

**Introduction**

The Parallel Artificial Membrane Permeability Assay (PAMPA) is a well-accepted screening assay for ADME properties (membrane permeability). Since the first successful demonstration of PAMPA by Kansy, et. al. (Reference 1), the artificial membrane has usually been prepared by impregnating a porous filter with a solution of lipids and other biological membrane constituents. The artificial membranes in PAMPA must be both robust enough to generate reproducible results in a screening environment and provide a good model of the *in vivo* biological membrane. While the traditional method—forming artificial membranes using lipid solutions—seems to provide good predictability for many compounds, it is challenged by limited reproducibility and the incorrect prediction of a group of drugs that are classified by the biopharmaceutical classification system (BCS) as high permeability compounds. Our investigations suggested that an excess amount of solvents and lack of structure of the artificial membrane may contribute to the underprediction of some high BCS permeability compounds. We have developed a novel lipid/oil/lipid tri-layer artificial membrane that does not contain excessive solvents. The pre-coated filter plates with the lipid/oil/lipid tri-layer artificial membrane (BD Gentest™ Pre-coated PAMPA Plate System) has been evaluated in comparison with traditional PAMPA methods for its predictability, stability, reproducibility, ability to reduce mass retention, and compatibility with buffers containing organic solvents.

**Materials and Methods**

The BD Gentest™ Pre-coated PAMPA Plate System (Cat. No. 353015) was used to perform permeability assays for 38 commercially available drug compounds. The permeability assay was carried out in a similar protocol as described in References 1-3. The 96-well filter plate, pre-coated with lipids, was used as the permeation acceptor and a matching 96-well receiver plate was used as the permeation donor. Compound solutions were prepared by diluting 10 mM DMSO stock solutions in PBS (in most cases we used a final concentration of 200 μM). As shown in Figure 1, the compound solutions were added to the wells (300 μL/well) of the receiver plate and PBS was added to the wells (200 μL/well) of the pre-coated filter plate. The filter plate was then coupled with the receiver plate and the plate assembly was incubated at room temperature without agitation for five hours. At the end of the incubation, the plates were separated and 150 μL solution from each well of both the filter plate and the receiver plate was transferred to UV-transparent plates. The final concentrations of compounds in both donor wells and acceptor wells were analyzed by UV-plate reader. Permeability of the compounds was calculated using the following formula:

$$P_e \text{ (cm/s)} = \frac{-\ln[1 - C_A(t)/C_{eq}]}{A \cdot (1/V_D + 1/V_A) \cdot t}$$

A = filter area (0.3 cm<sup>2</sup>), V<sub>D</sub> = donor well volume (0.3 mL), V<sub>A</sub> = acceptor well volume (0.2 mL), t = incubation time (seconds), C<sub>A</sub>(t) = compound concentration in acceptor well at time t, C<sub>D</sub>(t) = compound concentration in donor well at time t, and C<sub>eq</sub> = [C<sub>D</sub>(t)·V<sub>D</sub> + C<sub>A</sub>(t)·V<sub>A</sub>] / (V<sub>D</sub> + V<sub>A</sub>)

Figure 2 compares the structure of the artificial membrane of the traditional PAMPA and the lipid/oil/lipid tri-layer membrane of the BD Gentest Pre-coated PAMPA Plate System. The photo of coated and uncoated PVDF filters provides evidence that the lipid/oil/lipid tri-layer membrane does not contain excessive solvents, while the traditional PAMPA membrane contains excessive solvents that make the PDVF filter semi-transparent.

**Results**

**Predictability:** Predictability of a PAMPA method is evaluated by the correlation with human absorption and Caco-2 data. Figure 3 compares the performance of a traditional PAMPA and the BD Gentest™ Pre-Coated PAMPA Plate System by analyzing the correlation of the permeability data with the human absorption data of 38 compounds. Using the traditional PAMPA, there is a group of compounds with high human absorption property that are underpredicted (false negative). This group of compounds are correctly predicted using the BD Gentest Pre-Coated PAMPA Plate System. Figure 4 compares the performance of a traditional PAMPA and the BD Gentest Pre-Coated PAMPA Plate System by analyzing the correlation of the PAMPA permeability data with Caco-2 permeability data. Using the traditional PAMPA, there is a group of compounds with high Caco-2 values that are underpredicted, including antipyrine, caffeine, naproxen and ketoprofen. This group of compounds were correctly predicted using the BD Gentest Pre-Coated PAMPA Plate System. These results indicate that the new lipid/oil/lipid tri-layer artificial membrane improves the PAMPA predictability.

**Stability and Reproducibility:** Figure 5 compares the results obtained from three plates coated at different times and used for assays on the same day. The results obtained from the one-year-old plate and the six-month-old plate are almost identical to the results obtained from a freshly coated plate. These results indicate that the BD Gentest Pre-coated PAMPA Plate System is stable for at least one year when stored at -20°C and is highly reproducible from plate to plate.

**Mass Retention:** Some compounds can bind to the surface of the plates and/or be trapped inside the artificial membrane, resulting in high mass retention. Figure 6 compares the mass retention of three of these compounds using the traditional PAMPA and using the BD Gentest Pre-Coated PAMPA Plate System. These results indicate that the BD Gentest Pre-coated PAMPA Plate System reduces the mass retention of these compounds.

**Compatibility with organic solvents:** Low solubility compounds have been a challenge for permeability measurements. Using a buffer containing organic solvents helps to increase the solubility of these compounds. Figure 7 compares the permeability measurements of eight compounds in three buffer conditions: (1) PBS, (2) PBS + 10% methanol, and (3) PBS + 20% methanol. These results indicate that the artificial membrane has maintained its integrity and the correct ranking of the compounds can be obtained with buffers containing up to 20% methanol.

**Conclusions**

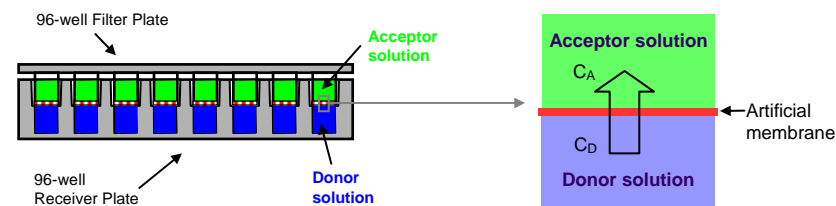
The BD Gentest Pre-Coated PAMPA Plate System, which contains a novel lipid/oil/lipid tri-layer artificial membrane, improves the PAMPA model through the following characteristics:

- Improved correlation with human absorption data
- Improved correlation with Caco-2 data
- Stability for more than one year when stored at -20°C
- Highly reproducible results obtained from plates coated at different times
- Reduced mass retention of “sticky” compounds
- Compatibility with buffers containing organic solvents (to improve low solubility compounds)

**Acknowledgement**

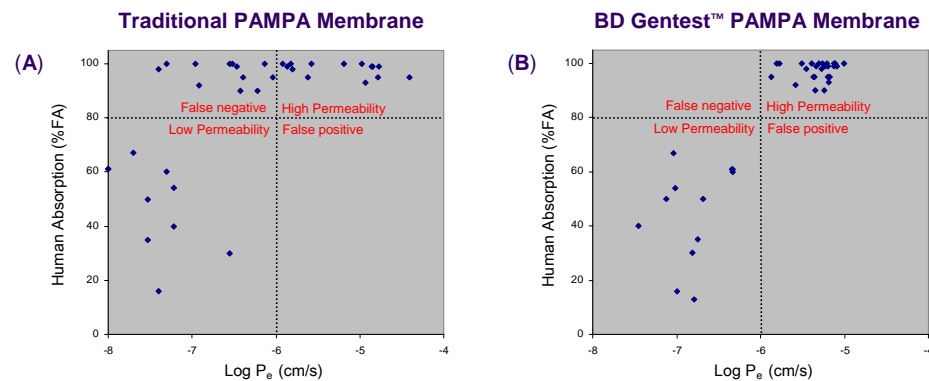
We thank Dr. Praveen Balimane and Karishma Patel of Bristol-Myers Squibb for their tremendous help in this work.

**1 Experimental Setup of PAMPA**



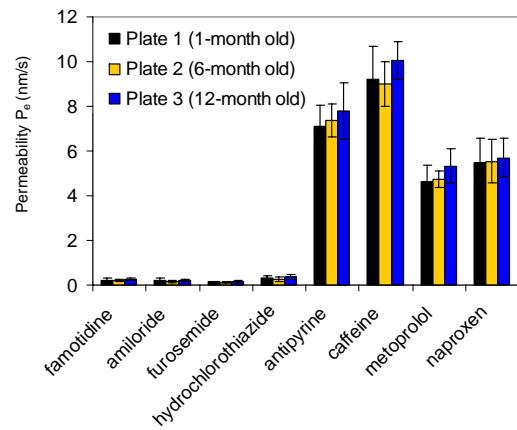
Compound solutions are added to the receiver plate (donor) and buffer is added to the pre-coated filter plate (acceptor). The plates are coupled together and incubated at room temperature for five hours. During the incubation, compounds in the donor solution permeate through the artificial membrane into the acceptor solution. By measuring the compound concentrations—C<sub>A</sub> and C<sub>D</sub>—in both solutions, permeability of the compounds can be calculated.

**3 BD Gentest™ PAMPA Membrane Improves Correlation with Human Absorption Data**



Comparison of the performance of traditional PAMPA membrane and the BD Gentest™ PAMPA membrane by analyzing the correlation of the permeability data with the human absorption data for a set of 38 compounds. The permeability data of the traditional PAMPA membrane and the human absorption data were cited from Reference 3. The permeability data of the BD Gentest PAMPA membrane were obtained using UV VIS measurements; both donor and acceptor buffers were PBS, pH 7.4; and the PAMPA plate system was incubated at room temperature for 5 hours without agitation.

**5 Reproducibility and Stability of the BD Gentest™ Pre-Coated PAMPA Plate System**



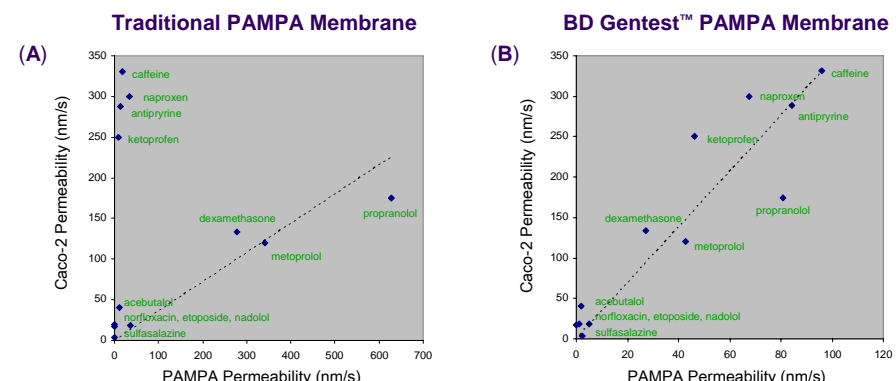
Comparison of PAMPA permeability values of 8 compounds obtained using 3 pre-coated plates prepared at different times: Plate #1—prepared one month before the day of assay; Plate #2—prepared 6 month before the day of assay; Plate #3—prepared one year before the day of assay

**2 Comparison of the Traditional PAMPA Membrane and the BD Gentest™ PAMPA Membrane**

(A) The PVDF filters in Row A were uncoated (B) The PVDF filters in Row B were coated with 2% DOPC in dedecane (traditional PAMPA). The filters appear semi-transparent due to the excessive amount of solvents. (C) The PVDF filters in Row C were coated with lipid/oil/lipid tri-layer artificial membrane. The filters do not appear semi-transparent because there were no excessive solvents.

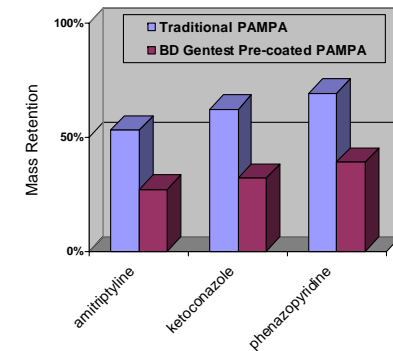
- The porous filter is soaked with a solution of lipids
- Excessive solvents
- Long permeation pathway
- A lipid-oil-lipid tri-layer structure is constructed in the pores of the porous filter
- No excessive solvents
- Short permeation pathway (closer to the biological membrane)

**4 BD Gentest™ PAMPA Membrane Improves Correlation with Caco-2 Data**



Comparison of the performance of traditional PAMPA membrane and the BD Gentest™ PAMPA membrane by analyzing the correlation of the permeability data with the Caco-2 permeability data for a set of 11 compounds. The permeability data of the traditional PAMPA membrane and the Caco-2 permeability data were cited from References 4-5. The permeability data of the BD Gentest PAMPA membrane were obtained using UV VIS measurements; both donor and acceptor buffers were PBS, pH 7.4; and the PAMPA plate system was incubated at room temperature for 5 hours without agitation.

**6 BD Gentest™ Pre-Coated PAMPA Plate System Reduces Mass Retention of “Sticky” Compounds**



Comparison of the mass retention of amitripyline, ketoconazole, and phenazopyridine using traditional PAMPA and the BD Gentest™ Pre-Coated PAMPA Plate System. Data of the traditional PAMPA are from Reference 2. Mass retention is calculated by:  $R = 1 - [C_D(t) \cdot V_D + C_A(t) \cdot V_A] / (C_0 \cdot V_D)$ , where C<sub>0</sub> is the initial compound concentration in donor well.

**References**

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