

SUPER MOSS

A documentary by Jean-Philippe Teyssier & Bruno Victor-Pujebet
Produced by Félicie Roblin

LOGLINE

They have survived climatic tragedies and nuclear contaminations thanks to their extraordinary biological characteristics: mosses, or bryophytes, have been conquering the planet for millennia. Recent discoveries are have sent shockwaves through the scientific community: SUPER MOSS invites us to discover them through the history of this extraordinary organism, in a journey from the infinitely small to the infinitely large



"My God, it's full of stars!"

Bowman, penetrating the monolith.
2001: Space Odyssey, Stanley Kubrick



SHORT SYNOPSIS

We're going to tell you a story, a scientific fable of sorts. Our hero is far more extraordinary than it appears at first sight. Moss has very little going for it; tiny, sometimes microscopic, vulnerable, shapeless, immobile. Even bryologists who dedicate themselves to their study, concur that moss is often underestimated and even misclassified within the botanical canon of international taxonomy... This peculiar plant, neglected for the past 50 years is enjoying a new renaissance thanks to extraordinary recent discoveries:

In 2019, the team of biologists and chemists under Bastien Nay (Ecole Polytechnique) and Emmanuel Baudouin (Pierre and Marie Curie University) turned the scientific world upside down by discovering a molecule derived from an extremely common and banal species of moss with strictly the same **devastating capacities as glyphosate**.

In 2016 Tim Lenton, a climatologist from the University of Exeter confirmed that mosses were the most important participating factor in the **rapid increase of oxygen in our atmosphere 450 million years ago**.

They were also the first to conquer the earth's crust, which was then made up of vast expanses of hardened and sterile lava, as can be seen today at the remarkable site of Lakagíggar in Iceland, where 27 km long fissures and 100 craters are entirely covered with moss.

Groa Bjork Ingimundardottir, biologist in Reykjavik has studied the conqueror nature of mosses on the volcanic and barren lands of Iceland and in the Lakagigar National Park. Their spores, aided by the wind and carried by the birds, travelled many kilometers before conquering the mysterious black island of Surtsey which erupted out of the ocean in 1963.

Peter Convey, terrestrial ecologist with the British Antarctic Survey, announced in 2016 that he had, with disconcerting ease, successfully brought back to life a moss that had been frozen in the **Antarctic permafrost for 1,500 years**, demonstrating moss's ability to fix the permafrost and slow down the unstoppable melting of the ice cap...

While Europe is only just discovering the triumphs of this organism, the Japanese have always celebrated it as much for its vigor as for its symbolic power; it holds the place of honor in their temples and sacred gardens. A team of Japanese bryologists, among the best in the world, effectively use mosses to map and determine cesium levels in the polluted and abandoned region of Fukushima and in Yakushima in the south of the archipelago, they

document how mosses “feed” the island’s immense cedars of the sacred forest.

The observation of this unloved botanical family has taken on a whole new dimension and has shaken up preconceived ideas.

This is the story of a miniscule, unspecified organism that Westerners trample on carelessly, but which is worshiped as a demigod in Japan. The Japanese consider moss as miniature universes.

SUPER MOSS is a philosophical ode to moss, documenting the substantial power of nature and resituating man to his rightful position.

SCIENTIFIC NOTE

SCIENTIFIC NOTE

SUPER MOSS will be based on the interventions of several scientists and will rely on 5 recent scientific publications written by our participants.

Radulanin A, a new natural based herbicide

Emmanuel Baudouin and Bastien Nay

Emmanuel Baudouin has been a biologist and Associate Professor at Pierre and Marie Curie University since 2006. Bastien Nay is a chemist, CNRS Research Director and associate Professor at Ecole Polytechnique. In a joint study published in 2019 in Chemistry a European Journal, researchers from the Organic Synthesis Laboratory of the École Polytechnique, the CNRS and the École Polytechnique synthesized a natural molecule, radulanin A, from a moss. It's herbicidal properties prove to be similar to the controversial glyphosate..

Bioengineering moss to grow on Mars

Jophiel Wiis

Jophiel Wiis is an astrophysicist who worked on the Space Moss project lead by Copenhagen University. SpaceMoss is an interdisciplinary project that combines two fields of science leading the way into the future: Space Physics and Synthetic Biology. Space Physics and human curiosity are propelling martian colonisation. However, technologies to make astronauts self-sufficient on Mars, so we can live there for a long time, is still an unsolved problem. This is where Synthetic Biology could provide a solution by creating genetically modified organisms that can produce needed components for astronaut survival.

We will film Jophiel testing the resistance of moss species in the Mars Chamber of the Niels Bohr Institute (University of Copenhagen), a device that recreates the biological and atmospherical conditions of the Mars Planet.

Cell regeneration in bryophytes and bioaccumulation

Masaki Shimamura

Masaki Shimamura currently works at the Department of Biological Science at Hiroshima University. Masaki does research in Botany, Cell Biology and Evolutionary Biology. His main research project is about the Morphogenesis in liverworts (a type of moss). He is also conducting scientific expeditions in contaminated areas such as the Fukushima exclusion zone to study the bioaccumulation of radioactive Cesium isotopes found in moss. We will follow him during one of this expedition at Fukushima.

Cultural and ecological importance of moss

Yoshitaka Oishi

Yoshitaka Oishi is an associate professor at Fukui Prefectural University's Center for Arts and Sciences. He has a PhD in agriculture from Kyoto University. He specializes in moss biology, and his research focuses on environmental applications of moss and its cultural and ecological importance. He has written *The Hidden Beauty of Moss*. We will accompany him during a visit to Saiho-ji Temple in Kyoto to highlight the cultural importance of moss in Japanese culture.

Millennial timescale regeneration in a moss from Antarctica

Peter Convey

Peter Convey is a terrestrial ecologist he has broad and diverse research interests, with over 250 publications in these fields. In a study published in the journal *Current Biology* (2014), Peter Convey and his team have demonstrated that, after over 1,500 years frozen in Antarctic ice, moss can come back to life and continue to grow. For the first time, this vital part of the ecosystem in both polar regions was shown to have the ability to survive century to millennial scale ice ages. This provides exciting new insight into the survival of life on earth.

The experiments will be reproduced and filmed in the laboratory or directly on site. Scientific concepts will be illustrated with animations or stop motion sequences.

DIRECTOR'S NOTE

DIRECTOR'S NOTE

Moss is our main character, facing its own obstacles, enemies, and allies. We will gradually build towards our character's transformation from insignificant towards hero. A narrator will guide the film's account. By turns calm, descriptive, and excited, the narrator will dare to draw parallels, tangents, and even confessions.

Thanks to new imaging technology, we will film moss as never before, crossing all the scales: nano, micro, macro, aerial, planetary...

We want to get so close to moss that the viewer will dive into their world and discover the beauty of their features and anatomy. We'll use endoscopic lenses, play on depth perception. We'll create a prototype micro-slider to allow for traveling shots. And time-lapses and slow motions will round out our options, allowing us to play on time scale.

Our art direction will make use of the contrast between the infinitely small and the hugeness of the landscapes we visit Iceland, Ireland, France, and Japan... These settings will help the viewer to understand the forms, history and symbolism of the mosses. Be they luminous or foggy, the settings will be captured in drone shots, but parsimoniously and only for clear narrative effect. We will pay particular attention to ambiance: the sun rising and setting, clouds moving above their shadows, rain beating down...

Stop-motion animation will also help us to frame complex scientific concepts. These magical moments will give depth to our fable.

We want to introduce each interviewee with a long focal shot of their feet walking across the landscape. Each time, we want to capture them in action, sharing their passion for moss

Our film aspires to be a visual poem based in science. We want to make a film that will surprise as we embark on this timeless journey to the core of that which is both infinitely small and infinitely vast.

The music, composed especially for the documentary will play a pivotal role inspired by the piano solo pieces from the albums of Nils Frahm or Ólafur Arnalds as well as Kate Bush's album which captures the spirit of winter, ice and snow (50 Words for Snow). This airy music will guide the viewer through the narrative to reinforce the emotions when necessary, encourage daydreaming and make the imagination blossom.

SYNOPSIS

SYNOPSIS

ICELAND. LAKAGÍGAR'S MOSS FIELDS.

The Lakagígar fissure is the product of the 1783 volcanic eruption, one of the most violent in earth's history. The lava destroyed everything on its path. For two centuries since then, a moss has been colonizing 100 % of the cooled lava: *Racomitrium lanuginosum*, one of the rare vegetal organisms able to grow on such surfaces. Jona Björk Jonsdottir has spent many years studying the *Racomitrium* and its relationship to the region's basalt rock. She is appalled by the damage caused by a few tourists, who crush the moss which will take several years for the footmarks to disappear from the landscape. Her team of rangers replaces the squashed areas with fresh moss cuttings to erase the hiker's traces. Jona Björk explains that the *Racomitrium* covering this entire area absorbs over 70% of its weight in water. Moss has always been the first stage of "ecological successions."

As stop-motion animation shows earth before the Paleozoic Era. About 450 million years ago, earth was made only of water and sterile volcanic rock. Only the oceans held life. For several millennia, the seaweed struggled to go beyond the water, learning to adapt to the atmospheric conditions. They became mosses, reached the ground, and settled definitively. They ended up creating a bedding for this mineral ground. By proliferating, moss provided the planet's atmosphere with a first stable source of oxygen, allowing other life forms to prosper.



The Lakagigar during winter, ICELAND



Huelgoat, Brittany - FRANCE
Moss' Habitat: Granite Cliffs, Narrow Valleys and Rainforests

FRANCE. HUELGOAT, RIVER D'ARGENT VALLEY

The opposite of Iceland's open plains and skies, everything here is cramped, packed in upon itself. We can hear the river covered by blocks of granite. Vincent Hugonnot leaning forward, crouching against a tree, lying with his nose to the ground, hanging from a cord with his face up against a mountain wall with his bryologist's magnifying glass out to identify a moss. It's *Funaria*, a very common moss across Europe. Vincent shows how the moss has captured hundreds of little drops of water on the tuft that are reaching up towards the sky. There are about 25,000 varieties of mosses, 2,000 of which are in Europe. They share in common the use photosynthesis thanks to little leaves. But they have no flower, fruit, or grain. Neither do they have real roots. So close to the earth, moss is in fact entirely connected to the sky. They take no nutritional sustenance from the ground. They develop by absorbing water and mineral particles absorbed through their entire aerial tissues. For both their growth and reproduction, they act as if their life cycle were taking place at the bottom of the sea.

A time-lapse shows how moss reproduces. Moss produces male and female gametes. The fertilization only happens when a drop of water falls atop the male and female gametes. The spermatozoids, skilled swimmers, use the water to reach the female gametes. Fertilization then takes place. A filament rises at the top of long stems, pulling along a little capsule.

Together, they are the sporophyte. Once it has reached it's furthest point, the capsule will start swelling... This urn contains thousands of little spores. The top and filament will end up twisting together, swelling, spinning, and freeing the spores. After exploding, these capsules bear strange stigmata : the peristoma, it is formed by a row of teeth on the edge of the urn's orifice. Its form is fundamental for bryologists as it can help to demark certain types of mosses that are otherwise similar.

FRANCE. STUDIO

Yet this moss that we destroy has unexpected resources. Vincent Hugonnot has dried a tuft of *Tortella toruosa* for several months. A common moss in Brittany, Vincent vaporizes it with some water and within 20 minutes the moss regains all of its characteristics from the day it was harvested. It's the phenomenon of reviving. During the dry seasons, some moss will lose up to 90% of their water and will then progressively pass into anhydrobsis, suspending all vital activity. This phase can last decades without stopping the moss's metabolism



Studio – FRANCE

Before and after photo of a dried moss that has been vaporized with water (20 minutes).

ICELAND. VATNAJÖKULL GLACIER

Peter Convey is a Welsh specialist of polar environments. He has been studying the effects of global warming on the permafrost. He replicates his experiment from 2014 that had stunned the scientific community. He prepares the tools to take his coring, pushing his blade into the ground and taking a sample of moss fibers. After doing this, Peter and his teams had rehy-



Peter Convey looking at the Vatnajökull glacier - ICELAND

drated the moss, which then regenerated very easily. The carbon dating had surprised the entire planet: the moss they'd taken was 1,500 years old. He had just resuscitated a zombie from the Ice Age. Indeed, moss dries up when temperatures fall, thus avoiding the potential risks of ice on their tissues. The melting of the ice cap and the permafrost has started to reveal another tale, one of surprising biological resilience.

ICELAND. VATNAJÖKULL TUNDRA

The melting of the Vatnajökull glacier seems to draw out the golden plovers. A ranger lies on his stomach, holding up binoculars. Benedikt Traustason has been watching the behavior of golden plovers and he is most fascinated by the chicks, whose feathers perfectly mimic the texture and color of the tundra's moss.

A polar fox passes through the nesting area without even noticing them. Close by is a mound of brown, lumpy matter that is riddled with cartilage and topped by a luminous moss. Its stems are golden and its sporophytes' capsules are black. This bryophyte belongs to an unusual moss family: it's a *splachnaceae*, growing only on the dejections of mammals such as polar foxes, or the bones and carcasses of animals. It also displays olfactory mimeticism, imitating the smell of carrion to attract coprophage flies to the capsules. The flies work as vectors to spread the spores, precisely to the ideal environment for a perfect cycle: moss with fly excrement.



Saiho-ji Temple in Kyoto, the Temple of Moss – JAPAN

JAPAN. KYOTO, SAIHO-JI

Close up on a tuft of *Leucobryum Glaucum*. The screen shows a x 100 zoom: the strains of moss appear as tree trunks and the leaves seem as huge tropical foliage. The earth starts moving and the trunks and foliage makes way for a strange character, galloping, a x 150 zoom appears on the screen. A collembola appears, eating decomposing vegetation and micro-mushrooms growing amid the strands of moss.

Under the X 1000 zoom that is noted, our new forest is seen to be moving all other: thousands of insects are moving beneath the collembola's legs; we can make out nematodes, mites, and tardigrades.

Quickly zooming out, the moss is shown to be at the foot of a bonsai, itself in a Zen garden in Kyoto: Saiho-ji, the Moss Temple. Japanese people have long practiced "reductionism". In parallel with their dream of encompassing nature's immensity, or to fit an ancient tree within a small ceramic case. The Japanese understand moss as a world that fits within the palm of a hand.

We see the foot of a gardener-monk bound in a Jikatabi (the shoes of Japanese gardeners). Kenta Deguchi is a Zen monk at Saiho-ji. Every day, moss reminds him of two essential pillars of Zen practice: melancholy and the changes of time, the Wabi and the Sabi. Moss isn't welcome in Western gardens.



Kunstformen der Natur- Planche n°72 Ernst Haeckel, 1904. in. La Garence Voyageuse spécial Bryophytes, Hiver 2014. N°108

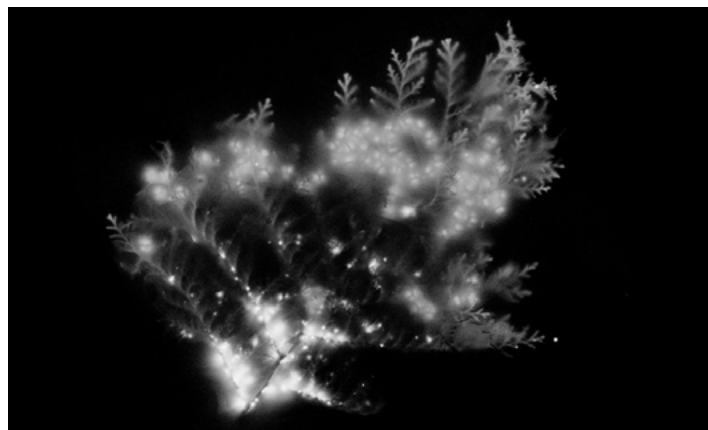
FRANCE. PARIS, SORBONNE UNIVERSITY PIERRE AND MARIE CURIE CAMPUS

A dozen meters from the Paris Pierre et Marie Curie university is a gardener using glyphosate to eliminate moss from a wood decked terrace. Inside the campus a young professor gets lost amid the many hallways, finally reaching the Developmental Biology Laboratory (LBD). The biologist, Emmanuel Baudouin and the chemist Bastien Nay discovered by chance a molecule coming from a moss known as *Radula Complanata*. They placed a drop of this molecule at the foot of several plants that had just been unearthed. The seedlings bend and die. This molecule is called Radulanine A. It is as fast acting as glyphosate. A moss has just overtaken a product that for the last 50 years has boasted of eliminating... moss.

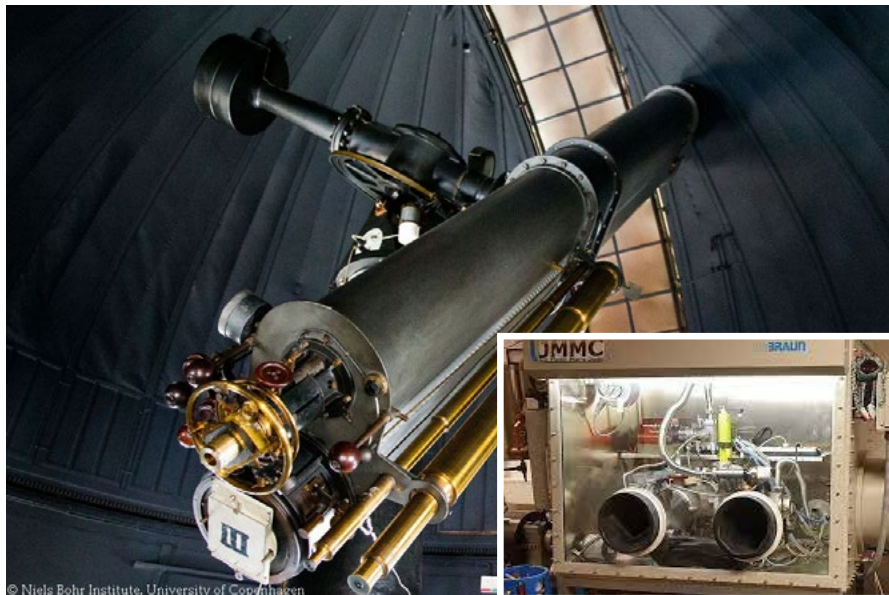
JAPAN. FUKUSHIMA PREFECTURE, KAWAUCHI AND TOKYO

Images of the Fukushima explosion. Kawauchi city is 20 kms far from the nuclear plant. In the nearby forest is Masaki Shimamura, bryologist, keeps his eyes stuck on his Geiger counter, taking samples of fresh moss and strains from the nest of a tit. He then travels Rikkyo University in Tokyo to analyze them, where he shows us superb black and white photos that reveal the cesium levels of everyday objects abandoned after the catastrophe. He then shows photos of the moss and the nest that he has sampled, which are even whiter. He explains that these mosses are very efficient bio accumulators of nuclear radiation. Their nutrition comes from the atmosphere and not the ground: what moss shows is what you breathe. They don't lose their leaves. Moss can grow as easily on concrete, tar, rock, trees, by riverside... the array of moss types is impressive, they can be found in both rural and urban settings.

Thanks to moss, he is able to precisely map the levels of radiation still present in the Fukushima area. The two maps that he's holding show that the contamination levels have not decreased in ten years. The mosses he's tested are exceptionally resilient. He is almost sure (and is trying to prove) that the huge catastrophe has not caused them any deformations.



Moss are bioaccumulative and stores Cesium near Fukushima - JAPAN



© Niels Bohr Institute, University of Copenhagen
 The telescope of Østervold Observatory in Copenhagen
 Lower right corner: the Mars Chamber of the University of Copenhagen — DENMARK

DENMARK. COPENHAGEN, ØSTERVOLD OBSERVATORY, NIELS BOHR INSTITUTE

In 2017 a young team of astrophysicists and molecular biologists set up a strange laboratory in the University of Copenhagen: The Space Moss Lab.

The collective is interested in the medical autonomy of future astronauts who will leave to conquer the planet: how to make them travel (without overloading the shuttles) and then store colossal quantities of drugs that are impossible to produce on site. What if mosses were a hope?

Physcomitrella patens is a bryophyte used in laboratories around the world as a model organism for studies on plant evolution. Today, synthetic biology makes it possible to genetically modify this moss very easily and in particular to attribute to it the genes of usual drugs: paracetamol, beta-blockers or “anti-freeze” properties to resist the temperature amplitudes of space etc. This moss can be cut and multiplied with a disconcerting ease. A few milligrams of “*Physcomitrella*-paracetamol” would allow to put it in culture to obtain large quantities in only a few days... and why not cultivate it directly on the Martian soil?

Thanks to a prodigious and unique device, able to reproduce the atmospheric conditions of Mars, Jophiel Wiis, young astrophysicist and member of the Space Moss Lab, is testing the behavior of this moss in the extreme conditions of the red planet. He promises to take it with him to the ISS to test its resistance in the vacuum of space if his application is accepted in 2024.



PARTICIPANTS

PETER CONVEY

Pete Convey is a terrestrial ecologist with 25 years' experience of working with British Antarctic Survey and in a wide range of polar environments field or teaching periods. He has demonstrated that, after over 1,500 years frozen in Antarctic ice, moss can come back to life and continue to grow.

VINCENT HUGONNOT

Professional bryologist. Author of the only manual on French species of bryophytes and a guide for moss lovers. He is a specialist in the ecology of mosses and their conservation. He has discovered a very new species of moss in Europe 4 years ago.

MAGNEA MAGNUSDOTTIR

Environmental and restoration manager at Orka náttúrunnar (ON), an Icelandic power company that produces and sells electricity to industry and households by harnessing renewable, mainly geothermal, resources. She helps restore moss fields that have been damaged because of the activities of ON powerplants.

BASTIEN NAY and EMMANUEL BAUDOUIN

Bastien Nay is a CNRS Research Director and Chemistry researcher, Associate Professor at Ecole Polytechnique. Emmanuel Baudouin is Associate Professor in Pierre and Marie Curie University (UPMC) since 2006. He completed his PhD in Plant Biochemistry in 1998 in Toulouse, in the group of R. Ranjeva, working on plant molecular responses against pathogens. He then joined the group of H. Hirt in the Department of Microbiology and Genetics of Vienna University for a two-year post-doctorate focused on plant phosphatase 2C family. Since his recruitment as Assistant Professor in 2000 in Nice University and his later move to UPMC, Emmanuel developed researches on the functions of reactive species derived from oxygen, nitrogen and sulfur in the signaling networks underlying plant responses to environmental cues.

YOSHITAKA OISHI

Associate professor at Fukui Prefectural University's Center for Arts and Sciences. He has a PhD in agriculture from Kyoto University. He specializes in moss biology.

MASAKI SHIMAMURA

Professor in the department of Biological Science, Hiroshima University. Director of the Bryological Society of Japan. Masaki does research in Botany, Cell Biology and Evolutionary Biology.

JOPHIEL WIIS

Jophiel Wiis is a Danish astrophysicist who worked on the Space Moss project lead by the Niels Bohr Institute of Copenhagen University.

JEAN-PHILIPPE TEYSSIER - AUTHOR

Jean-Philippe Teyssier is the co-author and presenter of ARTE's documentary series *Magic Garden* since March 2015 (4 seasons, 70 episodes). As of 2017, he has been developing various documentary projects at the crossroads of landscape, art and ecology. His many travels have intensified his love of botany, his desire to write and share the stories plants can share. He has a particular fondness for misunderstood and underestimated species, such as mosses. They play an important role in the development of his projects. He is also a landscape architect, a graduate of the National School of Landscape Architecture in Versailles and the Edinburgh College of Art.

BRUNO VICTOR-PUJEBET - CO-AUTHOR & DIRECTOR

Bruno Victor-Pujebet is a director and a DOP. He started his career as an assistant-director on feature films and commercials. His insatiable curiosity leads Bruno to documentaries and in particular scientific documentaries, which have enjoyed considerable national and international success. He directed *Lorette*, *Last Slum*, for *Planète*, *In the Cat's Paws* for Canal+, a road-movie shot in the steppes of Mongolia, winner of the Jury Prize in Val d'Isère, *These Animals That Disturb Us* for Arte, a fable on the relationship between man and animal. His latest productions include a feature docudrama *Paris, the Great Flood*, as well as a social feature documentary *Go to the Suburbs*, both for Canal+, *Diets*, *The Disturbing Truth*, a major prime time investigation for France 2, *Fire Ants* part of Arte's collection "The Conquerors." And more recently, *Inside Human Zoos*, also for Arte

ZADIG PRODUCTIONS

Established in 2001, Zadig Productions is an independent producer of documentary films, reports, and feature-length films. Zadig Productions is the association of six producers: Mélanie Gerin, Céline Nusse, Julie Perris, Félicie Roblin, Dominique Gibrail and Paul Rozenberg. The association is based around the independence of each producer and the coherence of the films produced as a whole. Zadig has over 150 films in its catalogue, and a presence in the most important television and film festivals. Zadig Productions is committed to producing quality documentary films on historical, cultural, social or even geopolitical issues. We cooperate with an array of TV channels in France and internationally, committed to compelling content.

arte DISTRIBUTION

the ultimate reference for factual documentaries



FLORENCE SALA

*Head of
International Distribution
& Marketing*

f-sala@arteFrance.fr



ALEC HERRMANN

*Head of
Catalog and Video
Acquisitions (DVD/VOD)*

a-herrmann@arteFrance.fr



AUDREY KAMGA
Sales Manager

a-kamga@arteFrance.fr

Canada, USA, South America,
Australia, New Zealand,
MENA Region



ISABELLE MONTEIL
Sales Manager

i-monteil@arteFrance.fr

UK, Ireland, Italy, Spain,
Portugal, Asia
language versions



SOPHIE SOGHOMONIAN
Sales Manager

s-soghomonian@arteFrance.fr

Eastern Europe, Russia, Africa
Israel, Greece
worldwide inflight



FRANKA SCHWABE
Sales Manager

f-schwabe@arteFrance.fr

Germany, Austria, Switzerland,
Belgium, France, Netherlands
Scandinavia, Iceland