Low-Cost, Portable, Pneumonia Diagnostic Device

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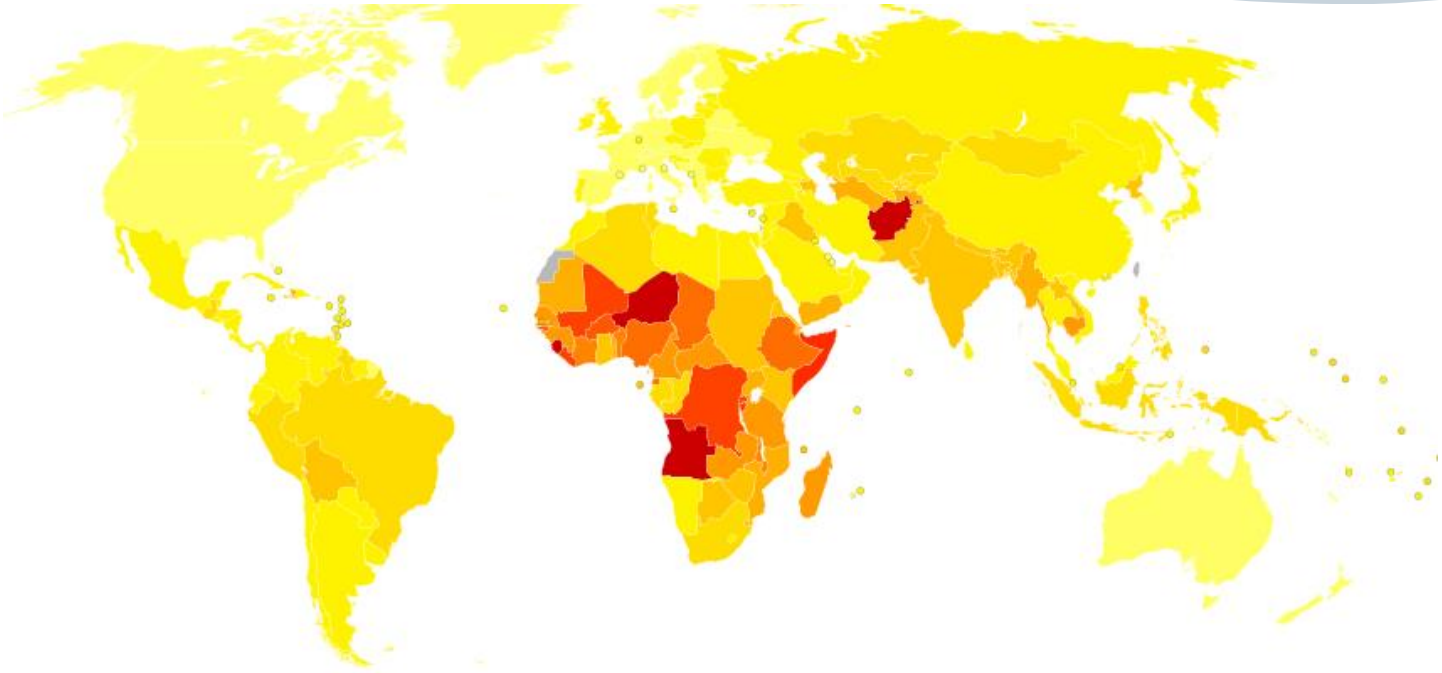
Team Members: Shay Aluko and Clark Ingram

Mentor: Dr. Dan Moran

Global Prevalence of Pneumonia

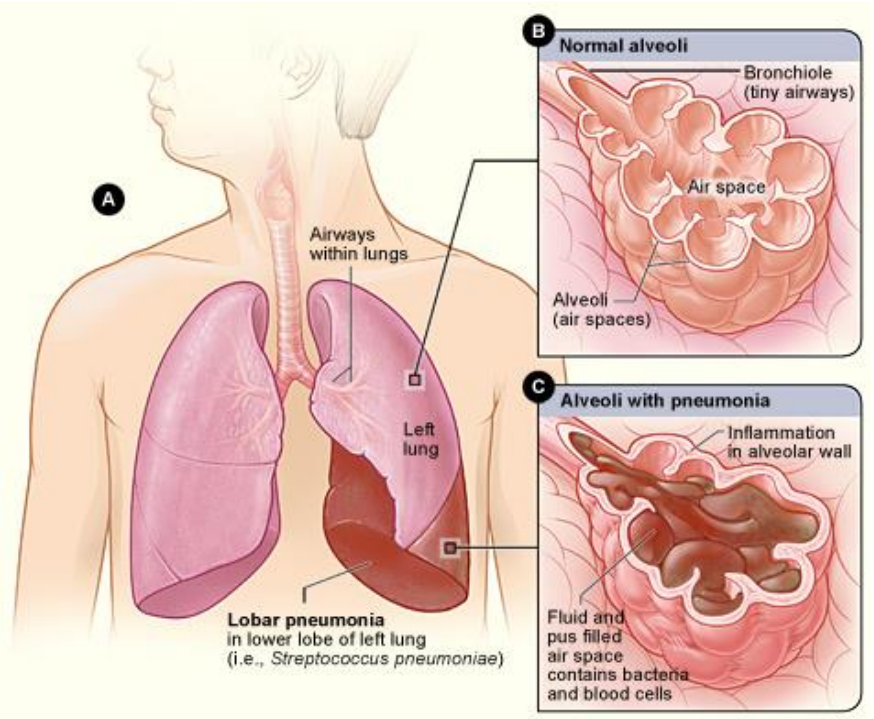


<100 | 100-700 | 700-1400 | 1400-2100 | 2100-2800 | 2800-3500 | 3500-4200 | 4200-4900 | 4900-5600 | 5600-6300 | 6300-7000 | >7000

References:
World Health Organization. "Pneumonia." ; World Health Organization "The top 10 causes of death"; http://www.who.int/mediacentre/factsheets/fs310/en/index4.html

Pneumonia Overview

* Inflammation of pulmonary alveoli
* Obstruction of oxygen exchange
* Impacts cellular function and infection can spread
* Individuals at risk
  * Compromised immune system
  * Infants and elderly
  * Environmental factors
* 3 most common symptoms
  * Cough with discharge
  * Fever
  * Difficulty breathing



References:

Mason: Murray and Nadel's Textbook of Respiratory Medicine: "Bacterial Pneumonia

National Health Service. "Pneumonia" http://www.nhs.uk/conditions/Pneumonia/Pages/Introduction.aspx

Mayo Clinic Staff. "Pneumonia" : http://www.mayoclinic.org/diseases-conditions/pneumonia/basics/definition/con-20020032

Classification of Pneumonia:

Classification by cause of infection

Microorganism:
- Bacterial Pneumonia
- Viral Pneumonia
- Fungal Pneumonia
- Mycoplasma Pneumonia

Substance inhalation:
- Aspiration Pneumonia

Commonness of Cause:
- Atypical Pneumonia
- Typical Pneumonia

Classification by Infection Severity

- Double Pneumonia
- Lobar Pneumonia
- Broncho-pneumonia

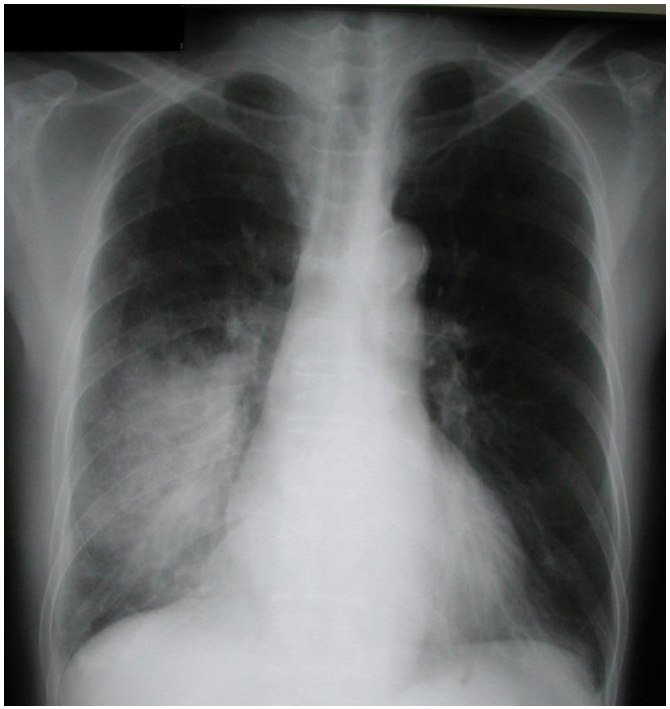
Classification by Location of Contraction

- Community Acquired Pneumonia
- Hospital Acquired Pneumonia
- Health-Care Acquired Pneumonia

References:
http://www.nhs.uk/conditions/Pneumonia/Pages/Introduction.aspx; *Encyclopedia of Infectious Diseases:* "Pneumonia"; National Center for Immunization and Respiratory Diseases: "Atypical Pneumonia" ; www.mayoclinic.org/diseases-conditions/pneumonia/basics/definition/con-20020032

Diagnosis and Treatment

* Diagnosis
  * Medical history and recording of symptoms
  * Recording of patient temperature
  * Listening to chest of individual for abnormalities
  * Additional diagnostic tests
* Treatment
  * Antibiotics
  * Fever reducers or cough medicine
  * More severe forms: hospitalization with fluid drainage



References:
http://www.nhs.uk/conditions/Pneumonia/Pages/Introduction.aspx; www.mayoclinic.org/diseases-conditions/pneumonia/basics/definition/con-20020032
http://www.nhlbi.nih.gov/health/health-topics/topics/pnu/diagnosis.html

Exploration of Existing Solutions

Portable X-Ray Device: MinXRay

* MinXray's CMDR-2S is an integrated device used for direct radiography in remote locations.
* **Advantages**
  * Portable, durable
  * Wireless capabilities
  * 6-8s image acquisition
* **Disadvantages**
  * Technician required for operation and interpretation
  * 149 lbs

References:
http://www.minxray.com/digital_compare.html,

Point-of-Care Ultrasound

* Point-of-care ultrasound refers to use of portable ultrasonography for diagnostic purposes.
* **Advantages**
  * Portable
  * Relatively inexpensive
* **Disadvantages**
  * Previous training required for interpretation
  * Interpretation of results varies

References:
http://www.amazon.com/Draminski-SonoFarm-Portable-Ultrasound-Scanner/dp/B00J9O9Z4K/ref%3Dsr_1_5?ie=UTF8&qid=1410641542&sr=8-5&keywords=portable+ultrasound
http://www.amazon.com/Zenith-Medical-Supplies-Hand-Held-Ultrasound/dp/B00HCQUY56/ref%3Dsr_1_1?ie=UTF8&qid=1410641544&sr=8-1&keywords=portable+ultrasound

Inspire: Respiratory Rate Monitor

* Pediatric device used to measure respiratory rates through breath recognition for Pneumonia diagnosis
* **Advantages**
  * High usability
  * Transmit Data
  * Durable for use in harsh conditions
  * Fast Results
* **Disadvantages**
  * Limited to Children

References:
http://www.inspirelivinginc.com/

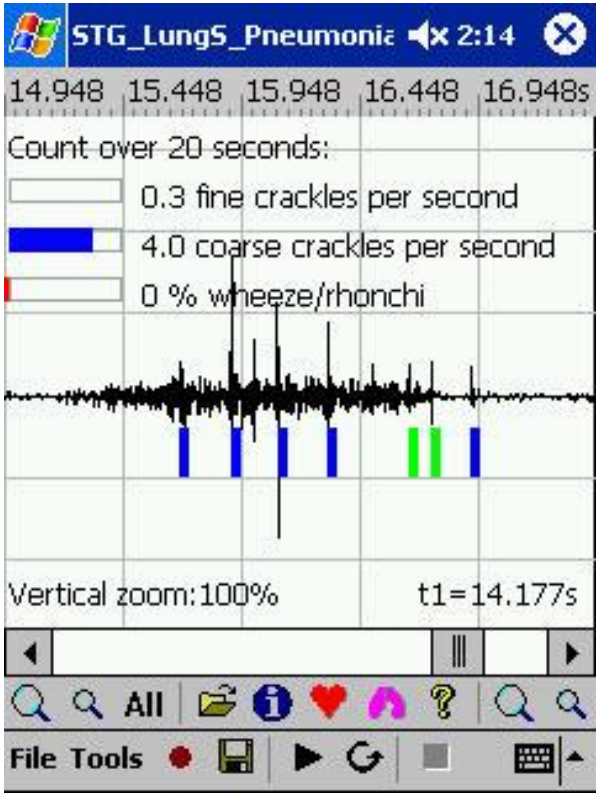
Smart-phone Powered Oximeter

* This oximeter uses LEDs and photo resistors to obtain absorbance information (based on percentage of hemoglobin in the blood) which is then analyzed on a mobile application.
* **Advantages**
  * Inexpensive
  * Portable
* **Disadvantages**
  * Requires smartphone for operation

References:
http://research.microsoft.com/en-us/collaboration/focus/health/smartphone_clinical_diagnosis.aspx

Automatic Analyzer of Lung Sounds

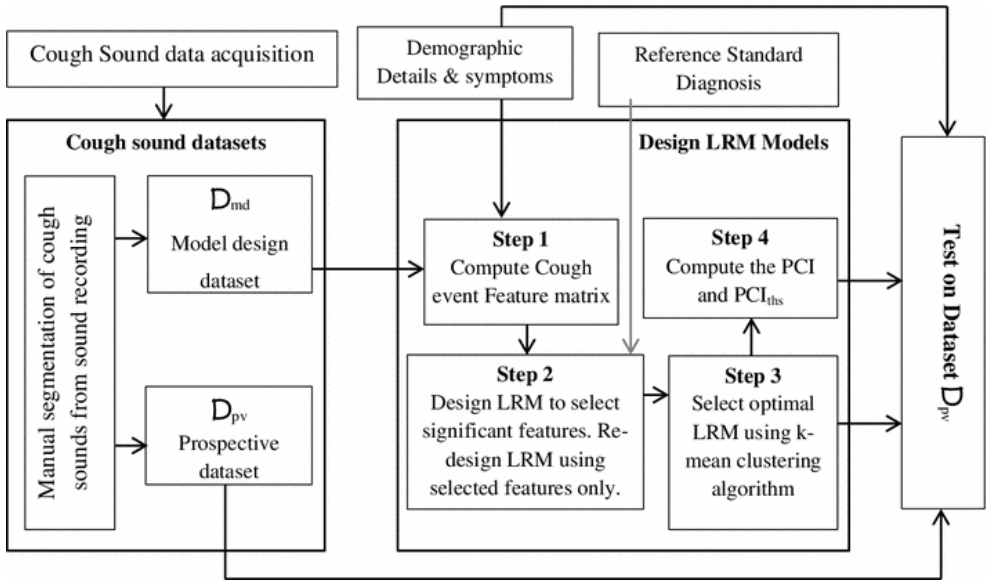
* Utilizes software to analyze lung sounds and diagnose respiratory illnesses, especially child pneumonia.
* **Advantages**
  * Noninvasive
  * High usability
  * Expertise not required
* **Disadvantages**
  * Requires access to a computer
  * Focus on childhood pneumonia



References:
http://www.google.com/patents/CN103417241A?cl=en

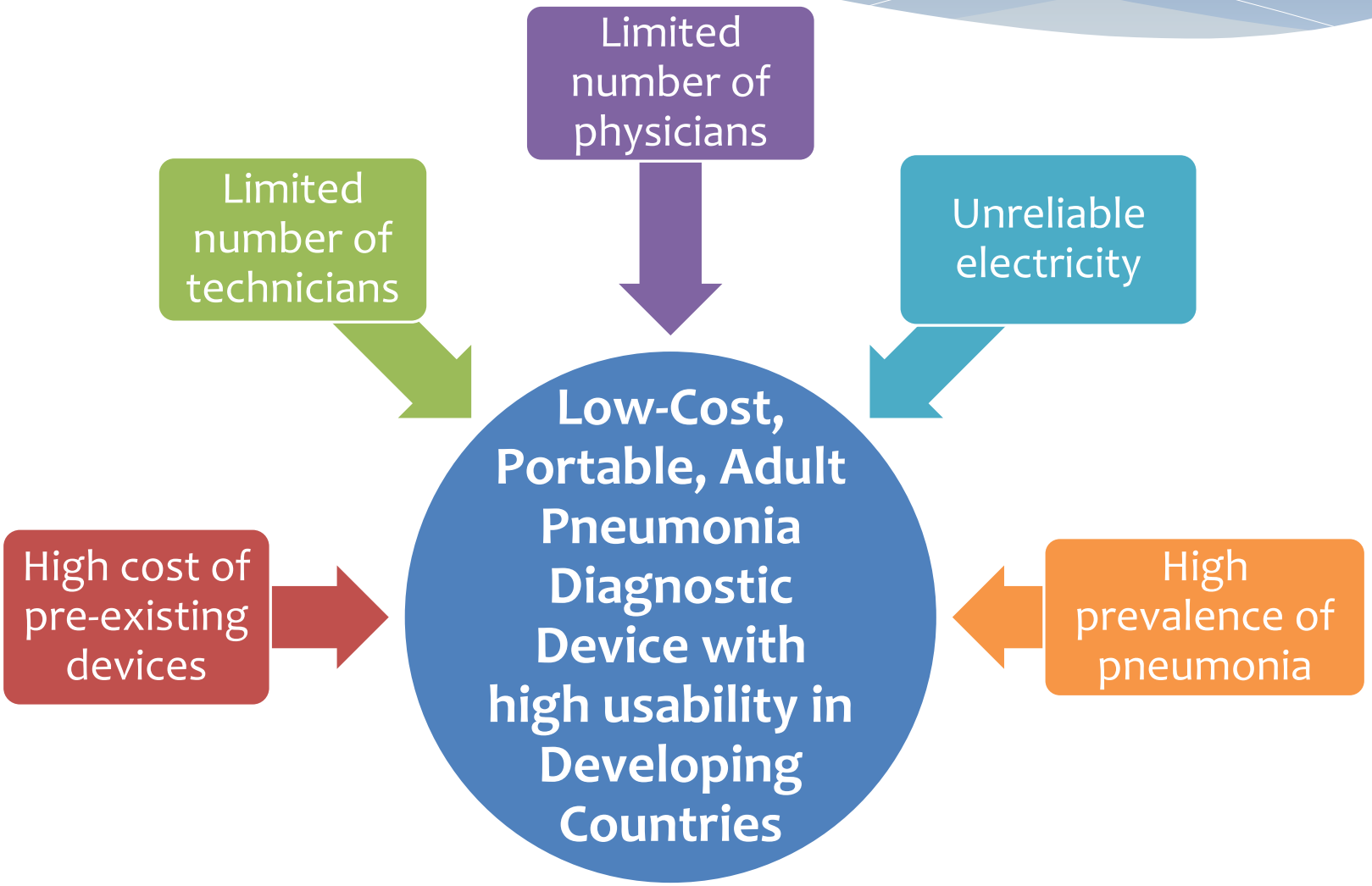
Cough Sound Analysis

* Researchers have developed a method of diagnosing pneumonia through cough sound analysis (which provides vital diagnostic information).
* **Advantages**
  * High accuracy of diagnosis
    * Sensitivity: 94%
    * Specificity: 75%
  * Inexpensive and noninvasive
* **Disadvantages**
  * Not yet implemented



References:
http://www.ncbi.nlm.nih.gov/pubmed/23743558

Need and Project Scope



Design Specifications

Portable and Inexpensive

- Compact: ≤ 1 liter
- Lightweight: ≤ 0.5 kg
- Low Product Cost: ≤ $150

Substantial Operation Time

- Operation Time: 1000 measurements: 8.3 hrs
- Lifetime: ≥ 2 years
- High Throughput: ≤ 30s per measurement

Reliable

- Temperature Resistant: [-10 °C, 55 °C]
- Water Resistant: ≤ 2-3 bar
- Sturdy: Withstand impact force ≤ 313 N*
- Low False + Rate: ≤ 10%
- Low False – Rate: ≤ 10%

Safe

- Noninvasive: No skin penetration
- Nontoxic (patient): ≤ 0.5 mSv*
- Nontoxic (user): ≤ 36.5 mSv*
- Shockproof: ≤ 25V DC

High Usability

- Operable by individuals 18+
- Unspecified language
- No experience or training required
- Minimal Time Setup: [10s, 15s]

Design Calculations

Device Sturdiness : (2m Drop Test)

$$Potential\ Energy = m * g * h$$

$$Conservation\ of\ Energy : m * g * h = \frac{1}{2} * m * v^2$$

$$v = \sqrt{2 * g * h} = \sqrt{2 * 9.81 \left(\frac{m}{s^2}\right) * 2m} = 6.26\ \frac{m}{s}$$

$$Momentum = m * v = 0.5kg\ * 6.26 \frac{m}{s} = 3.13 \frac{kg * m}{s}$$

$$Impulse(Change\ in\ Momentum) = Impact\ Force * Time\ to\ Stop$$

$$\therefore Impact\ Force = \frac{3.13 \frac{kg * m}{s}}{0.01s} = \mathbf{313N}$$

Design Calculations

Device Toxicity:

* Specification calculation to ensure device is less toxic than an x-ray scan (used commonly as a diagnostic test).

$$Total\ Effective\ Dose:$$

$$= 0.1\ \frac{mSv}{scan} * 5\ \frac{scan}{exam} * \frac{1\ exam}{year} = \frac{\mathbf{0.5\ mSv}}{\mathbf{year}}\ \boldsymbol{for\ the\ patient}$$

$$\boldsymbol{Increase\ the\ patient's\ cancer\ risk\ by\ 0.005\%}$$

$$Total\ Effective\ Dose:$$

$$= \left(0.1\ \frac{mSv}{scan} * 5\ \frac{scan}{exam} * \frac{20\ exam}{day} * \frac{365 day}{year}\right) * 1\% = \frac{\mathbf{36.5\ mSv}}{\mathbf{year}}\ \boldsymbol{for\ the\ user}$$

$$\boldsymbol{Increase\ the\ user's\ cancer\ risk\ by\ 0.37\%\ /year}$$

Design Schedule

	Aug 24	Aug 31	Sep 7	Sep 14	Sep 21	Sep 28	Oct 5	Oct 12
Mentor Agreement								
Project Idea Brainstorming								
Project Scope			9/8					
Development of Design Specifications								
Background Research/Need Recognition								
Existing Solutions Search								
Preliminary Written Report				9/19				
Preliminary Oral Report				9/22				
Webpage Operational							10/6	
Risk Analysis/DesignSafe							10/8	
Concept Generation								
Pugh Chart Analysis/Concept Selection								
Progress Written Report								

Past Work | Past Deadline | Future Work | Future Deadline

Design Schedule

	Oct 19	Oct 26	Nov 2	Nov 9	Nov 16	Nov 23	Nov 30	Dec 7
Decision Matrix/Concept Screening								
Progress Written Report	10/24							
Progress Oral Report		10/27						
Concept Embodiment								
Design Optimization Research								
Design of Software Involved								
Selection of Hardware Components								
Peer Review Due					11/19			
Final Written Report							12/1	
Final Oral Report							12/3	
Poster Competition								12/9

Past Work | Past Deadline | Future Work | Future Deadline

Team Responsibilities

Lauren
- Website design and updates
- Biological signal acquisition

Shay
- Biological signal acquisition
- Transmission of biological signal for processing

Clark
- Digital processing of the signal
- Symptom recognition for diagnosis

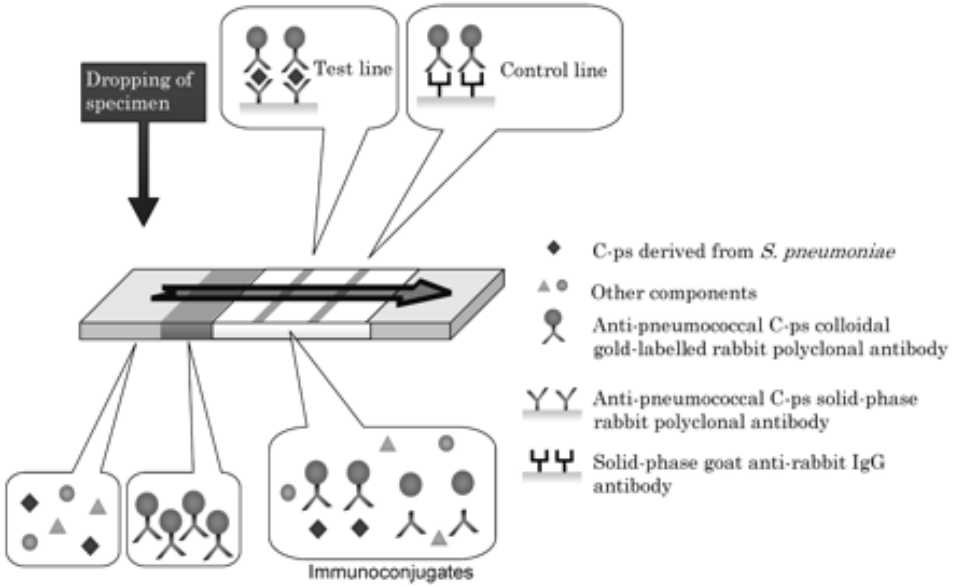
Acknowledgements

* **Team Members:**
  * Shay Aluko
  * Clark Ingram
* **Mentor:** Dr. Dan Moran
* **Professor:** Dr. Joseph Klaesner
* **TA:** Rebecca Gilson

Questions?

Direct Sputum Detection Kit

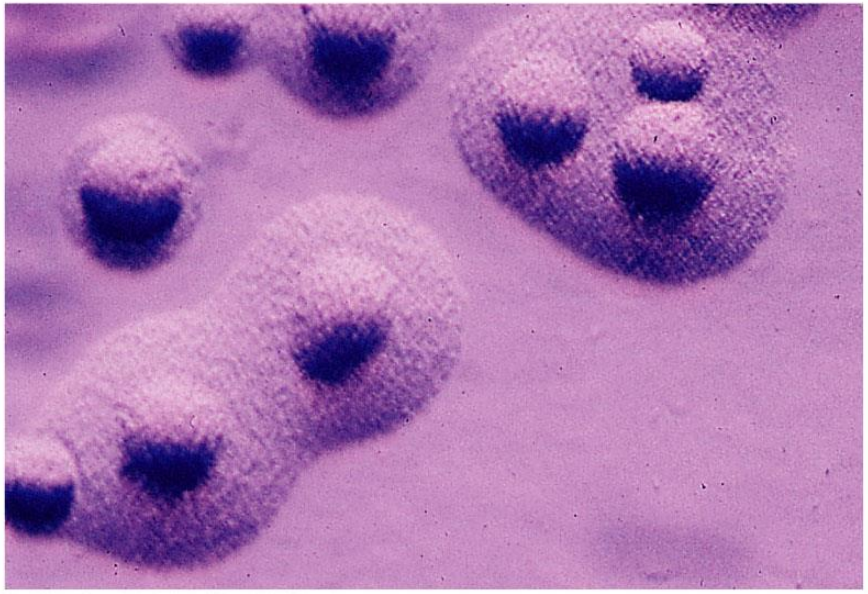
* This highly sensitive immunochromatography test kit uses antibodies against streptococcus pneumoniae to detect Pneumonia in adults.
* **Pros**
  * Sensitivity 94.4%
  * Specificity 88.2%
  * Portable
* **Cons**
  * Only identifies bacterial pneumonia caused by S. pneumoniae



References:
http://jmm.sgmjournals.org/content/57/7/820/F1.expansion.html

Mycoplasma Pneumonia Detection Kit

* This kit uses a loop-mediated isothermal amplification process to detect the presence of a particular bacterial strain indicative of pneumonia.
* Pros
  * Accurate
  * Simple to operate
* Cons
  * Limited to Mycoplasma Pneumonia
  * Requires 1 hour at a given incubation temperature



References:
http://www.google.com/patents/CN103276083A?cl=en

Pulse Oximetry, pH Levels, and CO2 Levels

* This device uses a venous blood sample and pulse oximetry to diagnose and detect pneumonia through a blood gas test.
* Pros
  * Reliable
  * Rapid results
* Cons
  * Requires a blood sample

pH	$[HCO_3]$	PCO_2	Condition	Common Causes
≤ 7.4	Low	Low	Metabolic acidosis	Kidney failure, shock, diabetic ketoacidosis
≥ 7.4	High	High	Metabolic alkalosis	Chronic vomiting, low blood potassium
≤ 7.4	High	High	Respiratory acidosis	Lung diseases, including pneumonia or COPD
≥ 7.4	Low	Low	Respiratory alkalosis	Breathing too fast, pain or anxiety

References:
http://www.google.com/patents/US7662632
http://www.healthline.com/health/blood-gases#Results4