

# Measurements of the induced transmembrane voltage with fluorescent dye di-8-ANEPPS

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Duration of the experiments: app. 60 min

Max. number of participants: 4

Location: Cell Culture Laboratory 1

Level: Advanced

## PREREQUISITES

Participants should be familiar with the Safety rules for handling with chemicals and Rules for sterile work in cell culture laboratory (following the recommendations of the Good laboratory practice). The basic knowledge of handling with cells is required for this laboratory practice.

## THEORETICAL BACKGROUND

When a biological cell is placed to an external electric field the induced transmembrane voltage (ITV) forms on its membrane. The amplitude of the ITV is proportional to the amplitude of the applied electric field, and with a sufficiently strong field, this leads to an increase in membrane permeability - electroporation. Increased permeability is detected in the regions of the cell membrane where the ITV exceeds a sufficiently high value, in the range of 250 – 1000 mV, depending on the cell type. In order to obtain an efficient cell electroporation it is therefore important to determine the distribution of the ITV on the cell membrane. The ITV varies with the position on the cell membrane, is proportional to the electric field, and is influenced by the cell geometry and physiological characteristics of the medium surrounding the cell. For simple geometric shapes the ITV can be calculated analytically (e.g. for a spherical cell, using Schwan's equation). For more complicated cell shapes experimental and numerical methods are the only feasible approach to determine the ITV.

**The aim** of this laboratory practice is to measure the ITV on a spherical and irregularly shaped cell by means of a fluorescent potentiometric dye di-8-ANEPPS.

## EXPERIMENT

Potentiometric fluorescent dyes allow observing the variations of the ITV on the membrane and measuring its value. Di-8-ANEPPS is a fast potentiometric fluorescent dye, which becomes fluorescent when it binds to the cell membrane, with its fluorescence intensity varying proportionally to the change of the ITV. The dye reacts to the variations in the ITV by changing the intramolecular charge distribution that produce corresponding changes in the spectral profile or intensity of the dye's fluorescence.

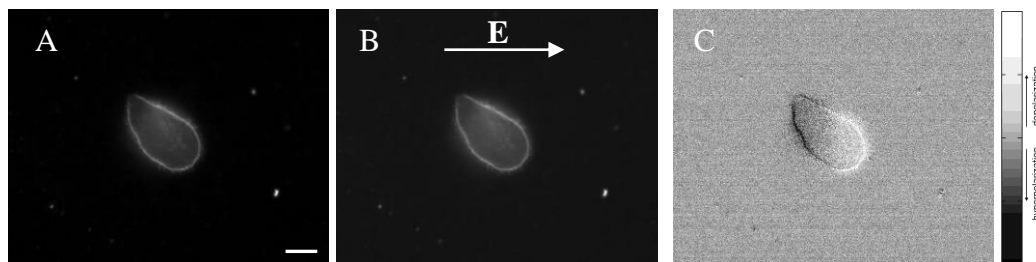
**Protocol:** The experiments are performed on Chinese hamster ovary cells (CHO) grown in Lab-Tek chambers (Nunc, Germany) in culture medium HAM-F12 supplemented with 8% fetal calf serum, L-glutamine (all three from Sigma-Aldrich, Steinheim, Germany) and antibiotics. When cells attach to the cover glass of a Lab-Tek chamber (usually after 2 to 3 hours to obtain attached cells of spherical shape), carefully replace the culture medium with 1 ml of SMEM medium (Spinner's modification of the MEM, Sigma-Aldrich, Steinheim, Germany) containing 30  $\mu\text{M}$  of di-8-ANEPPS and 0.05% of Pluronic (both Invitrogen,

Eugene, Oregon, USA). After staining for 12 min at 4°C, wash the cells thoroughly with pure SMEM to remove the excess dye.

Place the chamber under a fluorescence microscope (Zeiss AxioVert 200, Germany) and use  $\times 63$  oil immersion objective. Position two parallel Pt/Ir wire electrodes with a 4 mm distance between them to the bottom of the chamber. Set 35 V on a DC voltage supply (EA-PS 2332-025, Elektro-Automatik, Munich, Germany) and 50 ms duration on a custom made microprocessor-controlled switcher device. This will result in a voltage-to-distance ratio of  $\sim 88$  V/cm. The pulse must be synchronized with the image acquisition. Set the excitation wavelength to 490 nm and use ANEPPS filter to detect fluorescence (emission 605 nm).

Find the cells of interest. Acquire the control fluorescence image and subsequently the image with a pulse, using a cooled CCD camera (VisiCam 1280, VisiTron, Germany) and MetaFluor 7.1.1 (Molecular Devices, Downingtown, PA, USA). Apply four pulses with a delay of 4 s between two consecutive pulses. For each pulse, acquire two images, one immediately before (control image) and one during the pulse (pulse image) (Figures 1A and B).

Open the images in MetaMorph 7.1.1 (Molecular Devices, Downingtown, PA, USA), convert them to 8-bit and, for each pulse, obtain the difference image by subtracting (on a pixel-by-pixel basis) the control image from the image acquired during the pulse. Add 127, so that 127, i.e. mid-gray, corresponds to 0 V, brighter values to positive voltages, and darker levels to negative ones (Figure 1C). Average the four difference images to increase the signal-to-noise ratio. To quantify the changes in the fluorescence of the dye in the membrane, determine the region of interest at the site of the membrane and measure the fluorescence intensities along this region. Transform the fluorescence changes to the values of the ITV ( $\Delta F/F = \sim 8\%$  / 100 mV), and plot them on a graph as a function of the arc length.



**Figure 1.** Measurements of the induced transmembrane voltage (ITV) on an irregularly shaped CHO cell. (A) A control fluorescence image of a cell stained with di-8-ANEPPS. (B) Fluorescence image acquired during the exposure to a 35 V ( $\sim 88$  V/cm), 50 ms rectangular pulse. (C) Changes in fluorescence of a cell obtained by subtracting the control image A from the image with pulse B and shifting the grayscale range by 50%. The brightness of the image was automatically enhanced. Bar represents 10  $\mu\text{m}$ .

### FURTHER READING:

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- Pucihar G., Kotnik T., Valič B., Miklavčič D. Numerical determination of transmembrane voltage induced on irregularly shaped cells. *Annals Biomed. Eng.* 34: 642-652, 2006.

## NOTES & RESULTS

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