Foldscope: Paper Microscope for Lab Characterization

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Abstract- **Here we describe an ultra-low-cost origami-based approach for large-scale manufacturing of microscopes, specifically demonstrating bright field, dark field, and fluorescence microscopes. Merging principles of optical design with origami enables high-volume fabrication of microscopes from 2D media. Flexure mechanisms created via folding enable a flat compact design. Structural loops in folded paper provide kinematic constraints as a means for passive self-alignment. This light, rugged instrument can survive harsh field conditions while providing a diversity of imaging capabilities, thus serving wide-ranging applications for cost-effective, portable microscopes in science and education.**

Microscope is a device used for the visualization of tiny objects which are not visible to the naked eye. Traditional microscopes have been crucial for the advancement of contemporary science and medicine. Recent advancements in the field of microscopy have fueled its exponential growth rate. However, due to their expensive cost and complicated structure, modern microscopes remain in accessible to the majority of the public. Nonetheless, the fold scope paper microscope has made it possible for anyone to explore and understand the world of microbes and organisms. In this review, we have listed fold scope-based research projects in various domains, as well as their key properties when compared to traditional research microscopes. In addition, we have briefly explored the impact of a fold scope microscope on public health, clinical diagnostics forensic science, agriculture, basic science, developmental biology, and education. Moreover, the major drawbacks of paper microscopes and the current steps being taken to upgrade fold scope and its features are discussed in this review. Finally, we have concluded with our perspective that the microscope maybe updated to imitate the advancement of a conventional microscope.

Keywords- **Fold Scope, Paper Microscope, Laboratory Charecterization.**

Introduction

The microscope is a ubiquitous tool in science, providing an important visual connection between the familiar macroscopic world and the surprising microscopic world that underlies it. Since the invention of the microscope, the field has evolved to offer numerous imaging modalities with resolutions below 250 nm. Additionally, highly cost-effective DIY microscopes provide opportunities for hands-on science education in schools and universities. Ultimately, this platform will enable the global community of amateur microscopists to capture and share images of a wide range of samples. By combining optical design principles and origami, we present here a new platform for the cost-effective, large-scale production of flat panel microscopes. Fold Scope is an origami-based optical microscope that he can assemble in less than 10 minutes from flat sheets of paper. [2]

Fold Scope Paper microscopes allow everyone to explore and understand the world of microorganisms and living things. In this review, we have listed foldable research projects in different fields and their main features compared to traditional research microscopes .Additionally, we briefly explored the impact of folding microscopes on public health, clinical diagnostics, forensics, agriculture, basic science, developmental biology, and education. Additionally, this review will also discuss the main drawbacks of paper microscopes and current steps to upgrade the Fold scope and its features. Ultimately, we concluded the view that microscopes can be upgraded to mimic advances in traditional microscopy [1]. A fold scope is an optical microscope that can be assembled with simple parts: paper and a lens. The Fold Scope is a very affordable origami-style paper microscope .This is a portable, durable, and versatile microscope made primarily of waterproof paper that magnifies the wonders of the microscopic world without the space and expense of traditional research microscopes .Fold Scope aims to put science laboratory microscopes into the hands of people around the world. This is a real microscope with sufficient magnification and resolution to image living individual cells, organelles, embryos, swimming bacteria and more. It's affordable so you can use it anywhere. It brings science to everyday life. It is part of the Frugal Science Movement, which aims to make cheap and easy tools available for scientific use in developing countries [4]

Illustration no .1

Idea of Fold scope

In 2011, Manu Prakash, an assistant professor of bioengineering, first crystallized the idea of a "fold scope" while traveling in Thailand, noting that several remote clinics were equipped with state-of-the-art microscopes. I was surprised to see it. But I've never touched it with my finger. The estimated price of the tools was so high that everyone was afraid to touch them. After years of trial and error, he came up with "Fold Scope." Developed in 2014 by Stanford University's Manu Prakash and his student Jim Cybulski, FoldScope offers more than 2000x magnification with submicron resolution, weighs 8.8 grams, and fits in your pocket. (70 x 20 x 2 mm) and can be used for a long time with battery power. Up to 50 hours.It's a single coin-cell battery that's durable enough to withstand a fall from a three-story building and the trampling of the boot of a crazy, curious botanist.The best part is that it is a real microscope that costs around 300 INR (900-1000 for high magnification) and can be easily assembled within 10 minutes.(3)

History

The history of the fold scope began in 2012 with Manu. Prakash, a biophysicist at Stanford University, set out to develop an inexpensive, portable microscope that anyone could easily assemble. Prakash was motivated by his experience in India, where he saw how the lack of access to high-quality microscopes hampered scientific research and education. Prakash and his team experimented with different materials and designs before settling on his current design, which consists of his single sheet of paper folded into the shape of a microscope. The fold rifle scope includes a glass bead lens, an LED light source, and a battery-powered stage, all mounted on a paper structure. The first version of his Fold His Rifle Scope was introduced in 2014 and quickly gained attention due to its innovative design and potential impact. The Fold Rifle Scope was praised for its simplicity, durability, and low cost, earning it numerous awards and honors, including his $100,000 grant from the Gates Foundation.[2]

The first prototype of a fold rifle scope was created and fully fabricated using origami techniques. A lens and LED light source are embedded in the middle of the paper .The team tested the prototype on a variety of samples and found that it could produce high-quality images comparable to traditional microscopes. After further development and refinement, the Fold rifle scope was released for general distribution in 2014. Its low cost and ease of use make it a popular tool in educational programs, scientific research, and public health efforts around the world. Since its initial release, the folding oscilloscope has received several updates and improvements, including the addition of a smart phone adapter for capturing images and video, and various upgrades to its imaging capabilities. (5)

Defination

The folding oscilloscope started out as a simple product. Ideas to Solve the Problem However, scientific accessibility efforts are now evolving to provide portable, durable, and low-cost microscopes to communities around the world

.which functions similarly to a research microscope). A fold scope is a simple and effective tool consisting of a sheet of polymer (plastic) coated paper, a lens (2000 lenses), and a magnetic coupler, and is assembled according to the instructions provided in the DIY guidelines. Easy to use. Assembleable (multiple cardboard elements folded as needed to make it waterproof, tear-resistant and affordable (1)

Parts of Fold scope

The Fold Scope is a microscope with the following dimension

- Magnification: 140X
- Resolution: ~2 microns
- Rear focal length: ~0.5 mm
- Depth of field: ~ 0.01 mm
- Field of view: ~0.5 mm (diagonal radius)[10]

A folding telescope consists of a paper component, a magnetic component, and a lens.

- Paper components are made from synthetic materials that are waterproof, tear-resistant, and cost-effective.
- Magnetic components are used to align/properly position optical components and easily attach devices for display and projection on phones.
- The lens is a sphere of borosilicate glass embedded in a circular piece of black plastic.[10]

The Front View

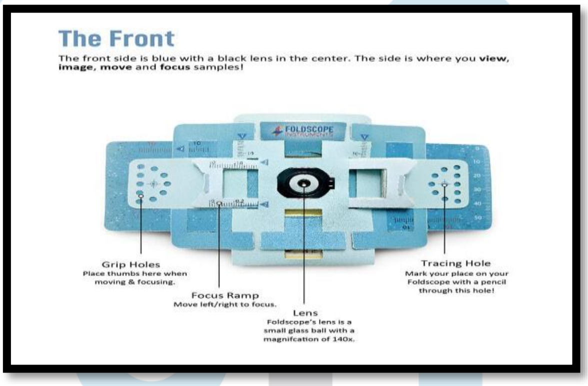


Illustration no 3

1. Grip Hole

Handle Holes Folding Endoscope Handle Holes are two small circular holes on each side of the microscope body that serve as handles for holding and manipulating the device. The grip holes are positioned to allow the user to easily and stably hold the Fold scope while adjusting focus or moving the stage bracket. It also makes it easier to carry the Fold scope and position it over different types of samples. (6)

2. Focus Ramp

Focus Lamp The focus lamp is a unique feature of the fold scope that allows you to easily adjust the magnification and focus of the microscope. The lamp is a small piece of paper attached to the plastic lens and runs the entire length of the fold scope body. By moving the lamp up and down, you can adjust the distance between the lens and the sample and change the magnification and focus of the imag e.The focus lamp has a scale with magnification values ranging from 1x to 140x. This allows users to easily track magnification and focus settings and adjust as needed to observe different types of specimens.[7]

3. lens

Fold the paper body of the scope. The lens is the main component responsible for magnifying the sample being viewed, allowing the user to see minute details and structures that are invisible to the naked eye. Folding scope lenses are designed to be very small and lightweight, making them easier to handle and reducing the overall cost of the microscope. Despite its small size, this objective can produce up to 140x magnification, allowing high-resolution imaging of small samples. [8]

4. Tracing hole

Tracing Hole Tracing Hole is a small feature on the Fold oscilloscope that allows the user to project an image onto a surface for tracing or drawing. This hole is located on the side of the body of the Fold oscilloscope and is aligned with the lens so that when the hole is placed against the lens he can project the image seen through the Fold oscilloscope onto the surface [7].

The back view

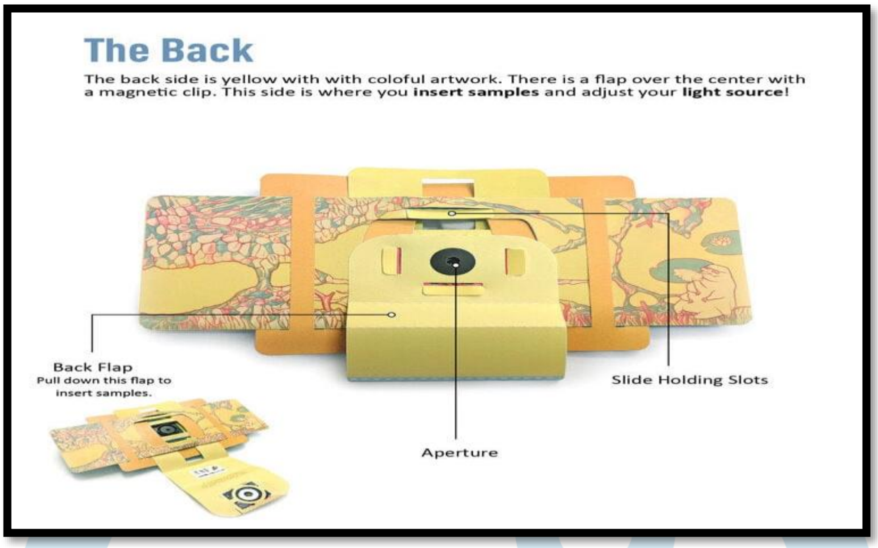


Illustration no 4

1.Back Flap

Back Cover The back cover is a small part of the Fold scope that performs several important functions. This is a small piece of paper located on the opposite side of the lens of the Fold rifle scope housing. The rear flap is designed to fold outward, providing a surface for the user to place specimens or samples for observation. When folded, the rear door also acts as a support for the Fold scope, helping to keep it stable and upright during use. This is especially useful when using Folds Cope in the field or in unstable environments where it is difficult to keep the microscope stable. In addition to serving as a support surface, the back flap has a printed reference scale for measuring the size of the sample or structure being observed. These scales are adjusted to the Fold scope's magnification settings, allowing users to quickly and easily determine the size of the sample being viewed.[9]

2.Aperature

Aperture The aperture is an important component of a fold rifle scope because it determines the amount and direction of light reaching the lens, influencing the quality and sharpness of the final image produced . The fold rifle scope's aperture is small and precisely designed to reduce flare and increase contrast for clearer, more detailed images. In addition to the role of illumination, the aperture of a folding riflescope also serves to focus the image .By adjusting the lens position and aperture of a fold rifle scope, users can fine-tune the focus of the image, allowing them to see more clearly and in detail.[8]

3.Slide holding slot

Slide Retention Slot The slide retention slot is a small feature on a folding endoscope that allows the user to hold the slide securely in place during viewing. The slot is located on the side of his Fold endoscope body and is designed to accommodate standard-sized microscope slides [7]

Sample and Slide

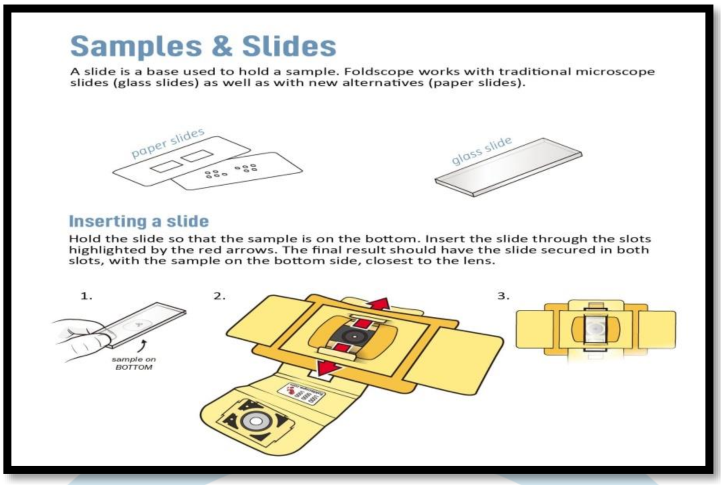


Illustration no 5

How to use

Fold Scope can be used in 3 easy steps.

- The first step is to assemble the Fold Scope unit by assembling the various parts from the flat sheets included in the Fold Scope kit.
- The second step is to collect and process the sample.
- The third captures images of objects using a smart phone connected to the Foldscope via magnetic coupling [11].

Viewing Methods of Fold scope

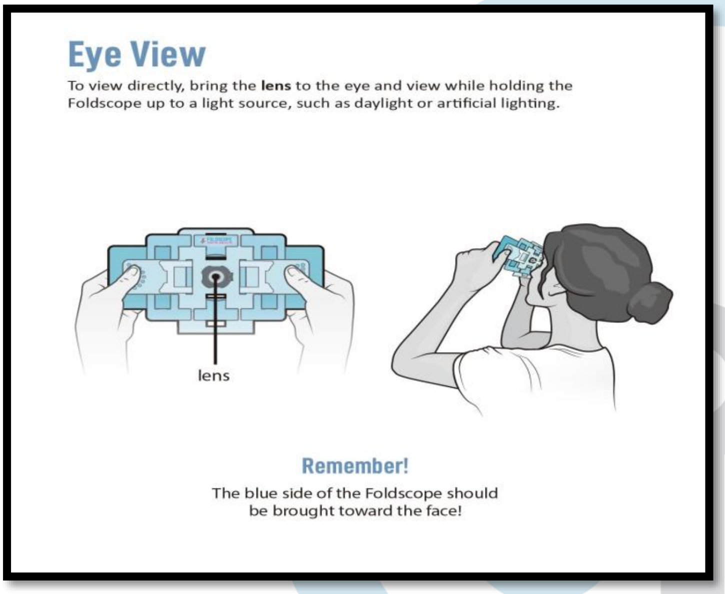
Fold Scope has 3 Possible Viewing Methods

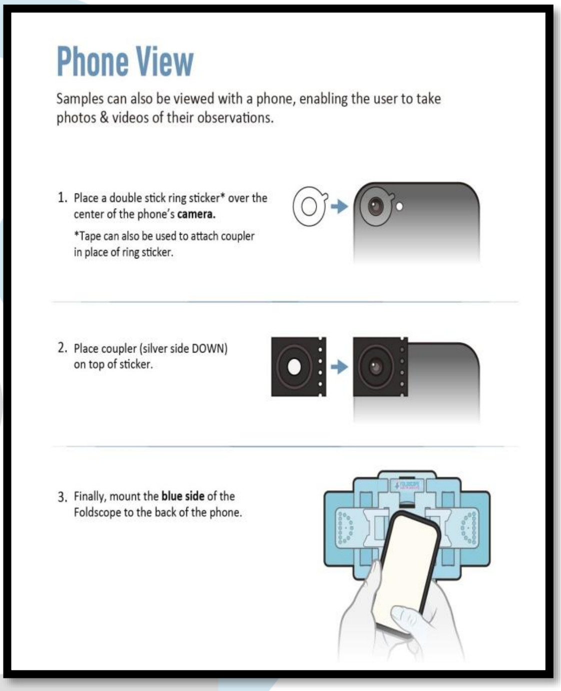
- Eye
- Phone
- Projection

Eye Method **Phone view**

Illustration no 8 Illustration no 9

Projection Method





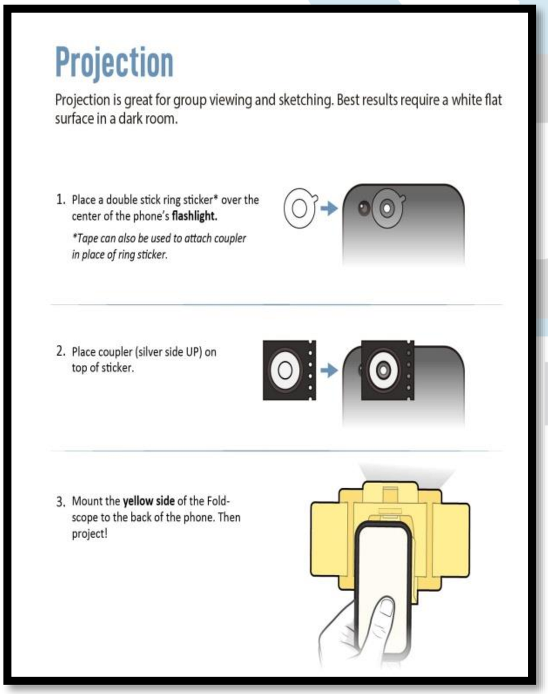


Illustration no 10

Unique Feature

The Fold Scope Origami based mini microscope has the following features:

- Assembles in 10-15 minutes from waterproof flat paper with puzzle pieces.
- Because it is small, it is safe and will not be damaged even if it falls from a high-rise building or is stepped on.
- Portable – Small enough to fit easily in your bag.
- No external power required for lighting.
- Can be viewed directly with the eye or projected onto a screen.
- Can be paired with a mobile phone to take photos.
- Can be used in bright field, fluorescence, or projection microscopy [11].

Benefits

Advantages of Using a Folding Paper Microscope Researchers working in this field are used to carrying their equipment around, but traditional microscopes are heavy, complex, expensive, and fragile. It does not tolerate moisture very well, and field conditions are difficult for traditional glass slides and lenses. Also, many older microscopes were only useful if you powered the built-in light.

In 2011, Manu Prakash of Stanford University traveled to Thailand and observed clinics that had microscopes but never used them. Scopes were so expensive that no one wanted to touch them. He realized the absurdity of shutting down scientific equipment because of cost and came up with a better solution. Fold scope, a foldable paper microscope, was born in Prakash's lab at Stanford University. Since then, thousands of Folds and Coopers have joined Microcosmos, a community of curious and adventurous Folds and Oscilloscope users who love to share their discoveries .These fold-his scope users, from the youngest school children to grandparents, know the benefits of using a foldable paper microscope.

1. Cost

folding rifle scope is inexpensive .They cost about $1.75 each to make. They require very little maintenance and can be easily and inexpensively replaced. Fold Scope's mission is to make science and STEM education equitable and accessible to all. By making a microscope out of (water-resistant) paper, this mission becomes a reality.[10]

2. Portability

The portable microscope fits in any pocket. You don't need a fancy, heavy case, and you don't need electricity to use the case effectively. Exploration becomes easier and more exciting when discoveries can be verified on the fly. Also, let your curiosity explode when you see something interesting that you need to investigate further. [10]

3. Compatibility

The folding scope is designed to work independently, but can be connected to a mobile phone to add magnification and share images to a database. The designers of the Fold Scope wanted to avoid the need for users to purchase additional expensive equipment to operate the microscope. However, they realized that compatibility with smartphones could improve the experience of using this inexpensive device [10].

4. Everyone can have their own

His Schools with limited resources often required students to share microscopes. The crease part is not included. These paper microscopes are so inexpensive that every student can have one of their own. This way you can start exploring and observing right away without having to wait in line. You can then share and compare your observations with your classmates. You can also participate in Fold Scope Microsomes individually or as a whole class to share your discoveries and learn more about what others have discovered.

The benefits of using the foldable paper microscope become clear once you receive and assemble it. If you can't wait to pursue your scientific curiosity, order a pre-assembled fold rifle scope and start using it right away. [10]

Application

1. Health Sciences

- ♦ Used for quantifying bacteria in food samples.
- ♦ Identify foodborne bacterial pathogens in street food.
- ♦ A method for rapid identification of microorganisms in wastewater.[1]

2. Clinical Diagnosis

- ♦ Diagnosis of dental plaque and urinary tract infections
- ♦ Testing for early stage cancer-causing cells.
- ♦ Early detection of cervical cancer.
- ♦ Inspection of histopathological analysis.
- ♦ Diagnosis of pulmonary infections and dermatophyte diseases.
- ♦ To detect biofilm-forming bacteria.

- ♦ To detect infections in fish in freshwater.
- ♦ Diagnosis of malaria, schistosomiasis and soil-transmitted helminthiasis in remote areasStudy crystal structures. [1]

3. Forensic Medicine

- ♦ Crime Analysis
- ♦ Scene observation and examination of evidence such as blood and hair [1]

4. Agriculture

- ♦ Identification of phyllosphere microorganisms
- ♦ Study of spore quality
- ♦ Identification of fungal infections in agricultural crops.
- ♦ Field testing of various plant samples for pollen, stomata and seed viability.
- ♦ For epidemiological research.
- ♦ Investigate hygienic animal husbandry.
- ♦ For gardeners to identify microorganisms on plants. [1]

5. Developmental Biology

- ♦ Used to study behavioral stages of zebrafish embryos and toxicity studies.
- ♦ Earthworm regeneration research. [1]

6. Education

- ♦ Breaks down barriers in biology classes and helps you learn independently. [1]

7. Biodiversity

- ♦ Provide taxonomic information about crops, microorganisms, and insects
- ♦ Identify antioxidant enzymes and secondary metabolites in exotic plant species
- ♦ Study the medicinal properties of native species . [1]

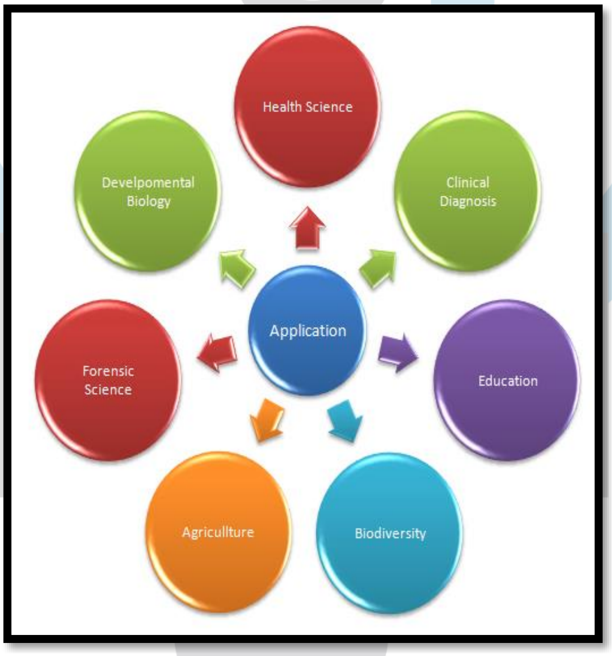


Illustration no 11

Measuring blood cells using Fold-Scope on your smart phone:

Blood is a special body fluid .It is made up of four main components: 4,444 plasma, red blood cells, white blood cells, and platelets.

Blood has various functions such as:

- Transports oxygen and nutrients to the lungs and tissues
- Forms blood clots to prevent excessive blood loss
- Transports cells and antibodies that fight infections
- Transports waste products to the kidneys and liver Blood Filter and Purify
- Regulate Body Temperature

The blood that flows through your veins, arteries, and capillaries is called whole blood and is a mixture of about 55 percent plasma and 45 percent blood cells. Approximately 7 to 8 percent of your total body weight is blood. An average-sized man has about 12 liters of blood in his body, and an average-sized woman has about 9 liters of blood in his body.

Red blood cells (also called red blood cells or red blood cells)

Red blood cells, known for their bright red color, are the most abundant cells in the blood, accounting for approximately 40 to 45 percent of the blood volume.The shape of a red blood cell is a biconcave disk with a flattened center.That is, the disk has a shallow, bowl-shaped depression on each side (red blood cells look like donuts).

Red blood cell production is controlled by erythropoietin, a hormone produced primarily in the kidneys. Red blood cells begin as immature cells in the bone marrow and are released into the bloodstream after approximately seven days of maturation. Unlike many other cells, red blood cells do not have a nucleus and can easily change shape to fit different blood vessels in the body.The lack of a nucleus makes red blood cells more flexible, but limits the cell's lifespan, damages the cell membrane, and depletes its energy reserves when moving through the smallest blood vessels.On average, red blood cells only live for 120 days

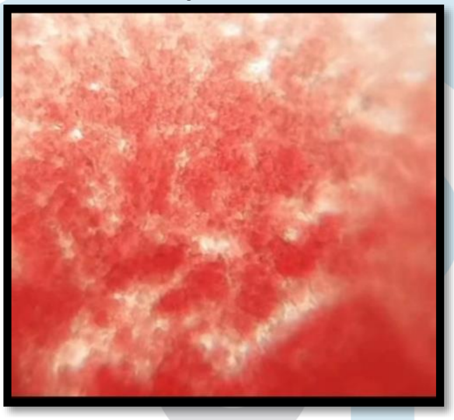


Illustration no.12

White blood cells (also called white blood cells)

White blood cells protect the body from infections. Their number is much lower than the number of red blood cells, making up about 1% of the blood.

The most common type of white blood cell is the neutron phil, an "immediate response" cell that makes up 55 to 70 percent of all white blood cells. Because each neutron phil has a lifespan of less than one day, the bone marrow must continually generate new neutronphills to maintain protection against infection. Neutrophil transfusions are generally ineffective because neutronphills do not remain in the body long.

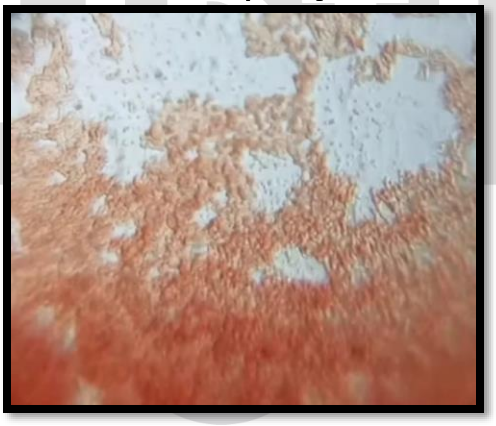


Illustration no 13

Chromosome

protein present in blood. In the presence of active thrombin, it is transformed into thin thread-like structures forming a network.

A chromosome is a DNA package that contains some or all of an organism's genetic material.

In most chromosomes, long, thin DNA fibers are covered with nucleosomes that form the packaging layer.

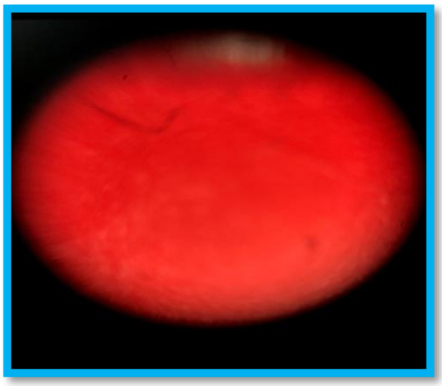


Illustration no.14

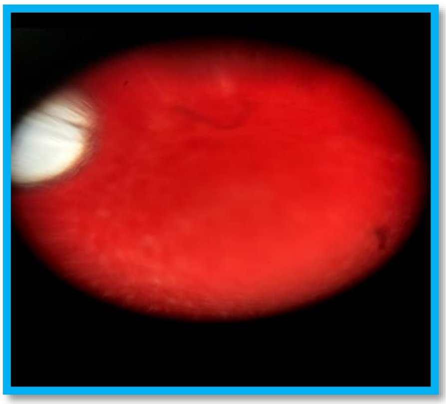


Illustration no 15

Conclusion

In summary, the Fold endoscope is a low-cost, portable, and easy-to-use microscope developed in 2014 by a research team at Stanford University. The device consists of paper, a magnet, and a lens. Assembles in minutes. The Fold scope has up to 140x magnification and can be used to examine a wide range of samples, including cells, tissues, and pathogens, as well as rocks, textiles, and electronic components.

This report details the history, design, performance, and applications of the Fold series. We have discussed the origin of the fold rifle scope, the material and construction of the device, its technical specifications and performance. We also provided an overview of the various fields and applications where Fold riflescopes are used, including biomedical research, education, agriculture, environmental monitoring, and more.

In my view, folding endoscopes are an important innovation in the field of microscopy because they address the issue of availability and affordability of scientific tools. The Fold oscilloscope makes microscopy accessible to a wide range of users, including students, researchers, and healthcare professionals in low-resource settings by providing a cost-effective and easy-to-use microscope. The potential impact is significant, as Fold scopes are already used in a wide range of applications in a variety of fields and could revolutionize the way we approach scientific research, education, and innovation.

Overall, the fold region represents an important step forward in the democratization of science and technology, and its impact is likely to continue to grow in the coming years. Fold Space has also helped advance science education and citizen science initiatives.

it's low cost and ease of use make it an ideal tool for classroom demonstrations and student projects, and is used in educational programs around the world. The Fold Scope team has also driven citizen science initiatives such as the Global Micro lens Project, which crowd sources the collection and analysis of microbial samples from around the world.

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