**Table S1.** Challenges and solutions for improved environmental monitoring of temperature, pH, dissolved oxygen (O2), and dissolved carbon dioxide (CO2) live-cell culture systems.

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| **Parameter** | **Challenges** | **Advantages** | **Solutions for improved environmental monitoring** |
| **Temperature** | Commercially available thermometers can give inaccurate readings (± 1 oC error). | A stable thermal environment ensures accurate control of dissolved gases and acid-base chemistry.  Low cost, but accurate measurements. | Traceable thermometers and temperature logging systems calibrated by an ISO [International Standards Organization] certified laboratory ensure accurate and precise temperature readings. ISO-certified thermometers are widely available at low cost (< US $100). |
| **pH/ acid-base chemistry** | Changes in media pH are commonly assessed using pH indicator dye. However, media color assessments that are done “by eye” may produce inaccurate readings. | Simple to measure with electrodes or *indicator dyes*.  Cost-effective and accurate measurements. | pH sensors calibrated with traceable buffer solutions (e.g.primary standards set by NIST [National Institute of Standards and Technology]) ensure highly accurate and precise pH readings.  pH meters and sensors are widely available at low to moderate costs (between US $300 -$1000). Traceable standard buffer solutions available at low cost (< US $100). Sensors compatible with sterilization and autoclaving are available.  pH sensing technologies are available for non-invasive measurements in cell cultures.  Color assessments of pH indicator dyes via absorbance spectrum analysis provide accurate measurements when calibrated with traceable standard buffer solutions. |
| **Dissolved O2** | Gaseous calibrations may be required (typically a two-point calibration of 100% air saturation, and 0% O2). | Accurate tracking of O2 regimes (e.g. hypoxic exposure).  Cost-effective and accurate measurements. | Dissolved O2 meters and sensors are widely available at low to moderate costs (between US $400- $2000). Dissolved O2 meters that compensate for temperature, altitude (pressure), and salinity are available. Dissolved O2 sensors compatible with sterilization and autoclaving are available.  Dissolved O2 sensing technologies are available for non-invasive measurements in cell cultures.  Simple calibration protocols for most sensors, typically involving air and N2 gas (100% saturation, and 0% O2, respectively). |
| **Dissolved CO2** | High-cost sensing systems.  Manufacturer calibrations may be required. | Permits tracing of CO2 regimes in culture, independent of pH (and acid-base regulation). | CO2 meters and sensors can achieve accurate and precise CO2 readings. Dissolved CO2 sensors compatible with sterilization and autoclaving are available.  Dissolved CO2 sensing technologies are available for non-invasive measurements in cell cultures, but some commercially available technologies are in the prototype phase. |
| **Agitation** | Agitation rates (e.g. impeller speed in bioreactor set-ups) control shear force affecting cell experimental responses. | Stable rates of agitation ensure accurate control of gas/atmosphere equilibration and uniform environmental conditions (i.e. prevent gradient from the air-medium interface to the cell layer). | Report rates of agitation/ flow. |
| **Relative humidity** | Variations in relative humidity are common.  Affects osmolarity as well as solute and gas concentrations, that in turn, affect diffusion. | Adequate levels and control of humidity prevent changes in medium viscosity, concentrations of salts and ions, gas solubility and osmolarity. | Low-cost sensors are available to monitor relative humidity levels inside incubators. Thermoset polymer based capacitive humidity sensors are fast, linear and are stable long-term. They also compatible with internal incubator conditions and available for in-line set-ups.  Advanced control systems for relative humidity are also available, including direct steam humidification and bidirectional humidity control. |