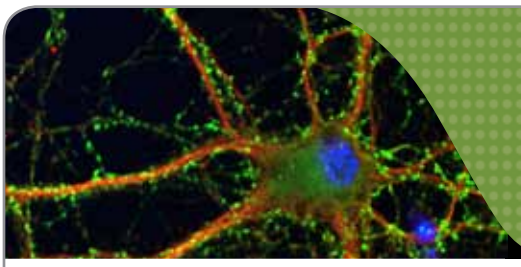

TECHNICAL BULLETIN

NeuroCult™ SM1 for Long-Term Primary Neuronal Culture

Introduction

Primary neuronal cultures represent a useful system in which to study neuronal biology in a simplified and controlled environment. Fully mature neuronal cultures are complex in morphology, featuring highly branched dendrites and extensive networks of synaptic connections.[1] The peak of dendritic growth and synaptogenesis doesn't occur until two to three weeks in culture, with some markers of synaptic maturity requiring three weeks or longer to reach their highest expression levels.[1-2] As such, the ability to establish and maintain long-term primary neuronal cultures is essential for the comprehensive study of neuronal development and function. While short-term culture of neurons can be a straightforward process, long-term (> 21 days) culture of relatively pure neuronal populations is technically challenging.[2]

The development of neuron-specific serum-free media formulations was pivotal to the evolution of modern primary neuronal culture techniques, enabling neurons to be cultured in the absence of undefined serum supplements or a supporting glial cell layer.[3] However, variability in the performance of a commonly used serum-free supplement[4-5] and discrepancies in the protocols for substrate coating and cell plating have resulted in inconsistency in the quality of neuronal cultures. Variability in protocols and culture media quality becomes more problematic when cells are plated at low density or cultured long term, because these conditions place additional stress on the cultured cells.

STEMCELL Technologies Inc. has developed a neuronal culture kit (Catalog #05712) comprising a neuronal basal medium (NeuroCult™ Neuronal Basal Medium) and serum-free supplement (NeuroCult™ SM1; Catalog# 05711) which, when used according to optimized protocols, consistently produces high yields of functional neurons from primary mouse and rat CNS tissues. NeuroCult™ SM1, based on the published B27 formulation,[3] is optimized to more reproducibly support the survival of mature neurons in long-term culture. Here we present data on the performance of NeuroCult™ SM1 for long-term culture of embryonic rat cortical neurons.

NeuroCult™ SM1 Cultures Show:

- significantly greater cell survival after 21 days in culture.*
- significantly greater neurite outgrowth and branching at 7 and 21 days in culture.*
- visibly mature neurons, featuring extensive dendritic arborization and appropriate expression of synaptic markers, after 21 days in culture.
- minimal variability attributable to supplement lot.

*When compared to primary neurons maintained in a traditional serum-free medium (TSFM).

Results

Primary Neurons Maintained with NeuroCult™ SM1 for 21 Days Appear Healthy and Mature

Primary neuronal cultures maintained with NeuroCult™ SM1 contain consistently high numbers of morphologically normal, healthy neurons. At seven days in vitro (DIV), cultured neurons show extensive neurite outgrowth and branching (Figure 1A). At 21 DIV, neuronal viability remains high, and neurites have developed into elaborate networks of processes indicating healthy, mature cultures (Figure 1B).

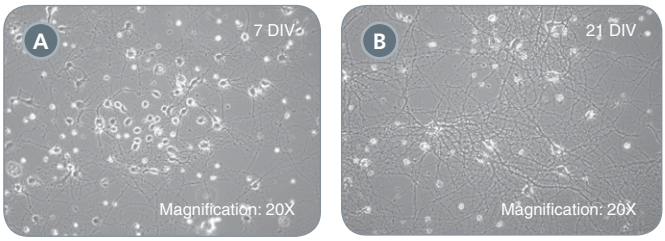

Figure 1. Morphology of Neurons in Representative NeuroCult™ SM1 Cultures at 7 and 21 Days in Vitro.

Primary rat E18 cortical neurons were cultured for 7 (A) and 21 (B) DIV in NeuroCult™ SM1 medium. (A) Phase contrast imaging at 7 DIV shows large numbers of viable neurons, with minimal cell clumping and extensive neurite outgrowth and branching. (B) After 21 DIV, large numbers of viable neurons with developed dendritic arbors remain in culture. Magnification 20x.

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Primary Neurons Maintained with NeuroCult™ SM1 Show Increased Cell Survival at 21 Days

The number of neurons in each culture condition was quantified using a semi-automated approach. The HCA-Vision Neurite Analysis Module was used to analyze images of class III β-tubulin-immunoreactive neurons captured using a Thermo Scientific ArrayScan® Infinity High Content Reader. Counting class III β-tubulin-positive cells revealed that NeuroCult™ SM1 cultures contain comparable numbers of neurons at 7 DIV, compared to a traditional serum-free medium formulation (TSFM; see Methods). However, after 21 DIV, NeuroCult™ SM1 cultures contain significantly higher numbers of class III β-tubulin-immunoreactive neurons, indicating significantly improved cell survival (Figure 2). This ability to support neurons with high viability in culture for 21 DIV was consistent among different lots of NeuroCult™ SM1 (data not shown).

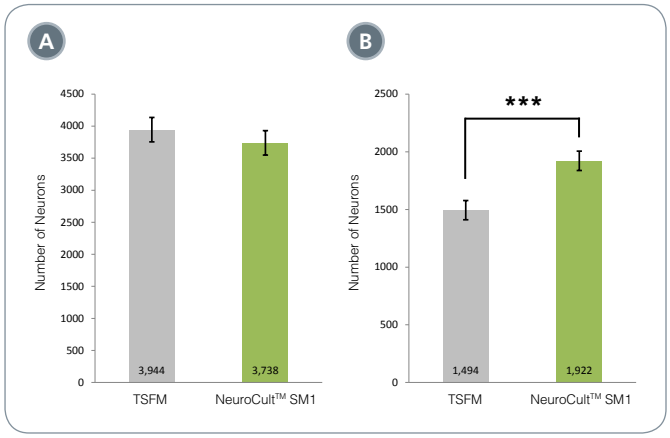

Figure 2. Number of Neurons in NeuroCult™ SM1 and TSFM Cultures After 7 and 21 Days in Vitro.

(A) Comparable numbers of neurons are obtained when cells are cultured for 7 days in NeuroCult™ SM1 compared to TSFM (n = 25; mean ± 95% CI; $p > 0.05$). (B) Significantly higher numbers of neurons are obtained when cells are cultured for 21 days in NeuroCult™ SM1 compared to TSFM (n = 25; mean ± 95% CI; ***$p < 0.001$; see Methods for details of statistical analyses).

Advantages of NeuroCult™ SM1 Neuronal Culture Kit:

- **SPECIALIZED**: NeuroCult™ SM1 is formulated to support improved cell survival in long-term primary neuronal culture.
- **OPTIMIZED**: Cultures feature increased neurite outgrowth and branching.
- **RELIABLE**: Product undergoes rigorous quality control testing with primary neuronal cultures.

Primary Neurons Maintained with NeuroCult™ SM1 Show Increased Neurite Outgrowth and Branching at 7 and 21 Days

Semi-automated analyses were also conducted to quantify total neurite outgrowth and extent of neurite branching. Neurons cultured for both 7 and 21 DIV in NeuroCult™ SM1 show significantly greater total neurite outgrowth (Figure 3) and increased neurite branch points (Figure 4) compared to neurons cultured in TSFM. Neurite outgrowth and branching serve as indicators of the extent of neuronal maturation in culture. The increase in both neurite outgrowth and branching observed between day 7 and day 21 is robust and indicative of culture conditions that facilitate neuronal maturation in vitro.

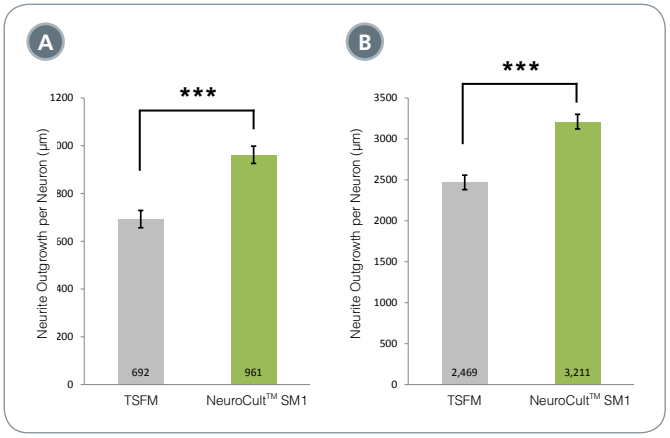

Figure 3. Neurite Outgrowth of Primary Neurons Cultured in NeuroCult™ SM1 and TSFM for 7 and 21 Days.

Significantly longer neurite outgrowth was observed for cells cultured for 7 (A) and 21 (B) days in NeuroCult™ SM1 compared to TSFM (n = 240 independent measures; mean ± 95% CI; ***$p < 0.001$).

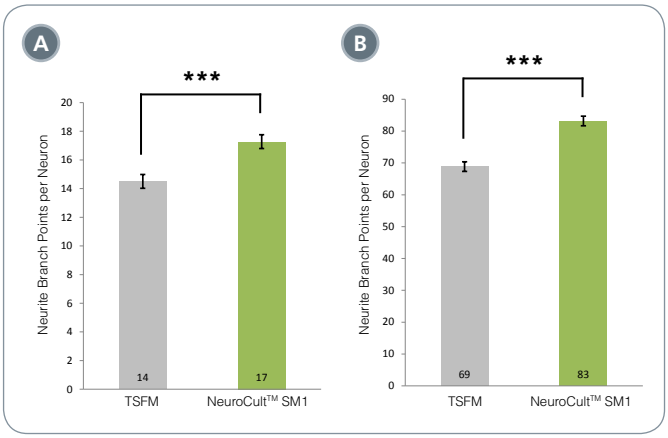

Figure 4. Neurite Branching of Primary Neurons Cultured in NeuroCult™ SM1 and TSFM for 7 and 21 Days.

Significantly more neurite branch points were observed for cells cultured for 7 (A) and 21 (B) days in NeuroCult™ SM1 compared to TSFM (n = 240 independent measures; mean ± 95% CI; ***$p < 0.001$).

Primary Neurons Maintained with NeuroCult™ SM1 are Mature and Functional

Immunocytochemistry was performed to verify that neurons cultured in NeuroCult™ SM1 for 21 days had reached maturity, as assessed by cellular morphology and the appropriate expression of synaptic markers. At 21 DIV, neurons cultured in NeuroCult™ SM1 show robust, punctate expression of pre- and post-synaptic markers (synapsin and PSD-95, respectively; Figure 5). Previous studies have demonstrated that NeuroCult™ SM1-cultured neurons are functionally active and exhibit normal electrophysiological profiles (data not shown; see Primary Neuronal Culture Brochure #29898 for more details).

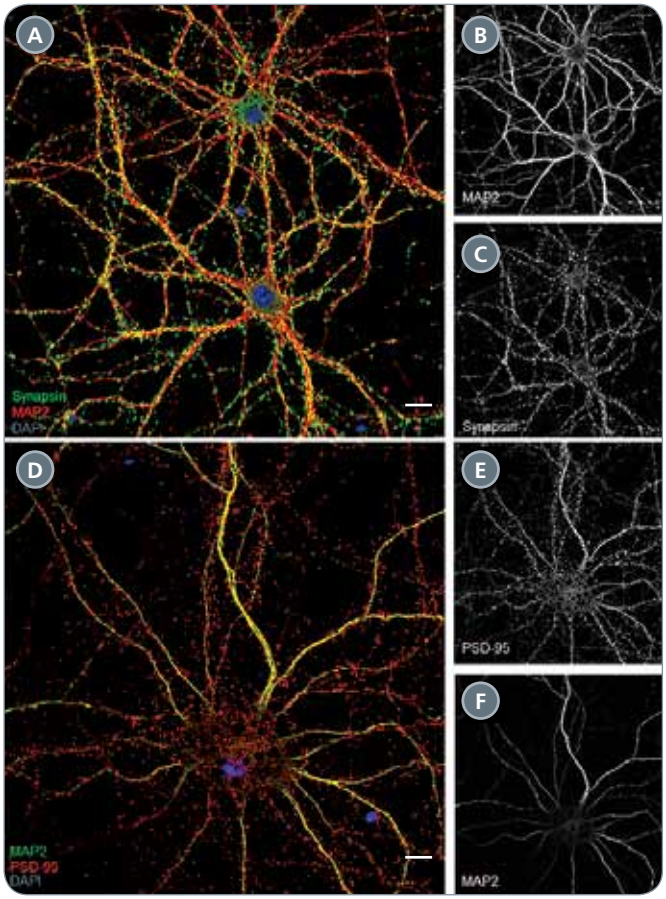

Figure 5. Expression of Pre- and Post-Synaptic Markers in Neurons Cultured for 21 Days in NeuroCult™ SM1.

Neurons cultured in NeuroCult™ SM1 for 21 days are phenotypically mature as indicated by the presence of an extensive dendritic arbor and appropriate expression and localization of pre- (Synapsin) and post-synaptic (PSD-95) markers. (A-C) Synapsin (green) staining is concentrated in discrete puncta distributed along the somata and dendritic processes, as defined by MAP2 (red) staining. (D-F) Dendritic staining observed for MAP2 and punctate staining for the postsynaptic marker PSD-95. Nuclei were counter-stained with DAPI. Scale bar 10 µm.

Summary

The experiments described here indicate that NeuroCult™ SM1 supports short-term neuronal survival comparable to levels observed with TSFM, but significantly greater neuronal survival after 21 days in culture. In addition, neurons cultured for 7 and 21 days in NeuroCult™ SM1 feature significantly greater neurite outgrowth and significantly greater numbers of branch points per neuron, when compared to neurons cultured in TSFM. Immunocytochemical staining also confirms expression and appropriate localization of pre- and post-synaptic markers. These results were consistent across different lots of supplement, indicating that NeuroCult™ SM1 reproducibly supports the long-term culture of viable, mature and functional neurons.

Materials and Methods

Primary Neuronal Culture

Glass coverslips were placed in individual wells of a 24-well plate and coated with 10 µg/mL poly-D-lysine. Cortices were dissected from E18 rat CNS (Brain Bits, Inc.) and enzymatically dissociated with 0.25% Trypsin/EDTA into a single-cell suspension. Cells were diluted in either NeuroCult™ SM1 plating medium (NeuroCult™ Neuronal Basal Medium, 2% NeuroCult™ SM1, 0.5 mM L-glutamine and 25 µM L-glutamic acid), or traditional serum-free plating medium (Neurobasal™ Medium, 2% B-27® (Life Technologies Inc.), 0.5 mM L-glutamine and 25 µM L-glutamic acid), and plated at a density of 60,000 cells/well or 320 cells/mm^2. Cells were plated in triplicate wells for each condition. After 3 days, the medium was replaced with NeuroCult™ SM1 maintenance medium (NeuroCult™ Neuronal Basal Medium, 2% NeuroCult™ SM1 and 0.5 mM L-Glutamine), or traditional serum-free maintenance medium (TSFM; Neurobasal™ Medium, 2% B-27® and 0.5 mM L-Glutamine). Half-medium changes were performed weekly throughout the duration of the culture period. Cells were cultured for a total of either 7 or 21 days.

Immunocytochemistry

Cells were fixed for 30 minutes in 4% paraformaldehyde (PFA) followed by three rinses for five minutes each in PBS. Cells were permeabilized in 0.3% Triton X-100 for five minutes, washed three times with phosphate-buffered saline (PBS), and incubated with primary antibodies diluted in PBS containing 10% goat serum for two hours at 37°C or overnight at 4°C. Following incubation with primary antibodies (see Table 1), the cells were rinsed three times with PBS for five minutes each time. Primary antibodies were detected with relevant fluorochrome-conjugated secondary antibodies diluted in PBS containing 2% goat serum. Cells were incubated with secondary antibodies (see Table 1) for 30 minutes at 37°C, followed by three 5 minute washes with PBS. Nuclei were counterstained with 5 µg/mL DAPI (Sigma) and coverslips were mounted.

NeuroCult™ SM1 for Long-Term Primary Neuronal Culture

ANTIGEN	HOST SPECIES	FLUORO-PHORE	SUPPLIER; CATALOG #	DILUTION
Neuronal Class III β-tubulin	Mouse	-	Covance; MMS-435P	1:1000
MAP2	Rabbit	-	Cell Signaling; 4542S	1:250
MAP2	Mouse	-	Millipore; MAB3418	1:200
Synapsin	Rabbit	-	Millipore; AB1543	1:1000
PSD-95	Mouse	-	Abcam; AB2723	1:1000
Rabbit IgG	Goat	FITC	STEMCELL Technologies; 10212	1:50
Mouse IgG (H + L)	Goat	DyLight 594	Thermo Scientific; 35510	1:500

Table 1. Antibodies Used in this Study

Cell Counting, Neurite Outgrowth and Branching Analyses

Neurons were detected by immunolabeling for the neuronal marker class III β-tubulin and nuclei were counterstained with DAPI. Images of neuronal class III β-tubulin-labeled neurons were captured with a Thermo Scientific ArrayScan® Infinity High Content Reader (previously Cellomics High Content Analysis (HCA) and Screening). Images were acquired from eight random areas per well in each of three replicate wells per condition for high-content analysis. The raw images from all samples were blinded and images were analyzed to determine which contained cell clumping as defined by more than three cells attached together. These images were not used for further quantification. The number of neurons (class III β-tubulin- and DAPI-positive), neurite outgrowth and neurite branch points were quantified using the HCA-Vision Neurite Analysis Module.

Microscopy

Phase contrast images were captured using an Olympus CKX41 inverted microscope. Confocal microscopy was performed using an Olympus Fluoview FV1000 laser scanning confocal microscope.

Statistical Analyses

Data were analyzed by JMP® statistical software using ANOVA statistical analyses. Preliminary analysis revealed an effect of the different tissue samples (i.e. the cells obtained on each experimental date were significantly different). To remove this effect from the analyses and enable a comparison of the medium formulations, the experimental date was used as a blocking factor. Analyses were then performed by standard ANOVA to compare the effect of medium formulation on the dependent variables of 1) number of neurons, 2) neurite outgrowth and 3) neurite branching. In preliminary analyses, a strong inverse relationship between cell number (i.e. measured cell numbers per field of view in the captured images) and neurite outgrowth was observed. Measured cell number in the field of view was therefore included in the outgrowth analyses as an independent variable, to isolate the effects of medium formulation from this very significant cell density effect. Similarly, a strong linear relationship between the numbers of neurite branch points and neurite outgrowth was observed. Neurite outgrowth was therefore included in the branching analyses as an independent variable, to isolate the effects of medium formulation. Data are represented by mean ± 95% confidence intervals (CI).

PRODUCT	UNIT SIZE	CATALOG #
NeuroCult™ SM1 Neuronal Supplement (50X)	10 mL	05711
NeuroCult™ SM1 Neuronal Culture Kit	500 mL*	05712

Table 2. Product Information

*Kit contains 1 unit of NeuroCult™ SM1 Neuronal Supplement and 5 units of NeuroCult™ Neuronal Basal Medium (100 mL).

References

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