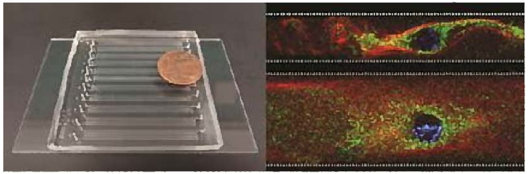
Universal Design Inside the Cell

The organelles inside cells appear to be conserved among all eukaryotes. Is the intracellular design, including the size and shape of organelles and their positions inside cells, also conserved? To examine this fundamental principle of intracellular design, our laboratory tackles the mechanisms controlling organelle design, especially focussing on the design of the cell nucleus, which all eukaryotes have. The size of the nucleus has been known to correlate with the size of the entire cell for more than 100 years. Hence, the nucleus can sense the space inside the cell and coordinate its size accordingly. However, we have only limited understanding of how organelles including the nucleus can sense the intracellular space and can control their own size and position inside the cell, and how the size and position can affect functions of the cell. To unravel these fundamental questions in the field of cell biology, we are attempting to manipulate environmental and spatial parameters of cells. To achieve this, we are combining a cell-free system for reconstructing organelles in vitro with some other techniques including microfluidics and molecular biology.



Micrometre-scaled channels (left) and nuclei reconstructed in vitro using the cell-free system (right: red, microtubules; blue, DNA; green, membranes).

About Researcher

HARA Yuki, Ph.D.

Ph.D. , 2010, The Graduate University for Advanced Studies (SOKENDAI)

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Study of Photo-responsive Behaviour in Amphibian

All animals receive various types of information from the environment and respond appropriately to them in order to survive. Light is one of the most important sources of environmental information for animals. Young larvae of the model amphibian Xenopus show a remarkable reflexive behaviour, the "shadow response", when subjected to a sudden decrease of light (shadow stimulus), which is the earliest photo-responsive behaviour during development. Newly hatched larvae cannot swim yet and lie on the bottom of a water tank without moving. When a sudden decrease of light intensity is applied to them (shadow stimulus), they quickly move upward and attach to the wall or water surface with the cement gland, an adhesive organ characteristic of young larvae of frogs. After attaching, the larvae become immobilised. We are studying this shadow response using various research approaches including behavioural, histochemical and molecular biology techniques. Our research goal is to elucidate the mechanisms behind the shadow response, as well as to determine its evolutionary significance.

Shadow response of Xenopus larvae. Larvae on the bottom show reflexive upward swimming when a shadow stimulus is applied.

About Researcher

HARADA Yumiko, M.S.

M.S., 1995, Nagoya University

Study of Ciliary Function in *Paramecium*

Cilia are eukaryotic organelles protruding from the cell surface, composed of a complex cytoskeleton, the axoneme, and bounded by an extension of the cell membrane, where ion channels, receptors and other signalling proteins control the axoneme bending for motility or sensing of chemicals or mechanical stimuli. Cilia can be motile, causing movement of mucous or cerebrospinal fluid, and sensory as in olfactory neurons and kidney cells. The failure of cilia to develop or perform their function leads to developmental problems and there are numerous human genetic diseases traced to ciliary dysfunction. Genes affecting cilia identified by the human disease phenotype often have functions that remain elusive. Because the organisation, composition and function of cilia have been highly conserved through evolution, we propose obtaining new insights into the ciliary function of eukaryotic cells by using Paramecium as a model. We have analysed genes encoding proteins possibly related to ciliary structure, biogenesis or function by both comparative genomics and proteomics using RNAi by a feeding method and the analysis of phenotypes.

Unicellular ciliated protist, Paramecium tetraurelia

About Researcher

HORI Manabu, Ph.D.

Ph.D., Yamaguchi University

Cell Biophysics

The surface of ciliated protozoa, such as Paramecium cells, is covered with a dense array of cilia. They swim in viscous fluid by beating their cilia. Ciliary movements are coordinated so as to maintain a constant phase difference between adjacent cilia. The coordinated beat cycles of a multitude of cilia can be seen as waves travelling on the cell surface. The formation of these travelling waves, called metachronal waves, requires a high degree of coordination between the beating cilia. However, it is still not fully understood how individual cilia can coordinate with one another to produce this sequential action. Crawling cell locomotion plays an essential role in complex biological phenomena, including development, wound healing, immune system function, and cancer metastasis. Crawling cells can create their own polarity and migrate in a certain direction even in the absence of any chemoattractant. Moreover, they have characteristic shapes dependent on their cell types. How they create their polarity and determine their shape are interesting questions. We are very interested in such self-organising ability of features of cell motility.

A sequential images of actin cytoskeleton in a crawling fish epidermal keratocyte viewed from different angles

About Researcher

IWADATE Yoshiaki,Ph.D.

Ph.D. ,1999,Waseda University

WEB ≫ http://biophysics.sci.yamaguchi-u.ac.jp/english.html

Geographic variation in male horn size of the rhinoceros beetle Trypoxylus dichotomus

The rhinoceros beetle Trypoxylus dichotomus is one of the most famous and popular insects for Japanese people, because the males of this species have a big body and an elongated horn on their head. However, the natural history of this beetle remains largely unknown. The extremely long horn of the males of this species is a typical example of a sexually selected trait. Males with a longer horn enjoy higher mating success because they have a higher probability of winning in intrasexual combat. However, male horns entail various costs, such as increasing energy demands, attracting predators, and decreasing foraging efficiency. The adaptive horn size will be determined by the balance between the costs and benefits, and the balance may vary depending on the ecological conditions the population experiences. Recently, I have found shorter-horned populations on some islands. The main goal of my research is identifying the ecological factors that contribute to the diversification of horn size in T. dichotomus.

Geographic variation in the horn size of male Trypoxylus dichotomus from three populations (Yamaguchi, Taiwan and Okinawa, from left to right)

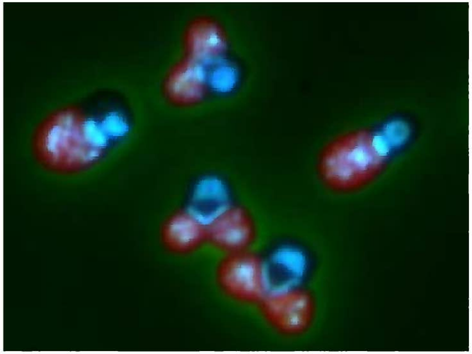
About Researcher

KOJIMA Wataru, Ph.D.

Ph.D., 2013, University of Tokyo

Environmental Adaptation of Microalgae and Basic Research for Biomass Production

Microalgae are one of the major groups in aquatic biomass. We have determined the complete genomic sequence of the unicellular red alga Cyanidioschyzon merolae, which represents a major component of the biomass in acidic hot springs. C. merolae is one of the primitive photosynthetic eukaryotes that have the simplest cell architecture. The cell contains a single nucleus, a single mitochondrion and a single chloroplast, one microbody (peroxisome), one Golgi apparatus with two cisternae and coated vesicles, one ER, a few lysosome-like structures and a small volume of cytosol. We have developed procedures for the genetic modification of this alga. We will characterise the mechanisms of carbon fixation and carbohydrate production in extreme conditions to create heat- and acid-tolerant algae for high biomass production by genetic modification.



The picture is a phase-contrast and fluorescent image of C. merolae stained by DAPI.

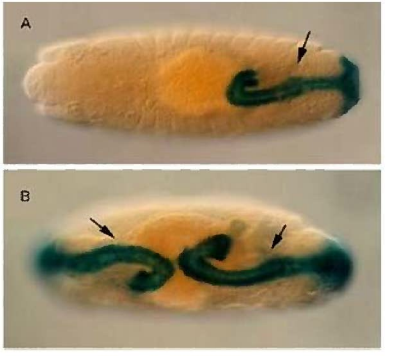
About Researcher

MISUMI Osami, Ph.D.

Ph.D., 2001, The University of Tokyo

Developmental Genetics of *Drosophila*

In the developmental process of animal embryos, during which the fertilised egg (single cell) repeatedly undergoes cell division, resulting in a large number of cells to form intricate body structures, various genes are activated/repressed through complex regulatory interactions. We are studying the function of genes involved in the development of Drosophila embryos, focussing mainly on the gut (intestine). Drosophila gut comprises three major parts: the foregut, midgut (endoderm), and hindgut, each of which consists of several characteristic cell types. Through analyses of the phenotypes associated with various mutations, as well as those associated with forced gene expression, we have discovered genes essential in controlling fate determination of the midgut and hindgut. The midgut fate is determined by GATA factor genes, and the hindgut by a T-box family gene, byn. Further subdivision is regulated by various secretory signalling factor genes. Important aspects of the function of fate-determining genes were found to be widely evolutionarily conserved among multicellular animals.



The hindgut of normal embryo (arrow in A). Hindgut-determining gene, byn, transforms foregut region to hindgut (bcd mutant).

About Researcher

MURAKAMI Ryutaro, Ph.D.

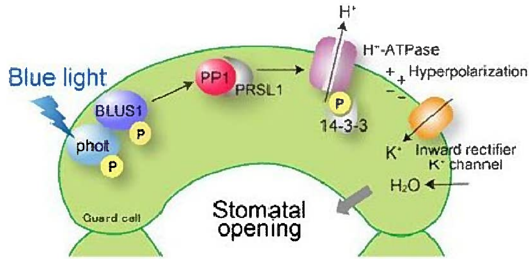
Ph.D. , 1985, The University of Tokyo

WEB ≫ http://www.sci.yamaguchi-u.ac.jp/sci/stafflist/rmurrakami

Molecular Basis of Blue Light Signalling and Responses by Plants

Plants convert light energy into chemical energy via the process of photosynthesis, which is critical to sustain biological activity on the Earth. Simultaneously, plants use light not only as an energy source for photosynthesis but also as an environmental signal to direct their growth and development. We aim to uncover the basic molecular mechanisms by which plants sense light signals and regulate developmental and physiological processes.

Phototropins are plant-specific light-activated receptor kinases controlling a wide range of blue light responses such as phototropism, chloroplast movement, stomatal opening and leaf flattening. All these responses serve to maximize photosynthesis to promote plant growth. Our group is interested in how phototropins transform light signals into physiological responses. In stomatal guard cells, the light signals perceived by phototropins create a driving force for stomatal opening through the activation of the plasma membrane H^+-ATPase via an unknown signalling process. We study the signalling mechanisms involved in light-dependent stomatal opening using biochemical, genetic and molecular biological approaches.



Model of blue light signalling leading to stomatal opening.

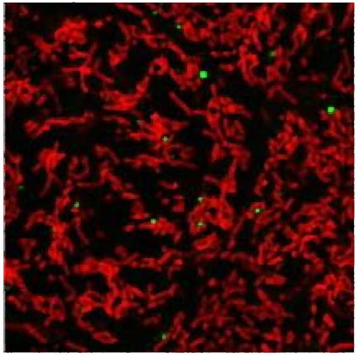
About Researcher

TAKEMIYA Atsushi, Ph.D.

Ph.D., 2005, Kyushu University

Cell Cycle and Organelle Construction during Early Embryogenesis of *Xenopus*

The degradation of maternal mRNA and the transcription of zygotic mRNA are required for the embryogenesis at the midblastula transition (MBT) in Xenopus laevis. Recently, the mechanisms of efficient degradation of mRNAs in the P-body (processing body) were reported. We demonstrated that Dcp1, one of the major components in the P-body, began to assemble after MBT in a manner dependent on the elongation of interphase, and that the maternal mRNA colocalized with the P-body. These findings suggest that the initiation of maternal mRNA degradation depends on the P-body appearance at MBT. The maternal mRNA degradation caused by the appearance of the P-body depends on the interphase elongation at MBT, and the Dcp1 accumulated on Xp54.



Mitochondria (Red) and P-body (green) in the cell in Xenopus neurula embryos.

About Researcher

UENO Shuichi, Ph.D.

Ph.D., 2003, University of Kyushu

Phenotypic Plasticity and Evolution in Butterflies

Many butterflies exhibit phenotypic plasticity in the shape and/or colour patterns of wings of adults and bodies of larvae and pupae. However, little is known about the regulatory mechanisms underlying the endocrine control of developmental plasticity in butterflies, except for the development of eye spots in the wings. My primary research focus is on developmental plasticity such as seasonal morph of wings and environmentally cued pupal colour, in some Papilionid, Pierid, Lycaenid and Nymphalid butterflies. The research groups of which I am a part have identified three hormonal factors: Summer-Morph-Producing Hormone (SMPH) associated with a seasonal morph change in wings of Polygonia c-aureum, and Pupal-Cuticle-Melanising Hormone (PCMH) and Orange-Pupa-Inducing Factor (OPIF) associated with body colour change in pupae of Papilio xuthus. To understand the evolution of phenotypic plasticity in butterflies, we are currently working to confirm the molecular diversity and the newly discovered physiological roles of novel hormonal factors, as key neuropeptides associated with developmental plasticity, among phenotypic and non-phenotypic butterflies.

The map butterfly Araschnia burejana. Left: An adult of the spring-morph type. Right: An adult of the summer-morph type.

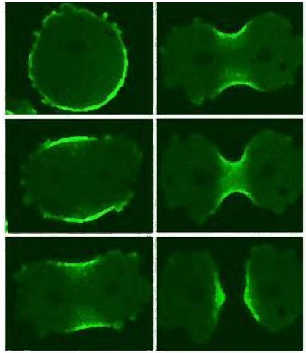
About Researcher

YAMANAKA Akira, Ph.D.

Ph.D., 2001, Hiroshima University

Mechanisms of Cytokinesis and Cell Migration

We focus on the signal transduction pathways and the mechanics that control the cytokinesis and migration of eukaryotic cells. Cytokinesis and cell migration are essential for biological processes, such as growth, morphogenesis, wound healing and metastasis of a variety of cancer cell types. Actin and myosin accumulate at the cleavage furrow to form a contractile ring and generate force to divide the cell into two daughter cells. They also accumulate at the rear of migrating cells to generate the driving force. Mutant cells deficient in myosin can neither properly divide nor migrate. Because the mechanism regulating the subcellular localisation of actin and myosin is still poorly understood, we use a powerful model system – Dictyostelium amoebae – to study it. Recently, we have also focused on the mechanism of cell membrane repair. We found that the molecular basis of membrane repair depends on actin and myosin.



Myosin II accumulates at the cleavage furrow in a dividing Dictyostelium cell.

About Researcher

YUMURA Shigehiko,Ph.D.

Ph.D., 1985, Osaka University

WEB ≫ http://web.cc.yamaguchi-u.ac.jp/~nenkin/TOPYUMURA