PROGRAMME

Tuesday, April 1st

14:00 - 17:00 ELGRA Management Committee Meeting.

17:00 - 19:00 **Registration** (Künstlerhaus, Lenbachplatz 8, Munich)

Wednesday, April 2

09:00 - 09:40 **Opening Ceremony**
Adresses from:
Dr. Marianne Cogoli-Greuter, President of ELGRA
Representative of ESA
Representative of the Government of Bavaria
Representative of the Technical University of Munich
Representative of the Bavarian Space Industry
Dr. Kurt Kemmerle, Organiser of the ELGRA - 03 Meeting

09:40 - 10:10 **Invited Lecture:**
ACES : ATOMIC CLOCK ENSEMBLE IN SPACE
N. Dimarcq, Ch. Salomon, A. Clairon, A. Jornod,
P. Thomann, C. Sirmain and S. Feltham

10:10 - 10:30 *Coffee break*

10:30 - 12:30 **Session I: Physical Sciences (Multiphase Flow / Surface effects)**
Chairpersons: H.C. Kuhlmann and A. Passerone

10:30 THE EFFECT OF VIBRATIONS ON INHOMOGENEOUS MATTER. SOME STUDIES IN WEIGHTLESSNESS
D. Beysens, Y. Garrabos, P. Evesque, D. Chatain,
C. Lecoutre and V. Nikolayev

10:50 PARTICLE ACCUMULATION STRUCTURES IN THERMOCAPILLARY FLOWS
St. Domesi, H. Kawamura, H. C. Kuhlmann, J. Leypoldt and D. Schwabe

11:10 BUBBLES INTERACTION IN MICROGRAVITY
N. Divinis, T.D. Karapantsios, V. Bontozoglou,
M. Kostoglou, A.C. Michels and R. de Bruijn

11:30 MICROGRAVITY BOILING AND TWO-PHASE FLOW - REVIEW OF EXPERIMENTAL APPARATUS AND RESULTS –
H. Ohta and A. Baba

11:50 PRELIMINARY RESULTS FROM THE FACILITY FOR ADSORPTION AND SURFACE TENSION (FAST) EXPERIMENT ONBOARD STS-107.
L. Liggieri, M. Ferrari, F. Ravera and A. Passerone

12:10 INSTABILITY OF A THIN LIQUID LAYER WITH SURFACTANTS
W. Ellermeier

12:30 - 14:15 *Lunch*

14:15 - 15:55 **Session II: Life Sciences (Human Physiology / Developmental Biology / Unicellular Organisms)**
Chairpersons: Ch. Dournon and H.-J. Marthy

14:15 EFFECTS OF HEAD DOWN TILT UPON LEPTIN AND STEROID LEVELS
F. Strollo, F. Celotti, P. Magni*, B.M. Uva, M. More,
A. Mambro, R. Corelli, G. Strollo, and G. Riondino

14:35 FISH AS MODEL SYSTEMS IN GRAVITATIONAL ZOOLOGY
R.H. Anken

14:55 RELATIONS BETWEEN THE STATIC VESTIBULO-OCULAR REFLEX AND FICTIVE SWIMMING IN TADPOLES (*XENOPUS LAEVIS*) AFTER A 9-DAY MICROGRAVITY EXPOSURE
E. Horn, L. Gualandris-Parisot, Ch. Dournon, and S. Böser

15:15 HYPERGRAVITY AFFECTS ON THE EMBRYONIC DEVELOPMENT OF CEREBRAL NEURONS IN CRICKETS (*ACHETA DOMESTICUS*)
U. Kirschnick, M. Schmäh, E. Horn, H.-J. Agricola

15:35 PARAMETERS OF GRAVITAXIS IN *EUGLENA GRACILIS* OBTAINED DURING SHORT TERM MICROGRAVITY PERIODS
M. Lebert, P. Richter, M. Ntefidou and D.-P. Häder

16:00 - 16:20 *Coffee break /* **Poster Session**

16:20 – 17:15 **Poster Presentations**

Life Sciences

COSMIC RADIATIONS AND GENETIC EXPRESSION IN HUMAN T-LYMPHOCYTES FROM BIRBA 1 MISSION

M.A. Meloni, P. Pippia, G. Galleri, M.G. Camboni, R. Negri, G. Costanzo, V. De Sanctis and A. Cogoli

MICROGRAVITY INDUCES APOPTOSIS IN HUMAN LYMPHOCYTES BY ACTIVATING 5-LIPOXYGENASE
M. Maccarrone, M. Meloni, N. Battista, M. Bari, G. Galleri, P. Pippia, A. Cogoli and A. Finazzi-Agrò

SUSCEPTIBILITY TO DAMAGE BY µG EXPOSURE REVEALS ALTERATIONS IN BASAL CELL METABOLISM. DIFFERENTIAL BEHAVIOUR IS SHOWN IN NORMAL AND IN TUMORIGENIC CELL LINES
P. Degan, A. Zunino, F. Cesarone, L. Ottaggio, S. Viaggi, St. Bonatti, P. Pippia, G. Galleri, M. Sancandi, A. Abbondandolo

ORIENTATION OF FLAGELLATES UNDER µG-CONDITIONS
K. Vogel and D.-P. Häder

DISCLOSING THE SITE OF OTOLITHIC CALCIUM UPTAKE IN DEVELOPING FISH USING FLUORESCENT CALCIUM-TRACERS
M. Beier, R.H. Anken and H. Rahmann

CALCIUM SUPPLY OF INNER EAR OTOLITHS IN FISH VISUALIZED BY ENERGY FILTERING TRANSMISSION ELECTRON MICROSCOPY (EFTEM)
M. Ibsch, R.H. Anken and H. Rahmann

MORPHOMETRY OF THE UTRICULAR MACULA IN MOTION SICK FISH: A PARABOLIC AIRCRAFT FLIGHT STUDY
A. Bäuerle, R.H. Anken, R. Hilbig, N. Baumhauer and H. Rahmann

DETERMINING THE THRESHOLD OF GRAVITY FOR INDUCING MOTION SICKNESS IN FISH: A DROP-TOWER EXPERIMENT
R.H. Anken and R. Hilbig

EFFECTS OF HYPERGRAVITY ON THE GROWTH OF INNER EAR OTOLITHS OF DEVELOPING FISH CORRELATE WITH MACULAR CARBONIC ANHYDRASE REACTIVITY
M. Beier, R.H. Anken and H. Rahmann

EFFECT OF HYPERGRAVITY ON SUCCINATE DEHYDROGENASE REACTIVITY IN FISH VESTIBULAR GANGLIA
J. Kempf, R.H. Anken, and H. Rahmann

BEHAVIOURAL RESPONSES TO HYPERGRAVITY ENVIRONMENT IN PERIADOLESCENT CD1 MOUSE
N. Francia, D. Santucci and E. Alleva

MR IMAGING METHODS FOR ASSESSING TRABECULAR BONE QUALITY AFTER PROLONGED SPACE FLIGHT
R. Toffanin, A. Accardo, I. Strolka, P. Szomolanyi, M. Cova, and F. Vittur

THE USE OF BODY-FIXED EXCITERS AND SERIES-ELASTIC DEVICES TO STUDY SPACE FLIGHT-INDUCED NEUROMUSCULAR CHANGES.
E. Gallasch

EFFECTS OF MICROGRAVITY ON IN-VITRO-MINERALIZATION OF ODONTOBLASTS
C. Möhl and M. Dreiseidler

The effects of microgravity and hypergravity on crab, *Carcinus maenas* (L.) statocyst interneurones.
P. J. Fraser (project supervisor), Denis G. Alferéz, R. Araújo, M. J. Carneiro and M. Pollard

Physical Sciences

"BUBBLE BATH" – PARABOLIC FLIGHT EXPERIMENTS WITH AQUEOUS FOAMS
M. Meier, D. Hille, M. Walter, M. Knoepke, R. Richter and G. Wallot

LLESCA-SCF ARTIFICIAL GRAVITY GENERATION
Ciurana, X., Gerones, I., Selga and J. Sola

Demonstration

REMOTE ACCESS TO LIFE SCIENCES EXPERIMENTS ON THE ISS OR IN GROUND-BASED FACILITIES - DEMONSTRATION OF A USER HOME BASE
M. Schuber, D. Seibt and P. Esser

17:15 - 18:55 **Session III: Education / User Support / Sounding Rocket / Soyuz Mission**
Chairpersons: R. Hemmersbach and M. Cogoli-Greuter

17:15 – 17:35 Students Presentations

The effects of microgravity and hyper-gravity on crab, *Carcinus maenas* (L.) statocyst interneurones
P. J. Fraser, D. G. Alferéz, R. Araújo, M. J. Carneiro and M. Pollard

LLESCA-SCF ARTIFICIAL GRAVITY GENERATION
Ciurana, X., Gerones, I., Selga and J. Sola

17:35 EXPERIENCES FROM A GERMAN-FRENCH PROJECT ON THE INTEGRATION OF PUPILS IN AN ACTUAL SPACE EXPERIMENT
E. Horn and Ch. Dournon

17:55 REMOTE ACCESS TO LIFE SCIENCES EXPERIMENTS ON THE ISS OR IN GROUND-BASED FACILITIES - DEMONSTRATION OF A USER HOME BASE
M. Schuber, D. Seibt and P. Esser

18:15 EURO LAUNCH, THE NEXT GENERATION OF EUROPEAN CONSOLIDATED SOUNDING ROCKETRY
S. Kemi, P. Turner and O. Norberg

18:35 THE DUTCH SOYUZ MISSION
J. J.W.A. van Loon and R. P. de Groot

20:00 **Reception at Keyser Threde**
Slide Show on MAXUS 4 Mission

Thursday, April 3

09:00 - 9:30 **Invited lecture:**
CELL BIOLOGY IN SPACE: FROM BASIC SCIENCE TO BIOTECHNOLOGY
A. Cogoli

9:30 - 12:10 **Session IV: Life Sciences (Cell Biology)**
Chairpersons: F. Strollo and S. Ambesi-Impiombato

9:30 MICROGRAVITY AND BONE CELL MECHANO-SENSITIVITY - RAPID NITRIC OXIDE PRODUCTION BY BONE CELLS IS FLUID SHEAR RATE DEPENDENT
R. G. Bacabac, T. H. Smit, S. Dijcks,
J. J. W. A. Van Loon and J. Klein-Nulend

9:50 FLG 29.1 CELL DIFFERENTIATION: A COMPARISON BETWEEN THE EFFECTS OF SIMULATED LOW G AND THOSE INDUCED BY ULTRASOUND EXPOSURE
M. Monici, F. Fusi, A. Cogoli, M. Paglierani, E. Biagi and P. A. Bernabei

10:10 WEIGHTLESSNESS-INDUCED ALTERATIONS AT SUBCELLULAR LEVEL IN CULTURED GLIAL CELLS
B.M. Uva, M.A. Masini, M. Sturla, G. Tagliafierro and F. Strollo

10:30 - 10:50 *Coffee Break*

10:50 AN INTERPLAY BETWEEN HSP70 AND IL-1 IS RESPONSIBLE FOR ENDOTHELIAL GROWTH ADVANTAGE IN SIMULATED MICROGRAVITY
S. IM Carlsson, M. TS Bertilaccio and J. AM Maier

11:10 SIMULATED MICROGRAVITY INDUCES PROGRAMMED CELL DEATH IN HUMAN THYROID CARCINOMA CELLS
A. Cogoli, P. Kossmehl, M. Shakibaei, H. Pickenhahn, M. Paul and D. Grimm

11:30 THE ROLE OF PROTEIN KINASE C IN LYMPHOCYTE LOCOMOTION: RESCUE OR CAUSE?
A. Sundaresan, D. Risin and N.R. Pellis

11:50 EARLY TRANSCRIPTIONAL RESPONSE OF HUMAN T-LYMPHOCYTES TO MICROGRAVITY CONDITIONS DURING A MASER FLIGHT
M. Cogoli-Greuter, R. Negri, G. Costanzo, G. Galleri, M.A. Meloni, T. Schopper and P. Pippia

12:10 – 14:00 *Lunch*

14:00 - 14:30 **Invited Lecture:**
LIFE AND PHYSICAL SCIENCES AND SPACE STATION UTILISATION AT ESA, FUTURE PERSPECTIVES AT A DIFFICULT TIME
P. Clancy

14:30 - 16:50 **Session V: Physical Sciences (Convection / Front Propagation)**
Chairpersons: L. Liggieri and T. Karapantsios

14:30 **GEOFLOW: EXPERIMENTS WITH GEOPHYSICAL APPLICATIONS IN THE FLUID SCIENCE LABORATORY ON ISS**
Ch. Egbers, V. Travnikov, P. Beltrame and R. Hollerbach

14:50 NATURAL CONVECTION IN ROTATING SPHERICAL GAP UNDER THE CENTRAL FORCE FIELD
V. Travnikov, R. Hollerbach and Ch. Egbers

15:10 COMPLEX DYNAMICS IN DIFFERENTIALLY HEATED CAVITIES UNDER LOW GRAVITY CONDITIONS
X. Ruiz, I. Mercader, O. Batiste, L. Ramírez-Piscina and J. Casademunt

15:30 - 15:50 *Coffee Break*

15:50 MICAST - THE EFFECT OF MAGNETICALLY CONTROLLED FLUID FLOW ON THE SOLIDIFICATION OF TECHNICAL AL-ALLOYS UNDER MICROGRAVITY CONDITIONS
M. Hainke, J. Friedrich and G. Müller

16:10 SEGREGATION ANALYSES OF SEMICONDUCTOR SINGLE CRYSTALS GROWN INSIDE MODELIZED INERTIAL MODE ORBITING SYSTEMS
X. Ruiz and M. Ermakov

16:30 COMBUSTION SYNTHESIS UNDER MICROGRAVITY CONDITIONS OF TITANIUM DIBORIDE-TITANIUM ALUMINIDES
R. Licheri, R. Orru, G. Cao, J. De Wilde, I. A. Beloki, D. J. Jarvis and L. Froyen

17:00 - 19:00 **ELGRA GENERAL ASSEMBLY**

20:00 ***Banquet***
ELGRA Award (Dr. Greg Briarty)

Friday, April 4

09:00 – 9:30 **Invited lecture:**
MICROENCAPSULATION IN MICROGRAVITY
T. L. Whateley

09:30 - 10:30 **Session VI: Physical Sciences (Transport coefficient)**
Chairpersons: A. Viviani and J. Richter

9:30 **APPLICABILITY OF SHEAR CELL TECHNIQUE FOR GROUND BASED DIFFUSION EXPERIMENTS OF LIQUID ALLOYS**
S. Suzuki, K.-H. Kraatz, A. Griesche, M.-P. Macht and G. Frohberg

9:50 THE DEVELOPMENT OF A SHEAR CELL FOR THE MEASUREMENT OF LIQUID DIFFUSION COEFFICIENTS UNDER MICROGRAVITY CONDITIONS
R. Smith

10 :10 THERMOLAB: HIGH-PRECISION THERMOPHYSICAL PROPERTY DATA OF LIQUID METALS FOR MODELLING OF INDUSTRIAL SOLIDIFICATION PROCESSES. RESULTS OF SURFACE TENSION AND DENSITY OF NI-BASED SUPERALLOYS
E. Ricci, D. Giuranno, R. Novakovic, A. Passerone, L. Battezzati, R.E. Brooks, P. N. Quested, I. Egry, S. Schneider, H. Fecht, R. K. Wunderlich, J.P. Garandet, B Vinet, K.C. Mills and S. Seetharaman

10:30 - 10:50 *Coffee Break*

10:50 – 12:30 **Session VII: Life Sciences (Plant Biology)**
Chairpersons: L.G. Briarty and F. Migliaccio

10:50 **IS THE UNCONVENTIONAL PLANT MYOSIN VIII INVOLVED IN GRAVI- AND MECHANOSENSING?**
D. Volkmann, A. Schick, A. Hlavacka and F. Baluška

11:10 THE EFFECTS OF SIMULATED MICROGRAVITY ON THE LIGNIFICATION OF YOUNG *EUCALYPTUS GLOBULUS*
P. GENOT, M. CABANE, J. BANVOY, N. LADOUCE, A. DAUPHIN, B. POLLET, J. GRIMA-PETTENATI, C. LAPIERRE AND V. LEGUE

11 :30 INVESTIGATING THE CIRCUMNUTATING MOVEMENTS OF ARABIDOPSIS ROOTS THROUGH THE RANDOM POSITIONING MACHINE
F. Migliaccio, S. Piconese and C. Rosi

11:50 HYPER-GRAVITY EFFECTS ON THE *ARABIDOPSIS* TRANSCRIPTOME
M. Martzivanou and R. Hampp

12:10 GENES POTENTIALLY REGULATED BY GRAVITY IN *A. THALIANA*
S. Centis-Aubay, G. Gasset, C. Mazars, R. Ranjeva and A. Graziana

12:30 – 14:15 *Lunch*

14:15 - 15:15 **Session VIII: Instrumentation / EU Project**
Chairpersons: J. J.W.A. van Loon and D. Karapantsios

14:15 FLUORESCENCE MINIATURE MICROSCOPE FOR BIOLAB
R.H. Huijser, G. Borst, G. Brandt, L. de Vos, P. Schiller and J. Kraemer

14:35 THE FAST FACILITY: FROM SPACEHAB TO ISS
F. Brandani, P. Falciani, M. Simoncini, F. Valgattarri and C.A. Schmidt-Harms

14:55 INTERNATIONAL MICROGRAVITY PLASMA FACILITY / DUST PARTICLE FACILITY
R. Seurig

15:15 PERSPECTIVES AND DIFFICULTIES TO ENTER "SPACE-RELATED LIFE AND PHYSICAL SCIENCES" INTO FP6
B. Roux and J. J.W.A. van Loon

15:35 DISCUSSION ON EU PROJECT

15:55 **Conclusions and Outlook**

16:00 **Closure of ELGRA - 03 Meeting**

INVITED LECTURES

ACES : ATOMIC CLOCK ENSEMBLE IN SPACE

N. Dimarcq [1], Ch. Salomon [2], A. Clairon [1], A. Jornod [3], P. Thomann [3], C. Sirmain [4], S. Feltham [5]

(1) SYRTE, Paris Observatory, 61 avenue de l'Observatoire 75014 Paris, France
(2) Laboratoire Kastler-Brossel, Ecole Normale Supérieure, 24 rue Lhomond, 75231 Paris cedex 5, France
(3) Neuchâtel Observatory, rue de l'Observatoire 58, 2000 Neuchâtel, Switzerland
(4) French Space Agency, CNES, 18 Avenue Edouard Belin, 31402 Toulouse, France
(5) European Space Agency, ESA / ESTEC, Keplerlaan, 2200 AG Noordwijk, The Netherlands
Corresponding author : noel.dimarcq@obspm.fr

The ACES project aims at operating ultrastable clocks on board the International Space Station. The laser cooled atom clock PHARAO and an hydrogen maser SHM will provide an ultra stable time scale whose frequency stability and accuracy are expected to reach the level of 10^{-16}. The launch is scheduled in 2006 and the mission duration will be between 18 months and 3 years.

The main scientific objectives of the ACES mission are the following :

- demonstration of the operation of new metrological instruments using atoms cooled with laser light
- tests of fundamental physics theories (measurement of the gravitational red shift, search for a possible drift of the fine structure constant, test of special relativity, …)
- worldwide comparison of frequency standards, improvement of atomic time scales
- study of electromagnetic waves propagation in atmosphere

Most of the scientific objectives rely on time and frequency comparisons between ACES space clocks and ground clocks. Such comparisons will be performed with a dedicated time and frequency microwave link. In order to reach the 10^{-16} level, the time stability of this link will be better than 10 ps over 1 day which is at least one order of magnitude better than clocks comparisons with current GPS techniques.

CELL BIOLOGY IN SPACE: FROM BASIC SCIENCE TO BIOTECHNOLOGY

Augusto Cogoli

Space Biology, ETH Zurich, Switzerland

Investigations conducted in space in the last twenty years have shown that important cellular functions like mitosis, differentiation and genetic expression are altered in conditions of weightlessness. Many of such effects can be reproduced in ground-based instruments like the fast rotating clinostat and the three-dimensional clinostat.
One of the most extensively studied system is the mitogenic activation of T cells *in vitro*. In an experiment in Spacelab in 1983 it was shown that activation, measured as the mitotic index, was depressed by more than 90% in microgravity. Several other investigations followed: it was seen that the genetic expression of interleukin 2 and its receptor, two crucial steps of the activation process, are significantly inhibited. Moreover, cytoskeletal structures are altered already a few seconds after exposure to zero g. Other cells systems like osteoclasts and thyroid carcinoma cells showed alteration of their behavior under conditions simulating microgravity. At the molecular level it was seen that the assembly of tubulin into microtubuli id profoundly altered.
Such findings have important implications in basic cell biology.
In the last three years it has been suggested that conditions of weightlessness may favor the formation of artificial tissues and organogenesis. In fact the lack of forces pulling the cells may contribute to the formation of three-dimensional structures. One example presently under investigation is the formation of cartilages in a scaffold-free system. Preliminary data with pig chondrocytes indicate that the structure obtained under simulated zero g are differing from those former at 1 g. Whether such changes are advantageous to the constructions of implants is the subject of future projects on board of the international space station.

MICROENCAPSULATION IN MICROGRAVITY

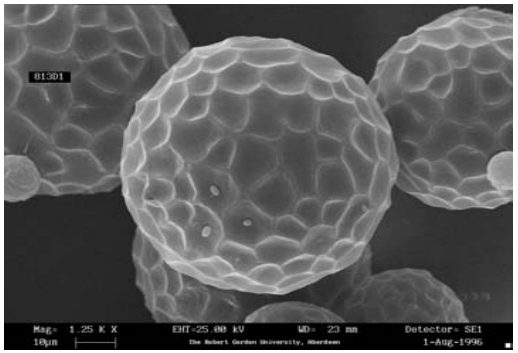
T. L. Whateley

University of Strathclyde, Department of Pharmaceutical Sciences, SIBS, Glasgow, G4 0NR, Scotland, UK.

Microencapsulation involves the containment of a wide range of materials in particles in the size range 1-500 micrometre and is used in pharmaceutical and veterinary products, medicines, gene delivery, drug delivery, vaccine delivery, cell encapsulation, artificial organs, agriculture, food, nutrition (Neutraceuticals), cosmetics, fragrances, paper technology, photocopying, photography and adhesives.

Many microencapsulation processes involve emulsion formation followed by mass transfer at the liquid/liquid interface. Understanding the fluid physics of interfacial transfer and especially interfacial turbulence is thus of fundamental importance in microencapsulation process optimisation. Interfacial turbulence affects interfacial transfer rate by a factor of 2-3. Such interfacial motion is triggered by local variations in interfacial tension caused by the Marangoni effect and/or thermocapillary convection.

As a result, microflows near the interface are generated which lead to surface patterns on the interfaces and internal circulations within the emulsion droplets. With polymer present in the internal emulsion droplet phase, these surface patterns become “fixed”, allowing detailed study of their polygonal nature. This Benard convection forming Benard cells leads to a favoured hexagonal cell structure but polygons may be formed. This SEM micrograph shows this effect.



It is proposed to study the emulsion/solvent evaporation microencapsulation process based on biodegradable polymers such as poly(lactic-co-glycolic acid) in microgravity. There are a number of sustained release microencapsulated products on the market based on this technology but they are US and Japanese products and Europe needs to become more competitive in this area. The microsphere preparation process is

experimentally simple and readily automated which is advantageous for the proposed microgravity studies. The formation of surface patterns on drug delivery microspheres resulting from Marangoni driven surface flows can be studied in detail in microgravity conditions.

ESA are thanked for initiating and supporting this work, in particular, Roger Binot and Ewald Kufner. Members of the Topical Teams are thanked for their input and support, especially Denis Poncelet, Pierre Colinet and David Bain.

SCIENTIFIC SESSION I:

PHYSICAL SCIENCES

(MULTIPHASE FLOW / SURFACE EFFECTS)

THE EFFECT OF VIBRATIONS ON INHOMOGENEOUS MATTER. SOME STUDIES IN WEIGHTLESSNESS.

D. Beysens[1,4], Y. Garrabos[2], P. Evesque[3], D. Chatain[1], C. Lecoutre[2], V. Nikolayev[1]

[1]ESEME, Service des Basses Temperatures, CEA-Grenoble, Grenoble, France
[2]ESEME, ICMCB, UPR9048 CNRS, 87,Av. Dr. A. Schweitzer, 33608 Pessac Cedex, France
[3] Lab. MSSMat, UMR 8579 CNRS, Ecole Centrale Paris, 92295 Châtenay-Malabry, France
[4]Postal address: ESEME, ICMCB, 87, Av. Dr. A. Schweitzer, 33608 Pessac Cedex, France; email: dbeysens@cea.fr

The influence of vibrations on a medium whose density is not homogenous leads to a large number of behaviours. The absence of earth gravity acceleration can simplify the situation. We will consider granular medium and multiphase systems (liquid-gas-solid) and will report only on the effect of sinusoidal vibrations with linear polarization of $X=A\sin(\omega t)$ type, where A is amplitude and ω the angular frequency.

In *granular mediums*, a vibrating wall gives a speed, and thus a temperature, to the particles, which then interact by collisions. According to the number density of the particles, very different behaviours are observed in weightlessness: resonance of one or a few particles without interactions, "gas" state (Knudsen gas), when the density increases and thus the interactions by collisions, "solid " state (formation of clusters) for still greater densities. In this last case, the cluster remains motionless and is stabilized by the collisions of a few particles with the walls.

In fluids, the heterogeneities are subjected to different velocities (difference ∇V) according to their density difference ($\nabla\rho$) such as $\nabla V \sim \nabla\rho$. A particularly interesting class of phenomena is concerned with "high frequency" vibrations, i.e. vibrations of time period shorter than the hydrodynamic times of the fluid. Average flows of large temporal scale are then superimposed to the movements of less amplitude that remain in phase with the vibration. These flows correspond to the non-linearities of the system, whose simplest illustration is the rise of a Bernoulli pressure difference $\nabla P \sim (\nabla V)^2$. This difference in pressure directs the heterogeneities perpendicularly to the direction of vibration, a general result for this class of phenomena.

The heterogeneity of density can be the result of different perturbations: thermal ($\nabla\rho = (\partial\rho/\partial T)\nabla T$) or due to the coexistence of a different phase (solid or fluid). As a consequence, vibrations induce various phenomena:

For example, during a *liquid - solid transition*, the vibration of the solid stimulates convections in the liquid, which can compensate those of thermo-capillary origin (and, on ground, almost cancel the thermo-gravitational convections).

In a *gas-liquid* system at equilibrium, a vibration excites a number of deformation modes of the vapour bubble, whose average value is a deformation perpendicularly to the vibration. Moreover, the vibration induces an average flow that reduces in an attraction by the walls. The bubble remains eventually stuck to one of the walls. The approach of the liquid-gas critical point is particularly interesting. The gas-liquid interfacial tension vanishes, as the difference in gas and liquid density. One observes close to the critical point large deformations of the gas inclusion, which can eventually take the shape of bands perpendicularly to the walls.

The effect of a vibration on a *one-phase fluid* with density heterogeneities as induced by a temperature gradient can be expressed by a vibrational Rayleigh number. This latter becomes particularly important close to the critical point as the coupling parameter $(\partial\rho/\partial T)_P$ becomes infinite (and thermal diffusivity vanishes). Convections thus occur in the zones of strongest density gradients, directed perpendicularly to the direction of vibration.

A last point is related to the dynamics *of liquid-gas phase transitions* under vibration. Here also, the vicinity of the gas-liquid critical point makes the study more interesting. Critical slowing-down makes easier the study of dynamics. The universal scaling laws allow density, interfacial tension and volume fraction of the phases to be varied in a scaled way. When the transition is made with volume fraction larger than 30%, phases are interconnected. The growth dynamics is accelerated by the shear flows imposed by the vibration only if the size of the domains exceeds the viscous boundary layer thickness $(\mu/\omega)^{1/2}$. When the volume fraction is lower than 30%, the domains of the minority phase order in rows perpendicularly to the direction of vibration.

PARTICLE ACCUMULATION STRUCTURES IN THERMOCAPILLARY FLOWS

Stefano Domesi[1], Hiroshi Kawamura[2], Hendrik C. Kuhlmann[1], Jens Leypoldt[1], and Dietrich Schwabe[3]

[1]ZARM, University of Bremen, Am Fallturm, D-28359 Bremen, Germany
[2]Science University of Tokyo, 2641 Yamazaki, Noda-shi, Chiba 278-8510, Japan
[3]I. Institute of Physics, University of Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany

Recent experimental investigations of fluid flows in thermocapillary liquid bridges have shown the accumulation of tracer particles under certain conditions. The nature of these particle accumulation structures (PAS) is strictly connected to the one of the thermocapillary flow, but it is still an open question under which conditions PAS can form and persist. Particularly interesting seem to be the dynamical PAS that arise in time-dependent (oscillatory) flows. Both further experimental and numeric analysis are required as approach to the analysis and microgravity conditions are necessary to consider the role of the liquid-particles density mismatch. In a first step, the transport of ideal (i.e. density-matched) numerical tracer particle distributed in bidimensional vortex-flow models is computed analytically and numerically to compare the effects of the numerical particle-path integration scheme, the grid density, and the interpolation scheme employed. Then real particles are considered and the numerical particle-transport model will be integrated into the code to compute the paths of particles which are initially uniformly distributed in a standard half-zone of a thermocapillary liquid bridge. Numerical calculations will parallel experimental tests and the simulations will be compared with the available experimental data. The final aim of the study is to extend the calculation in order to understand the physical phenomenon and to optimize technical applications in which PAS may occur.

BUBBLES INTERACTION IN MICROGRAVITY

Divinis[1,2], N., Karapantsios[1,*], T. D., Bontozoglou[2], V., Kostoglou, M.[1], Michels[3], A. C.,
and de Bruijn[3], R.

1: Dept. of Chemistry, Aristotle University, Univ. Box 116, 541 24 Thessaloniki, Greece.
2: Dept. of Mechanical Engineering, University of Thessaly, Pedion Areos, 38 334 Volos, Greece.
3: Van der Waals-Zeeman Instituut, Universiteit van Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, The Netherlands.

**Corresponding author*

This work investigates CO_2 bubbles growing adjacent to each other in supersaturated n-heptane when a heat pulse is given to a submerged small heater. Bubbles growing in close proximity on the heated surface soon start to interact with their neighbours. The reduced gravity environment of a parabolic flight allows bubbles to reach excessively large sizes without departing from the heater. This combined with the relatively slow diffusion-induced bubble expansion make bubble interactions easy to observe. Furthermore, the absence of buoyancy renders a spherical bubble shape during the whole course of growth. The number of simultaneous bubbles generated on the heater's surface depends greatly on the delivered power. For all bubbles expansion is fast at the beginning and slows down drastically at later times. Smaller bubbles are stiff and robust while larger bubbles are sensitive to residual vibrations and floppy. Phenomena such as bubble clustering, lifting, coalescence and detachment have been repeatedly observed. An interesting thermocapillary mutual attraction has been also noticed between bubbles adhered to the heater and others free-floating in the nearby liquid.

MICROGRAVITY BOILING AND TWO-PHASE FLOW - REVIEW OF EXPERIMENTAL APPARATUS AND RESULTS -

Haruhiko Ohta[1] and Atsushi Baba[2]

[1] Dept. Aeronautics and Astronautics, Kyushu University, Japan
[2] Office of Research and Development, NASDA, Japan

Researches on boiling and two-phase flow under microgravity conditions has history of more than 40 years. The importance of the researches in the present field is recognized again recently in Europe and US space agencies. The results of experiments will give important information for the clarification of the phenomena not obtained in the researches on ground because the microgravity environment can change one of the most important factors dominating the phenomena. Furthermore, the data is used for the design of high-performance thermal management systems inevitably required for the new space platforms of large scale having higher rate of electric consumption and longer distance of thermal energy transportation to radiators.

The present research reviews the specification of experimental apparatus in the research field subdivided into three major subjects, i.e., pool boiling, flow boiling and adiabatic two-phase flow. The various test sections are introduced here including those employed in the past experiments by drop towers of the laboratory scale because they contains many ideas to overcome the short microgravity duration. Transparent test sections developed by the present authors, i.e., transparent heated tubes and transparent flat heating surfaces for the experiments in narrow channels. The existing researches are reviewed in relation to the experimental hardware employed. In pool boiling experiments, interfacial phenomena induced by Marangoni force and microlayer behaviours concerning heat transfer mechanisms are reviewed. In flow boiling, the range of dominating parameters where reduction of gravity has serious effect on the interfacial phenomena or heat transfer is examined in the relation between Froude, Bond and Weber numbers, and effects of gravity on flow boiling heat transfer are summarized based on the experimental data mostly by the present authors. In adiabatic two-phase flow, the existing results on the flow regime classification in microgravity and effects of gravity observed in the behaviours of annular liquid film are examined.

The future direction of researches on boiling and two-phase flow in microgravity is proposed under the limited number of opportunities for the long-term experiments and under recent financial problems in the development of new facilities. The present review becomes great aid to find a solution for these problems.

PRELIMINARY RESULTS FROM THE FACILITY FOR ADSORPTION AND SURFACE TENSION (FAST) EXPERIMENT ONBOARD STS-107.

Libero Liggieri, Michele Ferrari, Francesca Ravera, Alberto Passerone

Institute for Energetics and Interphases (IENI-CNR), Dept. of Genoa, Genoa - Italy

Surface tension is one of the main parameter characterising liquid interfaces. Surfactant molecules - which are able to adsorb at the interface - are commonly utilised to lower the surface tension and to tune the dynamic properties of liquid interfaces. In fact, these properties are strictly linked to the surface rheology that is to the dynamic response of surface tension to perturbations of the interfacial area. Thus, the study of the dynamic properties related with the adsorption of surfactants is of paramount importance to understand the dynamics of systems at high specific area, like, for example, emulsions, foams, multiphasic flows, which are today widespread in a huge number of technologies and products. Thus, besides the remarkable scientific relevance, these studies are also important for many applications.

As shown by previous experience, microgravity can be fruitfully utilised for investigating adsorption dynamics, providing a purely diffusive environment and spherical interfaces, allowing very sensitive measurement techniques to be implemented.

Experiments for the investigation of the dynamic interfacial tension and the interfacial rheology of adsorbed surfactant layers are planned onboard STS-107 in January 2003, by using the ESA Facility for Adsorption and Surface Tension (FAST). FAST, which already flown aboard STS-95 in 1998, houses two Capillary Pressure tensiometers, which allow different aspects of adsorption dynamics to be investigated, according to different methodologies.

By this technique, the dynamic interfacial tension during the aging of freshly formed interfaces and the surface tension response to harmonic and non-harmonic perturbations of the interfacial area have been investigated. The experimental data allow the surface dilational visco-elasticity to be measured. This parameter is of fundamental importance to characterise the interfacial rheology of the adsorbed layer.

The STS-107 experiment campaign has been performed in the framework of the FASES (Fundamental and Applied Studies in Emulsion Stability) project, funded by ESA, whose main aim is to understand the links between adsorption dynamics and the stability of emulsions.

In this paper preliminary results of this experiment campaign will be given together with an evaluation of the facility performance. The measured dynamic interfacial tensions and dilational visco-elasticity will be discussed and compared with the prediction of models recently developed.

INSTABILITY OF A THIN LIQUID LAYER WITH SURFACTANTS

W. Ellermeier

Institut für Mechanik, TU Darmstadt

A liquid layer with a free surface adheres to a solid substrate in accelerated motion. The substrate's motion's effect upon stability is investigated.

The free surface of the layer is covered with a surfactant monolayer. In practice contaminations of the system inevitably lead to the existence of surface activity.

A particular feature of the model presented is the appropriate consideration of the free surface's metrics spatio-temporal evolution; in the current literature this is taken into account rather seldom.

For sufficiently small amplitudes of the substrate motion weakly nonlinear evolution equations for the development of layer thickness and surfactant adsorption in time and space are derived used for the discussion of the stability of the system.

The results exhibit various effects associated with the action of the surfactant. Its influence on the stability (parametric, modulational, absolute and convective) varies qualitatively with the amplitude of the substrate motion: It may either reduce or enhance stability according to the constitutive properties of the monolayer material.

A short excursion into the stability question for weak solubility of the surfactant concludes the investigation.

SCIENTIFIC SESSION II:

LIFE SCIENCES

(PHYSIOLOGY / DEVELOPMENTAL BIOLOGY / UNICELLULAR ORGANISMS)

EFFECTS OF HEAD DOWN TILT UPON LEPTIN AND STEROID LEVELS

F. Strollo, F. Celotti*, P. Magni*, B.M. Uva, M. More, A. Mambro, R. Corelli, G. Strollo, and G. Riondino**

Endocrine Unit, IRCCS-INRCA u University oLa Sapienzaö, Rome, Italy
** Endocrinology Institute, University, Milan, Italy*
*** DIBISAA, University of Genua, Italy*

Low androgen levels, increased sympathetic activity and nutritional disturbances including relative dehydration have been reported in male astronauts by various groups including ours. The low number of missions available for human physiology studies have made it necessary for space scientists to perform simulation studies on Earth in order to test their hypotheses. -6° head down tilt (-6° HDT) has been accepted worldwide as a suitable simulation method in the field of cardiovascular physiology experiments and for musculoskeletal research studies. It is anyway confined to few laboratories and only performed periodically. In fact, being extremely time- and resource-consuming when extended for weeks, it requires a huge organization effort by the experimental groups involved. A relatively recent mid-term HDT study showed a marked increase in circulating levels of leptin, a newly identified polypeptide produced by the adipose tissue as a function of fat energy stores. Leptin represents a neuroendocrine signal triggering the hypothalamus to potentate the sympathetic system and hereby enhancing thermogenetic and lipolytic activity. It has been shown by our group to inhibit testicular androgen production, probably by partially blocking the enzyme cascade leading from 17-hydroxyprogesterone to testosterone.

The aim of this study was to test whether an easily performed short-term -6° HDT might be able to simulate microgravity in terms of hormone changes and of indirect signs of sympathetic activation and eventually to try and speculate upon such changes.

20 young to middle age male and female subjects underwent a 5 hour -6° HDT in our laboratory. At 0h, 4h and 5h blood pressure, heart rate, leptin, androstenedione and testosterone levels were measured in men, the same parameters except or the last two, which where substituted for by estrone and estradiol, were measured in women. Paired U Wilcoxon test and repeated measure ANOVA were used to analyse among-gender and within-gender differences.

Our results showed lower systolic and diastolic blood pressure levels in women, together with higher leptin concentrations (according to the well known hormonal gender difference) than men. Within women no significant changes were shown. Conversely, men had lower systolic and diastolic blood pressure levels and only a slight decrease in androstenedione and in leptin levels at the end of the test.

Putting together our results with literature data, it is possible to speculate upon the possibility that opposite to what found after some days inflight - during the first few hours in -6 HDT the human subjects reacts with an attenuation rather than an increase of sympathetic system activity. This might be explained by cephalad-shift dependent baroreflex evocation, yet the occurrence of both lower blood pressure and lower leptin levels allows to hypothesize a leptin-mediated mechanism, through which leptin decrease primarily turns off hypothalamic sympathetic activation signals. To get closer to the mechanisms involved, we have validated a method including size-fractionation of total leptin by FPLC (Fast Protein Liquid Chromatography) to separate the bound from the free fraction and another assay to evaluate the expression of leptin receptors in peripheral lymphocytes by semiquantitative reverse transcription-polymerase chain reaction and by Western blot analysis. The lab is currently also setting up a radioimmunoassay to detect plasma levels of total and active ghrelin, a peptide involved in nutritional balance derived from various body areas including the stomach, a poorly explored organ in microgravity. The use of these methods in next HDT experiments might help to answer some of the physiological questions arisen from the present study.

FISH AS MODEL SYSTEMS IN GRAVITATIONAL ZOOLOGY

R.H. Anken

Zoological Institute, University of Stuttgart-Hohenheim, Garbenstr. 30, D-70593 Stuttgart, Germany

During the entire evolution of life on Earth, the development of all organisms took place under constant gravity conditions, against which they achieved specific countermeasures for compensation and adaptation. On this background, it is still an open question to which extent altered gravity such as hyper- or microgravity (centrifuge/spaceflight) affects the normal individual development, either on the systemic level of the whole organism or on the level of individual organs or even single cells. The present review provides information on this topic, focusing on the effects of altered gravity on developing fish as model systems even for higher vertebrates including humans, with special emphasis on the effect of altered gravity on behaviour and particularly on the developing brain and vestibular system.

Overall, the results speak in favour of the following concept: Short-term altered gravity (≤ 1 day) can induce transitional aberrant behaviour due to malfunctions of the inner ear, originating from asymmetric otoliths or, generally, from a mismatch between canal and otolith afferents. The vanishing aberrant behaviour is due to a reweighing of sensory inputs and neurovestibular compensation, probably on bioelectrical basis. During long-term altered gravity (several days and more), step by step neuroplastic reactivities on molecular basis (i.e., molecular facilitation) in the brain and inner ears possibly activate feedback mechanisms between the CNS and the vestibular organs for the regain of normal behaviour.

The following areas of research with animals at altered gravity need to be addressed in the future:
1. Maintenance of animals through two complete life cycles in the space environment (developmental deficiencies?).
2. Investigation of the peripheral and central vestibular system by ground-based studies (mutants, hypergravity experiments...), focusing on plasticity in developing animals as well as in adults.
3. Investigation of the effect of microgravity during critical developmental periods (imprinting phase for graviperception?).
Answers to these questions may be of crucial interest for basic gravitational research.

This work was financially supported by the German Aerospace Center (DLR) (FKZ: 50 WB 9997).

RELATIONS BETWEEN THE STATIC VESTIBULOOCULAR REFLEX AND FICTIVE SWIMMING IN TADPOLES (*XENOPUS LAEVIS*) AFTER A 9-DAY MICROGRAVITY EXPOSURE

Eberhard Horn[1,4], Lydie Gualandris-Parisot[2], Christian Dournon[3], and Sybille Böser[1]

[1] Gravitational Physiology, University of Ulm, Ulm, Germany;
[2] Centre de Biologie du Développement, Université Paul-Sabatier, Toulouse cedex, France;
[3] EA 3442 Genetic, Signaling, Differentiation, Université Henri Poincaré, Vandoeuvre-lès-Nancy cedex, France.

Sensory deprivation during early periods of life affects the development of sensory systems and causes long-lasting morphological and/or physiological modifications. Experiments with the amphibian *Xenopus laevis* which flew on the German D-2 mission (1993) and the Shuttle-to-Mir mission SMM-06 (1997) revealed that µg-exposure affects the development of the roll-induced vestibuloocular reflex (rVOR).
During the Soyuz taxi flight Andromède to ISS (October 2001), we extended these studies (1) by comparing embryos (stage 25-28) which had not yet developed their rVOR at launch with those (stage 45) which had developed it, and (2) by correlating the extent of rVOR modifications in the young group with modifications within their rhythmic activity patterns of spinal ventral roots (VR). Tadpole swimming, a stereotyped rhythmical activity, is a model to examine effects of altered gravity on the motor system since the movement simplicity makes it easy to detect basic changes. High speed camera recordings have shown that tadpoles (*Xenopus laevis*) raised in microgravity exhibited a lower tailbeat frequency than 1g-controls (Fejtek et al. 1998, J Exp Biol 201:1917-26). Swimming pattern is generated by a central oscillator. It is possible to observe the rhythmical, burstlike activity of motoneurons by extracellular recordings from ventral roots (VR) of the spinal cord in paralysed animals (*fictive swimming*). Typical for the swimming pattern is the rostrocaudal delay of activity in ipsilateral myotomes of different segments.
Results: (1) In young *Xenopus* tadpoles, µg induced a depression of the rVOR, in particular in animals which developed upward bended tails during the space flight; in older ones, the rVOR was depressed in tadpoles with upward-bended tails while it was augmented in tadpoles with a straight body shape. (2) After µg-exposure, the duration of episodes of fictive swimming was increased and the rostrocaudal delay was decreased compared to ground-reared 1g-controls; in addition, the burst duration of fictive swimming was slightly decreased. Readaptation of VR-acitivity was completed within 8 days. (3) Significant correlations between the extent of the rVOR and VR activity existed either only in µg-exposed animals (burst duration and rostrocaudal delay) or only in 1g-tadpoles (episode duration). In particular, the VOR-amplitude was significantly correlated with the VR-parameters burst duration, episode duration and rostrocaudal delay. In the µg-group, there was also a significant correlation between cycle length and rVOR gain during the back-down posture.
Conclusions: (1) Microgravity sensitizes or desensitizes the otolithic vestibular system to static roll-stimulation depending on pre-flight rVOR-experience. (2) There are evidences that µg-induced changes in fictive swimming have a vestibular origin. (3) The µg-induced reduction of macular activity may affect the development of descending reticulospinal and raphespinal projections to the spinal cord in a reversible manner. (4) The development of the rVOR network and the spinal motor

system reveals features which might be based on an intrinsic overall-relation or on a dependency of these subsystems mediated by descending pathways from the brainstem to the spinal cord.

[4] *Supported by DLR, grant 50WB0140 to Horn*

HYPERGRAVITY AFFECTS ON THE EMBRYONIC DEVELOPMENT OF CEREBRAL NEURONS IN CRICKETS (*ACHETA DOMESTICUS*)

Uta Kirschnick[1], Michael Schmäh[2], Eberhard Horn[2,3], Hans-Jürgen Agricola[1]

[1] *Cell Biology, Department of Zoology, University of Jena, Erbert-Str. 1, 07743 Jena*
[2] *Gravitational Physiology, University of Ulm, Albert-Einstein-Allee 11, 89081 Ulm*

Sensory and neuronal structures are susceptible to altered gravity in adult as well as in embryonic and post-embryonic systems. In contrast to sensory cells and synaptic contacts within sense organs, studies on identified neurones are rare. In some post-embryonic larvae of crickets (*Acheta domesticus*), the size of the GABAergic common inhibitor neurons located in the thoracic ganglia was modified by 3g-hypergravity. Microgravity had no effect on the structure of cerebral neurons but depressed the sensitivity of a position sensitive neurone in the ventral nerve cord in some postembryonic stages (Horn et al. 2002, Adv Space Res 30,819).

Here we present effects of 3g-hypergravity during embryonic development on the size of some perisulfakinin- (PSK) and allatostatin- (ASTA) immunoreactive (-ir) neurons within the brain of *Acheta*-embryos. Within the PSK-ir pattern, we focussed our interest on two protocerebral neurons, (1) the PDS-neurons with superior dorsally orientated somata whose axons project contralaterally, descending through the whole ventral nerve cord to the terminal ganglion (Agricola and Bräunig, 1995, in Breidbach and Kutsch, eds., The nervous systems of invertebrates, Birkhäuser, Basel) and (2) three local protocerebral interneurons. In the ASTA-ir pattern, we investigated the somata of two neuronal groups, which predominantly have intracerebral projection sites. Peptidergic neurons are of interest as they are generally involved in neuronal adaptation which might be the basis for gravity effects. We exposed 24-hours old eggs for 13 days to 3g-exposure. This period covers completely the period of neuronal proliferation.

The main observation was that the somata of the ASTA-ir cells were not affected by the 13-day hypergravity exposure of the embryos. Among PSK-ir cells, the somata of the small ones revealed a significant ($p<0.05$) decrease in soma size after 3g while the somata of the large cerebral PSK cells located close to the small ones as well as the somata of the PDS cells were unaffected. The number of all peptidergic cells was not affected by the 3g-exposure. By using a double-labelling technique, the PSK-ir and ASTA-ir neurons in the same embryos were considered. Thus, the modification of soma size only in small PSK neurons points to differences in the connectivity of peptidergic neurons to gravity sensitive systems, or to different time courses in the development of these neurons. Unspecific effects of gravity augmentation can be excluded as they probably would affect all the different types of PSK- and ASTA-neurons in a similar manner.

[3] *Supported by DLR, grant 50WB0140*

PARAMETERS OF GRAVITAXIS IN *EUGLENA GRACILIS* OBTAINED DURING SHORT TERM MICROGRAVITY PERIODS

M. Lebert, P. Richter, M. Ntefidou and D.-P. Häder

Lehrstuhl für Ökophysiologie der Pflanzen, FAU Erlangen, Staudtstr. 5, 91058 Erlangen, Germany

The unicellular flagellate *Euglena gracilis* regulates its position in the water column by means of gravi- and phototactic behaviour. Negative gravitaxis of *Euglena gracilis* is triggered by an active physiological mechanism, possibly supported by a physical torque due to the asymmetry of the cell body. Experiments indicate that gravitaxis is most likely triggered by mechano-sensitive ion channels which are activated when the cells deviate from the vertical swimming direction. A subsequent signal transduction chain involves the membrane potential, cAMP and calmodulin and results in reorientation strokes of the flagella. Crucial experiments were performed during sounding rocket (TEXUS and MAXUS) and parabolic flight experiments. During the short time microgravity periods the threshold of gravitaxis was determined (between 0.08 and 0.12 x g_n) and the kinetic of cAMP- and Ca^{2+} - changes were detected. Cells which encounter an acceleration stimulus after microgravity showed a transient, but significant increase of the intracellular cAMP-concentration. From cells which encounter a step from acceleration to microgravity no significant change of the cAMP concentration was detected. In the presence of gadolinium a blocker of mechano-sensitive Ca^{2+}-channels which strongly impairs gravitaxis, no significant change of cAMP was observed, which is an indication of the involvement of mechano-sensitive channels in the signal transduction chain of gravitaxis. Direct observations of the intracellular Ca^{2+}-concentration with the Ca^{2+}-fluorescence indicator Calcium Crimson revealed pronounced kinetic of Ca^{2+} due to reorientation respectively acceleration.

In several parabolic flight campaigns the above mentioned results were confirmed and extended by inhibitor studies. In addition, the membrane potential was monitored during the hypo- and hypergravity phases using the membrane potential indicator Oxanol VI. During hypergravity times a strong depolarization of the membrane was observed followed by a repolarization in the subsequent microgravity phase.

In the next campaign scheduled for spring 2003 the potential influence of a physical component on reorientation of *Euglena* will be analyzed.

POSTER SESSION

COSMIC RADIATIONS AND GENETIC EXPRESSION IN HUMAN T-LYMPHOCYTES FROM BIRBA 1 MISSION

M.A. Meloni, P. Pippia, G. Galleri, M.G. Camboni, R. Negri*, G. Costanzo, V. De Sanctis* *and A. Cogoli*****

Dip. Scienze Fisiol. Bioc. Cell., Univ.Sassari
**Dip. Biol. Cell. e Svil., Univ. Roma Sapienza*
***Centro Studio Acidi Nucleici, CNR, Roma*
****Space Biology Group, ETH, Zurich*

Living organisms, including cells, are affected, in space, by two new environmental conditions: microgravity and cosmic radiations. In the last years we demonstrated that the in vitro mitogenic activation of human T lymphocytes is remarkably depressed in microgravity. The aim of this work was to discriminate between the effects of microgravity and cosmic radiation in T cells. Ionizing radiations are of fundamental interest for space missions and International Space Station utilization. In order to evaluate the effects of cosmic radiations on the gene expression in human T lymphocytes we exposed these cells to high quote cosmic radiation during a stratospheric balloon trans-mediterranean flight. The genetic expression was analyzed by the cDNA micro-array hybridization technology, which allows the comparative and simultaneous estimate of hundreds of mRNAs. T-lymphocytes from human peripheral blood were obtained by gradient centrifugation on Histopaque-1077 and purified by human T cell enrichment columns (R&D System) via high affinity negative selection and activated about 8 hours before launching by addition of Con A, purified mouse anti-human monoclonal anti-CD 28 and protein G. Activated (A) and non activated (NA) cell cultures were sealed in 10 ml FALCON tubes and boarded in the balloon (BIRBA-1 mission, Trapani Milo, Italy, July 2000). Two cell samples (A+NA each) were set inside two special containers (Kayser, Italy) designed to maintain them in suitable and controlled conditions of temperature (37±1°C) and pressure (1±0.05 bar) during the flight. One of the two containers was partially shielded from cosmic radiation (fast neutrons component) to possibly detect eventual differential biological effects of radiation dose and composition. Activated T cells react to the ionizing stress by activating genes involved in cell cycle check-point (PP2A, NT5 and SUPTH), oxidative stress response (GPX1), heat shock proteins production (HSPB1, HSPD1 and HSF2) or by repressing genes involved in antigen recognition (HLA-C and HLA-DBQ1). Now we have a panel of genes candidate to be a target of cellular response to cosmic radiation. This opens interesting perspectives for utilization of DNA micro-arrays as extremely sensitive tools for biodosimetry and cell physiology monitoring in space missions. Further flights and independent analytical methods (Northern blot, RT-PCR) will be required to confirm the significance of these results.

MICROGRAVITY INDUCES APOPTOSIS IN HUMAN LYMPHOCYTES BY ACTIVATING 5-LIPOXYGENASE

Mauro Maccarrone, Mariantonia Meloni*, Natalia Battista°, Monica Bari°, Grazia Galleri*, Proto Pippia*, Augusto Cogoli# and Alessandro Finazzi-Agrò°

Department of Biomedical Sciences, University of Teramo, Italy;
** Department of Physiological, Biochemical and Cellular Sciences, University of Sassari, Italy;*
° Department of Experimental Medicine and Biochemical Sciences, University of Rome Tor Vergata, Italy;
 # Space Biology, ETH Zürich, Switzerland

Creating conditions similar to those that occur during exposure of cells to microgravity induced a 6-fold increase of apoptotic bodies and DNA fragments in human lymphocytes, paralleled by an early (within 2 hours) 4-fold increase in 5-lipoxygenase (5-LOX) activity, and by 5-fold decrease in mitochondrial membrane potential and increase in cytochrome c release (within 4 and 8 hours respectively). Similar membrane potential and cytochrome c release were observed in isolated mitochondria treated with physiological amounts of 5-LOX, and were enhanced by creating conditions similar to those that occur during exposure of cells to microgravity. 5-LOX inhibitors ETYA and caffeic acid completely prevented apoptosis, whereas the phospholipase A2 inhibitor MAFP and the 5-LOX-activating protein inhibitor MK886 reduced it to 65-70%. The intracellular calcium chelator EGTA-AM reduced 5-LOX activity and apoptosis to 30-40% of controls, whereas the p38 mitogen-activated protein kinase inhibitor SB203580 was ineffective. The caspase-3 and caspase-9 inhibitors Z-DEVD-FMK and Z-LEHD-FMK reduced apoptotic bodies to 25-30% of the control cells. Finally, creating conditions similar to those that occur during exposure of cells to microgravity did not induce apoptosis in human lymphoma U937 cells, which did not express an active 5-LOX.

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SUSCEPTIBILITY TO DAMAGE BY µG EXPOSURE REVEALS ALTERATIONS IN BASAL CELL METABOLISM. DIFFERENTIAL BEHAVIOUR IS SHOWN IN NORMAL AND IN TUMORIGENIC CELL LINES

Paolo Degan, Annalisa Zunino, Federico Cesarone, Laura Ottaggio, Sivia Viaggi, Stefania Bonatti, Proto Pippia, Grazia Galleri, Monica Sancandi, Angelo Abbondandolo.

Laboratory of Mutagenesis, IST, Genova,
Dipartimento di Oncologia Biologia e Genetica, Universita' di Genova,
Istituto di Mutagenesi e Differenziamento, CNR, Pisa,
Dipartimento di Fisiologia, Universita' di Sassari.

Microgravity (µg) may be an important tool in the study of the cellular response to stress in fact many physiological parameters result altered after exposure to µg. While many physiological parameters result altered after µg exposure, this tread is significantly related solely with a mechanical effect. Microgravity has been reported to elicit profound effects on living cells such as the reduction of the proliferative rate and the decrease of their metabolic potential, the increase in the apoptotic cell death and the induction of tissue atrophy also correlated with cytoskeletal and bone malformation. It may be important to point out how these modifications are similar to those induced by the ageing processes during the normal and pathological processes of senescence. The understanding of the mechanisms and the occurrence of these modifications by microgravity could be a powerful tool for the study of some of the physiological mechanisms for the control of cell growth. We have employed a simple methodological approach to study the effects of microgravity on different cell lines maintained in culture. µg exposure was accomplished in a Random Positioning Machine (RPM) from Fokker Space B.V., Leiden, NL, located in a warm room (37°C) at the University of Sassari. Cells were exposed to µg for 36 or 48 hours. Afterward a phase of recovery was allowed up to 48 hours. Aliquots of cells were taken during the various phases of the experiment. We were interested in following different physiological parameters in relationship with cellular cell cycle, basal metabolism and their ability to handle aggression from a damaging chemical agent. While the net ratio between cellular survival, viability and DNA susceptibility to damage are not significantly alternated by µg, basal metabolic indexes are found greatly susceptible. In fact they result in a decrease in energy production (ATP) and PARP. These alterations are mostly evident whenever these cells are challenged with a further stress, the chemical potassium bromate, a powerful DNA damaging agent, applied immediately afterward. In these conditions important defects in the managing of DNA repair and energy balance become evident.

Important differences between normal and cancerogenic cell lines also emerges in these conditions. This may be an important issue to elucidate with the aim to use these information for clinical purposes.

ORIENTATION OF FLAGELLATES UNDER µG-CONDITIONS

Kurt Vogel and Donat-P. Häder

Botany Institute, FAU University, Staudtstr. 5, D-8520 Erlangen, FRG

Introduction: The green flagellates, *Euglena gracilis*, orient in their habitat using extern stimuli such as light and gravity. In darkness they show a precise negative gravitaxis which brings them closer to the surface. In addition, the cells show positive phototaxis to move upward at low light intensities and negative phototaxis to move downward at high light intensities. So, the cells accumulate at a horizon of suitable light intensity with enough light for photosynthesis but not excessive light, which would damage their photosynthetic pigments. To get information about the perception of gravity and the relation between gravitaxis and phototaxis the orientation behaviour was studied during sounding rocket flights (TEXUS 23 and 28).

Material and Methods: For the experiment the cells were transferred into the experimental module (TEM 06-5) developed and manufactured by MBB-ERNO (Bremen, FRG) and adapted for four hours. The module carried a microscope unit with a 2.5 x objective operating in dark field modus. The organisms were observed in a circular cuvette (0.2 mm depth and 55 mm diameter) made from stainless steel and infrared transmitting filters. The cuvette was connected with a tube reservoir via a peristalic pump, which allowed a redistribution of the cell suspension. The frame of the cuvette had a lateral gap and allowed the irradiation of the organisms with parallel actinic light impinging at 15° inclination to the surface. The image was recorded by a CCD camera and sent to the ground control station by a video transmitter module. The movements of the cells were analyzed using an image analysis system developed in our laboratory. Two different programs are able to evaluate the velocity and orientation of all cells in an image sequence [1] and to track individual cells in real time [2].

Preliminary Results: Before lift off, after adapting the cells for about four hours in the module, they showed a high degree of gravitactic orientation. After lift off, when the video signal reappeared the cells showed an orientation, which was induced by centrifugal forces from the spin of the rocket. One minute after microgravity conditions were reached, the cells oriented randomly. Previous unpublished results with µg-simulation on a fast rotating clinostat showed that the cells keep their previous orientation for about 1 min under microgravity conditions. Both at 1-g and at µg conditions the swimming speeds showed a Gaussian distribution with an increased standard deviation under microgravity. The mean value of the swimming speed was about 25 % higher under microgravity conditions than in the control. In previous experiments it was shown that cells which swim upwards against the gravity force are slower than cells which swim downwards. In the first phase of the TEXUS 28 experiment the orientation behaviour of the cells in darkness was investigated and the results of TEXUS 23 [3] were verified.
In the second part of the experiment the cells were laterally irradiated with white light (300 W/m¨). Immediately after switching the light on the cells showed phobic responses followed by a negative phototactic orientation. In contrast to the TEXUS 23 experiment the optical unit was modified in order to get more information about the trace-patterns of single cells.

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DISCLOSING THE SITE OF OTOLITHIC CALCIUM UPTAKE IN DEVELOPING FISH USING FLUORESCENT CALCIUM-TRACERS

M. Beier, R.H. Anken and H. Rahmann

Zoological Institute, University of Stuttgart-Hohenheim, Garbenstr. 30, D-70593 Stuttgart, Germany

Since changing the gravity vector (concerning direction and amplitude) strongly affects inner ear otolith growth and otolithic calcium incorporation in developing fish, it was the aim of the present study to locate the site of mineralization in order to gain cues and insights into the provenance of the otoliths inorganic compounds.

Therefore, larval cichlid fish (*Oreochromis mossambicus*) were incubated in the calcium-tracer alizarin complexone (AC; red fluorescence). After maintenance in aquarium water for various periods (1h, 2h, 3h, 6h, 9h, 12h, 1d, 2d, 3d, 5d, 6d, 7d, 15d, 29d, 36d and 87d), the animals were incubated in the calcium-tracer calcein (CAL; green fluorescence). AC thus labelled calcium being incorporated at the beginning of the experiment and would subsequently accompany calcium in the course of a possible dislocation, whereas CAL visualized calcium being deposited right at the end of the test. Subsequently, the otoliths were analysed using a laser-scanning microscope, and it was shown that the initial site of calcium incorporation was located directly adjacent to the sensory epithelium and the otolithic membrane. Later, calcium deposits were also found on further regions of the otoliths surface area, where they had been shifted to in the course of dislocation. This finding strongly indicates that the sensory epithelium plays a prominent role in otolithic biomineralization, which is in full agreement with an electron microscopical study (Ibsch et al., this issue).

This work was financially supported by the German Aerospace Center (DLR) (FKZ: 50 WB 9997).

CALCIUM SUPPLY OF INNER EAR OTOLITHS IN FISH VISUALIZED BY ENERGY FILTERING TRANSMISSION ELECTRON MICROSCOPY (EFTEM)

M. Ibsch, R.H. Anken and H. Rahmann

Zoological Institute, University of Stuttgart-Hohenheim,
Garbenstr. 30, D-70593 Stuttgart, Germany

Inner ear otolith formation in fish is supposed to be performed by the molecular release of proteinacious precursor material from the sensory epithelia, followed by an undirected and diffuse precipitation of calcium carbonate (which is mainly responsible for the functionally important weight of otoliths). Previous experiments have shown that the provision of calcium is regulated by a (likely neuronal) feedback mechanism. The pathway of calcium into the endolymph, however, still remains obscure. Therefore, the presence of calcium within the utricle of larval cichlid fish Oreochromis mossambicus was analysed by means of energy filtering transmission electron microscopy (EFTEM). Electron spectroscopic imaging (ESI) and electron energy loss spectra (EELS) revealed discrete calcium precipitations, which were especially numerous in the proximal endolymph (P) as compared to the distal endolymph (D), clearly indicating a decreasing P-D gradient. This finding is in complete agreement with conclusions most recently drawn from physiological experiments. A decreasing proximo-distal gradient was also present within the proximal endolymph between the sensory epithelium and the otolith. Further calcium particles covered the peripheral proteinacious layer of the otolith. They were especially pronounced at the proximal surface of the otolith indicating that otolithic calcium incorporation takes place here, which may explain the decreasing P-D gradient. Other calcium precipitates were found to be accumulated at the macular junctions, which clearly supports an earlier suggestion that the endolymph is supplied with calcium via a paracellular pathway. Overall, the present results strongly suggest that the apical region of the macular epithelium is involved in the release of calcium and that calcium supply of the otoliths takes place in the proximal endolymph, which is in full agreement with a study employing fluorescent calcium-tracers. (Beier et al., this issue).

This work was financially supported by the German Aerospace Center (DLR) (FKZ: 50 WB 9997).

MORPHOMETRY OF THE UTRICULAR MACULA IN MOTION SICK FISH: A PARABOLIC AIRCRAFT FLIGHT STUDY

A. Bäuerle, R.H. Anken, R. Hilbig, N. Baumhauer, and H. Rahmann

Zoological Institute, University of Stuttgart-Hohenheim,
Garbenstr. 30, D-70593 Stuttgart, Germany

Humans taking part in parabolic aircraft flights (PAFs) may suffer from space motion sickness (SMS, a kinetosis). Since it has been repeatedly shown earlier that some fish of a given batch also reveal a kinetotic behaviour during PAFs (especially so-called spinning movements and looping responses) and due to the homology of the vestibular apparatus among all vertebrates, fish can be used as model systems to investigate the origin of susceptibility to motion sickness. Therefore, we examined the utricular maculae (they are responsible for the internalisation of gravity in teleosteans) of fish swimming kinetotically at microgravity in comparison with animals from the same batch who swam normally. On the histological level, it was found that the total number of both sensory and supporting cells of the utricular maculae did not differ between kinetotic animals as compared to normally swimming fish. Cell density (sensory and supporting cells/100μm^2), however, was reduced in kinetotic animals ($p<0.0001$), which seemed to be due to malformed epithelial cells (increase in cell size) of the kinetotic specimens. Susceptibility to kinetoses may therefore originate in genetically predispositioned malformed sensory epithelia.

This work was financially supported by the German Aerospace Center (DLR) (FKZ: 50 WB 9997).

DETERMINING THE THRESHOLD OF GRAVITY FOR INDUCING MOTION SICKNESS IN FISH: A DROP-TOWER EXPERIMENT

R.H. Anken and R. Hilbig

Zoological Institute, University of Stuttgart-Hohenheim,
Garbenstr. 30, D-70593 Stuttgart, Germany

It has been repeatedly shown earlier that some fish of a given batch reveal motion sickness (a kinetosis) at the transition from 1g to microgravity. In the course of parabolic aircraft flight experiments, it has been demonstrated that kinetosis susceptibility is correlated with asymmetric inner ear otoliths (i.e., differently weighed statoliths on the right and the left side of the head) or with genetically predispositioned malformed cells within the sensory epithelia of the inner ear (Bäuerle et al., this issue). Hitherto, the threshold of gravity for inducing kinetosis as well as the relative importance of asymmetric otoliths versus malformed epithelia for kinetosis susceptibility has yet not been determined.

Therefore, experiments will be carried out at the ZARM drop-tower facility in Bremen, Germany, employing larval cichlid fish (*Oreochromis mossambicus*), which will be kept in a camcorder-equipped centrifuge during the microgravity phases of the experiments and thus receive various gravity environments ranging from 0.1 to 0.9g. Videographed controls will be housed outside of the centrifuge receiving 0g. Based on the video-recordings, animals will be grouped into kinetotically and normally swimming samples. Subsequently, otoliths will be dissected and their size and asymmetry will be measured. Further investigations will focus on the numerical quantification of inner ear supporting and sensory cells as well as on the quantification of inner ear carbonic anhydrase reactivity. A correlation between (1) the results to be obtained concerning the g-loads inducing kinetosis and (2) the corresponding otolith asymmetry/morphology of sensory epithelia/carboanhydrase reactivity will further contribute to the understanding of the origin of kinetosis susceptibility.

EFFECTS OF HYPERGRAVITY ON THE GROWTH OF INNER EAR OTOLITHS OF DEVELOPING FISH CORRELATE WITH MACULAR CARBONIC ANHYDRASE REACTIVITY

M. Beier, R.H. Anken and H. Rahmann

Zoological Institute, University of Stuttgart-Hohenheim,
Garbenstr. 30, D-70593 Stuttgart, Germany

It has been shown earlier that hypergravity slows down inner ear otolith growth in developing fish. Otolith growth in terms of mineralization mainly depends on the enzyme carbonic anhydrase (CA), which is responsible for the provision of the pH-value necessary for calcium carbonate deposition and thus also is presumed to play a prominent role in Ménière´s disease (a sensory-motor disorder inducing vertigo and kinetosis).

Larval siblings of cichlid fish (*Oreochromis mossambicus*) were subjected to hypergravity (3g, hg; 6hrs) during development and separated into normally and kinetotically swimming individuals following the transfer to 1g (i.e., stopping the centrifuge; kinetotically behaving fish performed spinning movements). Subsequently, CA was histochemically demonstrated in inner ear ionocytes (cells involved in the endolymphatic ion exchange) and enzyme reactivity was determined densitometrically. It was found that both the total macular CA-reactivity as well as the difference in reactivities between the left and the right maculae (asymmetry) were significantly lower (1) in experimental animals as compared to the 1g controls and (2) in normally swimming hg-animals as compared to the kinetotically behaving hg-fish. The results are in complete agreement with earlier studies, according to which hypergravity induces a decrease of otolith growth and the otolithic calcium incorporation (visualized using the calcium-tracer alizarin complexone) of kinetotically swimming hg-fish was higher as compared to normally behaving hyper-g animals. The present study thus strongly supports the concept that a regulatory mechanism, which adjusts otolith size and asymmetry as well as otolithic calcium carbonate incorporation towards the gravity vector, acts via activation/deactivation of macular CA.

This work was financially supported by the German Aerospace Center (DLR) (FKZ: 50 WB 9997).

EFFECT OF HYPERGRAVITY ON SUCCINATE DEHYDROGENASE REACTIVITY IN FISH VESTIBULAR GANGLIA

J. Kempf, R.H. Anken, and H. Rahmann

Zoological Institute, University of Stuttgart-Hohenheim, Garbenstr. 30, D-70593 Stuttgart, Germany

Previous investigations revealed that altered gravity such as hypergravity (hg) effects various adaptation and compensation processes at the level of brain nuclei, which are connected to the inner ear by the vestibular nerve. Respective investigations on those neurons, which actually comprise the primary relay stations for vestibular inputs to the brain, i.e., the vestibular ganglia, have hitherto not been undertaken.

We were thus prompted to histochemically determine the reactivity of succinate dehydrogenase (SDH; a key enzyme of the respiratory chain and thus a marker for neuronal activity) in the ganglia utricularis and saccularis (the former transmits linear acceleration such as gravity from the inner ear to the brain, whereas the latter is involved in hearing) as well as (for control) in the diencephalic, non-vestibular Nucleus glomerulosus posterioris (NGp) of fish which had been kept at hg.

SDH-reactivity was histochemically demonstrated and densitometrically analysed on serial sections of entire heads of larval cichlid fish (*Oreochromis mossambicus*), which were kept for 14 or 21days at 3g hg (centrifuge).

It was found that SDH-reactivity within the utricular ganglion was significantly increased in experimental animals as compared to the 1g controls, whereas hg had no effect on SDH-reactivity in the saccular ganglion and in the NGp.

The present results provide a clear indication of the effect of altered gravity exclusively on the metabolic activity/plasticity of a peripheral, vestibular ganglion, which is directly involved in the transmission of gravitationally relevant inputs.

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BEHAVIOURAL RESPONSES TO HYPERGRAVITY ENVIRONMENT IN PERIADOLESCENT CD1 MOUSE

N. Francia, D. Santucci and E. Alleva

Behavioural Pathophysiology Section, Lab. Fisiopatologia di Organo e di Sistema, Istituto Superiore di Sanita, Viale Regina Elena 299, I-00161 Roma (Italy)

Increasing evidence from both ground-based and space research indicates that exposure to altered gravitational environments during "critical periods" of development affects the nervous system, eliciting neurobehavioural changes which may persist into adulthood. We investigated the behavioural responses of CD-1 mouse to hypergravity exposure during early adolescence. Twenty-eight-day-old male and female mice were exposed to 2g rotational-generated hypergravity for a single 60 or 120 min session and their behavioural repertoire was monitored before, during, and after rotation. Furthermore, the emotional/anxious responses (plus-maze test) and spatial learning performances (Morris water Maze test) were investigated respectively 24 h and 48 h after exposure. Behavioural observation indicated a transient mild sickness associated with hypergravity, with a decrease in spontaneous activity. Rotation per se induced an increase in emotional/anxious responses and a deterioration of spatial learning acquisition, while hypergravity specifically improved flexibility of spatial orientation.

MR IMAGING METHODS FOR ASSESSING TRABECULAR BONE QUALITY AFTER PROLONGED SPACE FLIGHT

R. Toffanin(1, 2), A. Accardo(3), I. Strolka(4), P. Szomolanyi1(4), M. Cova(5), and F. Vittur(1)

(1) Dept. BBCM, University of Trieste, Trieste, Italy
(2) PROTOS Research Institute, Trieste, Italy
(3) Dept. EEI, University of Trieste, Trieste, Italy
(4) Institute of Measurement Science, Slovak Academy of Sciences, Bratislava, Slovakia
(5) Dept. of Radiology, University of Trieste, Cattinara Hospital, Trieste, Italy

It is well known that weight acts on the skeleton by imparting a mechanical stimulus and that dynamic loading during walking and lifting is more important to normal growth and maintenance of the skeleton than resting loads. Space flights, during which astronauts are maintained under weightlessness conditions, induce in individuals some biological modifications leading to bone loss. This loss may lead to a significant increase in the risk of fracture and to the possibility of renal stone formation due to calcium mobilization from bones. Even though non weight-bearing bones are less affected than weight-bearing bones and the skeletal changes are proportional to mission length, bone abnormalities have not been observed in all space flight studies. Abnormalities in bone and mineral metabolism are major problems for astronauts but the magnitude of bone loss, the anatomical site of loss and the effects of flight duration are specific for each subject. A major concern is, therefore, the effect of extended weightlessness on bone structure and mass as a loss of cortical and trabecular bone volume and density, both of which can lead to decreased bone strength and an increased risk of bone fracture. Dual energy X-ray absorptiometry (DEXA), ultrasonic measurements of velocity (SOS) and broadband attenuation (BUA) have been used for the rapid determination of bone mineral density whereas computed tomography (CT) and, more recently, magnetic resonance imaging (MRI) have been used for quantifying the skeletal structure changes. In particular, MRI appears to be the most promising technique for the quantitative assessment of the bone microstructure. In this study we describe the use of projection reconstruction and conventional MRI-based methods for the in vivo assessment of trabecular bone at different anatomical sites. The efficacy of the various methods in the quantification of the main structural parameters derived from the three-dimensional MR images of the distal femur, calcareous and distal radius is investigated. The proposed methods could be applied to evaluate bone architecture and bone quality in astronauts after prolonged space flight exposure.

THE USE OF BODY-FIXED EXCITERS AND SERIES-ELASTIC DEVICES TO STUDY SPACE FLIGHT-INDUCED NEUROMUSCULAR CHANGES.

E. Gallasch

Physiology, University of Graz, Harrachgasse 21/5, A 8010 Graz, Austria

In microgravity neuromuscular control is affected by altered motor programs resulting from weight unloading and loss of proprioceptive information. Long-term missions further lead to a degradation of the muscle-skeletal apparatus resulting in post-flight phenomena such like increased reflex excitability and tremor.

To study such flight-induced accommodations/ adaptations in ISS astronauts we propose a new interactive mechatronic test set. The first part of the set consists of two body-fixable moving mass exciters with embedded accelerometers to assess arm impedance in different target postures and movements. Both exciters are tunable in frequency (2 - 20 Hz) and amplitude, which also allows the investigation of limb proprioceptive changes (vibration reflex, vibration threshold).

The second part of the proposed test set consists of a series elastic motor connected to ankle joint. The test procedures include flexion/ extension against isometric and elastic loads and braking against induced loads. These procedures would allow new insights into the forward control and reflex mechanisms in the ankle joint. Both body-fixed devices may also contribute to health monitoring and training.

EFFECTS OF MICROGRAVITY ON IN-VITRO-MINERALIZATION OF ODONTOBLASTS

C. Möhl, M. Dreiseidler

University of Bonn

Scheme for an experiment developed by students at the SOKRATES Course "Biology in Space"- Banyuls (2002).

Odontoblasts are differentiated cells, deriving from dental pulp, and producing the hard mineralized dentin matrix of the tooth. Thus, they have comparable structure and function to osteoblasts, which generate the mineralized bone matrix of the skeleton.

The gravity sensing and its specific signalling pathways in osteoblasts has been well determined in the past. However, the effects of microgravity on odontoblasts remain unidentified.

In our experiment, we plan to investigate the matrix mineralization of an odontoblastic cell line under different gravity conditions. Therefore it would be necessary to measure the amount of mineralized matrix and to examine the activity of proteins involved in the mineralization process.

WINNING TEAM of ELGRA STUDENTS CONTEST on PARABOLIC FLIGHT CAMPAIGNS: LIFE SCIENCES

THE EFFECTS OF MICROGRAVITY AND HYPERGRAVITY ON CRAB, *CARCINUS MAENAS* (L.) STATOCYST INTERNEURONES.

Peter J. Fraser[§] (project supervisor)**, Denis G. Alferéz[Φ], Roberto Araújo[Φ], Maria J. Carneiro[Φ] and Mairi Pollard[Φ]**

[§]Department of Zoology, School of Biological Sciences and [Φ]Department of Molecular and Cell Biology, University of Aberdeen, Regent Walk. AB24 2FX, Aberdeen, U.K.

Two parabolic flights were performed in which two sets of 4 crabs (*Carcinus maenas)* were oscillated at 0.3 Hz continuously during bouts of normal, hyper- and micro-gravity. The aim was to study the role of gravity in the statocyst, which is analogous to the human vestibular system in order to shed more light into "Space Adaptation Syndrome". Microgravity and hypergravity affect the discharge frequency of interneurones. During the two 1.8 g periods before and after each microgravity bout, output from statocyst interneurones was altered in a complex but repeatable way. A fluctuation was noticed on the discharge pattern for head up and head down cells, each giving opposite outputs during hypergravity. Changes in successive parabolas were similar, allowing averaging. The amplitude of the plate altered slightly during each different gravitational period, but this was considered unlikely to have contributed greatly to the results obtained. Furthermore during each gravity phase, it was noticed that equilibrium conditions were not reached.

„BUBBLE BATH“ – PARABOLIC FLIGHT EXPERIMENTS WITH AQUEOUS FOAMS

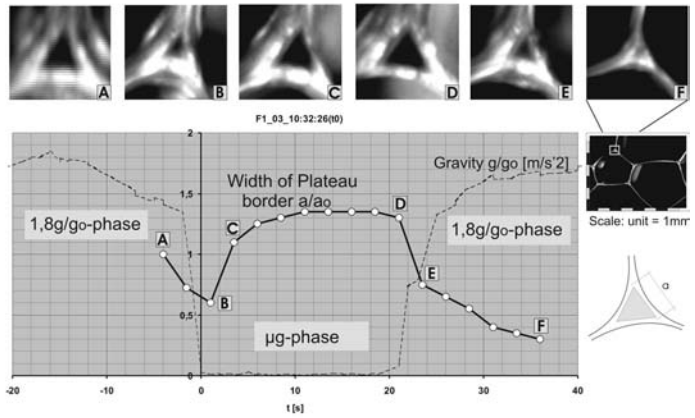
M. Meier, D. Hille, M. Walter, M. Knoepke, R. Richter, G. Wallot

During ESA´s 5th SPFC in 2002 an experimental series to characterize the stability of solid-particle-loaden foams was performed successfully. A team of students designed and constructed an experiment facility for the investigation on the stability of particle-loaded aqueous foams in the Airbus A300 ZERO-G environment. Within two flights 35 experimental runs could be absolved successfully during ESA`s parabolic flight campaign in September 2002. Analysis of the experimental data was done post-flight by image processing. The evaluation of the data showed a high degree of reproducibility, which proves the success of the applicated experiment procedures and the facility design.

Results of the flight experiments with foams under the regime of three succeeding gravity levels 1.8 g/g0 - µg – 1.8 g/g0 with transient regions in between in comparison with laboratory experiments are presented.

One of the main results is the obviously non-exponential decrease of the Plateau borders widths during the second 1.8 g/g0-phase. The forced drainage of this phase seems to be composited of two ranges, obeying different regimes (see figure below).

Behaviour of the Plateau borders on changing gravity conditions



The results show that the gravity induced drainage in the aqueous foam system can be clearly separated from the fluid flow induced by boundary tension forces by the specially designed experimental set-up under these environmental conditions. It is planned to perform further parabolic flight experiments with this facility by using more sophisticated measurement techniques.

WINNING TEAM of ELGRA STUDENTS CONTEST on PARABOLIC FLIGHT CAMPAIGNS: PHYSICAL SCIENCES

LLESCA-SCF ARTIFICIAL GRAVITY GENERATION

Ciurana, X., Gerones, I., Selga and J. Sola

This work investigates the performance of a centrifugal platform in a reduced gravity environment when its gravity center changes position continuously in a random fashion. The experiment was performed during the 5th Student Parabolic Flight Campaign of ESA and was meant to simulate the effect of people or cargo moving freely inside a space station. The displacement of the gravity center was realized by moving around a weight attached to the platform. The question is whether it is possible to restore the gravity center in real time by a simple countermeasure, such as the movement of another weight. On this account, a second weight was driven around by a PID controller in order to bring the platform back to its original revolution axis. Simple mathematical control algorithms were developed to operate the PID controller. Technical problems hampered the actual onboard testing of the employed control scheme. Yet, post flight analysis showed that the PID controller was capable of restoring an appreciable part of the onboard measured deviations of the platform's spinning stability.

REMOTE ACCESS TO LIFE SCIENCES EXPERIMENTS ON THE ISS OR IN GROUND-BASED FACILITIES - DEMONSTRATION OF A USER HOME BASE

Marianne Schuber, Dieter Seibt and Paul Esser

Europe voted for a decentralized support of the Columbus facilities involving Facility Responsible Centers and Facility Support Centers. User Home Bases will enable to access scientific data at the user's home lab via a remote link. By this approach scientists need not to be hosted at a Control Center to follow multiple or long-duration life sciences experiments in ISS facilities, e.g. with the BIOLAB. Moreover scientific–technical ground infrastructure and tools can be accessed by the scientists from their home labs. Being supplied with recent experimental data from BIOLAB or from ground-based facilities the experimenter can focus on research activities in the home lab. No duplication of this infrastructure will be necessary. Specific tools can be developed and adapted in accordance with the scientific requirements for processing and evaluation of experimental data.

This will be demonstrated during the course ELGRA meeting making use of the lab model of the Slow Rotating Centrifuge Microscope NIZEMI investigating biosamples located at the DLR Microgravity User Support Center in Köln. Remote access from Munich will be shown by processing of real-time video images for experiment evaluation.

SCIENTIFIC SESSION III:

EDUCATION

USER SUPPORT

SOUNDING ROCKET

SOYUZ MISSION

EXPERIENCES FROM A GERMAN-FRENCH PROJECT ON THE INTEGRATION OF PUPILS IN AN ACTUAL SPACE EXPERIMENT

Eberhard Horn[1] and Christian Dournon[2]

[1] Gravitational Physiology, Department of Neurobiology, University of Ulm, Ulm, Germany;
[2] EA 3442 Genetic, Signaling, Differentiation,Université Henri Poincaré, Vandoeuvre-lès-Nancy cedex, France.

The German-French biological experiment AQUARIUS-XENOPUS which flew on the Soyuz taxi flight ANDROMÈDE to the International Space Station ISS (launched October 21, 2001 in Baikonur/Kazakhstan) was extended by an outreach project. - Pupils of class 10 to 12 from Ulm/Germany and Tomblaine-Nancy/France were involved in this actual space experiment. They recorded swimming behavior of *Xenopus laevis* tadpoles by video used as a 1g-ground control for similar observations in µg-exposed tadpoles on ISS. The pupils were instructed to perform all experimental steps following the protocol of the video recordings on ISS which were done by the French cosmonaut Claudie Haigneré. After the flight, they evaluated swimming activity of both ground controls and space animals using parameters such as type, velocity and acceleration of swimming, or the distribution patterns of tadpoles within the miniaquaria.
The pupil project included theoretical components to introduce them to the field of gravitational biology. Nancy pupils established a homepage (www.xenope.com) about background and aim of their scientific project while Ulm pupils received an extended theoretical and practical education (1) about gravity effects on biological systems and what gravity means for life on Earth, and (2) on hardware used for biological research in Space. A feature of the project was the exchange of ideas between all pupils by internet and meetings which took place in Ulm (June 2001), Nancy (February 2002) and Paris (May 2002). Selected pupils also presented their work and the project at international conferences Life sciences (ESA: Stockholm, July 2002; ASGSB: Cape Canaveral, November 2002). The project lasted approximately 18 months. Nearly all pupils (12 girls, 4 boys) stayed with the project during the whole period; only 1 of 20 left the group after a 6 months participation.
We consider our approach as a successful way to include young people even from the high school level in space experiments on a cheap cost level and to bring the ideas of gravitational biology into curricula of European schools. The project also showed that personal engagement from the teachers and scientists as well as from the supporting agency staff is a prerequeisite for the success of cooperations between school and university such as the one presented here.

Supported by the German Space Agency (DLR), the French Space Agency (CNES), the City of Ulm, Astrium GmbH, the Minister of Education of Baden-Württemberg, and local institutions of the Nancy region.

USER SUPPORT AND OPERATIONS SERVICES FOR ISS UTILISATION - BIOLAB AS AN EXAMPLE OF A COLUMBUS PAYLOAD

M. Schuber, D. Seibt and P. Esser

DLR Microgravity User Support Center (MUSC)
Linder Hoehe 23b
D-51147 Köln

For the ISS utilisation a number of User Support and Operations Centers (USOCs) in Europe will interlink the experimenters in Materials Sciences and Life Sciences and the respective ISS payloads by providing a broad spectrum of support services. These services can be divided into pre-, in-flight and post-flight phase. The introduction into these user support services provided for experimenters will be illustrated by the example of services planned for BIOLAB as one of the Life Sciences core payloads on ISS. Main tasks are experiment and payload operations preparation, in-flight facility/experiment monitoring and control, post-flight facility evaluation, data distribution well as experiment evaluation support. ESA will make provide the BIOLAB Engineering Models and Science Reference Model(s) as well as the main communication components.

During all phases of an increment access to the utilisation of available ground model(s) and laboratory facilities for e.g. zero-g simulation and hyper-g equipment will be possible thus enabling an integrated operations and science support.

The BIOLAB dedicated USOCs will consist of a Facility Responsible Center (FRC) and a Facility Support Center (FSC). Experiment-Specific Support Centers (ESCs) from the experimenters home country may be involved for the operations preparation and in-flight operations performance of individual BIOLAB experiments. A direct connection from a USOC to a users` home base (UHB) may also be established. Currently the USOCs are starting the implementation of the centers infrastructure within the network of all involved European USOCs.

EURO LAUNCH, THE NEXT GENERATION OF EUROPEAN CONSOLIDATED SOUNDING ROCKETRY

Stig Kemi*, Peter Turner, Dr. Olle Norberg*****

** SSC Swedish Space Corporation, ESRANGE, Head of Sounding Rocket and Balloon Department, POB 802, SE-981 28 Kiruna, Sweden*
*** DLR German Aerospace Center, Head of MORABA-Mobile Rocket Base, Space Operations and Astronaut Training Directorate, D-82234 Oberpfaffenhofen, Germany*
**** SSC Swedish Space Corporation, ESRANGE, Head ESRANGE, POB 802, SE-981 28 Kiruna, Sweden*

With the successful planning, implementation and conduct of sounding rocket launches at ESRANGE, the European Sounding Rocket Launching Range of SSC at Kiruna in North-Sweden and of MORABA, DLR's Mobile Rocket Base of München-Oberpfaffenhofen of more than 30 years, an evolutionary step into the next century with the creation of "EURO LAUNCH", the European Technical Center for Sounding Rocketry has been established between DLR, the German Aerospace Center and SSC, the Swedish Space Corporation.

With "EURO LAUNCH" the long-lasting co-operation of ESRANGE and MORABA shall be enhanced, intensified and the sounding rocket center of competence shall be included into a European Network of Centers for Sounding Rockets and Balloons, whereas the technical competence for Balloon Launches shall remain at the Balloon Department of CNES, the French National Space Agency.

The comprehensive competence within the scope of the Network of Centers in Europa will be presented. The consolidation of competences and work distribution among the partners shall be detailed. The managerial structure of EURO LAUNCH and the embedding in the mother organizations SSC and DLR respectively will be explained.

The newly organized EURO LAUNCH is expected to provide improved services to experimenters in Europe with increase of competence, capability and efficiency.

THE DUTCH SOYUZ MISSION

Jack J.W.A. van Loon*, Rolf P. de Groot**

*Dutch Experiment Support Center (DESC), ACTA-Vrije Universiteit Amsterdam. ** National Instute for Space Research (SRON), Utrecht, The Netherlands.*

Later this year on 18th October 2003 the Dutch ESA cosmonaut / astronaut Andre Kuipers will be flying on board a Russian Soyuz to the International Space Station. During this mission he will perform various scientific and technological experiments. Since these Soyuz missions are becoming more regular for ESA we shall explain the setup for such a flight and explain the science opportunities.
Currently there are studies forseen in the field of biology, physical sciences, human physiology and technology. We shall shortly address all the experiments for this particular flight.

Planned experiments in life sciences:
The Influence Of Gravity On The Cytoskeleton And The Determination Of The Division Plane In Plants (TUBUL), prof.dr. A.M.C Emons (WU) and prof.dr. M. Dogterom (AMOLF)
Influence of Microgravity on the Activation of NF□ B (KAPPA) dr. M.P. Peppelenbosch, dr. H.H. Versteeg, AMC
Role of microgravity on actin metabolism in mammalian cells (ACTIN) prof.dr. J. Boonstra, UU and dr. P.T. van der Saag, NIOB
Oestrogen or NF□ B response of the osteoblastic U2OS-engineered cell in microgravity (OESTRO) dr. P.T. van der Saag, NIOB, et al. (F, I, D, CH, C, SF)
Microgravity and Bone Cell Mechanosensitivity (FLOW) dr. J. Klein-Nulend en dr. J. J.W.A. van Loon, VU / DESC
Physiological Parameters that Predict Orthostatic Intolerance After Spaceflight (HEART) dr. J.M. Karemaker, AMC, et al. (NL, USA)
24-hr profile of blood pressure and heart rate in microgravity (CIRCA) dr. J.M. Karemaker, AMC, et al. (NL, F)
Vestibular Adaptation to Gravity Transitions (SICSAS) dr. J.E. Bos, dr. E. Groen et al (TNO-HF)
Human Cerebral Cortex Plasticity to Long-term Microgravity Exposure. (CEREBRAL) dr. D. Robberts (MUSC, Charlotte, USA), dr. N. Ramsey (Univ. Utrecht), dr. F. Hoogenraad (Philips Medical Systems, Best), prof.dr. Snijders (Univ. Rotterdam), prof.dr. D. Stegeman (Univ. Nijmegen)

Planned experiments in physical sciences / astrobiology:
The Miller-Urey experiment in space (MILLER) prof.dr. P. Ehrenfreund (NL), dr. O. Botta (Oost), Mag. G.K. Kminek (USA)
Crystallisation of Rhodopsins in Microgravity (RHODOP) prof.dr. W. de Grip (KUN) et al. (NL)
Hydrodynamics of Wet Foams (FOAM) prof.dr. P. Lemstra (TUE), prof.dr. D. Langevin (F), dr. G. Verbist (Shell Research)
Advanced Photonic Devices in Microgravity (COLLOID) dr. G. Wegdam (UVA) et al. (USA, NL)
Transport processen in metal halide lamps (LAMP) prof.dr. G.M.W. Kroesen (TUE), dr. M. Haverlag Performance of heatpipes in microgravity (HEAT) dr. G. Grommers (Dutch Space), prof.dr. J.C. Legros (B) (Philips Lighting)

Planned technological experiments:
Tactile-torso-display aided orientation awareness and body awareness (JERKIN) Dr. J. van Erp en dr. H.J. van Veen, TNO.
Molecular and physiological analysis of bacterial samples isolated from manned space craft (SAMPLE) dr. H.J.M. Harmsen, RUG, dr. J. Krooneman, Bioclear environmental technology b.v., dr. P. Landidi (CH)

SCIENTIFIC SESSION IV:

LIFE SCIENCES

(CELL BIOLOGY)

**MICROGRAVITY AND BONE CELL MECHANOSENSITIVITY—
RAPID NITRIC OXIDE PRODUCTION BY BONE CELLS
IS FLUID SHEAR RATE DEPENDENT**

R. G. Bacabac[1], T. H. Smit[2], S. Dijcks[1], J. J. W. A. Van Loon[1,3], J. Klein-Nulend[1]

[1]Department of Oral Cell Biology, Academic Centre for Dentistry Amsterdam-Vrije Universiteit
[2]Department of Physics and Medical Technology, Vrije Universiteit Medical Center
[3]Dutch Experiment Support Center, Vrije Universiteit, Amsterdam, The Netherlands

INTRODUCTION:

The shear stress induced by the flow of interstitial fluid through the lacuno-canalicular network is a likely signal for bone cell adaptive responses [1]. We have shown recently that fluid shear stress affects bone cell activation by fluid flow [2]. However, not much is known about the nature by which bone cells respond to fluid shear stress induced by dynamic loading. Microgravity has catabolic effects on the skeleton of astronauts as well as on mineral metabolism of tissue cultures flown to space. Since microgravity provides a unique environment of unloading, the loss of bone in space is likely an exceptional form of disuse coupled with possible microgravity effects on the sensitivity of bone cells to stress. Precise control of the fluid environment for cell cultures is critical for investigating direct effects of microgravity on bone cell cultures in space. In this study we address the nature by which fluid shear stress activates bone cells by testing whether fluid shear stress with varying frequencies and amplitudes affects the nitric oxide (NO) production by MC3T3-E1 osteoblast-like cells. The *in vitro* model used in this study to test bone cell activation, induces dynamic fluid flow between parallel plates on bone cells to mimic *in vivo* fluidic shear stress. This study employed precise design conditions by which the parallel-plate flow chamber (PPFC) can be utilized for dynamic flow regimes.

MATERIALS AND METHODS:

The PPFC geometry, and flow frequencies were chosen such that the condition $h/\lambda_v<2$ holds, (h: distance between plates (300μm), λ_v: viscous penetration depth). This condition predicts that the maximum frequency allowed is 11.2Hz to induce dynamic quasi-steady flow regimes, for the PPFC (aspect ratio = 33.3), using cell culture medium.

MC3T3-E1 bone cells were cultured in α-MEM with 10% fetal bovine serum (FBS). For fluid shear stress treatments, 2 x 10^5 cells were seeded on glass slides (5cm^2), and incubated for 15 min with 1) steady flow (0.70Pa), 2) low amplitude pulsating fluid shear stress (PFSS, 0.70$\pm$0.31Pa) at varying frequencies (5Hz, 9Hz), and 3) high amplitude pulsating fluid shear stress (0.70$\pm$0.70Pa, 5Hz and 9Hz) with static controls, in α-MEM+2% FBS.

NO was measured in the conditioned medium using Griess reagent. Data from 5-9 separate experiments were collected and expressed as treatment over control (T/C) ratios. All results were analyzed with the non-parametric Wilcoxon rank sum test.

RESULTS:

The PFSS regimes were precisely designed to be composed of an average of 0.7Pa plus an oscillating component with low amplitude (0.31Pa), or high amplitude (0.70Pa), with varying frequencies lower than 11.2Hz (i.e., 5Hz, or 9Hz) using a computer operated pump. Treatment with low amplitude, high frequency PFSS (0.7$\pm$0.31Pa, 9 Hz) caused a rapid increase of NO to nearly 3-fold, within 5 min. However low amplitude, low frequency PFSS (0.70$\pm$0.31Pa, 5Hz) gave minimal effects on the production of NO by bone cells. Treatment with high amplitude PFSS (0.70$\pm$0.70Pa, 5Hz or 9Hz) caused a rapid increase of NO production by bone cells, in contrast with a low amplitude PFSS of the same frequency (0.70$\pm$0.31Pa, 5Hz or 9Hz, respectively). Higher PFSS rate induces higher NO production and PFSS regimes of similar maximum rate of stress elicit a similar response despite differing frequencies (9 Hz low amplitude or 5 Hz high amplitude). The results also suggest that the response to stress has a threshold between fluid shear stress rates 10 Pa/s and 15 Pa/s.

DISCUSSION:We investigated NO production since it is an essential step for mechanical loading-induced bone formation as observed in rats *in vivo* [3]. Hence, NO production in response to fluid shear stress is a meaningful parameter to measure bone cell activation.

The present study showed that the NO response of bone cells to fluid shear stress is dependent on the applied frequency and amplitude. We conclude that NO production by bone cells subjected to fluid flow is dependent on the rate of fluid shear stress. Thus, a useful parameter for the activation of bone cells by fluid flow is the rate of fluid shear stress. Precise control of bone cell activation is optimized by choosing appropriate fluid shear stress rates for maintaining bone cell cultures in space and for testing bone cell mechanosensitivity under microgravity environment.

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FLG 29.1 CELL DIFFERENTIATION: A COMPARISON BETWEEN THE EFFECTS OF SIMULATED LOW G AND THOSE INDUCED BY ULTRASOUND EXPOSURE

M. Monici(1), F. Fusi(2), A. Cogoli(3), M. Paglierani (4) E. Biagi (5) and P. A. Bernabei(6)

(1) Centre of Excellence in Optronics, Florence; (2) Dept. of Clinical Physiopathol., University of Florence;
(3) Space Biology Group, ETH-Technopark, Zurich; (4) Dept. of Human Pathol. and Oncol., Careggi Hospital, Florence;
(5) Dept. of Electronics and Telecomun., University of Florence; (6) Haematology Unit, Careggi Hospital, Florence

Many proofs have been found that gravitational alterations and other mechanical factors can affect cell behaviour. Cellular response to mechanical stress is a field of increasing research activity. Of particular interest are questions concerning the systems involved in propagating stress-induced signals into the cells (mechanotransduction), and the mechanisms by which cells alter their function in response to these signals. At present mechanisms of mechanotransduction at cellular level remain to be fully understood; nevertheless the research findings support the widely accepted hypothesis that the cytoskeleton has a fundamental role in mechanotransduction. It was demonstrated that gravity and other mechanical factors can intervene in cytoskeleton self-organization and will indirectly affect other cellular processes that in their turn depend on it.

A better understanding of how mechanical forces, at cellular level, may influence biochemical reactions and gene activity could be of consequence in a great number of applications ranging from the development of new strategies for prevention and therapy of diseases to the tissue engineering.

Gravity as a mechanical stimulus acts permanently on organisms as either static or dynamic stimulation. The weightless environment, both real and simulated by clinostats, may be used as a tool for studies on the role of gravity in the modulation of the cellular processes. Moreover, devices have been developed to expose the cells to different types of controlled mechanical stimuli (fluid flow, stretching, touching by glass micropipette, force application via magnetic beads, ultrasounds, laser-trap method).

Our research concerns mainly the role of mechanical factors in the regulation of haemopoietic cell differentiation and function. The investigation on the relationship between osteoclastogenesis and mechanical factors is a focal point of the research programme. It is a common opinion that studies on the response of bone cells or their progenitors to mechanical stimuli (gravitational alterations included) could have an important socio-economical follow-up. In fact they could be of consequence in drawing strategies for prevention and therapy of bone diseases, including osteoporosis, which is considered the principal bone disease both in USA and Europe as regards social costs.

In previous studies we found that, under simulated low gravity conditions, FLG 29.1 cells (a line characterized as an osteoclastic precursor model) assume the phenotypic characteristics of elements with a higher degree of differentiation, in comparison with control, and the ability to resorb bone.

This report describes a study on the behaviour of FLG 29.1 cells exposed to ultrasound stimulation.

The mechanical stress caused by ultrasound exposure affects cell morphology, cell proliferation, the expression of major osteoclastic markers and cytoskeletal proteins.

A comparison is made between the effect induced by ultrasound exposure and those observed in simulated low g conditions.

WEIGHTLESSNESS-INDUCED ALTERATIONS AT SUBCELLULAR LEVEL IN CULTURED GLIAL CELLS

B.M. Uva*, M.A. Masini*, M. Sturla*1, G. Tagliafierro*, F. Strollo**

**Dipartimento di Biologia Sperimentale, Universita di Genova, Italy*
***Unita Endocrinologicaö INRCA & Universita La Sapienza Roma, Italy.*

Previous on ground studies have shown that weightlessness disturbs the cytoskeleton, disrupts the nuclei and induces apoptosis in 70% of the cultured glial cells after 1h in simulated microgravity (Uva et al., 2001, Elgra News 57-58; Uva et al., 2002, Brain Research 132-139, Uva et al., 2002, European Journal of Histochemstry 46, 207-214). The glia is by far the most abundant component of the Central Nervous System. As glia is essential for the correct functioning of neurons any damage to the glia mar central nervous system activities. The cell membrane, the barrier between the cytoplasmic matrix and the extracellular fluid, exert a strict control on the water and ion balance inside the cell. Ion transport mechanisms and water channels are located at the plasma membrane level. The energy required by the cell relies upon ATP synthesis, which is accomplished by mitochondria. Lysosomes are the sites for intracellular catabolysis, they are the digestive apparatus of the cell and dispose useless or damages organelles, conversely, ribosomes are the sites of new synthesis. The integrity of all the intracellular organelles is therefore essential for a good cell functioning. Aim of the present research was to further investigate on the alterations caused at subcellular level, in cultured glial cells, by simulated microgravity.

For this purpose we used C6 glioma cell line in monolayer cultures kept in a Fokker 3D Clinostat under continuous rotation (60 rpm) for 15 min, 30 min, 1h, 20h and 32h (simulated microgravity 0g). Control cultures 1g were positioned on the support structure in order to submit the cells to the same vibrations. At the end of each experiment the cells were fixed with 4% paraformaldehyde or 2.5% glutaraldehyde. The fixed cells were submitted to immunohistochemistry or Electron Microscope procedures. Immunohistochemistry was performed using antisera to a-tubulin, to proteins of the inner mitochondrial membrane (AMA), to Na+/K+ATPase (a-subunit), to the carrier protein Na+/K+/Cl- cotransporter T4 NKCC1 and to the water channel Aquaporin 4. Immunostaining specificity was verified by omitting one of the steps of the immunohistochemical procedure, or by replacing the primary antiserum with non-immune rabbit serum or PBS. Nuclei were stained using 5mg/ml propidium iodide, 100 U/ml RNAse or 4,6-diamidino-2-phenylindole, dihydro chloride (DAPI). The results were visualised with a Transmission Electron Microscope, a conventional epifluorescence microscope (Olympus) and a laser scanning confocal microscopy system. Some cells were placed onto Leighton tubes (Costar Cambridge, UK) and submitted to the same rotation procedure, as described before, for Scanning Electron Microscope (SEM) analysis.

After 1h at 0g the plasma membrane appeared irregular and very thin in many sites where the outer coat seemed to be absent. Mitochondria were swelled and in many of them the inner cristae were disrupted. Damaged mitochondria were seen inside secondary lysosomes. Immunoreactivity for the Na+/K+/Cl- cotransporter protein and the Na+/K+ATPase was very low. Immunostaining for the water channels was very irregularly distributed. However after 20h in simulated microgravity many cells showed again undamaged intracellular organelles and clusters of undifferentiated cells appeared in the cultures. The clusters hosted many cells in mitosis and fully differentiated daughter cells were often present. The cells in the clusters were rich in free ribosomes, the intracellular organelles were normal and immunostaining for ion transport proteins and water channels was bright and normally distributed.

We conclude that gravity vector changes may induce only transient alterations at subcellular level in the cultured glial cells that might adapt to low gravity and restart normal activities.

AN INTERPLAY BETWEEN HSP70 AND IL-1 IS RESPONSIBLE FOR ENDOTHELIAL GROWTH ADVANTAGE IN SIMULATED MICROGRAVITY

Sofia IM Carlsson, Maria TS Bertilaccio and Jeanette AM Maier.

Department of Preclinical Sciences-LITA Vialba, University of Milan, Via GB Grassi 74, Milan, Italy.

All organisms on earth have developed to survive within the pull of gravity. Orbital space flights have clearly demonstrated that the absence or the reduction of gravity profoundly affects eukaryotic organisms, including man. Because i) endothelial cells are crucial in the maintenance of the functional integrity of the vascular wall, and ii) cardiovascular deconditioning has been described in astronauts, we evaluated whether simulated microgravity affected endothelial functions. We show that endothelial cells proliferate faster than controls when cultured in hypogravity. This may be due to an enhanced expression of heat shock protein 70, which in turn downregulates interleukin 1α, a potent inhibitor of endothelial growth, also implicated in promoting senescence. In addition, endothelial cells exposed to hypogravity rapidly remodelled their cytoskeleton and, after a few days, markedly downregulated actin. We hypothesize that actin downregulation represents an adaptative mechanism aimed at removing redundant actin fibers in response to simulated microgravity.

SIMULATED MICROGRAVITY INDUCES PROGRAMMED CELL DEATH IN HUMAN THYROID CARCINOMA CELLS

Augusto Cogoli*, Peter Kossmehl, Mehdi Shakibaei***, Holger Pickenhahn**, Martin Paul** and Daniela Grimm****

** Space Biology Group, ETH Zurich, Switzerland*
*** Institute of Clinical Pharmacology and Toxicology, Center for Space Medicine, Berlin, Germany*
**** Institute of Anatomy, FU Berlin, Germany*

The present study focuses on the effects of simulated microgravity on the human follicular thyroid carcinoma cell line ML-1 and the oxiphilic papillary thyroid cancer cell line ONCO-DG- 1 (ONCO). Cultured on a three-dimensional clinostat ML-1 and ONCO cells formed three-dimensional multicellular tumor spheroids (MCTS: Æ 0.3±0.01mm in diameter). After 24 and 48 h of clinorotation the ML-1 cells significantly decreased fT3 and fT4 secretion, but upregulated the TSH-receptor expression. In addition, as the production of vimentin, vinculin and extracellular matrix proteins (collagen I, III, laminin, fibronectin, chondroitin sulfate) were increased as compared to 1g controls. Furthermore, ML-1 and ONCO cells grown on the clinostat showed elevated amounts of the apoptosis-associated Fas protein, of p53 and of bax, but reduced quantities of Bcl-2. In addition, signs of apoptosis as assessed by TdT-mediated dUTP digoxigenin nick end labelling, DAPI staining, DNA laddering and 85-kDa apoptosis-related DNA fragments became detectable. The latter ones resulted from enhanced 116-kDa poly(ADP-ribose)polymerase activity. All these observations suggested that clinorotation elevates intermediate filaments, cell adhesion molecules and extracellular matrix proteins and simultaneously induces apoptosis in follicular thyroid cancer cells.

In conclusion, our experiments could provide a regulatory basis for the observation that astronauts show low thyroid hormone levels after spaceflight, which may be explained by the increase of apoptosis in thyrocytes as a result of simulated microgravity.

THE ROLE OF PROTEIN KINASE C IN LYMPHOCYTE LOCOMOTION: RESCUE OR CAUSE?

A. Sundaresan*, D. Risin, N.R. Pellis****

**Universities Space Research Association,*
***NASA Johnson Space Center, Houston, TX.*

Space travel and long-term space residence such as planned in the ISS era may invoke unique burdens on the immune system. An optimal immune response is required to counteract and withstand exposure to pathogens and disease. Important lymphocyte functions such as activation and locomotion are impaired in modelled microgravity as well as in space. Modelled microgravity (MMG) exerts effects on different cells in different ways. These effects could be selective, species and cell type specific. In human lymphocytes, calcium-independent Protein Kinase C (PKC) isoforms are differentially expressed in MMG. PKC-delta and -epsilon were found to be down-regulated by more than 50%, while calcium-dependent PKC-alpha expression was not significantly different in 1g vs. MMG-cultured lymphocytes. In order to determine if the differential expression of the calcium-independent isoforms was linked to locomotion inhibition in MMG, they were blocked in 1g cultures by specific inhibitors. Considerable optimization was necessary to arrive at doses that were not toxic to cells and yet successfully inhibited the PKC isoforms. It is anticipated that this approach will determine the participation of the isoforms in normal locomotion and set the strategy for elucidating the mechanism by which MMG modulates the expression and possibly the function of PKC in lymphocyte locomotion.

EARLY TRANSCRIPTIONAL RESPONSE OF HUMAN T-LYMPHOCYTES TO MICROGRAVITY CONDITIONS DURING A MASER FLIGHT

M. Cogoli-Greuter*, R. Negri, G. Costanzo**, G. Galleri**, M.A. Meloni**, T. Schopper* and P. Pippia****

** Space Biology ETH Technopark, Technoparkstr. 1, CH-8005 Zürich*
*** Department of Cell and Developmental Biology, University of Rome, La Sapienza, Piazzale A. Moro 5, I-00185 Rome*
**** Department of Physiological, Biochemical and cellular Sciences, University of Sassari, Via Muroni 25, I-07100 Sassari*

Experiments conducted in space have shown that T lymphocyte activation in vitro is remarkably reduced in microgravity. The data indicate that a failure of the expression of the interleukin-2 receptor (IL-2R, measured as protein secreted in the supernatant) is responsible of the loss of activity. Recent investigations have clearly shown that the expression of both IL-2 and IL-2Rα genes is significantly inhibited in simulated 0x*g*. In an experiment performed on a sounding rocket flight the expression of early genes in T-lymphocytes, activated with concanavalin A has been studied.

Peripheral blood lymphocytes from two different donors were filled into the cell chambers of the LIDIA experiment unit (developed and manufactured by Dutch Space Leiden) the day before flight. Two hours before scheduled launch the units were loaded into the CIS module and the samples brought to 37°C. MASER 9 was launched on March 16, 2002. As soon as microgravity conditions were established the cells were activated and than lysed after an incubation time of ca. 5.5 minutes. After recovery the samples were frozen. Control experiments were performed in an onboard 1xg centrifuge and on ground. The onboard centrifuge allows the comparison of the data obtained in microgravity with a 1x*g* control having the same history related to launch and re-entry.

Analyses were done by high-density filter-based cDNA microarrays constituted by single membranes containing approximately 4'000 known human genes.

In Con A activated T-lymphocytes a mild early transcriptional response to a short exposure to microgravity could be observed. From 1 donor about 1% of the genes monitored show significant modulation compared to a control in the onboard 1x*g* centrifuge. Some of the modulations were confirmed using thematic arrays containing a selected panel of human chemokines or interleukin receptors cDNAs. The same filters show modulation of a few genes not present on the microarrays, notably downregulation of IL-2Rα. Most of the modulations observed appear to be donor-dependent but 8 genes, including the small cytokine A5 RANTES, IL-10 Rβ and IL-1β were found to be similarly modulated in the two different donors examined.

SCIENTIFIC SESSION V:

PHYSICAL SCIENCES

(CONVECTION / FRONT PROPAGATION)

GEOFLOW: EXPERIMENTS WITH GEOPHYSICAL APPLICATIONS IN THE FLUID SCIENCE LABORATORY ON ISS

Christoph Egbers, Vadim Travnikov, Philippe Beltrame and Rainer Hollerbach[*]

Dept. of Aerodynamics and Fluidmechanics (LAS), Brandenburg Technical University of Cottbus, Germany; egbers@las.tu-cottbus.de; Fax: 0049-355-69-4891
[*] *Dept. of Mathematics, University of Glasgow, Glasgow, U.K.*

The „GEOFLOW“ is an ESA experiment prepared for the Fluid Science Laboratory on ISS under the scientific coordination (PI) of the Department of Aerodynamics and Fluidmechanics (LAS) at the Brandenburg Technical University (BTU) of Cottbus, Germany. The objective of the experiment is to study thermal convection in the gap between two concentric rotating (full) spheres. A central symmetric force field similar to the gravity field acting on planets can be produced by applying a high voltage between inner and outer sphere using the dielectrophoretic effect (rotating capacitor). To counter the unidirectional gravity under terrestrial conditions, this experiment requires a microgravity environment. The parameters of the experiment are chosen in analogy to the thermal convective motions in the outer core of the Earth. In analogy to geophysical motions in the Earth’s liquid core the experiment can rotate as solid body as well as differential (inner to outer). Thermal convection is produced by heating the inner sphere and cooling the outer ones. Further on, the variation of radius ratio between inner and outer sphere is foreseen as a parameter variation. The flows to be investigated will strongly depend on the gap width and on the Prandtl number. Results of preparatory experiments and numerical simulation of the space experiment will be presented.

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NATURAL CONVECTION IN ROTATING SPHERICAL GAP UNDER THE CENTRAL FORCE FIELD

Vadim Travnikov, Rainer Hollerbach, Christoph Egbers

Department of Aerodynamics and Fluid Dynamics, BTU Cottbus, D-03046 Cottbus

Convection in spherical shells under the influence of a radial force field is an important problem in classical convection theory.

It is difficult to reproduce in a terrestrial laboratory though, because there gravity is everywhere downwards rather than radially inwards. It turns out that one can produce a radial force field, by applying a voltage difference between the inner and outer spheres. The combination of the electric field and the temperature-dependence of the fluid's dielectric coefficient then produces an 1/r5 central force field. Of course, in a terrestrial laboratory one still has the external gravity as well. In order to eliminate this effect and produce a purely radial force field, an experiment is planned on the International Space Station.

In this talk we will present the results of numerical simulations intended to assist in the design of this experiment, for example in choosing the optimal radius ratios. We solve for the onset of convection in such an 1/r5 force field, as a function of the radius ratio (varying between 0.3 and 0.6), the Prandtl number (varying between 1 and 100), and the Taylor number (measuring an overall rotation of the whole shell, which will also be possible in the experiment).

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COMPLEX DYNAMICS IN DIFFERENTIALLY HEATED CAVITIES UNDER LOW GRAVITY CONDITIONS

X. Ruiz[1], I. Mercader[2], O. Batiste[2], L. Ramírez-Piscina[2], J. Casademunt[3]

[1]Applied Physics Lab. Facultat de Ciencies Químiques. Universitat Rovira i Virgili. Tarragona. Spain (also, Institut d'Estudis Espacials de Catalunya, IEEC. Barcelona. Spain).
[2]Dept. Física Aplicada. Universitat Politècnica de Catalunya. Barcelona. Spain
[3] Dept. Estructura i Constituents de la Materia. Facultat de Ciencies Físiques. Universitat de Barcelona. Spain

The purpose of this work is to gain quantitative insight into flow instabilities of small Prandtl number fluids in laterally heated cavities under conditions of low gravity. Two different thermal conditions, perfectly conducting and adiabatic, are applied to the upper and lower walls of the cavity. Geometry and material parameters used are relevant to actual semiconductor crystal growth experiments by the Bridgman method. Although a preliminary study in a cavity of aspect ratio (length/height) two and perfectly conducting walls was reported in the past [1,2], we present here the complete scenario for both perfectly conducting and adiabatic cases.

Numerical results were obtained by direct integration using two independent methodologies. The first one is based on the direct integration of the equations in primitive variables together with the corresponding boundary conditions using a second order time-splitting algorithm applied to a pseudospectral Chebyshev method. The second methodology is based on the direct integration of the same equations in primitive variables using two standard structured finite-volume schemes based on the SIMPLE and the PISO algorithms.

For small Rayleigh numbers a centro-symmetric flow pattern, the so-called Hadley cell, is obtained. But, increasing the value of the Rayleigh number we find in both cases a transition from steady flow to periodic oscillations through a Hopf bifurcation that maintains the centro-symmetry of the steady state. Further increasing of the Rayleigh number generates a complex dynamics dominated by the interaction of a Neimarck-Sacker and a flip bifurcation of periodic solutions. The symmetry group Z_2 of the equations plays an important role in the resulting bifurcation scenario preventing the apparition of some kinds of forbidden bifurcations. The above-mentioned interaction generates, mainly in the adiabatic case, low dimensional chaos as well as frequency locking windows inside Arnold tongues. The complex behaviour of the chaotic solutions should be distinguished from turbulence, here the flow is coherent in space and therefore chaos must be understood as purely temporal in nature. The occurrence of aperiodic behaviour can be traced back to the appearance of small secondary vortices near the lateral walls. These structures interact with the central one in a different way depending on the thermal condition applied. i.e., in the perfectly conducting case the isotherm distribution confines the main vortical structure in the center of the cavity and the secondary vortices move up and down. The use of adiabatic conditions breaks the rigidity of the isotherms enabling an expansion of the central structure and a drastic reduction of the secondary vortices in both sides.

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MICAST - THE EFFECT OF MAGNETICALLY CONTROLLED FLUID FLOW ON THE SOLIDIFICATION OF TECHNICAL AL-ALLOYS UNDER MICROGRAVITY CONDITIONS

M. Hainke, J. Friedrich, G. Müller

Crystal Growth Laboratory, Fraunhofer Institute IISB, Schottkystr. 10, 91058 Erlangen, Germany

In this paper, we report about the European research program MICAST. The project was initiated in 1998 by ESA to utilise the International Space Station. The research program within MICAST is focused on: a systematic analysis of, how the intensity of convection and the direction of the flow acts on the evolution of the mushy zone, on macro- and micro-segregation and on the morphology of dendrites. For simplifying the complex interactions the experiments within MICAST are carried out under well defined thermal and magnetically controlled, convective boundary conditions by using directional solidification.

In our group, we have developed the global thermal model tool CrysVUn [1], which is designed for the simulation of solidification processes. The software package is applied to solidification experiments performed within the MICAST project and used for the definition of suitable magnetic field parameters for the planned micro gravity experiments.

In this work, the influence of the forced flows due to the magnetic field is analysed both on a macro- as well as on a micro scale. Thereby numerical studies are presented in which the process parameters like growth velocity, gradient and magnetic field parameters are systematically varied, to investigate the effect on the overall shape of the two phase region. It appears that by the application of the RMFs, a macrosegregation effect is created due to the secondary flows entering the mushy region. Secondly, the results from the macro model serve as input parameters for a micromodel, developed by Roosz and co-workers [2]. This allows also the numerical prediction of microstructure characteristics, like the primary and secondary dendrite arm spacing. Preliminary results of this approach are presented in this work.

The parameter study is used to define an experiment scheduled on TEXUS41 with the so-called ARTEX [3] facility. This experiment will be a precursor experiment of a number of space experiments utilising the International Space Station.

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SEGREGATION ANALYSES OF SEMICONDUCTOR SINGLE CRYSTALS GROWN INSIDE MODELIZED INERTIAL MODE ORBITING SYSTEMS

X. Ruiz[1] , M. Ermakov[2]

[1] Applied Physics Lab. Universitat Rovira i Virgili. Tarragona, Spain. (also, Institut d'Estudis Espacials de Catalunya., IEEC, Barcelona, Spain. xruiz@quimica.urv.es)
[2] Institute for Problems in Mechanics, RAS. Moscow, Russia (ermakov@ipmnet.ru)

During inertial flight mode, orbiting systems remains fixed relative to some external celestial object, usually the sun. This fixed orientation forces the components of the μg-vector to change periodically in a single-frequency way. The frequency of these changes is very low –typically of the order of 1- 0.01 mHz- as well as the magnitude of the accelerations implied –typically of the order of 1-50 μg-. For a long time, researchers considered not significant the impact of this kind of quasi steady accelerations on the liquid systems at high temperatures. However, a report concerning InP:S growth during the European Retrievable Carrier, EURECA-1, mission using the Automatic Mirror Facility, AMF, concluded that, in that case, long crystal growth experiments should be carefully planned because the changes of orientation of the μg vector relative to the temperature gradient seems to really affect the quality of the resulting solid phase [1]. The present communication will try to deep inside this still open question using relevant liquid semiconductor systems virtually grown using a modelized Bridgman configuration.

Liquid phases at high temperature have been considered Boussinesq newtonian liquids and the variation of the μg-vector has been modelized using circularly polarized vibrations [2], that is to say, both gravity components have been defined as single valued harmonic signals of zero average with amplitudes ranging between 1 and 50 μg and frequencies between 1 and 0.01 mHz. Because of an exhaustive characterization of the resulting 3D scenarios is not practical due to the low frequencies –equivalently, long times- involved, we use a two levels strategy. The first one, reported here, consists in a thermosolutal 2D restricted analysis in order to only identify trends. However because of the low Rayleighs involved, 2D conclusions could not be as fictitious as it seem.

For 1 μg and in all the range of frequencies investigated neither steady nor fluctuating convection will perturb the growing process. Diffusion controlled solute transport conditions is not questionable. However in the case of 10 and 50 μg, virtual 'post mortem' analyses concerning the concentration of dopants in the crystal show a nonlinear dependence between segregation and vibroconvection driven by the external frequencies. Thus, to improve the crystal homogeneity in long crystal growth experiments inside inertial mode orbiting systems, isolation units could be active still below 10 mHz, the actual limit [3].

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COMBUSTION SYNTHESIS UNDER MICROGRAVITY CONDITIONS OF TITANIUM DIBORIDE-TITANIUM ALUMINIDES

Roberta Licheri(1), Roberto Orru(1), Giacomo Cao(1-2), Jimmy De Wilde(3), Inigo Agote Beloki(4), David John Jarvis(5), Ludo Froyen(3)

(1) Dipartimento di Ingegneria Chimica e Materiali, Centro Studi sulle Reazioni Autopropaganti (CESRA), UnitaÆ di Ricerca del Consorzio Interuniversitario Nazionale per la Scienza e Tecnologia dei Materiali (INSTM), Universita degli Studi di Cagliari, Piazza DÆArmi, 09123, Cagliari, Italy
(2) CRS4, VI Strada Ovest, Z.I. Macchiareddu, 09010 Uta (Cagliari), Italy
(3) Department MTM, K.U. Leuven, Kasteelpark Arenberg 44, B-3001 Heverlee, Belgium
(4) INASMET, Parque Tecnologico E-20009 Donostia - San Sebastian, Spain
(5) European Space Agency, Keplerlaan 1 u P.O BOX 299 u 2200 AG Noordwijk ZH, The Netherlands

Self-propagating combustion synthesis is characterized by the fact that once ignited, a relatively strong exothermic reaction is able to propagate as a combustion wave through the entire reacting mixture, without requiring any other energy supply. The main characteristics of this technique are its simplicity, relatively low power requirements, high combustion temperature (up to 4000 K) and front propagation velocities (up to about 25 cm per second). In addition, combustion synthesis technique often permits to obtain final products with purity and mechanical properties better than those prepared by conventional methods. This is because, since SHS processes are characterized by very high temperature gradients (about 105 K/cm) and large reaction rates, powders of any volatile impurities adsorbed on the reactants are eliminated ("self-cleaning") during the reaction, thus leading to materials with high purity. Furthermore, the temperature gradients combined with rapid cooling may form metastable phases and unique structures not possible by conventional methods of furnace synthesis.

It is well known that the structure and properties of materials produced by combustion synthesis strongly depend upon process conditions such as reactants composition, green density, particles size as well as external fields. In particular, the effect of the gravitational field on self-propagating reactions has recently received increasing attention. The driving force of these studies is that self-propagating reactions occur as a consequence of a complex series of stages (melting of reactants and products, spreading of the melt, drop coalescence, diffusion and convection, buoyancy of solid particles, densification of liquid products, etc.) most of which are significantly affected by gravity. It is apparent the importance to investigate the effect of gravity on the above mentioned phenomena in order to identify the detailed mechanism of reaction evolution and structure formation. Along these lines, interesting results have been recently obtained in USA, Japan, Canada and Russia, using low gravity environment.

In this work, the effects of gravity on combustion characteristics and product microstructure of titanium diboride/titanium aluminides composites were investigated under normal and low gravity conditions.

Low gravity combustion synthesis was carried out aboard reduced gravity aircraft, specifically AIRBUS 300 from Novespace (Bordeaux, France), in the framework of a parabolic flight campaign sponsored by ESA on March 2002.
Besides classical combustion synthesis experiments performed using free-standing cylindrical pellets, we also conducted combustion front quenching experiments using conical samples placed inside a copper block. This experimental approach is typically adopted to investigate the mechanism of structure formation occurring in combustion synthesis reactions.

As expected, under both microgravity and terrestrial conditions, it is found that combustion temperature and front propagation velocity decrease as the system exothermicity is augmented, i.e. when the aluminide/diboride molar ratio is increased. However, it is clearly seen that combustion synthesis and front propagation velocity are lower under microgravity conditions. This is consistent with the results obtained during combustion front quenching experiments. In fact, the extinction of the combustion front occurs earlier when the reaction is performed under reduced gravity conditions, thus displaying a lower system reactivity.

SESSION VI:

PHYSICAL SCIENCES

(TRANSPORT COEFFICIENT)

APPLICABILITY OF SHEAR CELL TECHNIQUE FOR GROUND BASED DIFFUSION EXPERIMENTS OF LIQUID ALLOYS

S. Suzuki, K.-H. Kraatz, A. Griesche*, M.-P. Macht* and G. Frohberg

Technical University of Berlin, Institute for Materials Science and Technology, Sekr.PN 2-3, Hardenbergstr. 36, D-10623 Berlin, Germany
**Hahn-Meitner-Institut Berlin, Glienicker Str. 100, D-14109 Berlin, Germany*

During three Spacelab Missions self-diffusion experiments were performed successfully in liquid metals in single-component systems by the long capillary technique. In multi-component systems results indicated segregation effects during the solidification. For measurements in alloys, therefore, our institute had developed a miniature shear cell, which delivered valuable results on the unmanned Russian Foton satellite in October 1999 (Foton12). This construction has been improved for experiments on Foton M1 in October 2002.

Because of the loss of the Foton M1 satellite we reduced the planned experimental program to ground experiments. Under special limiting conditions the results obtained in this shear cell are comparable to that of former μg-experiments. In the In-Sn system the measured diffusion coefficients as well as the reproducibility of the results correspond to those we found in space experiments (D2-Mission, Foton12).

Similarly graded results were obtained in Pd-metallic glasses, for which investigations with help of quasi-neutron scattering are the basis of the reference.

THE DEVELOPMENT OF A SHEAR CELL FOR THE MEASUREMENT OF LIQUID DIFFUSION COEFFICIENTS UNDER MICROGRAVITY CONDITIONS

Reginald Smith

Queen's University, Canada.

A knowledge of diffusion transport in liquids is of fundamental importance in studying and modeling metallurgical processes and crystal growth. However, currently available data, where they exist at all, are often widely inaccurate. Fortunately, it has been shown that microgravity can offer an environment with much reduced buoyancy problems and so permit the capture of more precise diffusion data. In order to perform liquid diffusion experiments under microgravity conditions, a modified shear cell has been developed. The shear cell can be used for diffusion in liquids with high reliability, simple operation and be totally enclosed in two protective metallic sheaths to permit use in a manned orbiting laboratory. In addition, the design permits use in ATEN, the advanced thermal processing facility being developed by the CSA for use on the international Space Station in combination with a microgravity g-jitter isolation mount.

The talk will review (a) the general features of ATEN as they relate to liquid diffusion experiments; (b) the design and testing of the shear cell to be used with ATEN, and (c) the CFD modeling of the influence of the shearing rate on the transport of solute during the initiation and completion of the diffusion anneal period.

THERMOLAB: HIGH-PRECISION THERMOPHYSICAL PROPERTY DATA OF LIQUID METALS FOR MODELLING OF INDUSTRIAL SOLIDIFICATION PROCESSES. RESULTS OF SURFACE TENSION AND DENSITY OF NI-BASED SUPERALLOYS

E. Ricci, D. Giuranno, R. Novakovic, A. Passerone (1); L. Battezzati (2); R.E. Brooks,
P. N. Quested (3); I. Egry, S. Schneider (4); H. Fecht, R. K. Wunderlich (5); J.P. Garandet, B Vinet (6); K.C. Mills (7); S. Seetharaman (8)

(1) CNR Intitute for the Energetics and Interphases – Dept. of Genoa – Via De Marini, 6 – 16149 Genoa-Italy
(2) IFM-Università di Torino, Torino, Italy
(3) Department of Materials, Imperial College STM, London,United Kingdom
(4) Zentrum für Erstarrung Unterkühlter Schmelzen, Köln, Germany
(5) Universität Ulm, Ulm, Germany
(6) Departement d'Etudes Materiaux, CEA/CEREM, Grenoble, France
(7) Materials Centre, National Physical Laboratory, Teddington, United Kingdom
(8) Department of Metallurgy, Royal Institute of Technology, Stockholm, Sweden

The *ThermoLab* project has been selected into the European Space Agency's MAP programme (Microgravity Applications Support Programme) as a result of an International Announcement of Opportunity. The aim of this project is to use the microgravity environment on board the International Space Station (ISS) for the precision measurement of thermophysical properties of industrial alloys for the optimization of industrial process design, product quality and resource consumption. The experiments shall be performed with the Materials Science Laboratory Electromagnetic Levitation facility, MSL – EML.

A central part of the project is a ground-based research programme for the measurement of these properties in the temperature range accessible with conventional thermoanalytical equipment as well as for the development of new measurement methods to which the microgravity results shall provide the benchmark data.

The following thermophysical measurements have been performed in the ground-based research programme:

- Calorimetry including the melting range, enthalpy of fusion, fraction solid and specific heat capacity.
- Thermal diffusivity by the laser flash method.
- Density by optical methods on levitated specimen.
- Surface tension by the oscillating drop, the pendant, and the sessile drop technique.

The project is performed in close collaboration with an industrial project user group which assists in the alloy selection and identifies those properties most in need for their particular application.

Here, we report the results on measurements of the surface tension and the density of the *CMSX – 4* Ni-base superalloy performed by different techniques : the sessile drop, the pendent drop and the oscillating drop technique in an electromagnetic levitation device. The surface tension resulted smaller than a weightened average of the individual components, indicating that the surface tension is determined by the presence of surface active elements such as Al rather than by

the refractories. This notion is supported by results of a model calculation of surface segregation in the of Ni-Al system which was taken as a first step approach to the CMSX-4 Ni-base superalloy.

SCIENTIFIC SESSION VII:

LIFE SCIENCES

(PLANT BIOLOGY)

IS THE UNCONVENTIONAL PLANT MYOSIN VIII INVOLVED IN GRAVI- AND MECHANOSENSING?

D. Volkmann, A. Schick, A. Hlavacka, F. Baluška

University of Bonn, Department for Plant Cell Biology, Kirschallee 1, D-53115 Bonn, Germany, email: unb110@uni-bonn.de

There are several indications mainly coming from experiments in reduced gravitational fields that the actomyosin system plays an important role in gravisensing of plants (1). The unconventional plant myosin of class VIII, has been localized by polyclonal antibody to the plasma membrane, especially to plant specific structures like plasmodesmata and pit fields (2), structures which are involved in cell to cell transport in plants and in cell to cell communication probably, too (3).

Investigating roots from cress (*Lepidium sativum*) and mays (*Zea mays*) after different treatments, i.e. growth in reduced gravitational fields (TEXUS 37, Photon 12), forced inversion in capillaries, and osmotic stress, we found localisation patterns for myosin VIII totally different from untreated control roots. Inflight roots showed prominent myosin labelling of plasmodesmata of transversal cell walls in the transition zone which is involved in transmitting the gravity stimulus to the site of gravity controlled growth response. Under mechanostress pronounced labelling of myosin is visible at plasmodesmata in gravisensing cells and envelopes of amyloplasts acting as statoliths in these cells. Epitope analysis of myosin VIII and investigations of mutants have to confirm a role of myosin VIII in gravi- and mechanosensing.

1) Braun et al. J. Plant Growth Regul. 21, 137-145 (2002)
2) Reichelt et al. Plant J. 19, 555-567 (1999)
3) Baluška et al. Plant Physiol. 126, 39-46 (2001)

THE EFFECTS OF SIMULATED MICROGRAVITY ON THE LIGNIFICATION OF YOUNG *EUCALYPTUS GLOBULUS*

P. Genot [1,2], M. Cabané[2] , J. Banvoy [2], N. Ladouce[3], A. Dauphin[1], B. Pollet[4] , J. Grima-Pettenati[3], C. Lapierre[4] and V. Legué[1]

[1]UMR 1136 INRA-UHP "Interactions Arbres/micro-organismes", Université Nancy I, BP 239, F-54506 Vandoeuvre les Nancy, France
[2]UMR 1137 INRA-UHP Nancy 1 "Ecologie et Ecophysiologie Forestières", Université Nancy I, BP 239, F-54506 Vandoeuvre les Nancy, France
[3]UMR CNRS/UPS 5546 "Signaux et Messages Cellulaires chez les végétaux", Pôle de Biotechnologie Végétale, BP 17, Auzeville, 31 320 Castanet Tolosan, France
[4]Laboratoire de Chimie Biologique, UMR 206 INRA-INA-PG, Institut National Agronomique, 78850 Thiverval-Grignon, France

Terrestrial vascular plants have evolved with the unique advantage of standing upright for shoots and downright for roots, this is reinforced in woody plants by the lignin synthesis or lignification. At the molecular level, lignification is considered to play a pivotal role to strengthen the cell walls of vascular plants. The studies of the regulation of wood formation suggested the importance of environmental factors such as gravity in wood structure and cell wall composition. Moreover, under a transverse and oblique gravitational force, trees can develop a reaction wood showing distinct and anatomical differences. These observations suggest that gravity mediates the pathway of lignin synthesis and the expression of genes involved in the wood formation. Until now, only few experiments were carried out under spaceflight conditions.

The objective of our studies is to gain some insights into the effects of simulated microgravity on the xylem formation and lignin biosynthesis. Our experiments were performed with young *Eucalyptus globulus* grown in vitro, on a slowly clinostat. The analysis of wood formation at the anatomical level showed some differences in the organisation of the vessel in stems and roots and in the development of the vascular tissues. Lignin in stem and roots was enriched in G units and the activity of enzymes involved in lignin biosynthesis was modified. Our experiments showed that young trees grown under simulated microgravity displayed significant changes in lignification, demonstrating the role of gravity in this process.

This project was financial supported by The French Space Agency (CNES) and by the Lorraine district.

INVESTIGATING THE CIRCUMNUTATING MOVEMENTS OF ARABIDOPSIS ROOTS THROUGH THE RANDOM POSITIONING MACHINE

F. Migliaccio, S. Piconese, C. Rosi

Institute of Environmental Biology and Forestry, Consiglio Nazionale delle Ricerche, Monterotondo (Rome) Italy

The root growth habit of two Arabidopsis wild-types (Wassilewskija and Colombia), of the left handed mutant 1-6C, and of the auxinic and gravitropic mutants aux1, eir1 and rha1 was studied on the RPM, comparing it with 1g unidirectional conditions. The primary root pattern of 7 day old roots made to grow on hard-agar plates was considered.

By 1 g conditions, as it was already known and confirmed through the presented experiments, the primary roots of the wild-types grew by slanting to the right-hand, those of the mutant 1-6C by slanting to the left-hand, and those of the mutants aux1 and eir1 through random movements. On the other hand, the roots of the rha1 mutant grew down the dishes along an almost straight line.

By contrast, on the RPM the wild-type seedlings produced large loops to the right-hand, the mutants 1-6C loops to the left-hand, and the auxinic mutants eir1, aux1 and rha1 just random movements. The wild-type plants and 1-6C mutants thus appeared animated by a form of chiral circumnutation, which is lacking in the auxinic and gravitropic mutants.

Consequently, it was suggested that the plant hormone auxin should be involved not only in gravitropism, as is known, but also in root chiral circumnutation.

On the other hand, gravity appeared to regulate the chiral circumnutating movements, since the scatter among the different samples was significantly lower in 1g conditions in the wild-types with respect to the gravitropic and auxinic mutants. It is proposed to distinguish two kind of circumnutation in plants, e.g chiral and non-chiral, of which only the chiral is auxin dependant.

HYPER-GRAVITY EFFECTS ON THE *ARABIDOPSIS* TRANSCRIPTOME

Maria Martzivanou, Rüdiger Hampp

University of Tübingen, Physiological Ecology of Plants, Auf der Morgenstelle 1, 72076 Tübingen, Germany

Callus cultures of *Arabidopsis thaliana* (cv. Columbia) in Petri dishes were exposed to altered g-forces by centrifugation (1 to 10 g). Using semi-quantitative RT-PCR transcripts of genes coding for metabolic key enzymes (ADP-glucose pyrophosphorylase, ADPG-PP; ß-amylase, fructose-1,6-bisphosphatase, FBPase; glyceraldehyde-P dehydrogenase, GAPDH; hydroxymethylglutaryl-CoA reductase, HMG; phenylalanine-ammonium-lyase, PAL; PEP carboxylase, PEPC) were used to monitor threshold conditions for g-number (all) and time of exposure (ß-amylase) which led to altered amounts of the gene product. Exposure to approx. 5 g and higher for 1h resulted in altered transcript levels: transcripts of ß-amylase, PAL, and PEPC were increased, those of ADPG-PP decreased, while those of FBPase, GAPDH, and HMG were not affected. This probably indicates a shift from starch synthesis to starch degradation and increased rates of anaplerosis (PEPC: supply of ketoacids for amino acid synthesis). In order to get more information about g-related effects on gene expression, we used a 1h-exposure to 7 g for a microarray analysis, using a commercial *A. thaliana* chip with 4,105 unique annotated clusters / genes (IncyteGenomics). Transcripts of more than 200 genes were significantly increased in amount (ratio 7g / 1g control; $2^{1.6}$ and larger). They fall into several categories. Transcripts coding for enzymes of major pathways form the largest group (25%), followed by gene products involved in cellular organisation and cell wall formation / rearrangement (17%), signalling, phosphorylation/dephosphorylation (12%), proteolysis and transport (10% each), hormone synthesis plus related events (8%), defence (4%), stress-response (2%), and gravisensing (2%). Many of the alterations are part of a general stress response, but some changes related to the synthesis / rearrangement of cell wall components could be more hyper-g-specific. We only found few gene products, which were decreased in relation to 1g controls, and these were less significant (ratio < $2^{1.6}$). We thus assume that g-forces above a threshold of about 5g for 1h are sensed by plant cells in general, causing distinct metabolic responses, which obviously in part are regulated by gene expression. Based on the microarray data we constructed macroarrays containing genes coding for enzymes of defined metabolic pathways, signalling cascades etc. (“theme” arrays). These are now used for screening changes in gene expression upon hyper-g, micro-g and klinostat treatments.

SCIENTIFIC SESSION VIII:

INSTRUMENTATION / EU PROJECT

FLUORESCENCE MINIATURE MICROSCOPE FOR BIOLAB

R.H. Huijser [(1)], G. Borst [(1)], G. Brandt [(2)], L. de Vos [(2)], P. Schiller [(3)], J. Kraemer [(3)]

[(1)] Dutch Space B.V., P.O. Box 32070, 2303 DB Leiden, The Netherlands
[(2)] OIP Sensor Systems, Westerring 21, B-9700 Oudenaarde, Belgium
[(3)] ESTEC, P.O. Box 299, 2200 AG Noordwijk, The Netherlands

A prototype fluorescence miniature microscope ('Fluor-MiMi') has been developed under ESA contract (no. 15656/NL/ND) that serves as a demonstration model of an eventual flight instrument for use on the ISS Biolab facility of ESA. The flight instrument is aimed to fit inside a so-called 'Advanced Experiment Container' (AEC; inner volume <168 x 118 x 140 mm³) and, as such, can be accommodated in duplo on both the static (microgravity) and on the centrifuge (1xg reference) rotor of Biolab. Temperature control of the AEC and its experiment specimen will be provided by the Biolab incubator environment.

The Fluor-MiMi prototype instrument consists of three parts: (1) optical system, (2) sample holder on XY-scan and focus (Z) tables and (3) electronics. The optical system enables bright field or phase contrast microscopy (diffused white LED illumination, automated change of observation mode) and fluorescence microscopy. The current implementation is based on use of GFP for study of live objects (473 nm solid state laser input , >510 nm filtered detection). Off-line and/or automated change of objectives allows a 10x - 40x magnification range, and corresponding field of views. Microscope images in NTSC video format are generated by a built-in B&W CCD camera.

The sample holder allows accommodation and automated change of observed specimen and is designed such that (automated) liquid management can be added for the flight situation. For this, use can be made of the Biolab provisions or liquids can be stored and dispensed from within the AEC. For the prototype instrument the XYZ-table for the sample holder has been constructed from commercial elements, allowing a scan range of 5 mm in all directions. For the flight instrument a suitable further miniaturisation by dedicated construction of this element is foreseen.

The electronic system, which will be housed inside the AEC in the flight model, is based on a micro-controller with embedded software and interface cards for control of, and power supply to, all motorised elements and light sources and for read-out of all sensors (temperatures, end switches, proximity). The prototype system is completed with a PC as 'user interface' and video equipment.

The prototype model has been subjected to a series of performance tests in which optical test objects (resolution, focus, etc.) and representative (non living) biological specimen were used. This paper will report on the design details of the instrument, on the results of the performance tests and will present conclusions and recommendations on the projected use in Biolab. Finally, the possible use of the Fluor-MiMi prototype (and/or flight-type instruments) for microgravity simulation experiments in biology on a Random Positioning Machine will be illustrated.

THE FAST FACILITY: FROM SPACEHAB TO ISS

Brandani Fabio[1], Piergiuseppe Falciani[1]*, Madine Simoncini[1], Fabio Valgattarri[1], C.A. Schmidt-Harms[2]

1) Galileo Avionica SpA, Space Equipment Business Unit, via A. Einstein, 35, 50013 Campi Bisenzio (Italy) e-mail: piergiuseppe.falciani@officine-galileo.finmeccanica.it
2)E S A, MSM-GMM, Keplerlan 1 AG Noordwijk ZH- The Nederland; e-mail: Christian.Schmidt-Harms@esa.int

The Facility for Adsorption and Surface Tension studies (FAST) is a multi-user and multi-mission Facility capable to perform basic studies in the field of Physical-Chemistry of surfaces under Microgravity environment. This Facility is a candidate for the International Space Station and this fact is the completion of about twelve years of activity, beginning from 1999, the year in which the experimental activities of the surface tension studies was started on the MITE module, launched with the Sounding Rocket Maser4. At the end of October 1998, FAST has flown aboard of the SPACEHAB (mission STS-95), while the nest flight (mission STS107) is scheduled on January of 2003. Presently, the Phase A Study regarding the FAST accommodation on the Columbus Laboratory has been completed. The aim of this paper is to give an overview of this Facility and its implementations for the ISS.

INTERNATIONAL MICROGRAVITY PLASMA FACILITY / DUST PARTICLE FACILITY

R. Seurig

Kayser-Threde GmbH, Wolfratshauserstr. 48, D-81379 München

The results of Phase A for the consolidated IMPF/DPF (International Microgravity Plasma Facility / Dust Particle Facility) Laboratory, and its science objective, will be presented. It is anticipated that this multi-user modular research laboratory for „complex plasma“ and „interactions in cosmic and atmospheric particle systems“ will be available onboard the International Space Station in 2008.

PERSPECTIVES AND DIFFICULTIES TO ENTER "SPACE-RELATED LIFE AND PHYSICAL SCIENCES" INTO FP6

Bernard Roux and Jack van Loon

In December 2001 a document on “New Opportunities for a Euro-Russian Partnership” was signed by the EC, ESA and Rosaviakosmos. This document reviews co-operation opportunities and proposes the establishment of a long-term space partnership between Europe and the Russian Federation. Satellite navigation, launchers and global monitoring of the environment and security (GMES) are currently the three areas of immediate mutual interest.
To support co-operation and partnership between Europe and Russia, the European Commission’s Sixth research Framework Programme (FP6) (2002-2006) welcomes the participation of Russian partners from research and industry in Integrated Projects and Network of Excellence.
A workshop: “Europe-Russia Co-operation in the Space Sector in the context of FP6” has been co-organized by EC, ESA and Rosaviakosmos in Moscow on 23-24 January 2003. The aim was to offer a unique opportunity for both European and Russian researchers in the space sector and related applications to meet, discuss and explore opportunities for collaboration under FP6 not only in the three areas mentioned above, but also in three additional areas of interest, including *“Space related life and physical sciences”*.
The objectives of the Moscow event are to:

- Raise awareness of the opportunities for co-operation in space research between Europe and Russia
- Inform the European and Russian space research communities of the aims, opportunities and conditions of FP6
- Provide an opportunity for European and Russian organisations engaged in space-related research to meet network and strengthen the foundation for future co-operation and partnership.

The Commission would like to continue the structure of the workshop on the EU-Russia space research website. It is hoped that working groups will be created for each of the six areas addressed at the Moscow event (Cordis Focus n°214, 10.02.20039. *EC created this working area and gave the moderators (ESA and Rosaviakosmos) access to build up their area and load documents*.

We plan to report about the different steps doen in the domain of Europe-Russia co-operation in the Space Sector in the context of FP6:

- Before Moscow workshop, in particular the Expression of Interest for Network of Excellence (NoEs), sent to EC under the auspices of ELGRA; these NoEs are complementary to Integrated Projects proposed by ESA;
- During Moscow workshop, were a parallel session was devoted to *“Space-related life and physical sciences”*; and a synthesis was made by Marc Heppener (ESA-MSM; co-chairman of working groups n°4) who suggested to organize a joint ESA-Rosaviakosmos working group, in order to make joint proposal to EC;
- After the workshop, in paerticular the interactions with the ESA moderator (Marc Heppener) of the newly installed EU-Russia space research website.