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National Geographic: The Invisible World

By Alex Pomansanof

Though remarkably sensitive and
accurate
the human eye is an extremely limited
device a surprisingly
narrow window on our world
In the fragile film of a soap
bubble lies a normally
unseen realm a miniature liquid
kaleidoscope
too small for our eyes to see
Vivid detail is also hidden within
an instant of time
Many events are simply too fast to
be seen with the unaided eye
When time is compressed
once motionless sights magically
come to life
A voracious army of fire ants
devours a helpless cricket
It is an awesome
day long process too slow
for us to notice
Beyond the spectrum of visible
light lie strange
and extraordinary sights images
created with forms of energy
which elude the naked eye
Today, as never before
cameras and other instruments
that see are radically expanding the
of our vision and knowledge
and altering forever our image
of the world
Join us now on a visual journey beyond
the limits of the naked eye
on a voyage into "The Invisible World"
We are visual creatures
reliant on our eyes as our primary
link with the world
Able at a glance to estimate size
measure depth, register movement
make sudden shifts in focus
and instantly distinguish s million
different colors,

our eyes are the most highly developed
of all living species
Yet, despite our eyes' amazing powers
and remarkable versatility
there are infinite sights around
us to
which we are totally blind
If our vision is expanded beyond
its normal bounds
a whole new world of experience
suddenly unfolds
Through the specialized eyes of
cameras come new dimensions of seeing
Fleeting movement hidden by time...
details shrouded by distance
and size
are revealed as vivid images
which our eyes alone could
never discern
The camera must often come to the aid
of our blinkered sense of sight
What thousands of eyes have
witnessed firsthand
we must rely on a camera to
actually see
Possessed with powers to reveal
the world in myriad ways
that our unaided eyes cannot
cameras and other imaging tools are
extending enormously the limited
reach of our vision probing
once distant
and unimagined realms that lie hidden
all around us
We delight in exploring the world
we can see
But even up close
our eyes can barely resolve objects
that are one three hundredths of
an inch in diameter a fraction
the size of a tiny grain of sand
What seems very small in human scale is
but the threshold of a microcosm
beyond the limits of our eyes

In a tiny drop of water
a bounty of life too small to see
Like spaceships from an alien world
delicate creatures called plankton
silently maneuver
through their seemingly
boundless universe
Completely unknown until the invention
of the microscope some 400 years ago
the discovery of plankton and other
microlife provoked unparalleled wonder
When seen for the first time
it was difficult to believe
that living things could be so
small-that a single
drop of water could contain
a miniature world
Indispensable tools of science
modern microscopes fitted
with cameras can now easily
recapture the sights
that were seen when man first
glimpsed the microworld
Bacteria. Discovered in 1674
their tiny size and great abundance
seemed nearly inconceivable
A slice of leaf revealed a complex
structure of tiny living cells
which no one had dreamed existed
Blood was seen to be composed of
millions of free-floating corpuscles
The sight of a cell dividing
seemed a miracle
of nature-another astounding discovery
which would help to lay the foundations
of modern biology and medicine
With a microscope that filters
the direction of incoming light
the composition of the physical
world can be vividly explored
When a liquid transforms into
a solid-as
when water turns to ice-the
tiny crystals

that will form its structure
organize into shape
Recorded on film at actual speed
we can witness the other invisible
process known as crystallization
Seeing with a beam of electrons
rather than with light
a powerful new instrument called
the scanning electron microscope
has penetrated an uncharged level
of detail and size
For David Scharf, a researcher
and photographer
it is a means to explore a whole
new world of inner space
Though we seem to be leaving some
distant planet's surface
our voyage, in fact, is much
more contained
The cratered terrain we have left
behind is the surface of a moon rock
the size of a grain of sand
The fragile structure of an alyssum
flower is barely visible to the eye
In the vacuum chamber of
the microscope
a focused beam of electrons
will be aimed
across the flower's surface to
form a magnified image
Zap
Through the microscope's probing eye
the tiny flower reveals a delicate
structure of unexpected complexity
When magnified more than 20,000 times
we can see single grains of pollen
If we spy a little closer on the
intimate places we know
we might come to feel like strangers
in our own familiar world
Zigzags of rough-hewn channels
gouged into a surface
are a magnified view of
the narrow grooves

in an ordinary phonograph record
This barren, rutted terrain is not
as remote as it seems
It is the porous surface of the
tip of a ball-point pen
A tangled network of sinuous fibers
when enlarged 4,000 times
hardly resembles what we usually see
as a smooth sheet of writing paper
In the sofas and beds of even our
best kept homes
microscopic dust mites quietly
live their lives
Like miniature dinosaurs from
a long lost world
their bodies rarely grow large
enough for the naked eye to see
Dependent on us for survival
dust mites feed primarily
on the flakes of dead
which our bodies constantly shed
What at first sight appears to
be a crude medieval machine
is actually a precision instrument
nearly all of us depend on
Its roughly chiseled surface offers
little clue
that this clumsy contraption is
actually the complex movement of
an ordinary wristwatch
Our skin itself hides a miniature world
from the normal view of our eyes
When seen at high magnification
an alien landscape appears
Stubbles of hair grow like tree
stumps in a terrain
whose complex ecology supports
a wide variety of life
On almost any strand of hair
tiny fungi can be found
In numerous forms, their population
on our hair
and skin numbers in the tens
of thousands

Our intimate fellow travelers
fungi have lived with us through
evolution
to establish a permanent niche
in the habitat of our skin
In the roots of everyone's eyelashes
live tiny mites
called Demodex folliculorum
Apparently they cause us no harm
But why they are there and exactly
what they do have yet to be discovered
The varied micro-landscapes on the
surface of our bodies
also fall prey to less
desirable guests
Meet Pediculus humanus capitis
the head louse a tiny
and bothersome pest
which lives its life firmly attached
to a single strand of hair
Sarcoptes scabiei, the scabies mite
is a microscopic creature that makes
a comfortable home
by burrowing directly into the skin
On the warm, moist regions
of our skin
there is life in enormous abundance
Bacteria the simplest form of
free living life-are constantly with us
A single bacterium can multiply to
more than a million in about
eight hours
and mo matter how much we wash
millions remain on our skin
Each of us is the keeper of a huge
invisible zoo
In fact, at any given time
there are as many creatures
on our bodies
as there are people on Earth
If our numerous companions do
not inspire our love
at least we have the consolation
of knowing

that we are never completely alone
At the Enrico Fermi Institute of
the University of Chicago
a new frontier of the microworld
has recently been bridged
Using a powerful electron microscope
which took 14 years to develop
Dr. Albert Crewe has captured
on film
what no one had ever seen
You are looking at atoms-uranium atoms
The smaller single specks are
individual atoms
each with a diameter of only a
few billionths of an inch
The larger masses are clusters
of several atoms
Colorized artificially to enhance
our view
atoms exhibit unpredicted movement
revealing that solid objects
when seen on an atomic scale
are actually a sea of moving particles
The level of magnification
of the movies
on the home TV screen is
about ten million,
maybe 20 million, depending on
the size of your TV set
That's about the equivalent to blowing
a basketball up
to the size of the Earth
The ability to see single atoms
to isolate them at that
could have considerable importance
Where it will lead is very
difficult to
except what we have is
a new technology
a new way of looking at
materials in the world
And every time you have a new way
of looking at things
you find out something new

We are exiled from other worlds
by time as well as by size
In a world of motion
there is infinite detail too fast
for the unaided eye
In the 1870s an ingenious photographer
Eadweard Muybridge
invented a way to record movements
normally too quick to be seen
A wager about the stride of
a running horse
brought Muybridge to the stock farm
of a wealthy Californian
With a battery of 24 cameras
that were activated by threads
stretched across a track
Muybridge captured aspects of motion
that had never been witnessed before
Muybridge's patron had bet that all
four legs of a running horse
were sometimes simultaneously
off the ground
Stop-action photography proved him
to be right
By projecting his photographs in
rapid succession
the first motion pictures were born
The movement of people as well
as animals became
for Muybridge a passionate
subject of study
Much more than just a
technical curiosity
Muybridge's pioneering work was the
first photographic analysis
of the dynamics of physical motion
Today, modern high-speed cameras
can record rapid motion
with a clarity that Eadweard Muybridge
could only have dreamed of
Slow-motion film is now
a commonplace tool
in analyzing athletic performance
For Dr. Gideon Ariel

a physical education expert
and a former discus thrower on the
Israeli Olympic team
slow-motion film is just the first
in the scientific coaching
of athletes
Dr. Ariel has turned to the computer
for aid in the analysis of movement
Slow-motion film of an athlete
is projected frame
by frame onto a recording screen
Each touch of a sonic pen transmits
into the computer memory
the dynamically changing positions
of the athlete's joints and limbs
Human movement is governed by
the same laws of motion
that apply to the entire
physical world
And from the visual information
contained in the film
the computer can rapidly calculate
the interrelationship of force
acceleration, and velocity in the
athlete's movements
Computer-created images combined
with a mass of numerical data
can pinpoint
where athletic technique
is hindering performance
So, what coaches in the past thought
they can see with eyes
we are finding out you can not do
You have to quantify.
With the advent of computers
we can provide the coaches
with much more objective
reliable information on how
the body moves
Dr. Ariel's computer analysis
of Olympic discus
thrower Mac Wilkins revealed
that useful energy which would
effect his throw

was being wasted on ground friction
Additional force was being spent
by not rigidly planting his forward
leg at the moment of the throw
Based on this analysis
Wilkins altered his
throwing technique
Several months later
in international competition
he threw the discus over 13 feet
farther than he ever had before
and set a new world record
In a remarkable laboratory at the
Massachusetts Institute of Technology
time and motion are
dramatically dissected
With the aid of a pulsating
strobe light
Dr. Harold Edgerton can freeze a flurry
of movement onto a single plate of film
Dr. Edgerton developed the strobe
light in 1931
Unable to see how electric
motors behaved
when they rotated at various speeds
he designed a light which
could flash so quickly
and brightly that motion seemed
to stop
Now we're going to do an experiment
here to take a picture of a
bullet-a very high-velocity bullet
as it cuts this playing card in two
The playing card will be attached
to this tape
The bullet will come out of the
gun at 2,800 feet per second
If we aim it correctly
it'll cut through the card
And we want to turn on a light
a very special strobe light
that lasts less
than a millionth of a second
in order to stop the bullet

effectively on film
and make a sharp, clear photograph
The sound of the bullet will trigger
the strobe light
which creates an image on film
A first shot will
test Dr. Edgerton's aim
Here we go
Now, the event as the strobe
light reveals it
Less than a millionth of a second
is permanently frozen in time
Another striking example of the
strobe's revealing power is
what Edgerton calls "making applesauce"
Perhaps the most dramatic of
Dr. Edgerton's visual techniques
combines the powerful strobe light
with a high-speed
motion-picture camera
There you go. All set?
Three, two, one, two
Stretching events thousands of times
reveals invisible detail
that can be seen and studied
in no other way
The explosion of a firecracker
now slowed down 1,200 times
Examine the "plop" of a milkdrop
and it becomes a magical vision of
hydrodynamic behavior
Unbounded by our human sense of time
specialized cameras can also record
events much too slow to see
For nature cinematographer
Ken Middleham
the technique of time-lapse
photography
provides a fascinating window
on an otherwise hidden realm
By taking single photographs at longer
than normal intervals
time and events are compressed
into a dramatic new scale

The two weeks it takes for
an orange to spoil
are telescoped into several seconds
A bunch of unripened bananas mature
before our eyes
The natural world is alive in ways
we cannot see-constantly in the
process of incredible transformation
Over a period of days
tiny worms devour the leaf of a tree
An apple provides a week-long meal
for dozens of hungry grubs
In only four days a dead field
mouse is consumed
by a mass of maggots
From the unstoppable process of decay
there inevitably springs new life
in full and beautiful abundance
Even the passage of years is not
a barrier
for the time-lapse camera
In less than half a minute
a boy can grow from four to 20
and then return again to childhood
Our eyes perceive the world
only in the language of light
Yet light, visible light
is but a narrow slice of
energy contained
within an infinite spectrum of
electromagnetic waves
that constantly vibrate
all around us
When scientists analyze light
breaking it apart into its
component wavelengths
the familiar rainbow of colors
from red to violet appears
Colors are the brain's code
for the wavelengths of light
we can see
Beyond this band of energy
our naked eyes go blind
The world around us hides

numerous sights
from our limited
light-sensitive eyes
By equipping a camera with
a sensitive filter
we can see the world reflected
in ultraviolet
light-the invisible wavelengths
of energy beyond the color
In the 1930s, scientists discovered
that honeybees have
a visual sensitivity
that extends beyond our own
On its daily search for nectar
the bee can sense its surroundings
in ultraviolet light
Some flowers we see
as solidly colored
have a very different
appearance to the bee
When viewed in ultraviolet light
new shadings and patterns appear
Helping to guide the bee
to nectar and pollen
ultraviolet markings
hidden from our eyes
have been discovered
on numerous flowers
Unseen ultraviolet rays stream
abundantly from the sun
but they are only one kind of
invisible light
that we must rely on cameras to reveal
We see the light of a burning match
but an image of its heat eludes us
If our eyes could see the part of
the spectrum
where red light turns to
infrared or heat
our view of the world would suddenly
take on a new and expanded scope
A technique called
schlieren photography
allows us to see heat energy

that constantly flows all around us
A valuable new tool in medicine
super-sensitive infrared cameras
can detect slight variations
in skin temperature
which often signal early warnings
of cancerous tumors and other diseases
Each color represents a one-half
degree difference in temperature
Red areas are the warmest
blue the coolest
To a doctor's trained eye
the body's varied heat patterns
show a wealth
of vital diagnostic information
once hidden from his view
By photographing a subject
with visible light
only the outer surface details are
recorded by the camera
Using another form of energy
invisible to the eye
we can penetrate solid matter
and create an image on film
Discovered in 1895
x-rays were briefly considered
by some to be a threat to
feminine modesty
However, fears were allayed at
first sight of the image
and the x-ray was quickly put to use
as a valuable new tool of medicine
Today, the power of the x-ray
is expanding our knowledge
of the past
When fragile Egyptian mummies are
subjected to modern x-ray analysis
scientists gain new insight into
their little-known culture and lives
What time and wrappings have hidden
x-rays can still reveal
X-rays of Yuya, a royal adviser
show obvious dental disease
Thuya, his wife, suffered painfully

from arthritis and a badly curved spine
The infant Pediamon received a less
than noble burial
His arms were amputated and his legs
were broken to fit an undersized coffin
For an unidentified mummy
a less desirable fate
Legs are intact
but the torso is
mysteriously missing
Pharaoh Amenhotep I
X-raying directly through his
beautifully preserved coffin reveals
that his body had been damaged
by ancient grave robbers
and repaired by priests
five centuries later
Perhaps no pharaoh is better known
that the young king Tutankhamun
Penetrating rays show that
his golden mask
was constructed in several parts
He beard was added last
attached to the chin by
a tapered peg
The body of King Tut itself has
undergone careful analysis
in hopes of finding evidence as to
the cause of the young pharaoh's death
X-rays, however, show a young man
in good health
And unless there is evidence still
to be discovered
the reason for Tut's early death
may remain forever a mystery
Sound, like light, or heat, or x-rays
radiates all around us in the form
of vibrating waves
This image of a human hand was made
with high-frequency sound
Using this technique
doctors can now see soft
internal tissue
that was not safely

accessible before
Sensitive sound-imaging cameras
are today
revolutionizing prenatal care
Okay, I'm just going to
get one quick look
A tiny developing fetus can be seen
and monitored during growth
in the womb
Seen here in profile
its head on the top right
the fetus arches its back
and stretches
It hiccups... then moves its arm
and slightly turns its head
The baby's now sort of turned around
and it's looking at us to see
what we're doing
I can take a picture of the baby
for you
I'll put this freeze frame
which freezes the image for us
Today, a mother's first baby picture
is often made
with sound before the child is born
Pretty good
See there the baby's head
And everything else looks fine
The baby's moving around a lot
The baby's heart is beating fine
and you have a normal amount of
amniotic fluid for this time
Who's it look like? You or Brad
I think it looks like me
A striking means of
photography discovered
at the turn of the century
shows apparent fields
of energy emanating from our bodies
It is known as Kirlian or
electrophotography
and almost everything filmed
with this technique shows an
active surrounding aura

Controversial and only
partially understood
Kirlian photography is now
undergoing serious investigation
as a possible diagnostic tool
To make a Kirlian photograph
a finger is placed over a sheet
of unexposed film
which receives a burst of electricity
from a metal plate beneath it
When the film is developed
the Kirlian aura appears
Dr. Thelma Moss has conducted research
on Kirlian photography at UCLA
People are always asking
"What is this Kirlian
photography all about?"
And the answer is
"Nobody really knows."
But we've got some ideas
that are intriguing to us
because they are not the
conventional ideas
about what exists around
the human body
We believe that not only is
there air surrounding us
but that we are emanating
something from ourselves
that is energetic-bioenergetic
if you like-and that tells us
a great deal about
what is going on inside the body
Kirlian fingertip images taken over
several hours vary their intensity
as a depressant drug takes effect
A mild stimulating drug seems to
cause an activating pattern
These Kirlian photographs record
the sequence
of a woman's monthly menstrual cycle
A yogi's hands before
and then during a state
of deep concentration

Though powerfully evocative
the meaning and value of
the Kirlian image
still remains largely unknown
With further research it may prove
to be a new frontier of our knowledge
At the Fermi National Accelerator
Laboratory near Chicago
we are being brought ever closer
to an ultimate frontier
With huge, exotic equipment
scientists are working to better see
and understand the smallest
possible particles
of which all matter is made
Only 25 years ago, atoms
composed of protons
neutrons, and electrons
were regarded as the
smallest basic objects
Today it seems that atoms
are built of
even tinier things called quarks
Fermilab is, in a sense
the world's largest and
most powerful microscope-
an awesome collection of machinery
designed to shatter atoms to pieces
and see the objects within
Buried underground
a four-mile ring of powerful magnets
guides a narrow beam of particles
which is rapidly accelerated
When fired at their target
they will act like a powerful hammer
to break an atom apart
The process begins with
a giant generator
and a massive jolt of power
Hurled within seconds to nearly
the speed of light
the beam of particles is aimed to
strike the tiny nuclei of atoms
The collision will be photographed

by several sensitive cameras
When projected onto
an analyzing table
the resulting pictures show the
scattered tracks left
by hundreds of liberated
subatomic particles
Each type of particle has its own
distinguishing signature
of curving or spinning lines
By carefully recording and studying
these trails
we are gradually learning more
about the now smallest
and most elusive units of
matter the still
unseen entities called quarks
Quarks, however, may well be composed
of even smaller things
We still do not know where, or if ever
the world of the small will stop
High above the Sonoran Desert
near Tucson, Arizona
the Kitt Peak National Observatory
is focusing our vision
onto the realm of the very large
The world's biggest collection
of astronomical
Kitt Peak is dominated
by the 19-story dome of the powerful
Mayall telescope
Like most modern optical telescopes
it is really a colossal camera with
which to photograph the sky
Galaxies. Only 60 years ago their
existence was just a theory
But with the construction of larger
and larger telescopes
thousands were seen and photographed
Today astronomers estimate
that the universe contains at least
each with 100 billion stars
Powerful instruments like
the Mayall telescope

are now seeing the heavens
more clearly
than has ever been possible
Its light-collecting mirror can
photographically detect objects
more than six million times fainter
than the unaided eye can see
Astronomers today rarely
look through a telescope directly
An array of computers and image
intensifiers record
and make visible objects
that the eye alone is not sensitive
enough to see
Artificial colorizing shows
subtle details
that would otherwise be missed
Revealed on the telescope's computer
enhancement screen
the world's first image of the surface
of a star other than our sun
Known as Betelgeuse
it lies 600 light years from Earth
The computer-colorized contrasts
on its surface
are believed to be huge regions of
varying hot and cold
Resolving this image through the
telescope was like photographing
a grain of sand from several
miles away
Probing ever deeper into
the enormity of the sky
the powerful eye of the
telescope is extending
our horizons toward the limits
of space and time
From this exploration
new and astonishing sights
are offering
clues to such baffling questions as
What are stars?
How do galaxies form
Does the universe have an end

At the Salt Lake City campus of
the University of Utah
a frontier of vision that was once
as remote as the darkness
of outer space
has now been dramatically entered
Craig has been totally blind
for 15 years
But in a bold experiment
doctors have surgically implanted
on the visual cortex
of his brain an array of 64 tiny
electrodes
This ingenious feat of
medical engineering
allows Craig to be literally
"plugged in" to the outside world
Bypassing his useless eyes
and optic nerves
doctors can send images in the form
of electrical signals
directly to the visual center
of his brain
Okay, Craig, that's fine
For Craig, it is a strange
new contact
with his long lost sense of sight
When Craig was linked to a
television camera
he reported "seeing" both vertical
and horizontal lines
In this experiment
a computer system will
generate patterns
of dots representing the
braille alphabet
It is the same six-dot code
used in touch braille
The images that Craig sees will
appear something like this
Go. First word

I:
Okay, next word

Okay. "H", "A", "D", had
Next word
"A", "C", "A", "T", cat, "A", "N", "D"
Next word
And
Craig has little trouble "seeing"
the letters
that will form a sentence
but scientists are working toward
even more dramatic goals
I had a cat and ball
Researchers now foresee a day
when a miniaturized system-including
cameras for the eyes
electronics in the glasses
and electrodes on the
brain-will provide
artificial vision for the blind
In the time it takes to blink an eye
cameras can transport us to wondrous
new realms
Revealing once hidden places that span
from the reaches of outer space
to the inner depths of nature
the magic eyes of cameras are
dramatically transforming
our knowledge and perception
In coming years
our vision of the world will be
stretched to newer boundaries
For today we have only begun
to explore
the invisible worlds all around us