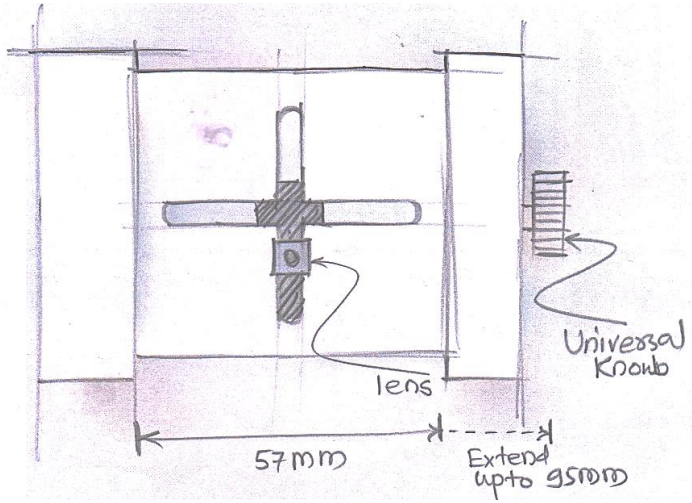



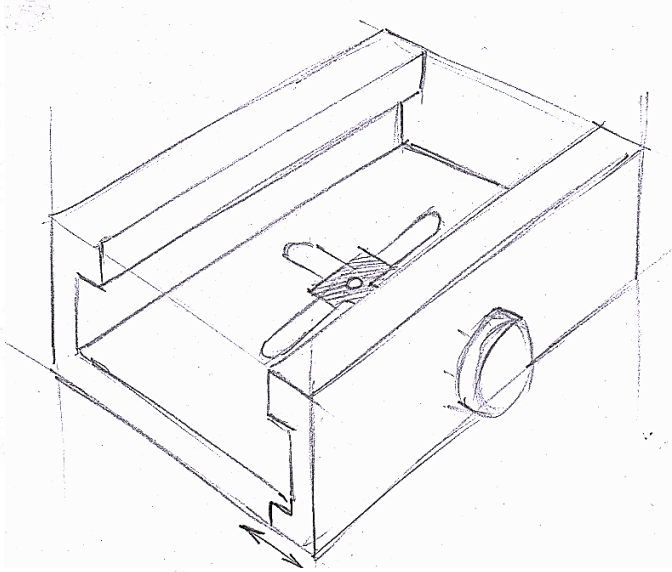

This mood board is focused on providing the sense of safety and gentleness with undertones of reliability. Rounded curves are the strong design element here along with simplicity and smoothness achieve soothing shapes that rests in the hand.

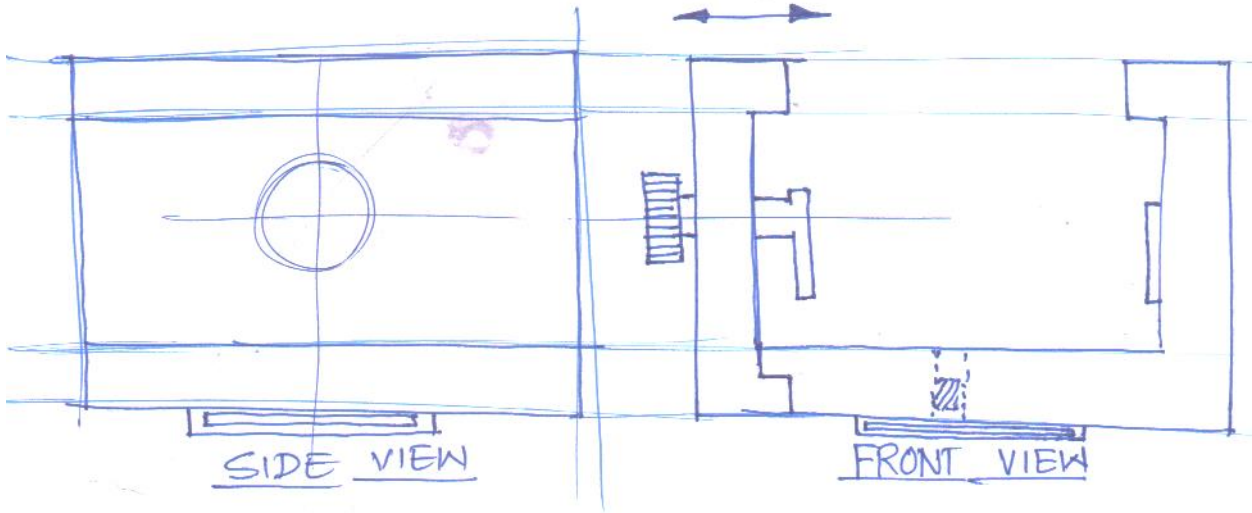
# Concept Generation

## Concept 1



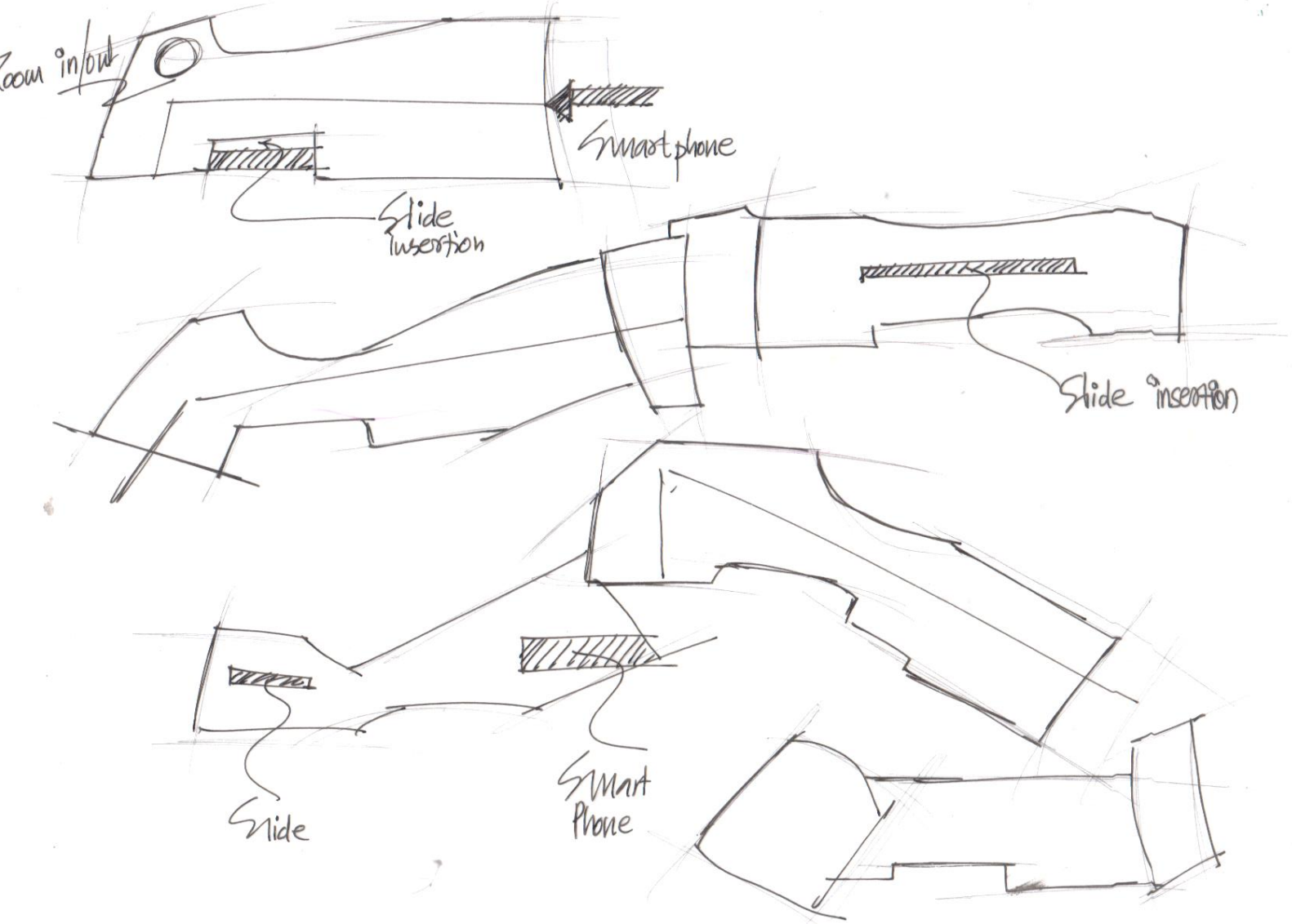


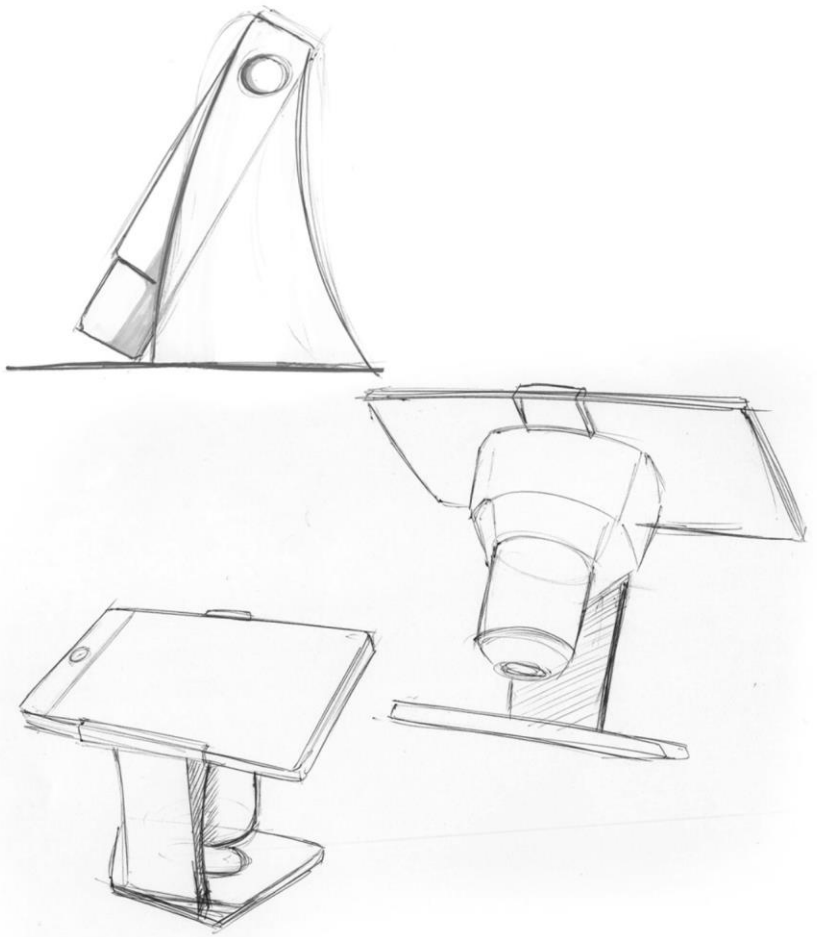





# Concept Generation

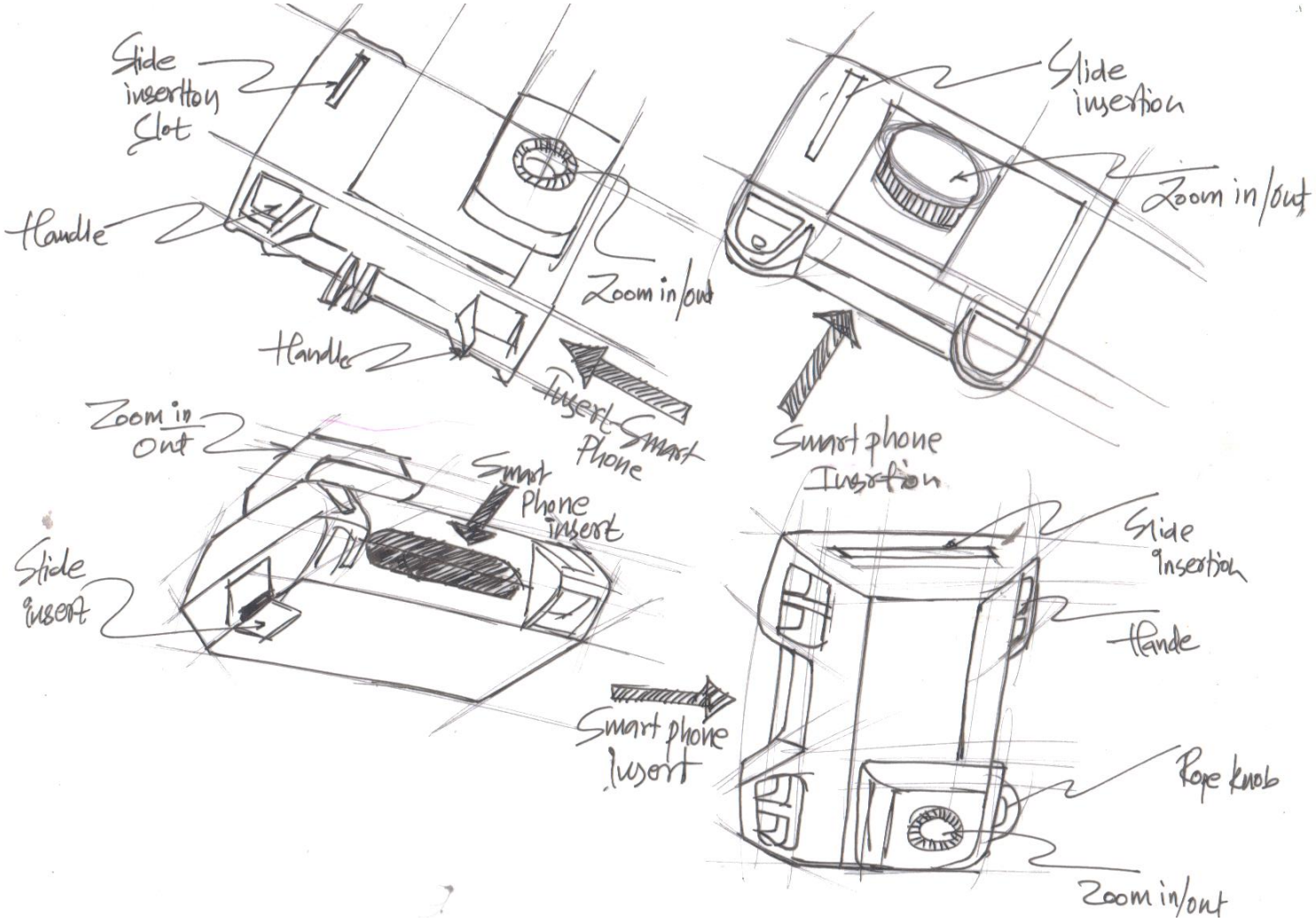
## Concept 2

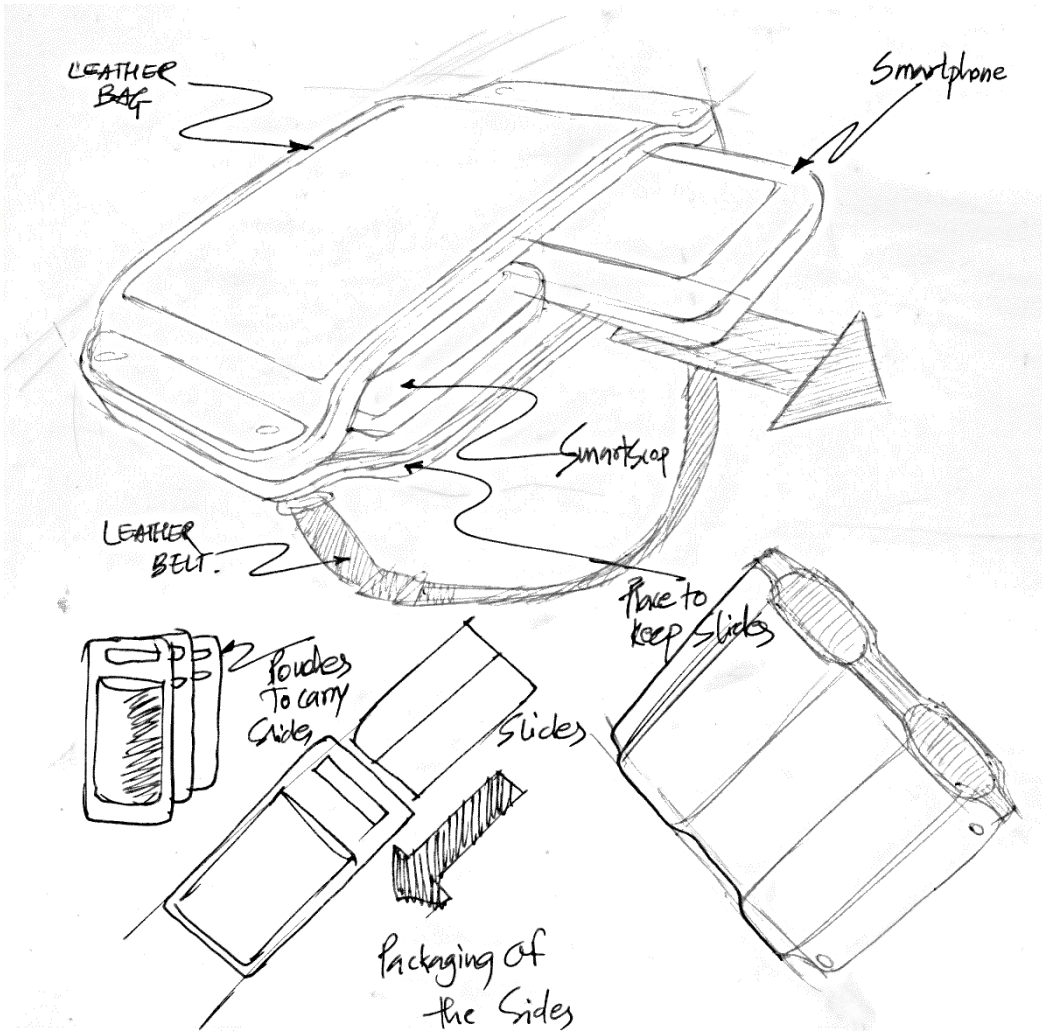


# Concept Generation

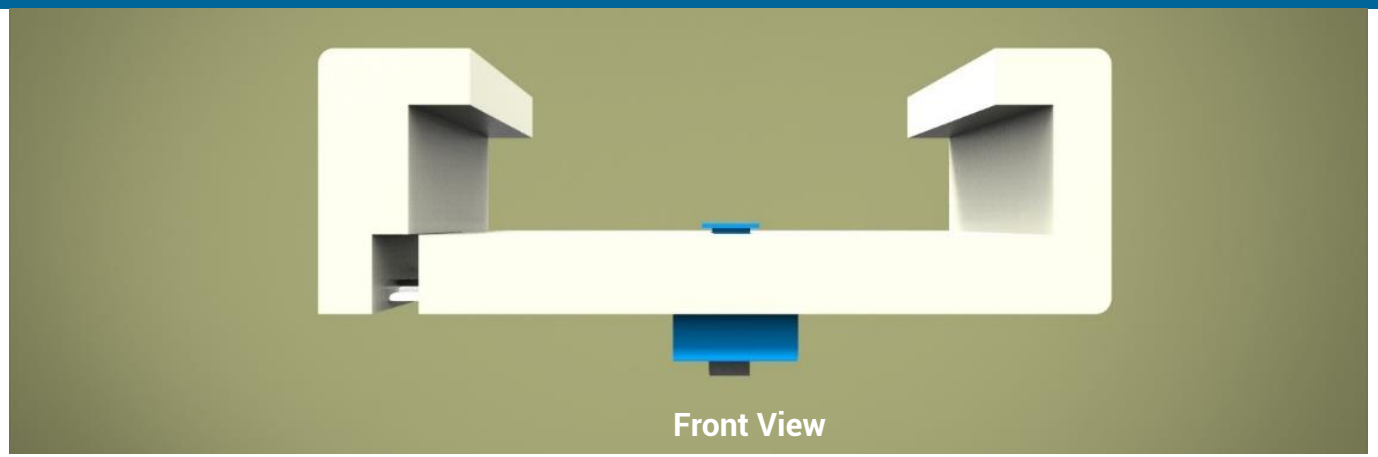
## Concept 3

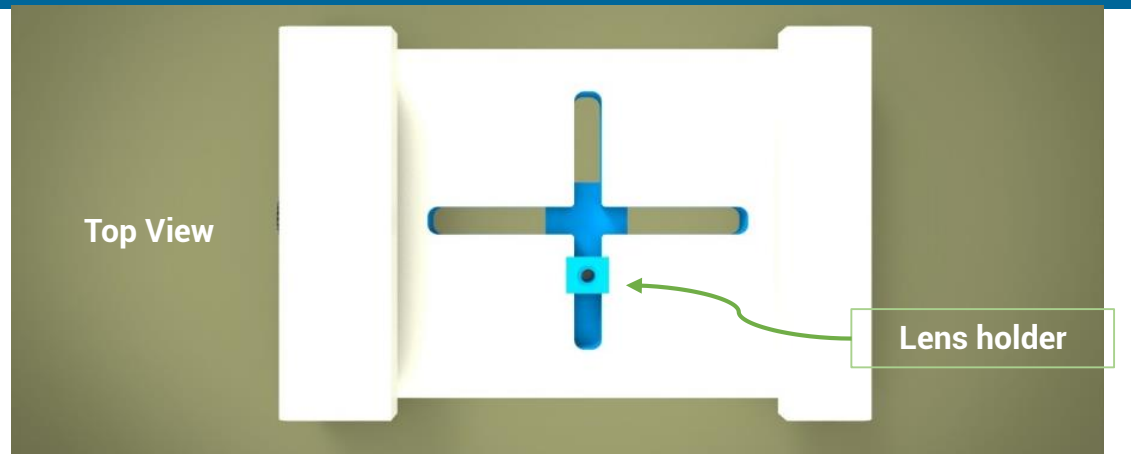


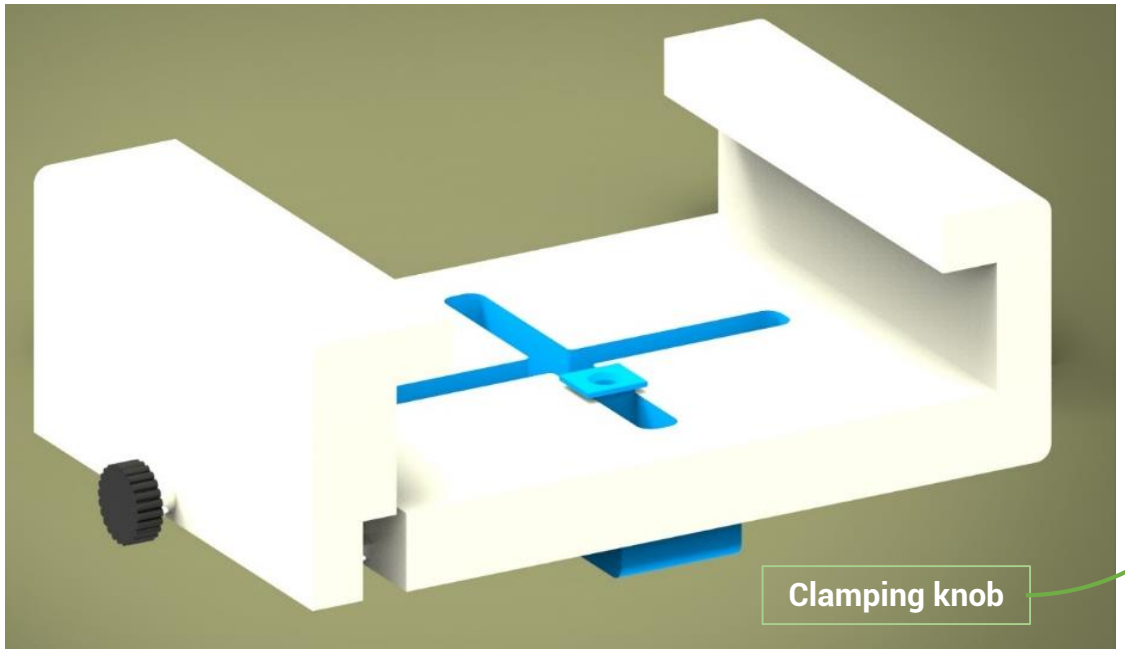



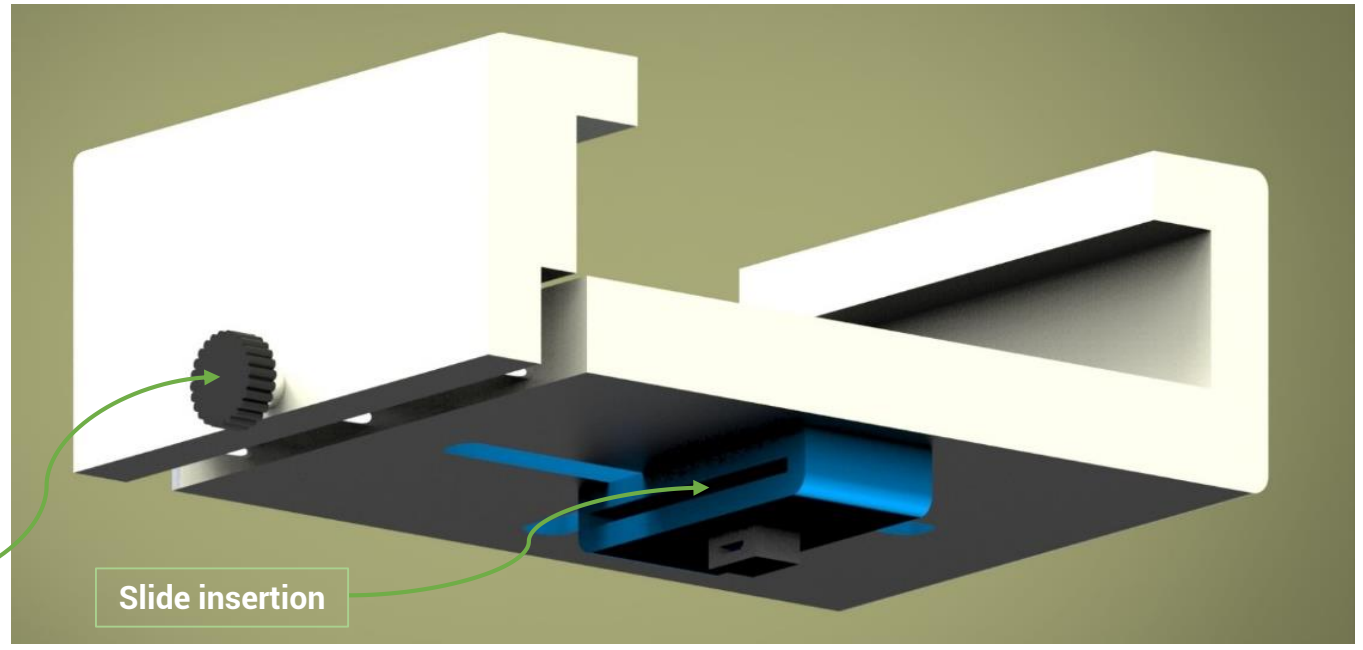
# Concept Evaluation

## Concept 1 CAD model



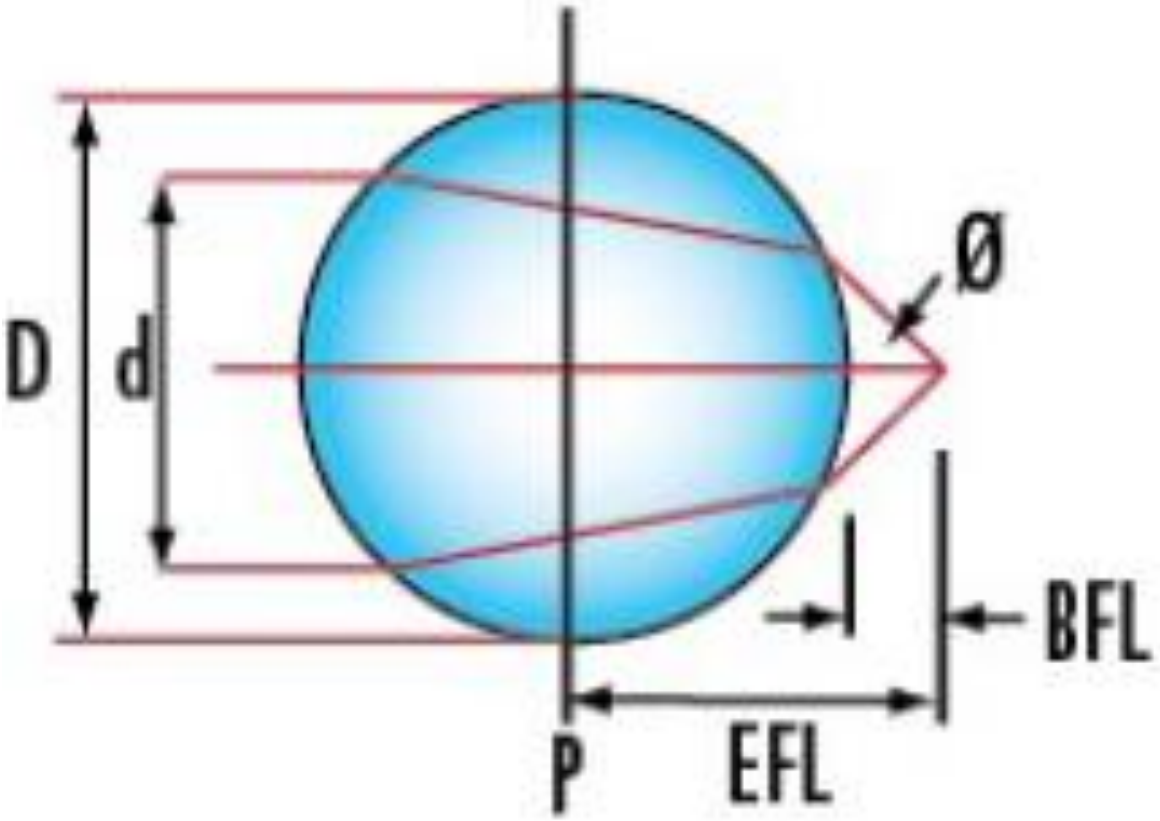



Concept Evaluation

Innovative New Concept

Concept Improvisation

# Understanding Ball lens/Glass bead




**Diameter of Input Source (d),**

**Diameter of Ball Lens (D),**

**Effective Focal Length of Ball Lens (EFL),**

**Back Focal Length of Ball Lens (BFL)**

**Index of Refraction of Ball Lens (n).**

Ball lenses are great optical components for improving signal coupling between fibers, emitters, and detectors. They are also used in endoscopy, bar code scanning, ball preforms for aspheric lenses, and sensor applications.

# Concept Improvisation

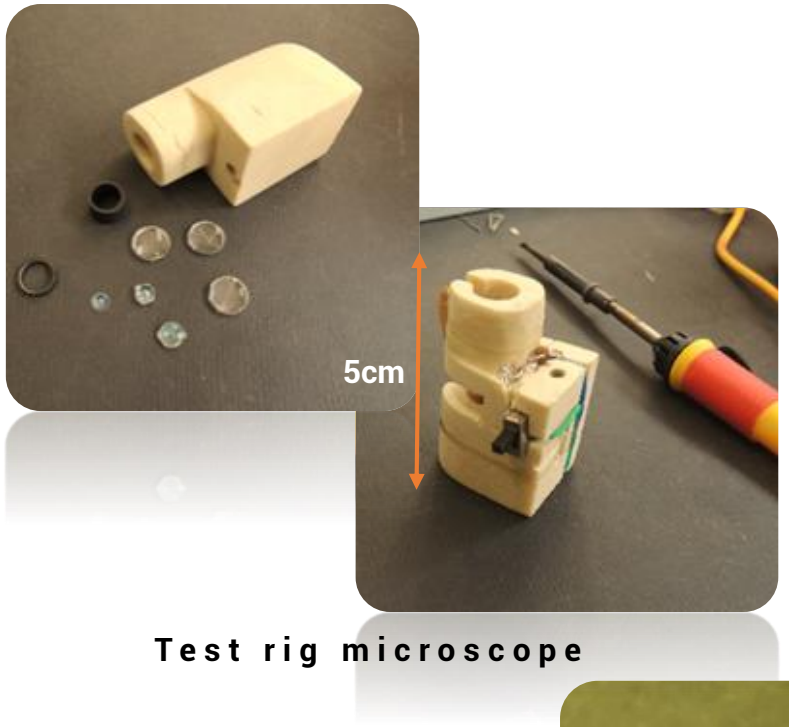
## Why Ball lens ?


**Hindustan Glass Beads ,Mumbai**

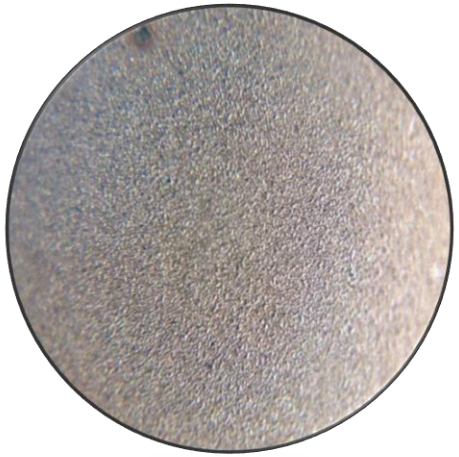
- Spherically shaped
- A constant refractive index
- Made from commonly available glasses or other transparent optical substrates
- Reduced size
- Availability
- Cost benefits.

## Concept Improvisation

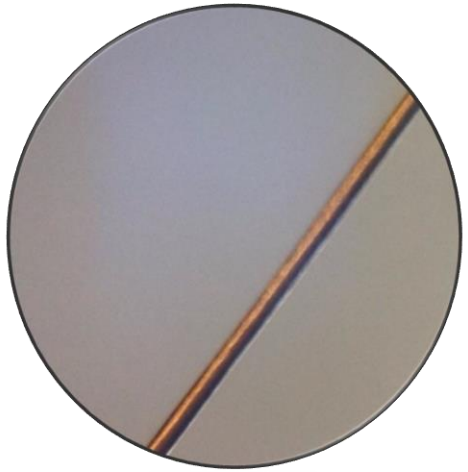
# Experimental study with Ball lens and it's result



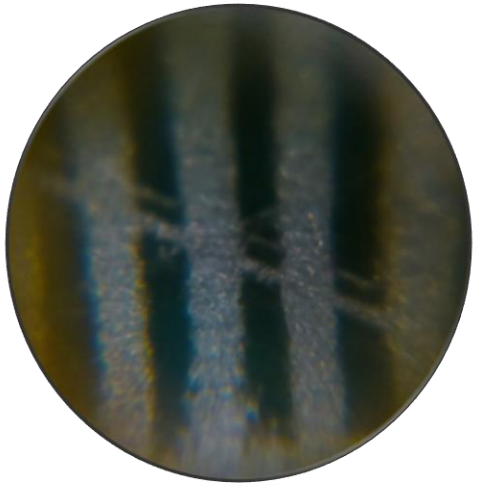

**Test rig microscope**



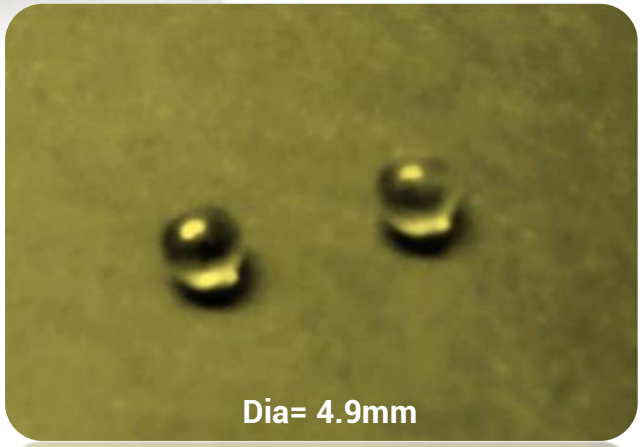
Stained blood slide with 200x magnified blood cells.



*Human hair with 200x Magnification.*



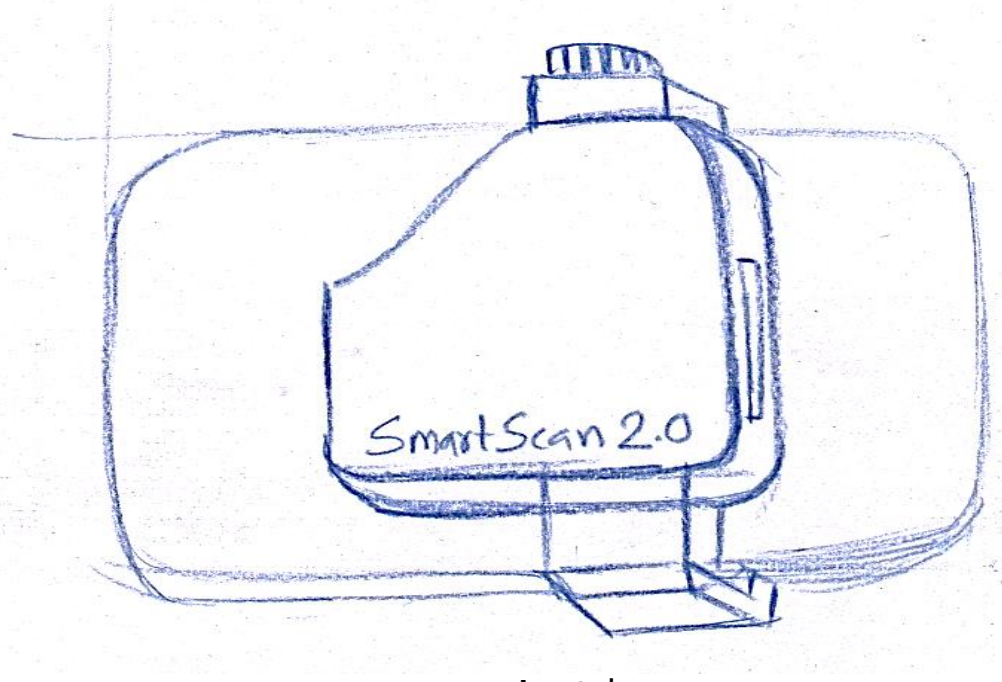
*Steel rule.*



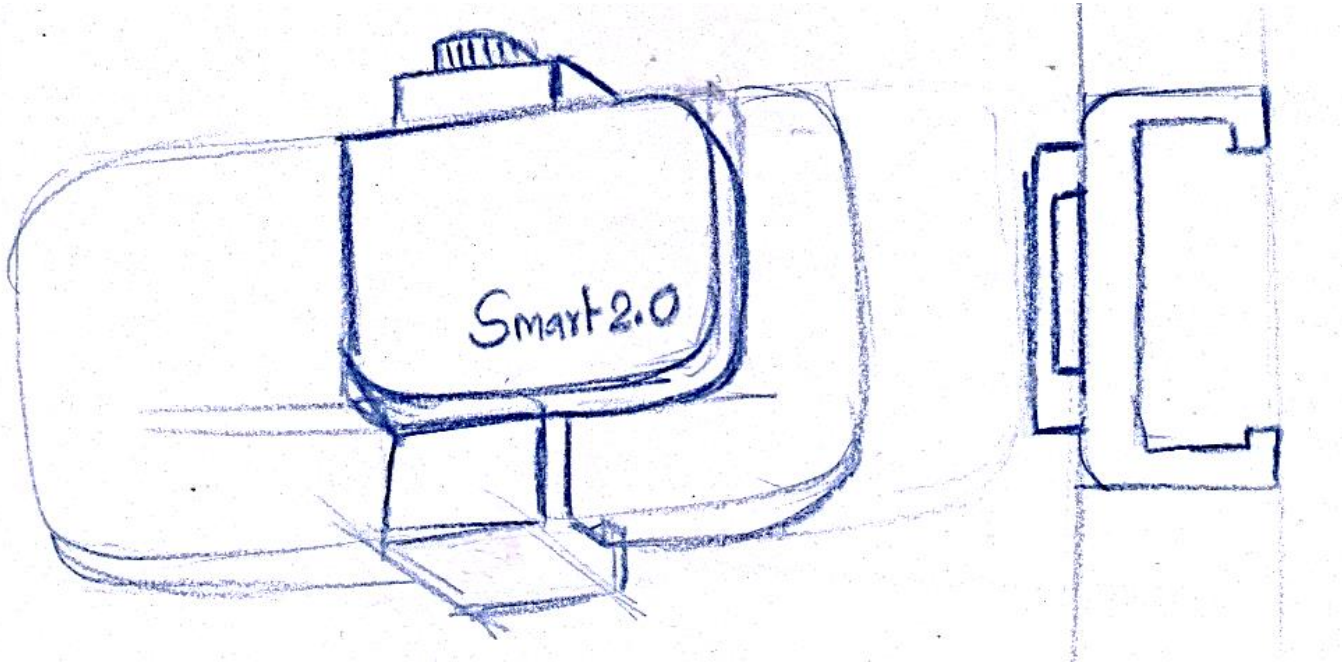

So, In this way the base requirement of max.200 x magnification of the stained blood cells is achieved by using this simple glass beads having diameter 4.9mm. Due to this the height of the add-on device is reduced from 5cm to almost 1cm.

# Finalizing the Concept

## Final Concept



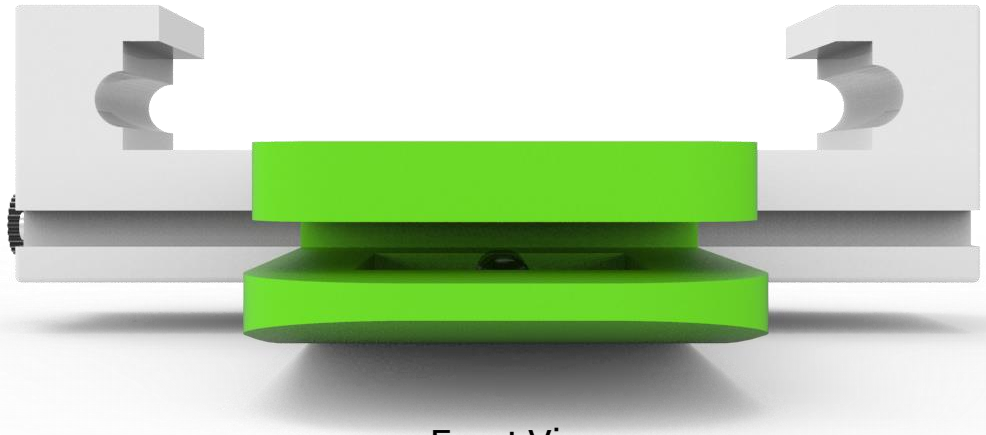

**Iteration 2nd**



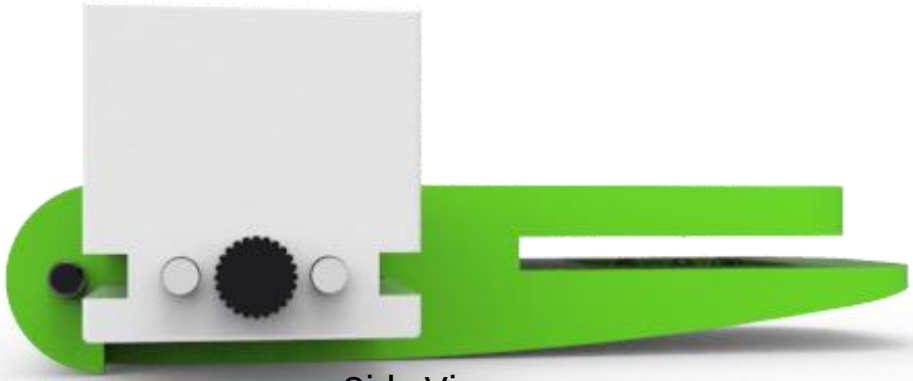

**Iteration 1st**

# Finalizing the Concept

## Concept CAD model

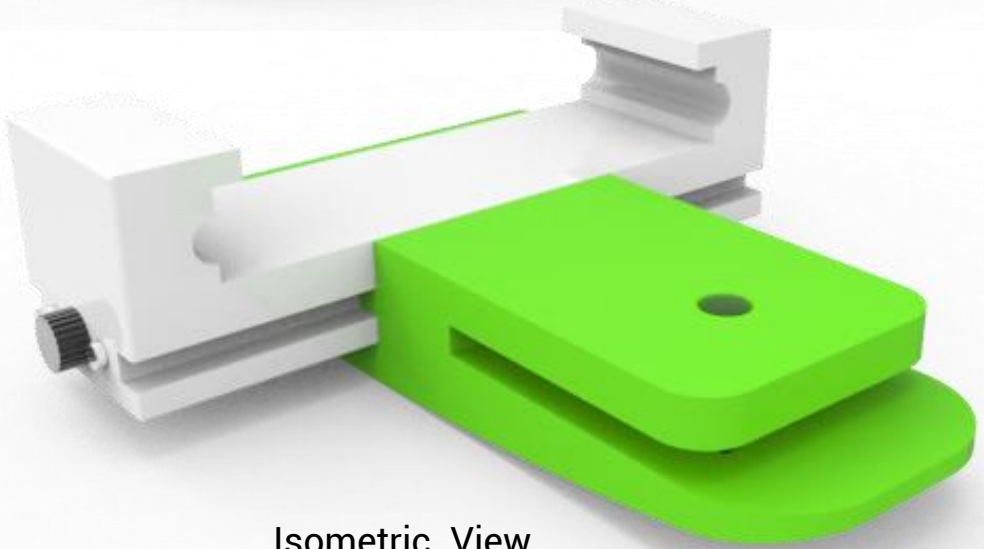


Front View



Side View

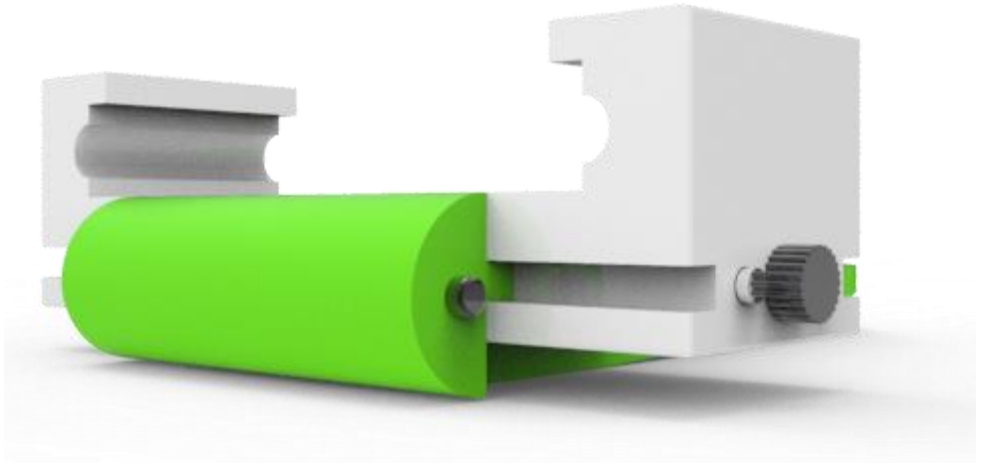

Back side View

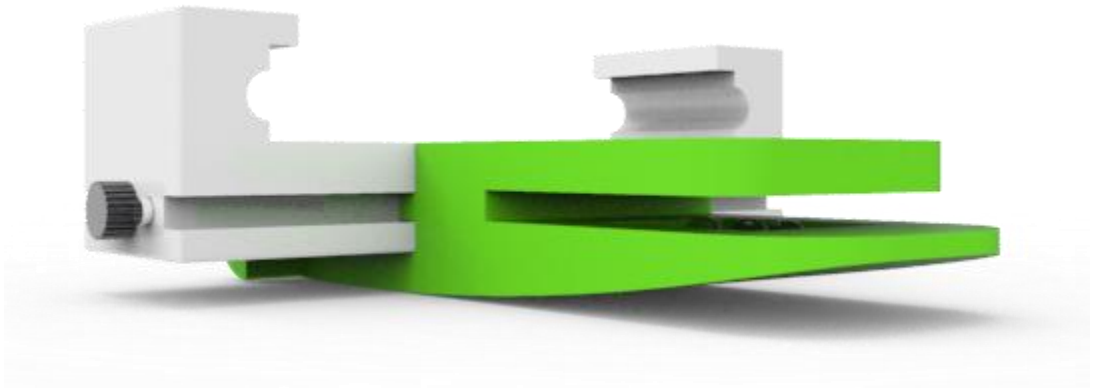


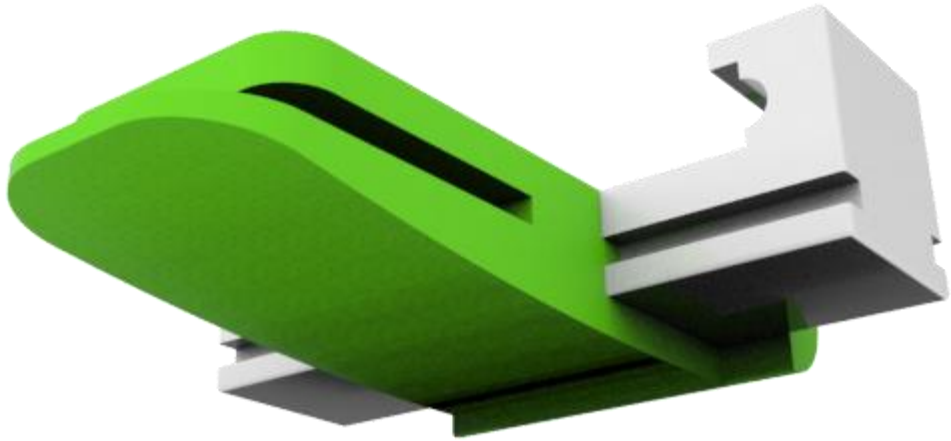
Isometric  View

# Finalizing the Concept

## Concept CAD model



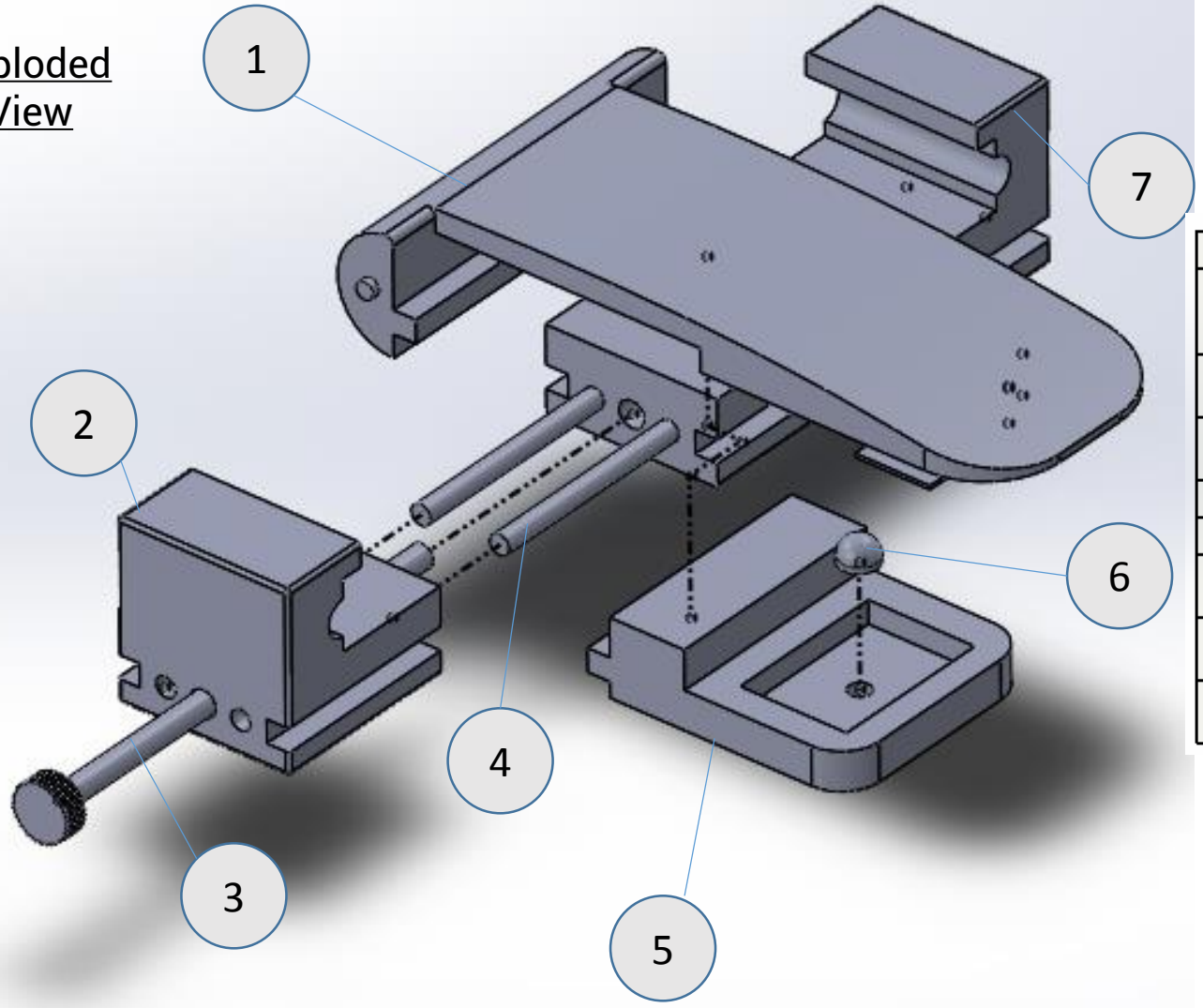




# Finalizing the Concept

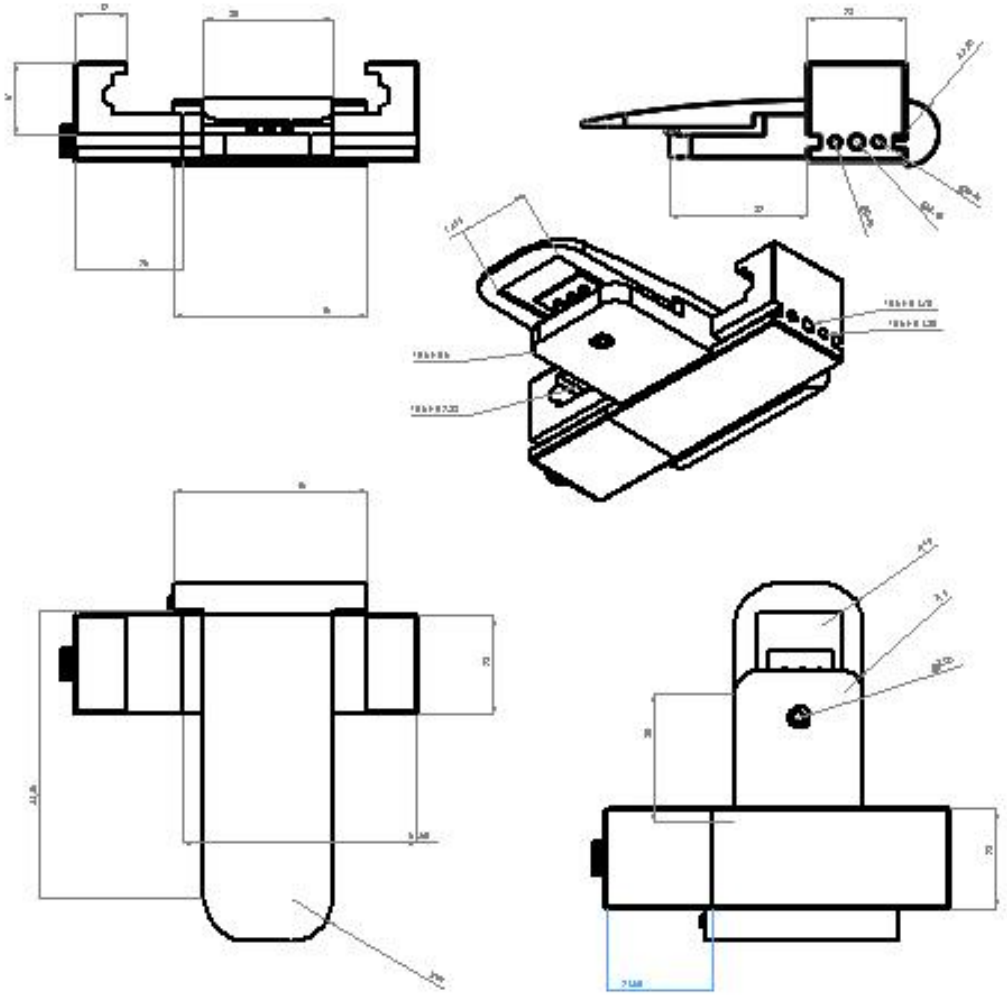
## BOM

Exploded View



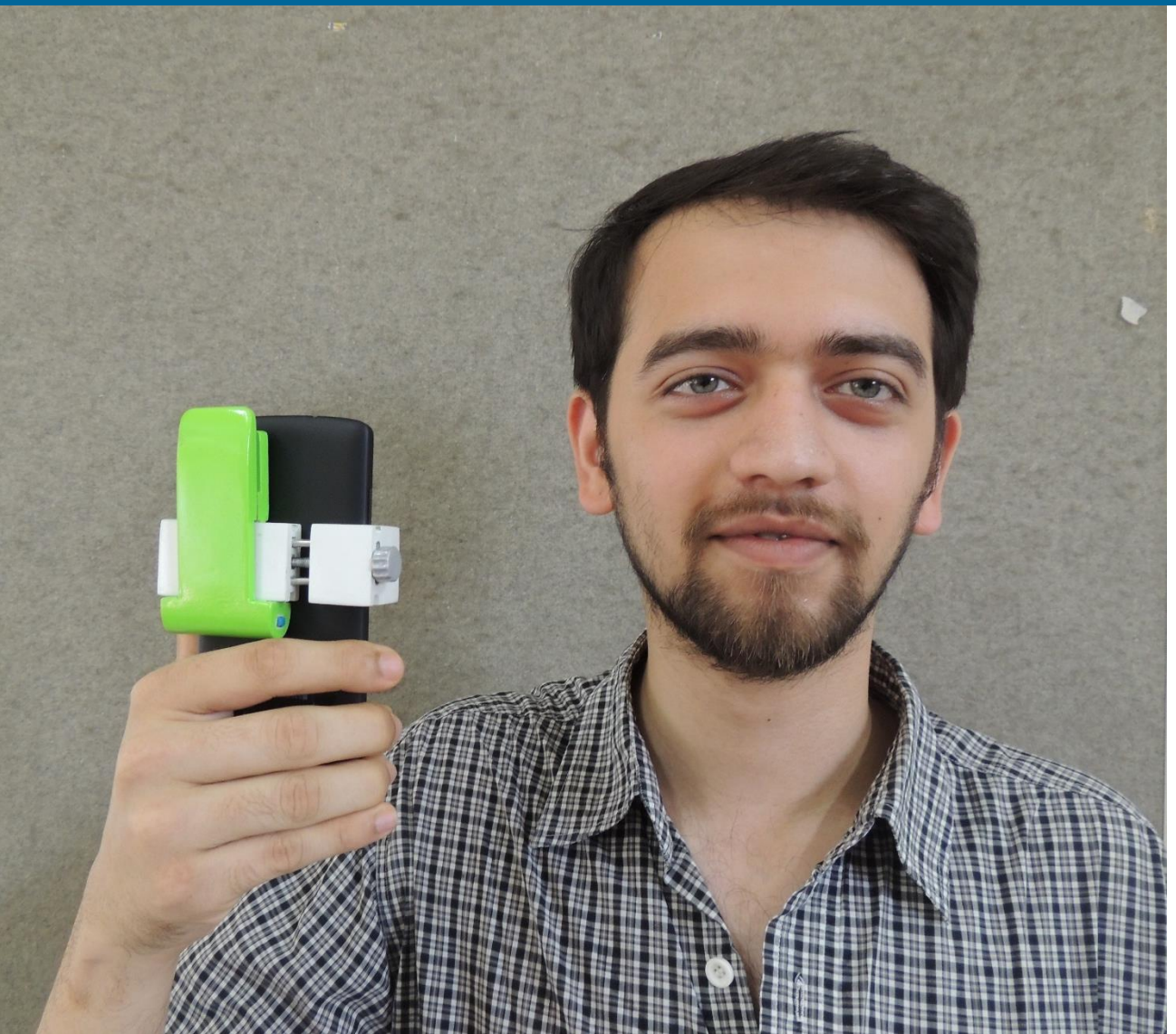

| BOM Table | | | | |
|---|---|---|---|---|
| ITEM NO. | PART NUMBER | Material | Manufacturing Process | QTY. |
| 1 | Main Body | Acrylonitrile butadiene styrene (ABS) | Injection Molding | 1 |
| 2 | Base Part 2 | Acrylonitrile butadiene styrene (ABS) | Injection molding | 2 |
| 3 | Bolt | Steel | Rolling | 1 |
| 4 | Slider | Steel | Wire Drawing | 1 |
| 5 | Main Body Part 2 | Acrylonitrile butadiene styrene (ABS) | Injection Molding | 1 |
| 6 | Lens | Glass Bead | Droplet technology | 1 |
| 7 | Base Body Part 1 | Acrylonitrile butadiene styrene (ABS) | Injuction Molding | 1 |

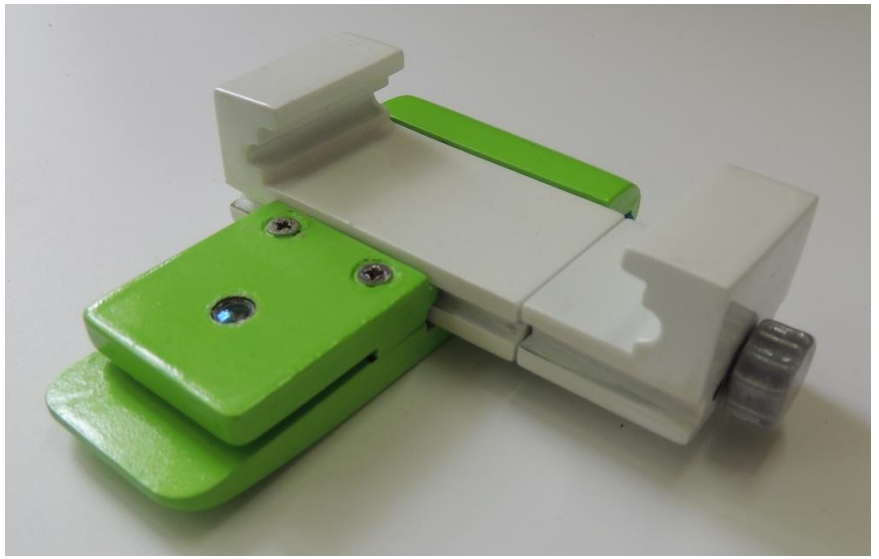
# Dimensions

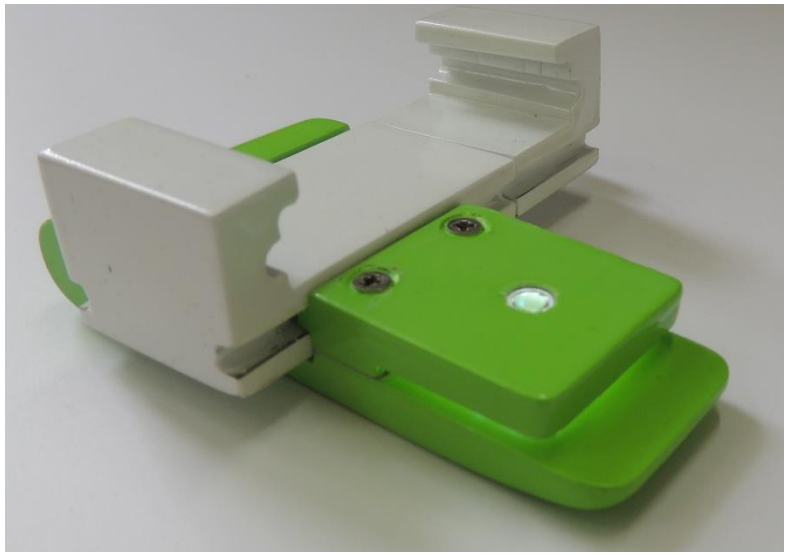


# Actual Product

**1:1 working model**

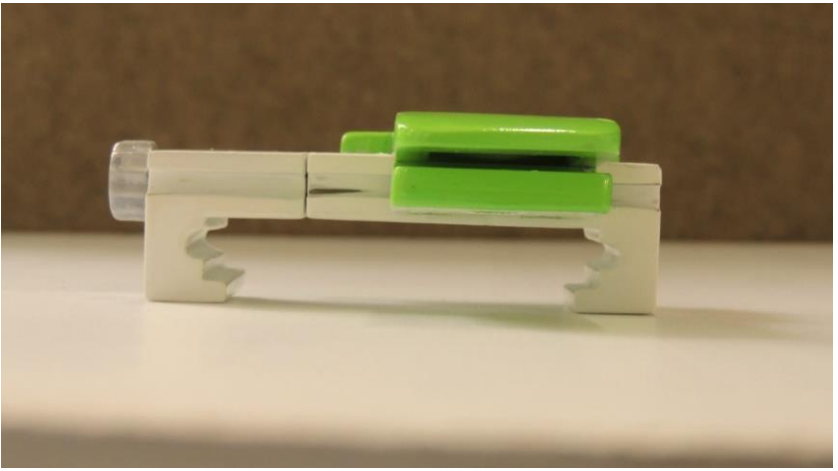


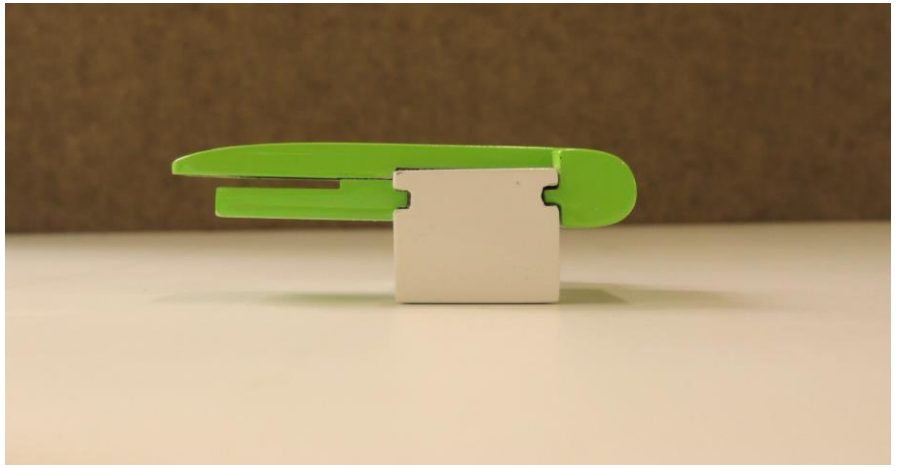


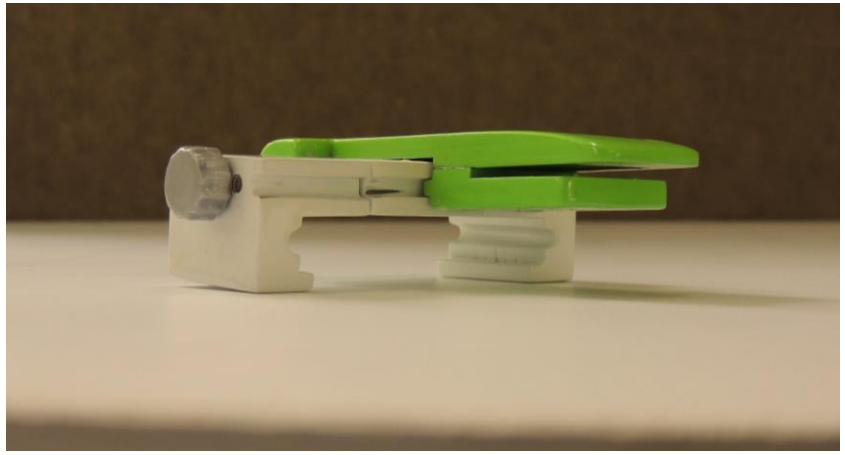


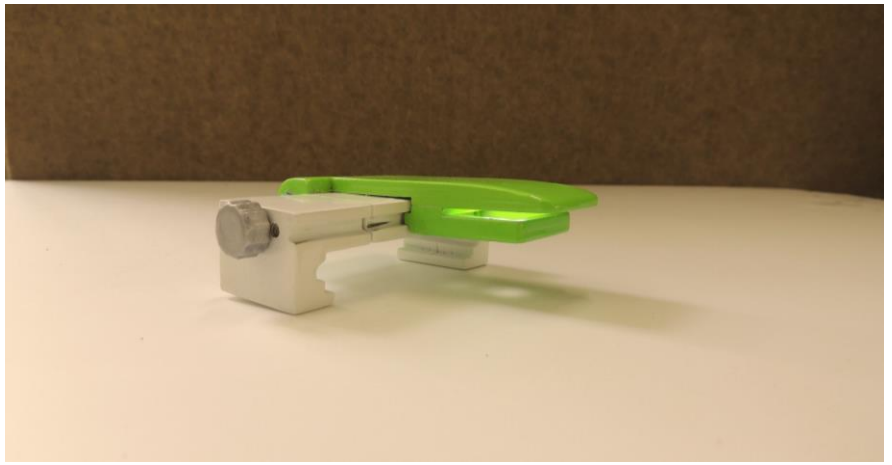
# Actual Product

**1:1 working model**







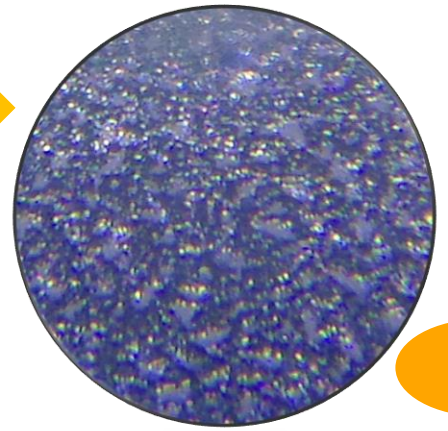


# Validation

## User feedback

- Bapat's Pathalogy Lab,Powai
- Zoctr Family Clinic,Powai
- Health spring Community Medical center,Powai
- Sangivani Pathalogy Lab,Powai
- Quaklife Pathalogy Lab,Bhandup

10 MP



1000x

# Conclusion

**Advantages of the design are:**

**- Allows unskilled people to use**

**- Much faster process due to digitization and semi automatic diagnosis process (can be)**

**- Very accurate database for everyone to use**

**If implemented, the system has the potential to revolutionize the world of blood diagnosis, specially in developing countries like India.**

# THANK YOU

# References.


1. Ministry of Health and Welfare, India, 2010, *Rural Health Care System in India*, p1-4
2. PricewaterhouseCoopers, 2007, *Healthcare in India, Emerging Market Report*, p 7-8.
3. Ministry of Health & Family Welfare, Government of India, *Annual Report 2009-10,* p 1-5
4. Economist Intelligence Unit, March 2009, *Healthcare Analysis - Healthcare in India: Rural Development*, p 1-2
5. M V Ramana Murthy, Mobile Computing and Wireless Networks, CDAC, Bangalore, *Mobile based Primary Health Care System for Rural India,* p2-7
6. Jiang Jiehui and Prabhu Kandachar, Faculty of Industrial Design Engineering (IDE), Delft University of Technology, The Netherlands, 2008, *Opportunities for Healthcare Design Interventions for Rural Migrants in Urban China,* p 1-3
7. Ashok Jhunjhunwala, Suma Prashant, Sameer Sawarkar, Rural Technology & Business Incubator, IITM, Chennai, 2009, *Healthcare in Rural India: Challenges*, p46-47
8. Neha Madhiwalla, Centre for Studies in Ethics and Rights, Mumbai, National Medical Journal of India, 2007, *Healthcare in Urban Slums in India,* p 1-2
9. "The World in 2015: ICT facts and figures." 2014. *ITU*. Accessed Jan22. http://www.itu.int/en/itu-d/statistics/Pages/default.aspx.
10. Tseng ,Derek, Onur Mudanyali ,Cetin Oztoprak, Sehan O.2010 "Smartphone Based Computational Microscopy Using Multi-frame contact Imaging in a fiber optic array." 13(20. Oct),2014-4030
11. "The World in 2015: ICT facts and figures." 2014. *ITU*. Accessed Jan22. http://www.itu.int/en/itu-d/statistics/Pages/default.aspx.
12. Tseng ,Derek, Onur Mudanyali ,Cetin Oztoprak, Sehan O.2010 "Smartphone Based Computational Microscopy Using Multi-frame contact Imaging in a fiber optic array." 13(20. Oct),2014-4030.