SEEING: A Photon's Journey Across Space and Mind – Final 11/16/2015

SCENE	VISUAL	AUDIO
1	Montage of beautiful images and sights	**NARRATOR** timecode: **00:17** Our universe is filled with beauty.
2	Introductory fly-through of the eye and brain (fast) Time-lapse of the night sky.	**NARRATOR** timecode: **00:49** All of this natural beauty would be unseen by our brains if not for events that happen tens of millions of kilometres away from our world. timecode: **00:59** To understand how we are able to see the world around us, we must first travel off this planet and into the core of a distant star.

3	Pull up shoot off the galactic plane Big bang animation Model of a hydrogen atom Animation of a collapsing cloud in a H II region in the galaxy Fly into a cloud to see a proto-planetary disk and protostar. Animation of a protostar and material fall onto the surface. Move down through the surface to the core – bright white with atoms bumping together then sped up and more violent to show the start of the fusion process.	**NARRATOR** timecode: **01:11** Stars are made up of the most abundant element in the universe – hydrogen. Hydrogen makes up 90% of the baryonic matter in the Universe. Baryonic matter is the stuff made up of atoms. timecode: **01:30** Hydrogen was formed as the result of the Big Bang. Each hydrogen atom consists of a proton orbited by a single electron. timecode: **01:41** When great amounts of hydrogen gas coalesce in the outer spiral arms of a galaxy, gravitational forces make the gas collapse to form interstellar clouds. timecode: **01:54** Denser areas in these clouds continue contracting and form protostars with proto-planetary disks - the beginnings of new star systems. timecode: **02:07** As Gravity continues to collapse the balls of gases, the density and temperature increase in the protostar cores. These conditions strip the atoms of their electrons allowing the protons to stick together when they collide – starting a process called fusion.

4	 Model of a helium atom with electrons in orbit. Animation of an electron being struck by a photon and jumping from the ground state to a higher orbit and returning while releasing a photon.	**NARRATOR** timecode: **02:59** A basic model of an atom shows an electron orbiting the nucleus like a planet orbits a star. The difference is that in principle, the planet can have any orbit, but an electron must jump between allowed orbits,, if it absorbs or emits the right amount of energy.

5	Elevator animation step by step Show cooler photons being released. Live action footage of Las Vegas that Robin still has to film…	**NARATOR** timecode: **03:22** To better understand this principle, imagine an electron riding on an elevator. The elevator is engaged upward when a photon strikes the electron, lifting it to a higher orbit. timecode: **03:38** Once the electron reaches the higher orbit it can fall back to the lowest "ground state" releasing a photon of light on the way down. timecode: **03:48** The electron can also make stops at lower orbits on its return, releasing photons of energy at each stop. timecode: **03:58** We see the released photons as colored light. High energy is seen as violets and blues, low energy as oranges and reds. timecode: **04:11** We can see this process on Earth when we see a neon light. Neon lights and other glowing tubes are filled with specific gasses to generate the desired color when excited with electricity.

6	Move from the core to the surface of the star and show photons streaming off the surface into space.	**Narrator** timecode: **04:28** Back in the star, the interaction of photons and electrons continue from the core outward to the surface over hundreds of thousands of years, until the energy contained in the photons reaches the star's surface. Once at the surface photons race away at the speed of light - 300,000 kilometers a second. timecode: **04:53** The photons will travel through the near-emptiness of space until they collide with another particle. Let's follow a photon on its journey across the galaxy.
7	Animation of M42 – highlight per the VO copy.	**Narrator** timecode: **05:08** Moving away from this star, our photon starts a journey that will take over 1,300 years to reach Earth and its final destination. timecode: **05:19** The star that generated the photon we are following belongs to a star cluster called the Trapezium, located in front of the Great Nebula in Orion. As we move away from the star we see the large nebula stretches 24 light years across – roughly 225 trillion kilometers!

	Animation of nebula interacting with high-energy photons.	timecode: **05:43** You see that the nebula displays many different colors. These colors are generated in several ways. timecode: **05:51** The red and blues that we see are hydrogen and oxygen electrons dropping down to their ground states after having been excited by the stars residing in the cloud. timecode: **06:03** The white areas are starlight reflected by the dust in the nebula. The photons that hit the dust particles are scattered in different directions depending upon the angle of incidence of each photon.
8	Fly through from M42 to Earth.	**NARRATOR** timecode: **06:19** Our photon is now moving across space, along with billions upon billions of other photons from the star and nebula. Their destination will be the beginning of another journey across a young stargazer's eye

		and mind.
9	Visual intermission of a tour of the galaxy.	**Music (Seeing theme)**
10	Approaching the solar system (animators note: make sure this motion is in the correct orientation from M42 to earth.)	**NARRATOR** timecode: **07:59** Our photon and his companions have survived the journey to our solar system without being absorbed or deflected by other particles. Their travel is about to end but there is one more hurdle for the photons to overcome – our atmosphere.
11	Animation of the upper atmosphere	**NARRATOR** timecode: **08:17** Up to this point the photon has been traveling through the near-emptiness of space, now it's about to pass through our dense atmosphere of air and moisture.

	Photo-animation of the night sky with stars twinkling.	timecode: **08:28** Here the photon and his companions will be jostled through a condition called refraction caused differing pockets of density in our atmosphere. Not all will make it without being scattered or absorbed. timecode: **08:44** This is where stars get their twinkle. Up to this point the photons have travelled a straight course. It's only when the photons hit the atmosphere that their paths get bend back and forth and we see it as twinkling stars.
12	Push in on our girl on the balcony Animation of the optical path of the telescope	**NARRATOR** timecode: **09:05** Our photon has survived its journey and is now entering into a telescope being used by a young lady who is observing the nebula in Orion. timecode: **09:18** The photon hits the glass of the lens and

	Light cone to the eye. Cut back to the girl looking up.	its course is bend several times by the telescope's lenses and those in the eyepiece until the photon and its companions are focused to a single point. timecode: **09:35** The photon's journey that has taken more than 1,300 years to this point is about to end. timecode: **09:42** Call it a special delivery from the galaxy when you consider all that the photon and its energy had to go through to get to this point in space and time.
13	POV animation of the photon crossing into the eye synched to the narration.	**NARRATOR** timecode: **09:58** The photon crosses the distance from the eyepiece to the front of the girl's eye – avoiding the blink of her eyelid. timecode: **10:11** The photon hits the outer surface of the eye called the cornea. The cornea is made up of special cells that create a transparent membrane. timecode: **10:22** The photon crosses through the cornea to the lens sack, which hold the crystalline lens.

		timecode: **10:29** This lens focuses the photon to the back of the eye but before it reaches that point it passes through a slimy transparent goo called the vitreous humour, which keeps the eyeball from collapsing under its own weight. timecode: **10:49** Let's stop at this point on the journey to look back at some structures of the eye we passed by. timecode: **10:56** Looking back along the path we see a large black circular diaphragm call the iris that opens and closes based on the amount of light that strikes the back of the eye. The iris forms our pupil – the porthole of our eye. timecode: **10:56**
	Animation of the iris opening and closing	We've all gone from a dark room to the bright outdoors and experienced temporary blindness as the iris closes to limit the amount of light that is allow to the back of the eye. That was our iris at work making sure the pupil was open to the correct size allowing enough light in to see but not blind us with it's brightness. In fact, the white of the eye, the sclera, is opaque so that the only light entering the eye is that through the pupil. timecode: **11:53**

	POV animation.	Passing through a few layers of tissue, we can see some special micro muscles called ciliary zonules, attached on one end to the ciliary muscles and on the other to a girdle around the crystalline lens. The zonules and the girdle work together to shape the lens to focus the light to a given point on the back wall of the eye. timecode: **12:20** As we age, the crystalline lens begins to harden and the girdle and zonules have difficulties warping it. This creates a condition called presbyopia -where we have trouble focusing on things up close. timecode: **12:39** Anyone over the age of 45 has to overcome the affects of presbyopia by using reading glasses. timecode: **12:50**
	Cataract animation.	A second condition happens to the crystalline lens as it ages. The lens clouds over due to a lifetime exposure to UV light and becomes a cataract, which if not removed and replaced with a new artificial lens, can lead to blindness. timecode: **13:11** Cataracts are one of the leading causes of blindness, yet sight can be restored in a simple procedure that takes only a few minutes. timecode: **13:25**
	Wide view of the retina	

	Flyover of the retina	Turning back around we see the back of the eyeball that is called the retina. The final destination for our photon. timecode: **13:35** The photon's journey will end here at the retina but not the data it possesses. The data are made up of the color and intensity of the original source – the star, more than a thousands of light years away. timecode: **13:51** The job of the retina is to encode that data in a way that the brain can interpret it.
14	Animation to support narration.	**NARRATOR** timecode: **14:02** Looking across the retina, which makes up about 2/3 of the back of the eyeball, we see some features that break up this apparently smooth surface. timecode: **14:14** First, we see the arteries and veins that carry the blood to and from the retina and the other tissues of the eye. timecode: **14:26** Next, we see a disk that is of lighter color

		compared to the surrounding area. This is the optic nerve head. We will see in a moment how the data contained in the photon and the others traveling with it will get transmitted to the brain via this nerve. timecode: **14:46** Looking directly ahead we see a darker area. This is the macula, the eye's sweet spot. This is where the crystalline lens focuses the light it receives.
15	Photo-animation of a sensor Animation to match VO Create a side motion on dome to startle the audience	**NARRATOR** timecode: **15:01** The best way to imagine the retina is to think of it like the sensor in your digital camera, however, instead of using pixels, the retina uses cells called photoreceptors. timecode: **15:17** The majority of the retina is made of photoreceptor cells called rods, which are very sensitive to light but relay only white light at low-resolution to the optic nerve. This is due to the pigment in the rods, which reacts to the photons when they hit the cell, which in turn sends only one type of signal to the brain. timecode: **15:44** Rods allow us to see in low light and detect motion in our peripheral field of view. timecode: **15:57**

		The point on the macula that the crystalline lens focuses light is called the fovea. The fovea is like a 2.5mm pothole in the otherwise homogenous surface of the retina. timecode: **16:15** If the shape of the eyeball is too elongated, the focused light will fall short creating a condition called near-sightedness or myopia. timecode: **16:29**
	Side view of the eyeball and light paths to match narration.	If the eyeball is instead elongated vertically, the focus point will fall behind the retina creating far-sightedness or hyperopia. timecode: **16:40**
	Show lenses changing the focal points.	Glasses or contacts lenses with specific prescriptions can eliminate the affects of both myopia and hyperopia. timecode: **16:53**
	Animation to support VO	About 15 degrees of our eye's field of view is focused on the fovea and the densely packed area of photoreceptor cells. These photoreceptor cells are called cones, which detect color when photons hit them. timecode: **17:10** The cones transmit a specific color based on the reaction of one of three pigments that the cell may contain. This process

		allows us to see the many visible wavelengths of light that illuminate our world. timecode: **17:28** To understand the different roles rods and cones play in our sight we need to see how they are connected to the optic nerve.

16		**NARRATOR**
		timecode: **17:37**
	Animation to match narration	If we look at a cross section of the retina we will see three distinct layers of cells.
		timecode: **17:44**
		The first layer is filled with ganglion cells that are connected directly to the optic nerve through fibers that run back to form the optic disk and optic nerve. This is the furthest extension of the brain and the only part of the brain that is visible without invasive surgery.
		timecode: **18:05**
		The retina has often been called the window to the soul. That's because many of the changes to the body due to disease are first seen as changes to the retina.
		timecode: **18:18**
	Live-action footage of an eye exam.	Ophthalmologists and optometrist, who specialize in the eye, can detect diseases like Type-2 diabetes long before other methods just by observing an individual's retinas.
		timecode: **18:33**
		So when you get your eyes examined by either an optometrist or ophthalmologist they're checking for more than just your vision, they're checking your overall heath.
		timecode: **18:44**
		Optometrists and ophthalmologists are your eye health care team and you should visit one of them at least every two years.

		timecode: **18:55** Over the age of 40, it is best to be seen once a year to catch age-related diseases at their earliest stages.

17	Animation to support VO	**NARRATOR** timecode: **19:08** The ganglion cells connect to the next layer of cells known as bipolar cells. Bipolar cells connect the rods and cones to the ganglion cells in a couple different ways. timecode: **19:20** Cones connect one to one to ganglion cells. This direct connection is critical for the brain to detect detail and color to achieve visual acuity. timecode: **19:33** Rods connect to ganglion cells in bundles via secondary cells called horizontal and amacrine cells. This arrangement creates a visual scanner of sorts that works well in low light and captures motion better than the cones.
18	Animation to support VO.	**NARRATOR** timecode: **19:52** Our photon and its companions, focused by the lenses of the telescope and crystalline lens, strike the cones in the

		fovea, and their physical journey has now ended. The photons are now extinguished, but not the data they carried. timecode: **20:11** The cones react to the photons' strike and emit a chemical signal that in turn generate a signal across the bi-polar cell to the ganglion cell. Here, the ganglion cell responds by triggering a electric signal that then travels up the optic nerve to the visual cortex of the brain; but we will see that the path is not a direct one.
19	Top down view of the optic nerve path.	**NARRATOR** timecode: **20:49** Our optic nerve system splits our eyes field of view into two hemispheres – right and left. If we look at this system from the top down, the fibers leave the optic disk as a single bunch, timecode: **21:05** but when the nerve pass through the bony optic canal and reach the optic chiasm, the fibers divide into right and left visual fields. The right field travels to the left side of the brain while the left travels to the right side of the brain. timecode: **21:28** This arrangement provides our brain the ability to see stereoscopically and diminishes the blind spot that the optic

		nerve creates in each eye by having the other eye fill in the missing data.
20	Top down and POV animation to support VO	**NARRATOR** timecode: **21:43** After the optic chiasm, the two nerves strands then run separate but parallel courses through the optic tracts to the lateral geniculate nucleus on each side of the brain. timecode: **22:01** From here the optic nerve strands separate and spread out to form the optic radiation providing nerve pathways two main sections of the visual cortex. Here the data received from the eye is split into two sections - information from the fovea and from the peripheral portions of the retinas. timecode: **22:27** Some of the optic nerve splits off before the lateral geniculate nucleus and travels to the brain stam to process reflex responses to light, motion and adjusting the focus of the crystalline lens. timecode: **22:44** The processing of information from the eye to the brain is complex requiring half of its resources. Research continues to reveal how the brain sees and deepens our appreciation for sight.

21	Animation and live-action to support narration.	**NARRATOR** timecode: **23:02** Our sight is the most important sense we possess. Taking care of it should be one of our leading health concerns. timecode: **23:12** Wear sunglasses when outdoors to protect the retinas from ultraviolet light. And protect the skull when doing action sports. timecode: **23:21** Avoid coming close to sharp objects that can penetrate the eye. timecode: **23:31** Eat a proper diet and exercise to avoid developing type II diabetes that can lead to blindness. timecode: **23:51** stare out into the distance for 1 out of every 20 minutes or so to rest your eyes and prevent fatigue from reading or doing near work. timecode: **23:06** Wear safety glasses when the possibility of debris entering the eye exists timecode: **24:16** Follow these simple rules and your eyes and brain will see for a lifetime.

22	Night sky time lapse of the Milky Way	**NARRATOR** timecode: **24:27** So next time you look up at the night sky, think about all that went into the process that allows you to the see its stars. Cherish those few lucky photons that journeyed quadrillions of miles just to land on your retina, and trigger your brain to see.

