

User Guide | CG000732 | Rev B

Chromium GEM-X Single Cell 3' Reagent Kits v4

with Feature Barcode technology for Cell Surface Protein

For use with:

Chromium GEM-X Single Cell 3' Kit v4
16 rxns PN-1000691 | 4 rxns PN-1000686

Chromium GEM-X Single Cell 3' Chip Kit v4
4 chips PN-1000690

Chromium GEM-X Single Cell 3' Feature Barcode Kit v4
16 rxns PN-1000702

Dual Index Kit TT Set A
96 rxns PN-1000215

Dual Index Kit NT Set A
96 rxns PN-1000242

Notices

Document Number

CG000732 | Rev B

Legal Notices

© 2024 10x Genomics, Inc. (10x Genomics). All rights reserved. Duplication and/or reproduction of all or any portion of this document without the express written consent of 10x Genomics, is strictly forbidden. Nothing contained herein shall constitute any warranty, express or implied, as to the performance of any products described herein. Any and all warranties applicable to any products are set forth in the applicable terms and conditions of sale accompanying the purchase of such product. 10x Genomics provides no warranty and hereby disclaims any and all warranties as to the use of any third-party products or protocols described herein. The use of products described herein is subject to certain restrictions as set forth in the applicable terms and conditions of sale accompanying the purchase of such product. A non-exhaustive list of 10x Genomics' marks, many of which are registered in the United States and other countries can be viewed at: www.10xgenomics.com/trademarks. 10x Genomics may refer to the products or services offered by other companies by their brand name or company name solely for clarity, and does not claim any rights in those third-party marks or names. 10x Genomics products may be covered by one or more of the patents as indicated at: www.10xgenomics.com/patents. The use of products described herein is subject to 10x Genomics Terms and Conditions of Sale, available at www.10xgenomics.com/legal-notices, or such other terms that have been agreed to in writing between 10x Genomics and user. All products and services described herein are intended FOR RESEARCH USE ONLY and NOT FOR USE IN DIAGNOSTIC PROCEDURES.

Instrument & Licensed Software Updates Warranties

Updates to existing Instruments and Licensed Software may be required to enable customers to use new or existing products. In the event of an Instrument failure resulting from an update, such failed Instrument will be replaced or repaired in accordance with the 10x Limited Warranty, Assurance Plan or service agreement, only if such Instrument is covered by any of the foregoing at the time of such failure. Instruments not covered under a current 10x Limited Warranty, Assurance Plan or service agreement will not be replaced or repaired.

Support

Email: support@10xgenomics.com

10x Genomics

6230 Stoneridge Mall Road

Pleasanton, CA

Document Revision Summary

Document Number

CG000732 | Rev B

Title

Chromium GEM-X Single Cell 3' Reagent Kits v4 with Feature Barcode technology for Cell Surface Protein

Revision

Rev A to Rev B

Revision Date

August 29, 2024

Description of Changes

- Updated for general minor consistency of language and terms throughout
- Updated at multiple instances throughout:
 - Chromium X/iX instrument to Chromium X Series instrument
 - Chromium X/iX Chip Holder to Chromium X Series Chip Holder
 - Chromium X Series Accessory Kit name and part number
No change in functionality
- Updated firmware version note in Tips & Best Practices section and in Run the Chromium X Series Instrument section

Table of Contents

Introduction

Chromium GEM-X Single Cell 3' Reagent Kits v4	7
10x Genomics Accessories	11
Third-Party Items	11
Protocol Steps & Timing	12
Stepwise Objectives	13
Cell Surface Protein Labeling Guidelines	20

Tips & Best Practices

Step 1: GEM Generation and Barcoding

1.0 Get Started	33
1.1 Prepare Master Mix	34
Assemble GEM-X Chip	35
1.2 Load GEM-X Chip	39
1.3 Run the Chromium X Series Instrument	41
1.4 Transfer GEMs	42
1.5 GEM-RT Incubation	43

Step 2: Post GEM-RT Cleanup & cDNA Amplification

2.0 Get Started	45
2.1 Post GEM-RT Cleanup – Dynabeads	47
2.2 cDNA Amplification	50
Step Overview (steps 2.2 & 2.3)	51
2.3 cDNA Cleanup – SPRIselect	52
2.3A Pellet Cleanup for 3' Gene Expression Library	53
2.3B Transferred Supernatant Cleanup for Cell Surface Protein	54
2.4 Post cDNA Amplification QC & Quantification	55

Step 3: 3' Gene Expression Library Construction

3.0 Get Started	58
Step Overview (Step 3.1d)	59
3.1 GEX Fragmentation, End Repair & A-tailing	60
3.2 GEX Post Fragmentation, End Repair & A-tailing Double Sided – SPRIselect	62
3.3 GEX Adaptor Ligation	63

Table of Contents

3.4 GEX Post Ligation Cleanup – SPRIselect	64
3.5 GEX Sample Index PCR	65
3.6 Post Sample Index PCR Double Sided Size Selection – SPRIselect	66
3.7 Post Library Construction QC	67
Step 4: Cell Surface Protein Library Construction	
4.0 Get Started	69
4.1 Sample Index PCR	70
4.2 Post Sample Index PCR Size Selection – SPRIselect	72
4.3 Post Library Construction QC	73
Step 5: Sequencing	
Sequencing Libraries	75
Illumina Sequencer Compatibility	75
Sample Indices	76
Library Sequencing Depth & Run Parameters	76
Library Loading	77
Library Pooling	77
Data Analysis and Visualization	79
Troubleshooting	
GEM Generation & Barcoding	81
Chromium X Series Errors	85
Appendix	
GEM-X Chip Loading Overview	87
Post Library Construction Quantification using KAPA qPCR	88
LabChip Traces	89
Oligonucleotide Sequences	90

Introduction

Chromium GEM-X Single Cell 3' Reagent Kits v4	7
10x Genomics Accessories	11
Third-Party Items	11
Protocol Steps & Timing	12
Stepwise Objectives	13
Cell Surface Protein Labeling Guidelines	20

Chromium GEM-X Single Cell 3' Reagent Kits v4

Refer to SDS for handling and disposal information

Chromium GEM-X Single Cell 3' Kit v4, 16 rxns PN-1000691

Chromium GEM-X Single Cell 3' GEM Kit v4 16 rxns, PN-1000693 Store at -20°C			
		#	PN
	RT Reagent E	1	2001106
	RT Enzyme E	1	2001105
	Template Switch Oligo B	1	2001027
	Reducing Agent B	1	2000087
	Cleanup Buffer	2	2000088
	cDNA Primers	1	2000089
	Amp Mix	1	2000047

Library Construction Kit C 16 rxns, PN-1000694 Store at -20°C			
		#	PN
	Fragmentation Enzyme	1	2000090
	Fragmentation Buffer	1	2000091
	Ligation Mix	1	2001109
	DNA Ligase	1	220110
	Library Amp Mix	1	2000531

10x
GENOMICS

Chromium GEM-X Single Cell 3' Gel Bead Kit v4 16 rxns, PN-1000692 Store at -80°C		
	#	PN
GEM-X Single Cell 3' Gel Bead v4	2	2001128

10x
GENOMICS

Dynabeads™ MyOne™ SILANE PN-2000048 Store at 4°C		
	#	PN
Dynabeads MyOne SILANE	1	2000048

Chromium GEM-X Single Cell 3' Kit v4, 4 rxns PN-1000686

Chromium GEM-X Single Cell 3' GEM Kit v4 4 rxns, PN-1000688 Store at -20°C			
		#	PN
	RT Reagent E	1	2001106
	RT Enzyme E	1	2001146
	Template Switch Oligo B	1	2001027
	Reducing Agent B	1	2000087
	Cleanup Buffer	1	2000088
	cDNA Primers	1	2000089
	Amp Mix	1	2000103

10x
GENOMICS

Library Construction Kit C 4 rxns, PN-1000689 Store at -20°C			
		#	PN
	Fragmentation Enzyme	1	2000104
	Fragmentation Buffer	1	2000091
	Ligation Mix	1	2001109
	DNA Ligase	1	220131

10x
GENOMICS

Chromium GEM-X Single Cell 3' Gel Bead Kit v4 4 rxns, PN-1000687 Store at -80°C			
		#	PN
	GEM-X Single Cell 3' Gel Bead v4 (4 rxns)	1	2001128

10x
GENOMICS

Dynabeads™ MyOne™ SILANE PN-2000048 Store at 4°C			
		#	PN
	Dynabeads MyOne SILANE	1	2000048

Chromium GEM-X Single Cell 3' Chip Kit v4, 4 chips PN-1000690

Chromium Partitioning Oil B <i>Store at ambient temperature</i>			
		#	PN
	Partitioning Oil B	4	2001213

Chromium Recovery Agent <i>Store at ambient temperature</i>			
		#	PN
	Recovery Agent	4	220016

Chromium GEM-X 3' Chip & Gaskets <i>Store at ambient temperature</i>			
		#	PN
	GEM-X 3' Chip	4	2001097
	X/iX Chip Gasket, 2-pack	2	3000656



Chromium GEM-X Single Cell 3' Feature Barcode Kit v4, 16 rxns PN-1000702

Chromium GEM-X Single Cell 3' Feature Barcode Kit v4			
16 rxns, PN-1000702			
Store at -20°C			
		#	PN
	Feature cDNA Primers 2	1	2000097
	Amp Mix	1	2000047

10x
GENOMICS

Dual Index Kit TT Set A, 96 rxns PN-1000215

Dual Index Kit TT Set A		
Store at -20°C		
	#	PN
Dual Index Plate TT Set A	1	3000431

Dual Index Kit NT Set A, 96 rxns PN-1000242

Dual Index Kit NT Set A		
Store at -20°C		
	#	PN
Dual Index Plate NT Set A	1	3000483

10x Genomics Accessories

Product	Part Number (Kit)	Part Number (Item)
10x Vortex Adapter	120251	330002
10x Magnetic Separator B*	1000709 (Chromium X/iX Series Accessory Kit)/	2001212
Chromium X/iX Chip Holder (also referred to as Chromium X Series Chip Holder)	1000821 (Chromium X Series Accessory Kit)/ 1000707 (GEM-X Transition Kit)	3000598

*10x Magnetic Separator (PN-230003) is untested but interchangeable with the 10x Magnetic Separator B (PN-2001212).

Third-Party Items

Successful execution of Chromium Gene Expression Solutions requires third-party reagents, kits, and equipment in addition to those provided by 10x Genomics. All third-party reagents and consumables should be obtained prior to starting this library construction workflow.

Refer to the Chromium GEM-X Single Cell Gene Expression v4 & Immune Profiling v3 - Protocol Planner (CG000748) for a detailed list of the following third-party items:

- Additional reagents, kits, and equipment
- Recommended pipette tips
- Recommended thermal cyclers



10x Genomics has tested all items listed in the Protocol Planner. These items perform optimally with the assay. Substituting materials may adversely affect assay performance.

Protocol Steps & Timing

Steps	Timing	Stop & Store
Sample Preparation	variable*	
		*Refer to the appropriate Demonstrated Protocols for details.
Step 1: GEM Generation and Barcoding (page 32)		
1.1 Prepare Master Mix (page 34)	20 min	
1.2 Load GEM-X Chip (page 39)	10 min	
1.3 Run the Chromium X Series Instrument (page 41)	6 min	
1.4 Transfer GEMs (page 42)	3 min	
1.5 GEM-RT Incubation (page 43)	55 min	 4°C ≤72 h/-20°C ≤1 week
Step 2: Post GEM-RT Cleanup & cDNA Amplification (page 44)		
2.1 Post GEM-RT Cleanup – Dynabeads (page 47)	45 min	
2.2 cDNA Amplification (page 50)	40 min	 4°C ≤72 h/-20°C ≤1 week
2.3 cDNA Cleanup – SPRIselect (page 52)		
2.3A Pellet Cleanup	30 min	 4°C ≤72 h/-20°C ≤4 weeks
2.3B Supernatant Cleanup	20 min	
2.4 Post cDNA Amplification QC & Quantification (page 55)	50 min	
Step 3: 3' Gene Expression Library Construction (page 57)		
3.1 GEX Fragmentation, End Repair & A-tailing (page 60)	50 min	
3.2 GEX Post Fragmentation, End Repair & A-tailing Double Sided – SPRIselect (page 62)	30 min	
3.3 GEX Adaptor Ligation (page 63)	25 min	
3.4 GEX Post Ligation Cleanup – SPRIselect (page 64)	30 min	
3.5 GEX Sample Index PCR (page 65)	40 min	 4°C ≤72 h
3.6 Post Sample Index PCR Double Sided Size Selection – SPRIselect (page 66)	30 min	 4°C ≤72 h/-20°C long term
3.7 Post Library Construction QC (page 67)	50 min	
Step 4: Cell Surface Protein Library Construction (page 68)		
4.1 Sample Index PCR (page 70)	40 min	
4.2 Post Sample Index PCR Size Selection – SPRIselect (page 72)	20 min	 4°C ≤72 h/-20°C long term
4.3 Post Library Construction QC (page 73)	50 min	

Stepwise Objectives

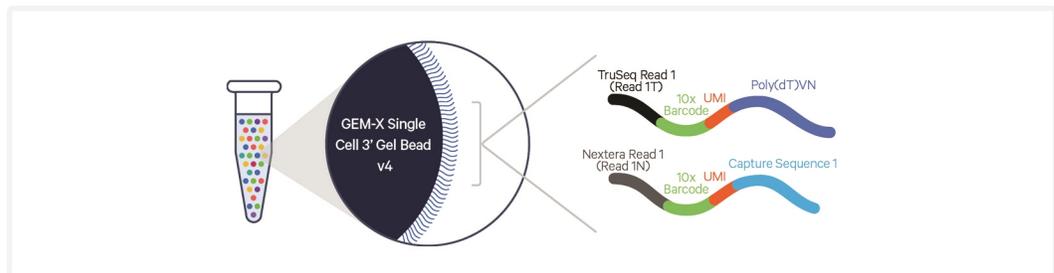
The Chromium GEM-X Single Cell Gene Expression v4 with Feature Barcode technology upgrades short read sequencers to deliver a scalable microfluidic platform for assessing cell surface protein expression combined with 3' digital gene expression of the same single cell by profiling 500-20,000 individual cells per sample. A pool of ~3,600,000 10x Barcodes are sampled separately to index each cell's transcriptome and cell surface protein. It is done by partitioning thousands of cells into nanoliter-scale Gel Beads-in-emulsion (GEMs), where all generated DNA molecules share a common 10x Barcode. Libraries are generated and sequenced from the DNA molecules and 10x Barcodes are used to associate individual reads back to the individual partitions.

This document outlines the protocol for generating Single Cell 3' Gene Expression and Cell Surface Protein libraries from the same cells.

GEM-X Single Cell 3' Gel Beads v4

In addition to the poly(dT) primer that enables the production of barcoded, full-length cDNA from poly-adenylated mRNA, the GEM-X Single Cell 3' Gel Beads v4 also include an additional primer sequence (Capture Sequence 1) that enables the capture and priming of Feature Barcode technology compatible targets or analytes of interest.

Gel Bead Primers

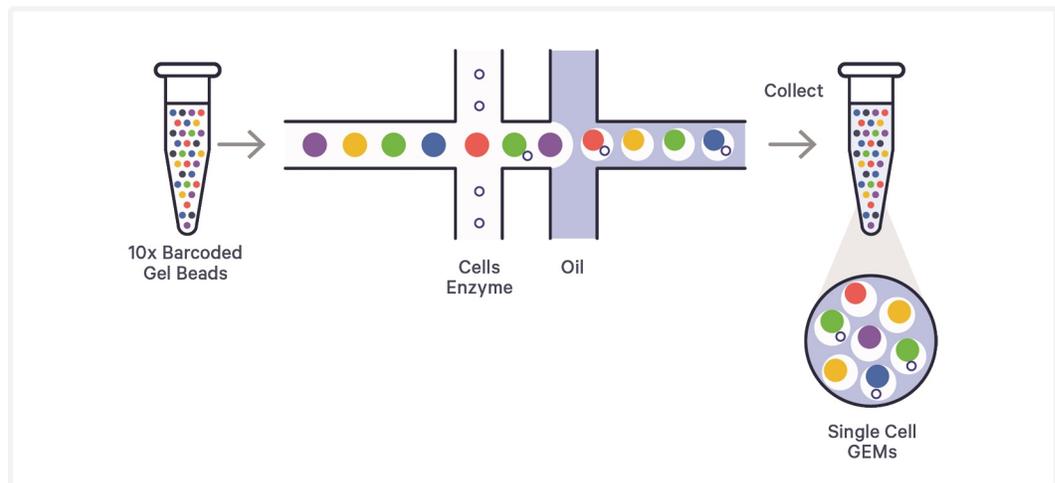


The poly(dT) primers along with the capture sequence primers are used in this protocol for generating Single Cell 3' Gene Expression and Cell Surface Protein libraries.

Step 1: GEM Generation & Barcoding

GEMs are generated by combining barcoded Gel Beads, a Master Mix containing cells, and Partitioning Oil B onto GEM-X 3' Chip. To achieve single cell resolution, cells are delivered at a limiting dilution, such that the majority (~90-99%) of generated GEMs contain no cell, while the remainders largely contain a single cell.

GEM-X Chip Workflow



Immediately following GEM generation, the Gel Bead is dissolved, primers are released, and any copartitioned cell is lysed. The poly(dT) and the capture sequence primer in the gel bead are engaged simultaneously in two different reactions inside individual GEMs.

A. Primers containing:

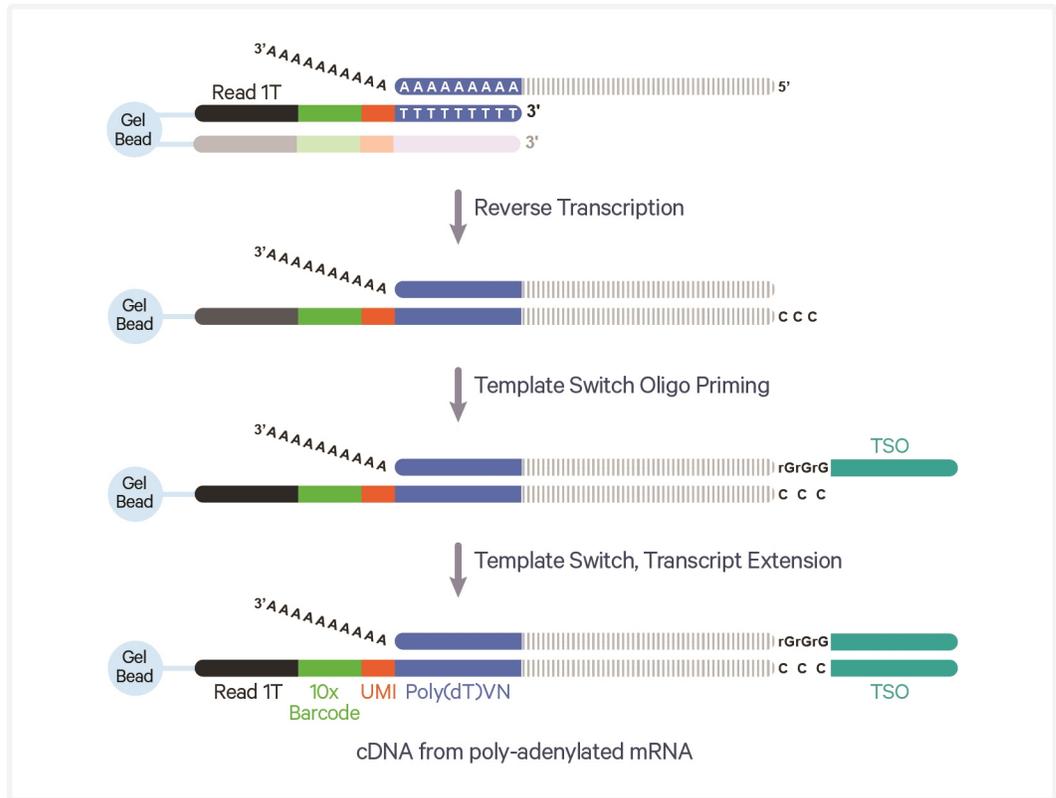
- an Illumina TruSeq Read 1 (Read 1T: read 1 sequencing primer)
- 16 nt 10x Barcode
- 12 nt unique molecular identifier (UMI)
- 30 nt poly(dT) sequence

B. Primers containing:

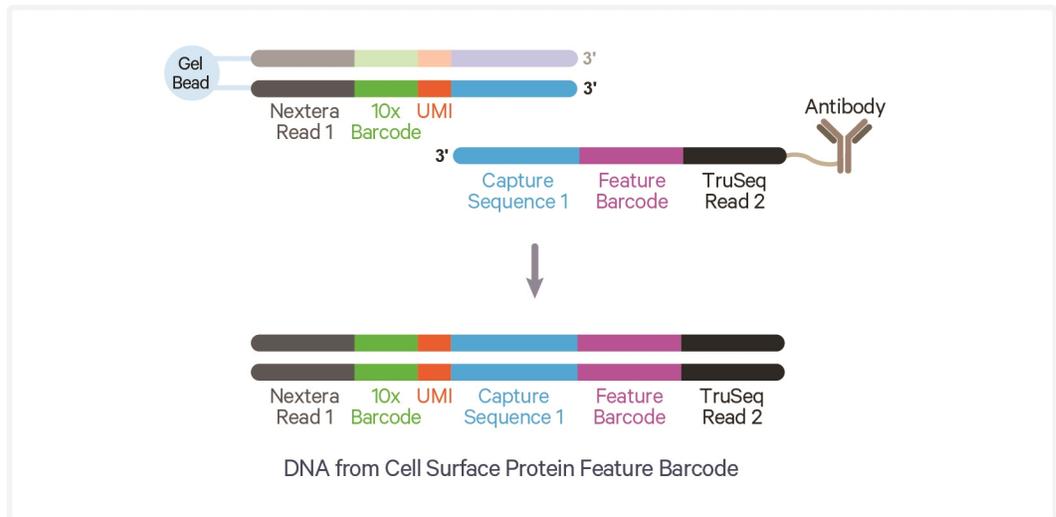
- an Illumina Nextera Read 1 (Read 1N; read 1 sequencing primer)
- 16 nt 10x Barcode
- 12 nt unique molecular identifier (UMI)
- Capture Sequence 1

Both primers are mixed with both the cell lysate and a Master Mix containing reverse transcription (RT) reagents. Incubation of the GEMs produces barcoded, full-length cDNA from poly-adenylated mRNA from reagents in (A) and barcoded DNA from the cell surface protein Feature Barcode oligonucleotides from reagents in (B).

Inside Individual GEMs - A. Gene Expression Primer



B. Feature Barcode Primer

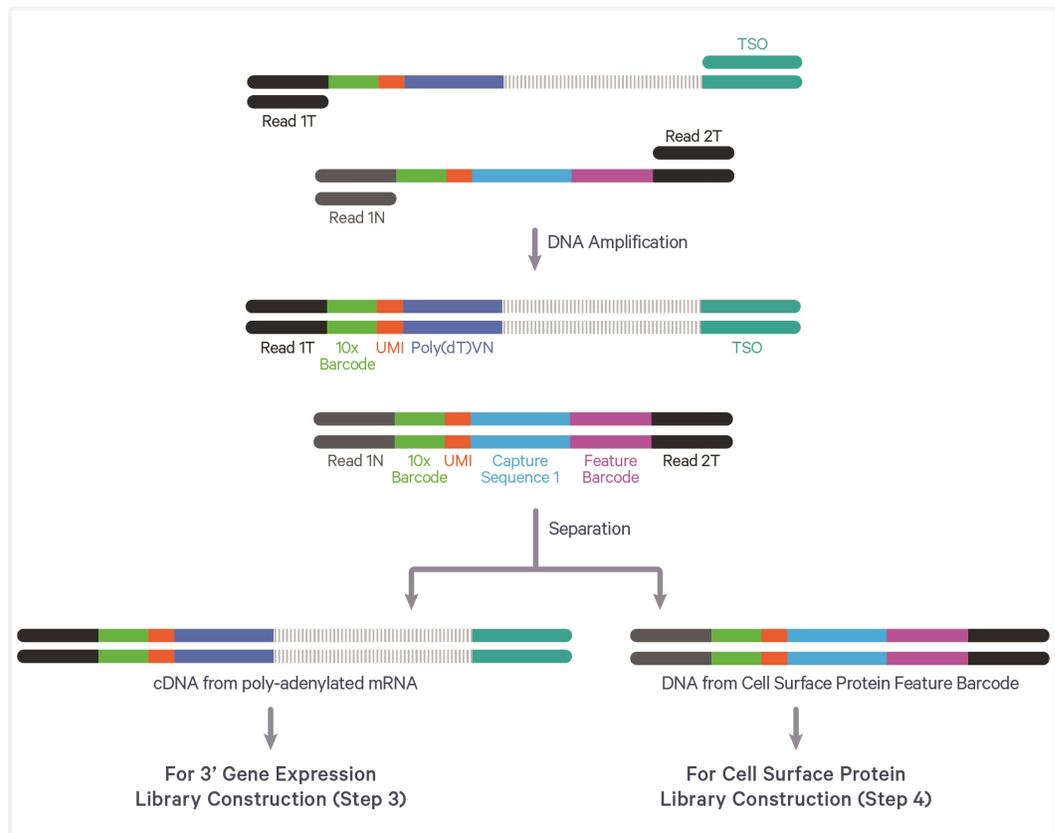


cDNA from poly-adenylated mRNA and DNA from cell surface protein Feature Barcode are generated simultaneously from the same single cell inside the GEM.

Step 2: Post GEM-RT Cleanup & cDNA Amplification

After incubation, GEMs are broken and pooled fractions are recovered. Silane magnetic beads are used to purify the cell barcoded products from the post GEM-RT reaction mixture, which includes leftover biochemical reagents and primers. The cell barcoded cDNA molecules are amplified via PCR to generate sufficient mass for library constructions. Size selection is used to separate the amplified cDNA molecules for 3' Gene Expression and Cell Surface Protein library construction.

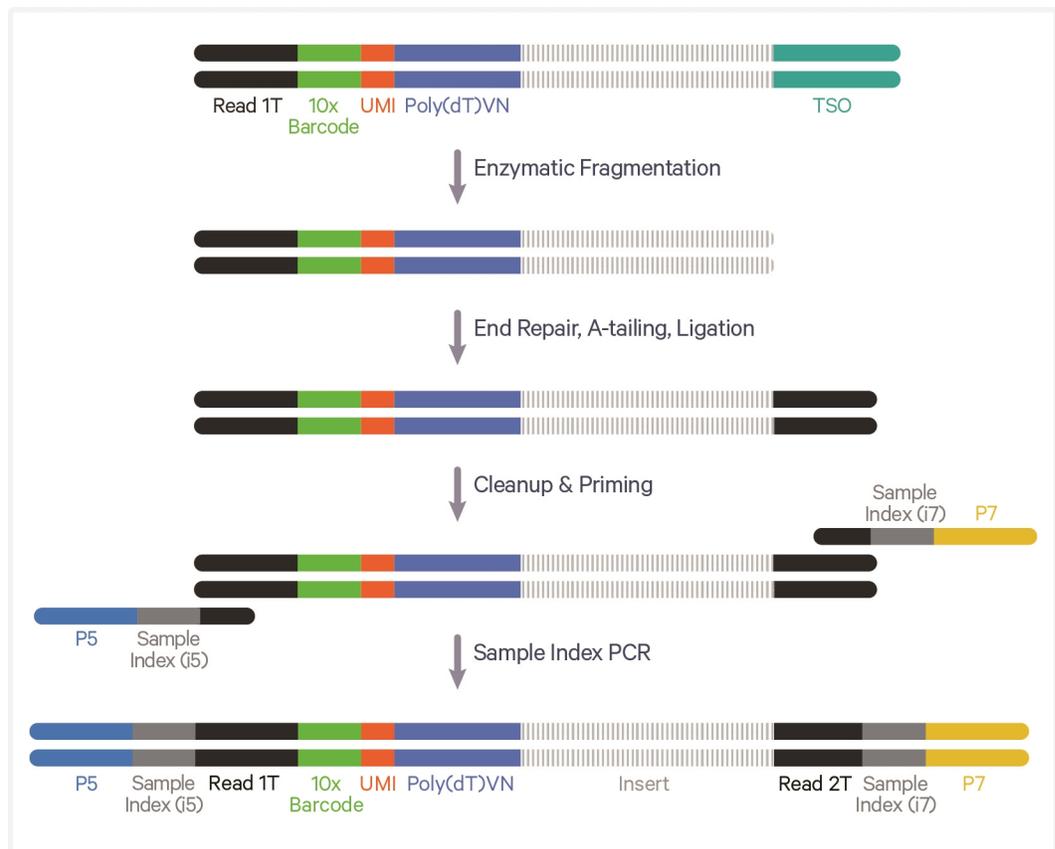
Pooled cDNA Amplification



Step 3: 3' Gene Expression Library Construction

Enzymatic fragmentation and size selection are used to optimize the cDNA amplicon size. P5 and P7 adaptors, i7 and i5 sample indexes, and TruSeq Read 2 (read 2 primer sequence) are added via End Repair, A-tailing, Adaptor Ligation, and PCR. The final libraries contain the P5 and P7 primers used in Illumina amplification.

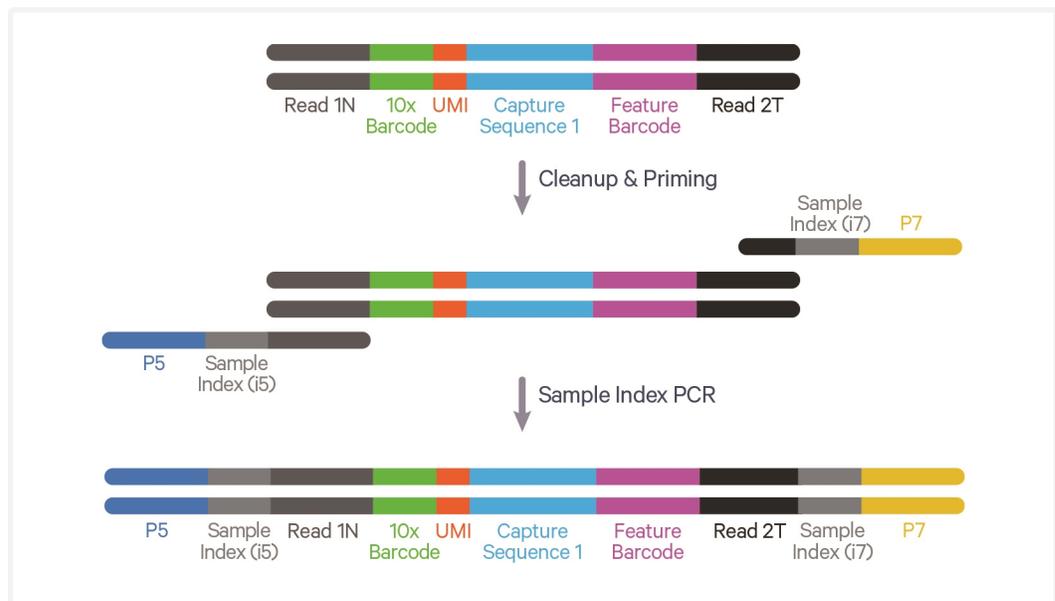
Amplified cDNA Processing (dual index)



Step 4: Cell Surface Protein Library Construction

Amplified DNA from cell surface protein Feature Barcode oligonucleotides is used for library construction. P5 and P7 adaptors, i7 and i5 sample indexes, and TruSeq Read 2 (read 2 primer sequence) are added via PCR. The final libraries contain the P5 and P7 primers used in Illumina amplification.

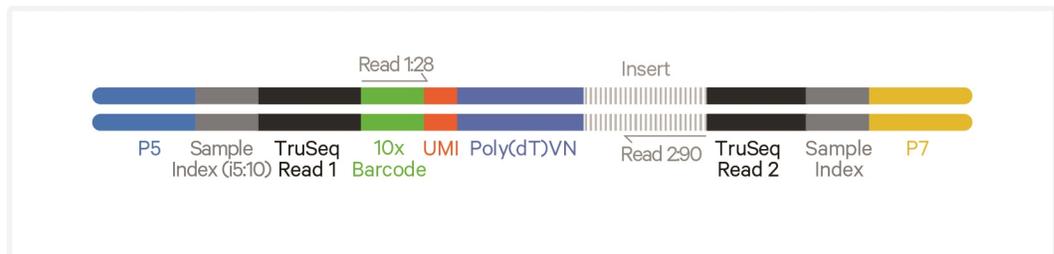
Amplified DNA Processing (dual index)



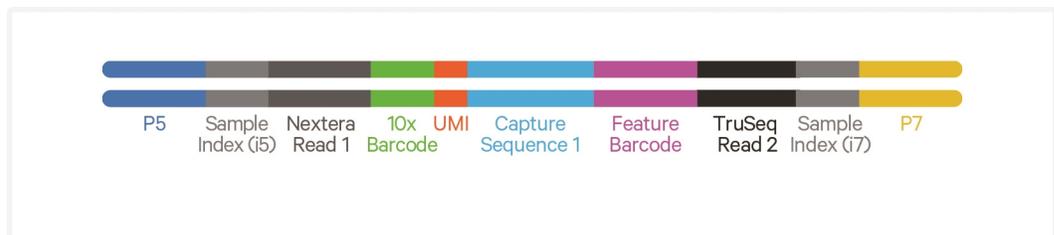
Sequencing

The Single Cell 3' libraries comprise standard Illumina paired-end constructs which begin and end with P5 and P7. The 16 bp 10x Barcode and 12 bp UMI are encoded in Read 1, while Read 2 is used to sequence the cDNA fragment in 3' Gene Expression libraries and the Feature Barcode in the Cell Surface Protein libraries. i7 and i5 sample index sequences are incorporated as the sample index reads. Standard Illumina sequencing primer sites TruSeq Read 1 and TruSeq Read 2 in the 3' Gene Expression libraries and Nextera Read 1 and TruSeq Read 2 in the Cell Surface Protein libraries are used in paired-end sequencing. Illumina sequencer compatibility, sample indices, library loading and pooling, recommended read depths and run parameters are summarized in the sequencing chapter.

Chromium Single Cell 3' Gene Expression Library



Chromium Single Cell 3' Cell Surface Protein Library

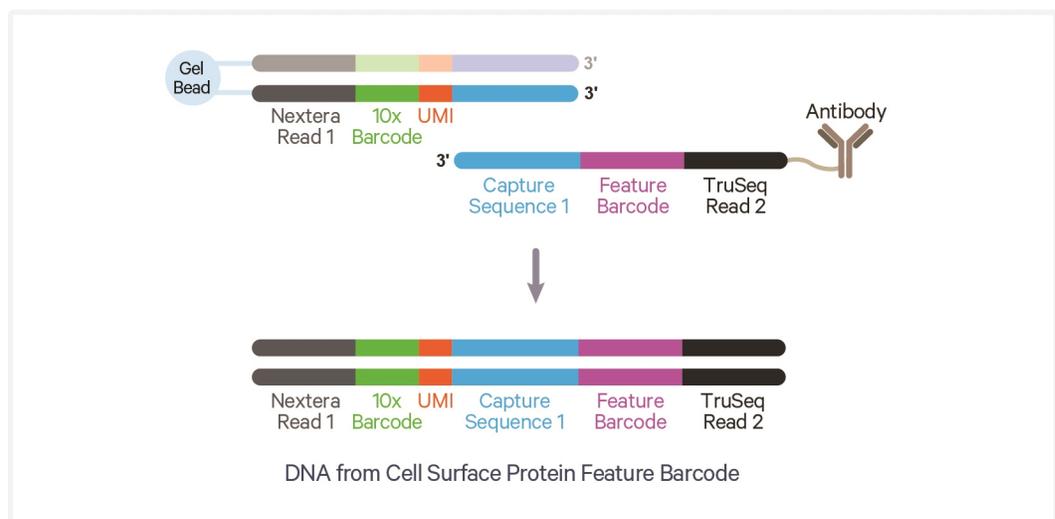


See [Oligonucleotide Sequences on page 90](#)

Cell Surface Protein Labeling Guidelines

Overview

Cell surface proteins can be labeled using a Feature Barcode oligonucleotide conjugated to a specific protein binding molecule, such as an antibody. The Feature Barcode conjugated molecule bound to the cell surface protein can be directly captured by the Gel Bead inside a GEM during GEM generation and amplified (see [Stepwise Objectives on page 13](#) for assay scheme specifics). The amplified DNA generated from the Feature Barcode can be used for Cell Surface Protein Library Construction.



Demonstrated Protocols for cell surface protein labeling

- For antibody-oligonucleotide conjugation guidance and cell surface protein labeling protocol, consult [Demonstrated Protocol Cell Surface Protein Labeling for Single Cell RNA Sequencing Protocols with Feature Barcode technology \(Document CG000149\)](#).



Failure to label cell surface proteins with a Feature Barcode oligonucleotide conjugated to a specific protein binding molecule prior to using the cells for GEM Generation & Barcoding will preclude generation of Cell Surface Protein library.

Tips & Best Practices



Icons



Tips & Best Practices section includes additional guidance



Signifies critical step requiring accurate execution



Troubleshooting section includes additional guidance



GEM-X specific protocol step updates



Version specific protocol step updates

Emulsion-safe Plastics

- Use validated emulsion-safe plastic consumables when handling GEMs as some plastics can destabilize GEMs.
- Consult Chromium GEM-X Single Cell Gene Expression v3 & Immune Profiling v4 - Protocol Planner (CG000748) for a detailed list of plastics and other consumables.

Cell Concentration

- The optimal input cell concentration depends upon the desired cell recovery target:

Optimal Input Cell Concentration	Cell Recovery Target
700-1,200 cells/ μ l	500-10,000 cells
1,300-1,600 cells/ μ l	10,000-20,000 cells

- The presence of dead cells and debris in the suspension may reduce the recovery rate. Consult the following documents for more information on preparing cells:
 - 10x Genomics Single Cell Protocols Cell Preparation Handbook (Documents CG00053)
 - Best Practices to Minimize Chromium Next GEM Chip Clogs and Wetting Failure (Document CG000479)

Multiplet Rate (%)	# of Cells Loaded	# of Cells Recovered
~0.20%	~725	~500
~0.40%	~1,450	~1,000
~0.80%	~2,900	~2,000
~1.20%	~4,350	~3,000
~1.60%	~5,800	~4,000
~2.00%	~7,250	~5,000

Multiplet Rate (%)	# of Cells Loaded	# of Cells Recovered
~2.40%	~8,700	~6,000
~2.80%	~10,150	~7,000
~3.20%	~11,600	~8,000
~3.60%	~13,050	~9,000
~4.00%	~14,500	~10,000
~4.40%	~15,950	~11,000
~4.80%	~17,400	~12,000
~5.20%	~18,850	~13,000
~5.60%	~20,300	~14,000
~6.00%	~21,750	~15,000
~6.40%	~23,200	~16,000
~6.80%	~24,650	~17,000
~7.20%	~26,100	~18,000
~7.60%	~27,550	~19,000
~8.00%	~29,000	~20,000

General Reagent Handling

- Fully thaw and thoroughly mix reagents before use.
- Keep all enzymes and reagent mixes on ice during setup and use. Promptly move reagents back to the recommended storage.
- Calculate reagent volumes with 10% excess of 1 reaction values.
- Limit Partitioning Oil exposure to air to minimize evaporation.
- If using multiple chips, use separate reagent reservoirs for each chip during loading.
- Thoroughly mix samples with the beads during bead-based cleanup steps.

50% Glycerol Solution for Addition to Unused Chip Wells

- Purchase 50% glycerol solution from Ricca Chemical Company, Glycerin (glycerol), 50% (v/v) Aqueous Solution, PN-3290-32.

OR

- Prepare 50% glycerol solution:
 - Mix an equal volume of water and ≥99% Glycerol, Molecular Biology Grade.
 - Filter through a 0.2 µm filter.

- Store at **-20°C** in 1-ml LoBind tubes. 50% glycerol solution should be equilibrated to room temperature before use.

Pipette Calibration

- Follow manufacturer's calibration and maintenance schedules.
- Pipette accuracy is particularly important when using SPRIselect reagents.

Chromium X/iX or X Series Chip Holder

- Chromium X/iX or X Series Chip Holders encase GEM-X 3' Chips.
- The holder lid flips over to become a stand, holding the chip at 45 degrees for optimal recovery well content removal.
- Squeeze the slider on the back (right side) of the holder toward the middle to unlock the lid and return the holder to a flat position.



GEM-X Chip Handling

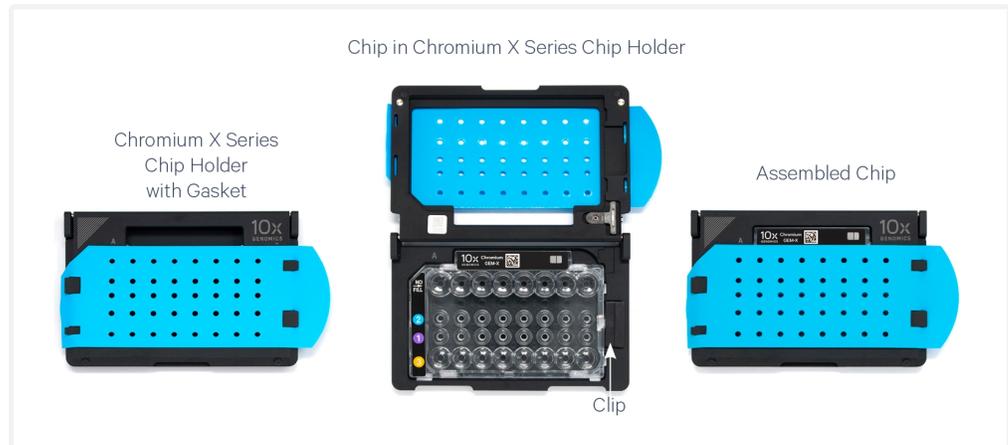
- Minimize exposure of reagents, chips, and gaskets to sources of particles and fibers, laboratory wipes, frequently opened flip-cap tubes, clothing that sheds fibers, and dusty surfaces.
- After removing the chip from the sealed bag, use in **≤24 h**.
- Execute steps without pause or delay, unless indicated. When using multiple chips, load, run, and collect the content from one chip before loading the next.
- Fill all unused input wells in rows labeled 1, 2, and 3 on a chip with an appropriate volume of 50% glycerol solution before loading the used wells. DO NOT add glycerol to the wells in the top NO FILL row.
- Avoid contacting the bottom surface of the chip with gloved hands and other surfaces. Frictional charging can lead to inadequate priming of the channels, potentially leading to wetting failures.
- Minimize the distance that a loaded chip is moved to reach the Chromium X series instrument.
- Keep the chip horizontal to prevent wetting the gasket with oil, which depletes the input volume and may adversely affect the quality of the resulting emulsion.

GEM-X Chip & Holder Assembly with Gasket

- Close the holder lid. Attach the gasket by holding the tongue (curved end, to the right) and hook the gasket on the left-hand tabs of the holder. Gently pull the gasket toward the right and hook it on the two right-hand tabs.
- DO NOT touch the smooth side of the gasket.
- Open the chip holder.
- Align notch on the chip (upper left corner) and the open holder with the gasket attached.
- Slide the chip to the left until the chip is inserted under the guide on the holder.
- Depress the right hand side of the chip until the spring-loaded clip engages.
- Keep the assembled unit with the attached gasket until ready for dispensing reagents.

One of the rows of the gasket will not align with the GEM-X chip wells. This is expected and will not impact the assay.

A generic image representative of the GEM-X 3' Chip is shown below. The Chromium X/iX Chip Holder is also referred to as Chromium X Series Chip holder.



GEM -X Chip Loading

- Place the assembled chip and holder flat (gasket attached) on the bench with the lid open.
- Dispense at the bottom of the wells without introducing bubbles.
- When dispensing Gel Beads into the chip, wait for the remainder to drain into the bottom of the pipette tips and dispense again to ensure complete transfer.
- Refer to [Load GEM-X Chip on page 39](#) for specific instructions.

Chromium X Series Instrument Firmware

- Firmware version 2.0.0 or higher is required in the Chromium X/iX instrument to run the GEM-X chips.
- Firmware Version 2.2.0 or higher is required in the Chromium Xo instrument to run the GEM-X chips.
- The current firmware version of the instrument will be displayed on the instrument homescreen.
- Consult the Chromium X Series Instrument User Guide with Readiness Test (CG000396) for detailed instructions on updating the firmware.

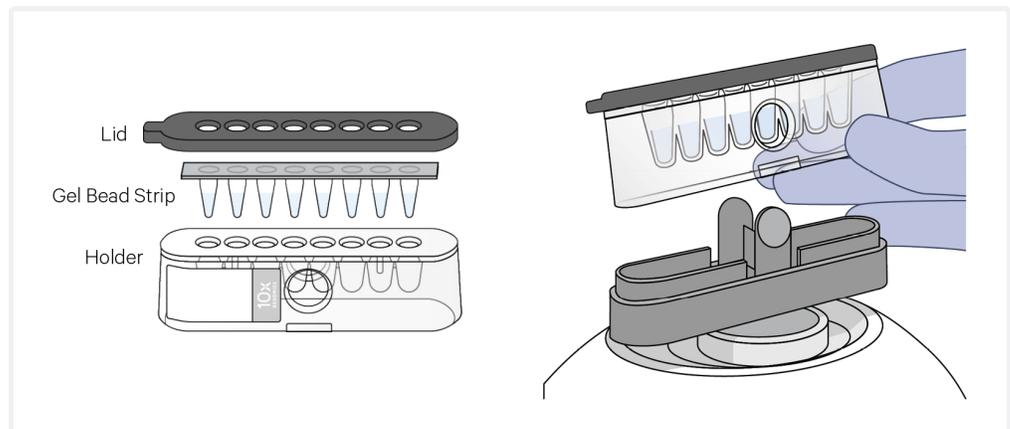
Gel Bead Handling

- Use one tube of Gel Beads per sample. DO NOT puncture the foil seals of tubes not used at the time.
- After removing the Gel Bead strip from the packaging, equilibrate the Gel Bead strip to **room temperature** for at least **30 min** before use.
- Store unused Gel Beads at **-80°C** and avoid more than 12 freeze-thaw cycles.



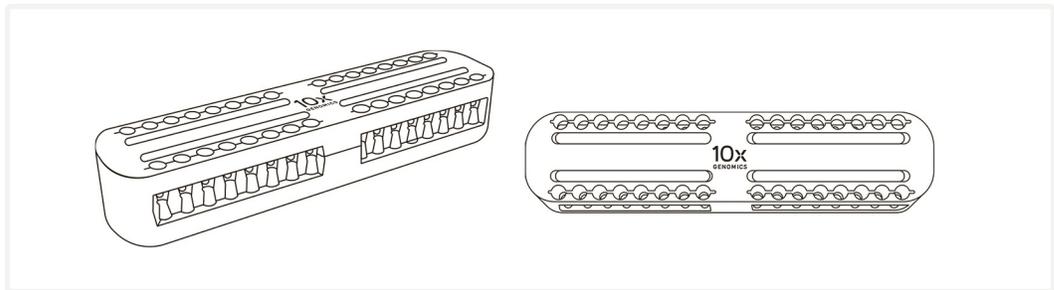
DO NOT store Gel Beads at **-20°C**.

- Snap the tube strip holder with the Gel Bead strip into a 10x Vortex Adapter. Vortex **30 sec**.
- Centrifuge the Gel Bead strip for **~5 sec** after removing from the holder. Confirm there are no bubbles at the bottom of tubes and the liquid levels look even. Place Gel Bead strip back in the holder and secure the holder lid.
- If the required volume of beads cannot be recovered, place the pipette tips against the sidewalls and slowly dispense the Gel Beads back into the tubes. DO NOT introduce bubbles into the tubes and verify that the pipette tips contain no leftover Gel Beads. Withdraw the full volume of beads again by pipetting slowly.



10x Magnetic Separator B

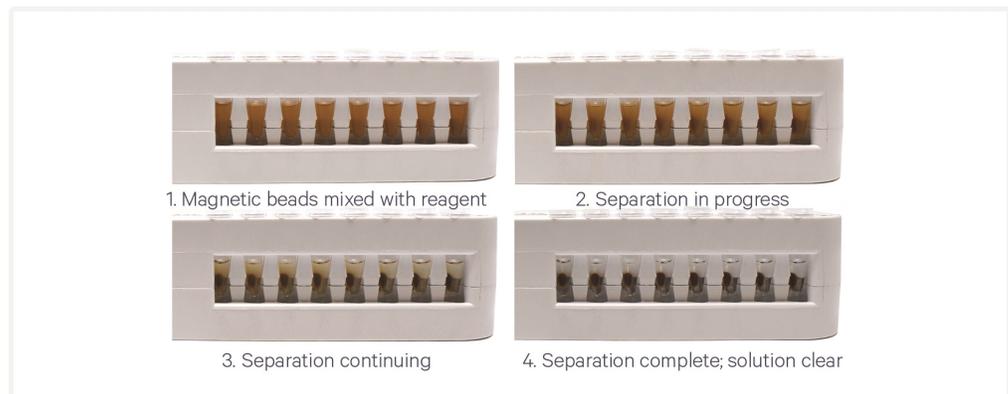
- Images below are illustrative - actual appearance of magnetic separator may vary. Guidance applies to all 10x Magnetic Separators.
- Offers two positions of the magnets (high and low) relative to a tube, depending on its orientation. Flip the magnetic separator over to switch between high (magnet•**High**) or low (magnet•**Low**) positions.
- If using MicroAmp 8-Tube Strips, use only the high position (magnet•**High**) throughout the protocol.



Magnetic Bead Cleanup Steps

- During magnetic bead based cleanup steps that specify waiting “until the solution clears”, visually confirm clearing of solution before proceeding to the next step. See panel below for an example.
- The time needed for the solution to clear may vary based on specific step, reagents, volume of reagents etc.
- Images below are representative - actual color of magnetic separator may vary. Guidance applies to all 10x Magnetic Separators.

Visually Confirm Clearing of Magnetic Bead Solution



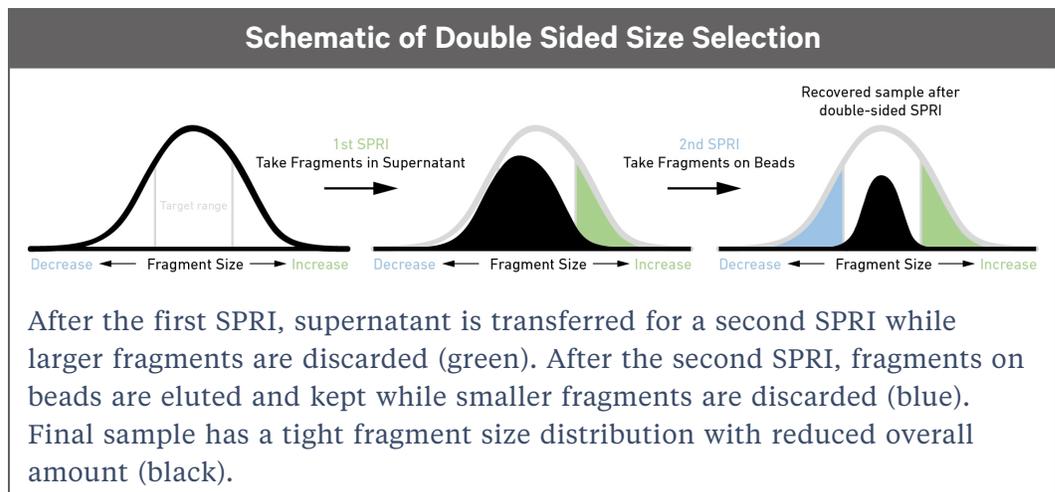
SPRIselect Cleanup & Size Selection

- After aspirating the desired volume of SPRIselect reagent, examine the pipette tips before dispensing to ensure the correct volume is transferred.
- Pipette mix thoroughly as insufficient mixing of sample and SPRIselect reagent will lead to inconsistent results.
- Use fresh preparations of 80% Ethanol.

Tutorial — SPRIselect Reagent:DNA Sample Ratios

SPRI beads selectively bind DNA according to the ratio of SPRIselect reagent (beads).

$$\text{Example Ratio: } \frac{\text{Volume of SPRIselect reagent added to the sample}}{\text{Volume of DNA sample}} = \frac{50 \mu\text{l}}{100 \mu\text{l}} = \mathbf{0.5X}$$



Tutorial — Double Sided Size Selection

a. First SPRIselect: Add **50 µl** SPRIselect reagent to **100 µl** sample (**0.5X**).

$$\text{Ratio: } \frac{\text{Volume of SPRIselect reagent added to the sample}}{\text{Volume of DNA sample}} = \frac{50 \mu\text{l}}{100 \mu\text{l}} = 0.5X$$

b. Second SPRIselect: Add **30 µl** SPRIselect reagent to supernatant from step a (**0.8X**).

$$\text{Ratio: } \frac{\text{Total Volume of reagent added to the sample (step a + b)}}{\text{Original Volume of DNA sample}} = \frac{50 \mu\text{l} + 30 \mu\text{l}}{100 \mu\text{l}} = 0.8X$$

Enzymatic Fragmentation

Ensure enzymatic fragmentation reactions are prepared on ice and then loaded into a thermal cycler pre-cooled to **4°C** prior to initiating the Fragmentation, End Repair, and A-tailing incubation steps.

Sample Indices in Sample Index PCR

- Choose the appropriate sample index sets to ensure that no sample indices overlap in a multiplexed sequencing run.
- Verify and use the specified index plate only. DO NOT use the plates interchangeably.
- Each well in the Dual Index Plate contains a unique i7 and a unique i5 oligonucleotide.

Index Hopping Mitigation

Index hopping can impact pooled samples sequenced on Illumina sequencing platforms that utilize patterned flow cells and exclusion amplification chemistry. To minimize index hopping, follow the guidelines listed below.

- Remove adaptors during cleanup steps.
- Ensure no leftover primers and/or adaptors are present when performing Post-Library Construction QC.
- Store each library individually at **4°C** for up to **72 h** or at **-20°C** for **long-term** storage. **DO NOT** pool libraries during storage.
- Pool libraries prior to sequencing. An additional 1.0X SPRI may be performed for the pooled libraries to remove any free adaptors before sequencing.
- Hopped indices can be computationally removed from the data generated from single cell dual index libraries.

Step 1:

GEM Generation and Barcoding

1.0 Get Started	33
1.1 Prepare Master Mix	34
Assemble GEM-X Chip	35
1.2 Load GEM-X Chip	39
1.3 Run the Chromium X Series Instrument	41
1.4 Transfer GEMs	42
1.5 GEM-RT Incubation	43

1.0 Get Started



Firmware Version v2.0.0 or higher is required for Chromium X/iX and v2.2.0 or higher is required for Chromium Xo instrument.

Item	10x PN	Preparation & Handling	Storage	
Equilibrate to Room Temperature				
<input type="checkbox"/>	GEM-X Single Cell 3' Gel Bead v4	2001128	Equilibrate to room temperature 30 min before loading the chip.	-80°C
<input type="checkbox"/>	● RT Reagent E	2001106	Vortex, verify no precipitate, centrifuge briefly. If a precipitate is observed, warm the tube with hands until the precipitate dissolves. Vortex and centrifuge briefly.	-20°C
<input type="checkbox"/>	● Template Switch Oligo B	2001027	Centrifuge briefly, resuspend in 65 µl Low TE Buffer. Vortex 15 sec at maximum speed, centrifuge briefly. Resuspended solution can be used immediately. After resuspension, store at -80°C . Thaw at room temperature for ≥ 30 minutes in subsequent uses.	-20°C
<input type="checkbox"/>	○ Reducing Agent B	2000087	Vortex, verify no precipitate, centrifuge briefly.	-20°C
Place on Ice				
<input type="checkbox"/>	Labeled Cell Suspension	—	Consult Demonstrated Protocol Cell Surface Protein Labeling for Single Cell RNA Sequencing Protocols with Feature Barcode technology (CG000149)	—
<input type="checkbox"/>	● RT Enzyme E	2001105/ 2001146	Centrifuge briefly before adding to the mix.	-20°C
<input type="checkbox"/>	1X PBS	—		—
Obtain				
<input type="checkbox"/>	Partitioning Oil B	2001213	—	Ambient
<input type="checkbox"/>	GEM-X 3' Chip <i>Verify name and PN</i>	2001097	See Tips & Best Practices.	Ambient
<input type="checkbox"/>	X/iX Chip Gasket	3000656	See Tips & Best Practices.	Ambient
<input type="checkbox"/>	Chromium X/iX or Chromium X Series Chip Holder	3000598	See Tips & Best Practices.	Ambient
<input type="checkbox"/>	10x Vortex Adapter	330002	See Tips & Best Practices.	Ambient
<input type="checkbox"/>	50% glycerol solution <i>If using < 8 reactions</i>	—	See Tips & Best Practices.	—

1.1 Prepare Master Mix

a. Prepare Master Mix on ice. Pipette mix 15x and centrifuge briefly.

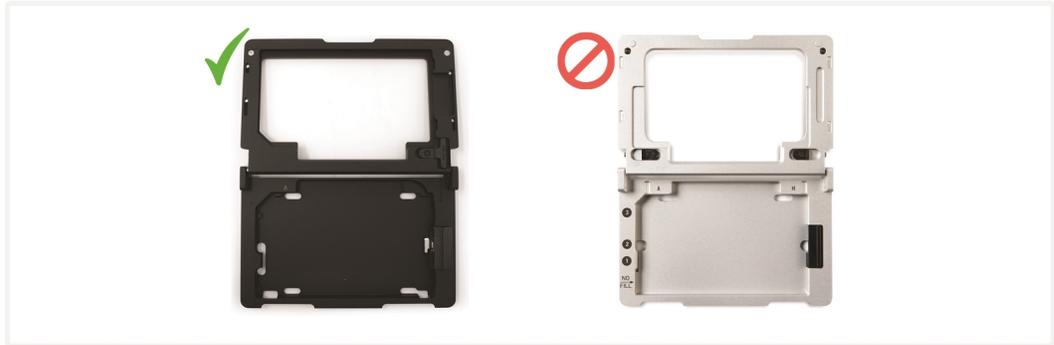
Master Mix		PN	1X (μ l)	4X + 10% (μ l)	8X + 10% (μ l)
	RT Reagent E	2001106	16.3	71.7	143.4
	Template Switch Oligo B	2001027	3.1	13.6	27.3
	Reducing Agent B	2000087	2.0	8.8	17.6
	RT Enzyme E	2001105/2001146	7.0	30.8	61.6
Total		-	28.4	125.0	249.9

b. Add **28.4 μ l** Master Mix into each tube of a PCR 8-tube strip on ice.



Assemble GEM-X Chip

The GEM-X chip is only compatible with Chromium X/iX Chip Holder (also referred to as Chromium X Series Chip Holder; PN-3000598). DO NOT use any other holder.



See [Tips & Best Practices on page 21](#) for chip handling instructions.

- Close the holder lid.
- Attach the gasket by holding the tongue (curved end, to the right) and hook the gasket on the left-hand tabs of the holder. Gently pull the gasket toward the right and hook it on the two right-hand tabs.
- DO NOT touch the smooth side of the gasket.
- Open the chip holder.



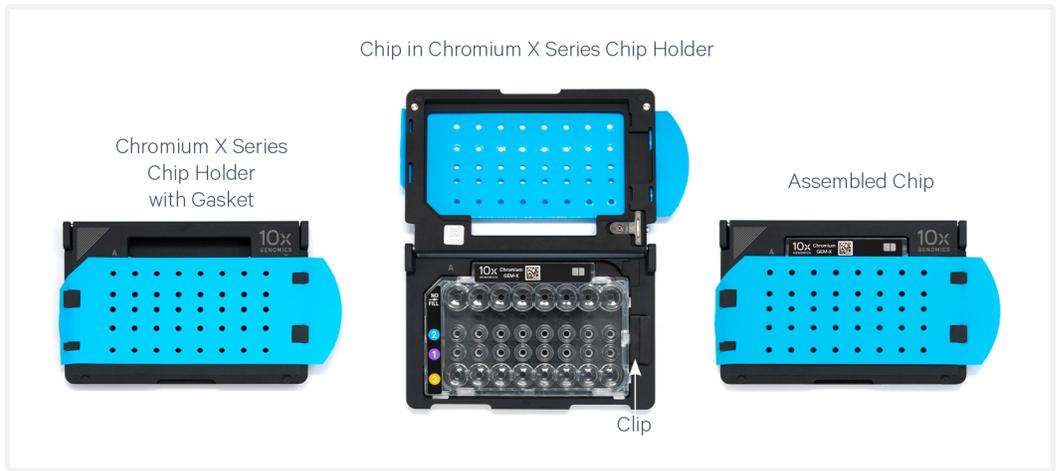
- Remove the chip from the sealed bag. Use the chip within ≤ 24 h.
- Align notch on the chip (upper left corner) and the open holder with the gasket attached.
- Slide the chip to the left until the guide on the holder is inserted into the chip. Depress the right hand side of the chip until the spring-loaded clip engages.

A generic image representative of the GEM-X 3' Chip is shown on the next page.

- Keep the assembled unit with the attached gasket open until ready for and while dispensing reagents into the wells.
- After loading reagents, close the chip holder. DO NOT press down on the top of the gasket.



For GEM generation, load the indicated reagents only in the specified rows, starting from row labeled 1, followed by rows labeled 2 and 3. DO NOT load reagents in the top row labeled NO FILL. See step 1.2 for details.



Cell Suspension Volume Calculator Table

For step 1.2 of this protocol.



DO NOT add PBS directly to single cell suspension. Add PBS to the Master Mix. See step 1.2c.

Cell Recovery Target – 500-10,000

Cell Stock Concentration (Cells/ μ l)	Volume of Cell Suspension Stock per reaction (μ l) Volume of PBS per reaction (μ l)										
	Targeted Cell Recovery										
	500	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
100	7.3	14.5	29.0								
	29.4	22.1	7.6								
200	3.6	7.3	14.5	21.8	29.0	36.3					
	33.0	29.4	22.1	14.9	7.6	0.3					
300	2.4	4.8	9.7	14.5	19.3	24.2	29.0	33.8			
	34.2	31.8	26.9	22.1	17.3	12.4	7.6	2.8			
400	1.8	3.6	7.3	10.9	14.5	18.1	21.8	25.4	29.0	32.6	36.3
	34.8	33.0	29.4	25.7	22.1	18.5	14.9	11.2	7.6	4.0	0.3
500	1.5	2.9	5.8	8.7	11.6	14.5	17.4	20.3	23.2	26.1	29.0
	35.2	33.7	30.8	27.9	25.0	22.1	19.2	16.3	13.4	10.5	7.6
600	1.2	2.4	4.8	7.3	9.7	12.1	14.5	16.9	19.3	21.8	24.2
	35.4	34.2	31.8	29.4	26.9	24.5	22.1	19.7	17.3	14.9	12.4
700	1.0	2.1	4.1	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7
	35.6	34.5	32.5	30.4	28.3	26.2	24.2	22.1	20.0	18.0	15.9
800	0.9	1.8	3.6	5.4	7.3	9.1	10.9	12.7	14.5	16.3	18.1
	35.7	34.8	33.0	31.2	29.4	27.5	25.7	23.9	22.1	20.3	18.5
900	0.8	1.6	3.2	4.8	6.4	8.1	9.7	11.3	12.9	14.5	16.1
	35.8	35.0	33.4	31.8	30.2	28.5	26.9	25.3	23.7	22.1	20.5
1000	0.7	1.5	2.9	4.4	5.8	7.3	8.7	10.2	11.6	13.1	14.5
	35.9	35.2	33.7	32.3	30.8	29.4	27.9	26.5	25.0	23.6	22.1
1100	0.7	1.3	2.6	4.0	5.3	6.6	7.9	9.2	10.5	11.9	13.2
	35.9	35.3	34.0	32.6	31.3	30.0	28.7	27.4	26.1	24.7	23.4
1200	0.6	1.2	2.4	3.6	4.8	6.0	7.3	8.5	9.7	10.9	12.1
	36.0	35.4	34.2	33.0	31.8	30.6	29.4	28.1	26.9	25.7	24.5
1300	0.6	1.1	2.2	3.3	4.5	5.6	6.7	7.8	8.9	10.0	11.2
	36.0	35.5	34.4	33.3	32.1	31.0	29.9	28.8	27.7	26.6	25.4
1400	0.5	1.0	2.1	3.1	4.1	5.2	6.2	7.3	8.3	9.3	10.4
	36.1	35.6	34.5	33.5	32.5	31.4	30.4	29.4	28.3	27.3	26.2
1500	0.5	1.0	1.9	2.9	3.9	4.8	5.8	6.8	7.7	8.7	9.7
	36.1	35.6	34.7	33.7	32.7	31.8	30.8	29.8	28.9	27.9	26.9
1600	0.5	0.9	1.8	2.7	3.6	4.5	5.4	6.3	7.3	8.2	9.1
	36.1	35.7	34.8	33.9	33.0	32.1	31.2	30.3	29.4	28.4	27.5
1700	0.4	0.9	1.7	2.6	3.4	4.3	5.1	6.0	6.8	7.7	8.5
	36.2	35.7	34.9	34.0	33.2	32.3	31.5	30.6	29.8	28.9	28.1
1800	0.4	0.8	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.3	8.1
	36.2	35.8	35.0	34.2	33.4	32.6	31.8	31.0	30.2	29.4	28.5
1900	0.4	0.8	1.5	2.3	3.1	3.8	4.6	5.3	6.1	6.9	7.6
	36.2	35.8	35.1	34.3	33.5	32.8	32.0	31.3	30.5	29.7	29.0
2000	0.4	0.7	1.5	2.2	2.9	3.6	4.4	5.1	5.8	6.5	7.3
	36.2	35.9	35.2	34.4	33.7	33.0	32.3	31.5	30.8	30.1	29.4

Volumes that would exceed the allowable PBS volume in each reaction

Low transfer volume that may result in higher cell load variability

Optimal range of cell stock concentration to maximize the likelihood of achieving the desired cell recovery target (500-10,000 cells)

Cell Recovery Target – 10,000-20,000

Volume of Cell Suspension Stock per reaction (µl) | Volume of PBS per reaction (µl)

Cell Stock Concentration (Cells/µl)	Targeted Cell Recovery										
	10000	11000	12000	13000	14000	15000	16000	17000	18000	19000	20000
100											
200											
300											
400	36.3										
	0.3										
500	29.0	31.9	34.8								
	7.6	4.7	1.8								
600	24.2	26.6	29.0	31.4	33.8	36.3					
	12.4	10.0	7.6	5.2	2.8	0.3					
700	20.7	22.8	24.9	26.9	29.0	31.1	33.1	35.2			
	15.9	13.8	11.7	9.7	7.6	5.5	3.5	1.4			
800	18.1	19.9	21.8	23.6	25.4	27.2	29.0	30.8	32.6	34.4	36.3
	18.5	16.7	14.9	13.0	11.2	9.4	7.6	5.8	4.0	2.2	0.3
900	16.1	17.7	19.3	20.9	22.6	24.2	25.8	27.4	29.0	30.6	32.2
	20.5	18.9	17.3	15.7	14.0	12.4	10.8	9.2	7.6	6.0	4.4
1000	14.5	16.0	17.4	18.9	20.3	21.8	23.2	24.7	26.1	27.6	29.0
	22.1	20.7	19.2	17.8	16.3	14.9	13.4	12.0	10.5	9.1	7.6
1100	13.2	14.5	15.8	17.1	18.5	19.8	21.1	22.4	23.7	25.0	26.4
	23.4	22.1	20.8	19.5	18.1	16.8	15.5	14.2	12.9	11.6	10.2
1200	12.1	13.3	14.5	15.7	16.9	18.1	19.3	20.5	21.8	23.0	24.2
	24.5	23.3	22.1	20.9	19.7	18.5	17.3	16.1	14.9	13.6	12.4
1300	11.2	12.3	13.4	14.5	15.6	16.7	17.8	19.0	20.1	21.2	22.3
	25.4	24.3	23.2	22.1	21.0	19.9	18.8	17.6	16.5	15.4	14.3
1400	10.4	11.4	12.4	13.5	14.5	15.5	16.6	17.6	18.6	19.7	20.7
	26.2	25.2	24.2	23.1	22.1	21.1	20.0	19.0	18.0	16.9	15.9
1500	9.7	10.6	11.6	12.6	13.5	14.5	15.5	16.4	17.4	18.4	19.3
	26.9	26.0	25.0	24.0	23.1	22.1	21.1	20.2	19.2	18.2	17.3
1600	9.1	10.0	10.9	11.8	12.7	13.6	14.5	15.4	16.3	17.2	18.1
	27.5	26.6	25.7	24.8	23.9	23.0	22.1	21.2	20.3	19.4	18.5
1700	8.5	9.4	10.2	11.1	11.9	12.8	13.6	14.5	15.4	16.2	17.1
	28.1	27.2	26.4	25.5	24.7	23.8	23.0	22.1	21.2	20.4	19.5
1800	8.1	8.9	9.7	10.5	11.3	12.1	12.9	13.7	14.5	15.3	16.1
	28.5	27.7	26.9	26.1	25.3	24.5	23.7	22.9	22.1	21.3	20.5
1900	7.6	8.4	9.2	9.9	10.7	11.4	12.2	13.0	13.7	14.5	15.3
	29.0	28.2	27.4	26.7	25.9	25.2	24.4	23.6	22.9	22.1	21.3
2000	7.3	8.0	8.7	9.4	10.2	10.9	11.6	12.3	13.1	13.8	14.5
	29.4	28.6	27.9	27.2	26.5	25.7	25.0	24.3	23.6	22.8	22.1

Volumes that would exceed the allowable PBS volume in each reaction

Optimal range of cell stock concentration to maximize the likelihood of achieving the desired cell recovery target (10,000-20,000 cells)



1.2 Load GEM-X Chip

TIPS

- After removing chip from the sealed bag, use in **≤24 h**.
- Open the lid (gasket attached) of the assembled chip and lay flat for loading.
- Ensure that the Gel Beads are properly thawed and ready to use.
- When loading the chip, raising and depressing the pipette plunger should each take **~5 sec**. When dispensing, raise the pipette tips at the same rate as the liquid is rising, keeping the tips slightly submerged.

Color Legend

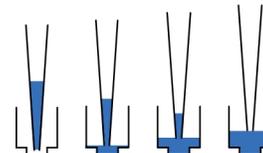
- 2: Gel beads
- 1: Sample
- 3: Oil

The Chromium X/iX (X Series) Chip Holder, Chip Gasket X/iX, and GEM-X chip images shown below are representative and do not show the specific color & label. Chip holder and gasket should be black and blue in color, respectively. Refer to [Assemble GEM-X Chip on page 35](#) for details.

GEM-X 3' Chip, gasket attached
Representative chip image



Pipette technique



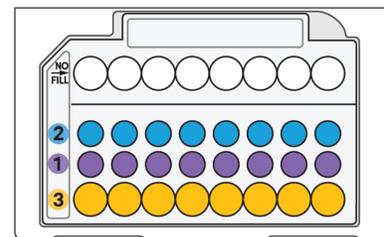
a. If loading less than 8 samples/chip, add 50% glycerol solution to each unused well in row 1, 2, and 3

- **60 µl** in each unused well in row labeled **1**
- **60 µl** in each unused well in row labeled **2**
- **250 µl** in each unused well in row labeled **3**

DO NOT add 50% glycerol solution to the wells in top row labeled NO FILL.

DO NOT use any substitute for 50% glycerol solution.

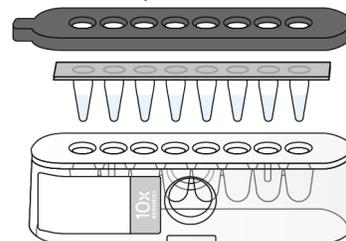
Glycerol
in GEM-X 3' Chip



b. Prepare Gel Beads

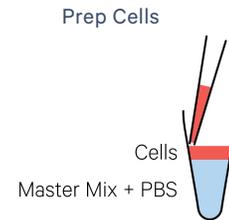
- Snap the tube strip holder with the Gel Bead strip into a 10x Vortex Adapter. Vortex **30 sec**.
- Centrifuge the Gel Bead strip for **~5 sec**.
- Confirm there are no bubbles at the bottom of the tubes & the liquid levels are even.
- Place the Gel Bead strip back in the holder. Secure the holder lid.

Prep Gel Beads

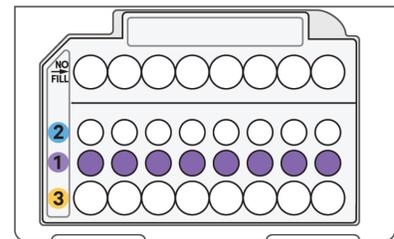


c. Prepare Master Mix + Cell suspension

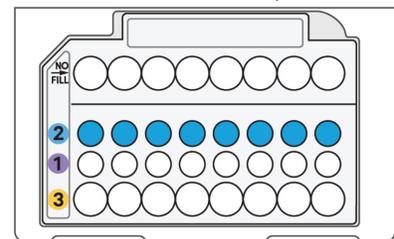
- Refer to the [Cell Suspension Volume Calculator Table](#) on page 37.
- Add the appropriate volume of PBS to Master Mix.
- Add corresponding volume of **single cell suspension** into the Master Mix. *Total of 65 μ l in each tube.* Gently pipette mix the cell suspension before adding to the Master Mix.

**d. Load Row Labeled 1**

- Gently pipette mix the Master Mix + Cell Suspension.
- Using the same pipette tip, dispense **60 μ l** Master Mix + Cell Suspension into the bottom center of each well in **row labeled 1** without introducing bubbles.
- Wait **30 sec.**

60 μ l Master Mix + Cell Suspension
in GEM-X 3' Chip**e. Load Row Labeled 2**

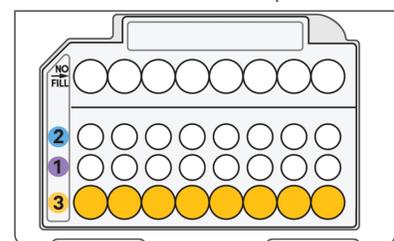
- Puncture the foil seal of the Gel Bead tubes.
- Slowly aspirate **60 μ l** Gel Beads.
- Dispense into the bottom center of each well in **row labeled 2** without introducing bubbles.
- Wait **30 sec.**

60 μ l Gel Beads
in GEM-X 3' Chip**f. Load Row Labeled 3**

- Dispense **250 μ l** Partitioning Oil B into the wells in **row labeled 3** by pipetting two aliquots of **125 μ l** from a reagent reservoir.



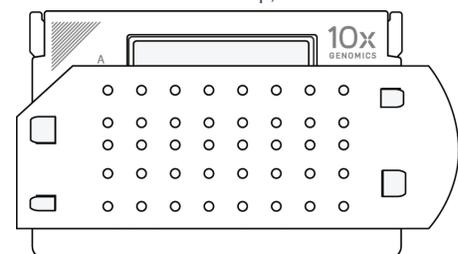
Failure to add Partitioning Oil B to the row labeled 3 will prevent GEM generation and can damage the instrument.

250 μ l Partitioning Oil B
in GEM-X 3' Chip**g. Prepare for Run**

- Close the lid (gasket already attached). DO NOT touch the smooth side of the gasket. DO NOT press down on the top of the gasket. Keep horizontal to avoid wetting the gasket.

*Run the chip in Chromium X series instrument **immediately** after loading the Partitioning Oil B.*

GEM-X 3' Chip, closed

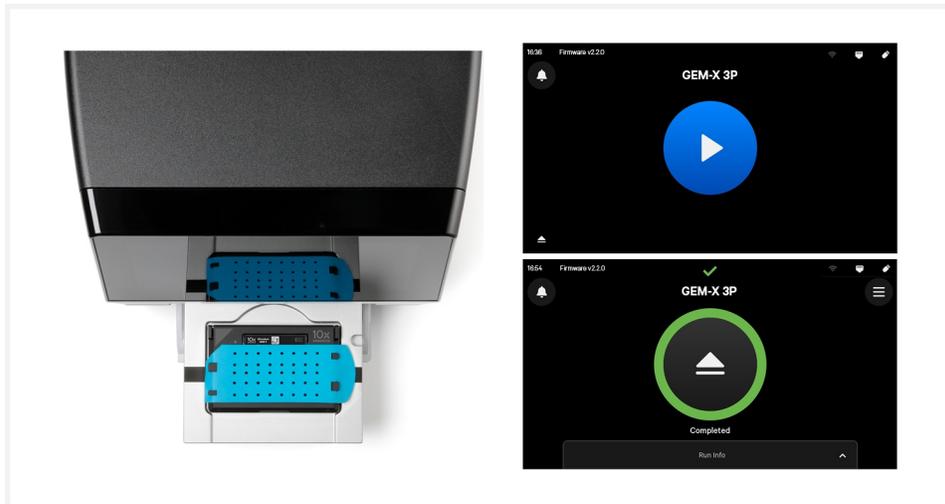


1.3 Run the Chromium X Series Instrument

 *Firmware Version 2.0.0 or higher is required if the Chromium X/iX instrument is used for this protocol.*

Firmware Version 2.2.0 or higher is required if the Chromium Xo instrument is used for this protocol.

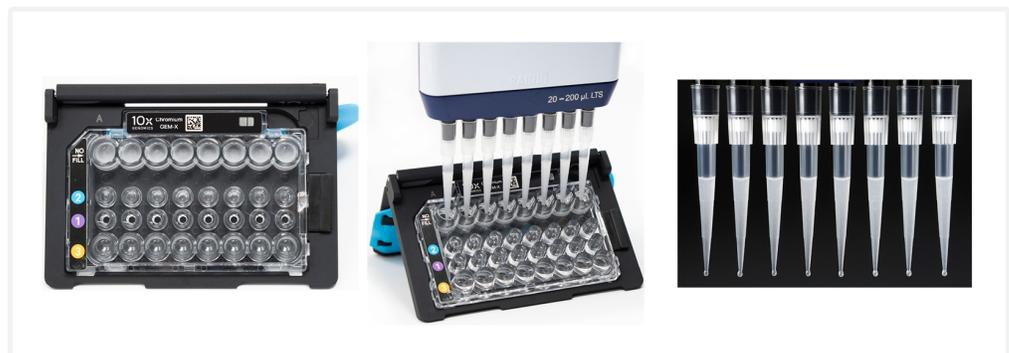
Consult the Chromium X Series Instrument User Guide with Readiness Test (CG000396) for detailed instrument operation instructions and follow the instrument touchscreen prompts for execution.



- a. Press the eject button on the instrument to eject the tray.
If the eject button is not touched within **1 min**, tray will close automatically. System requires a few seconds before the tray can be ejected again.
- b. Place the assembled chip with the gasket in the tray, ensuring that the chip stays horizontal. Press the button to retract the tray.
- c. Confirm GEM-X 3P program on the screen. Press the play button.
-  d. At completion of the run (**~6 min**), the instrument will chime. **Immediately** proceed to the next step.

1.4 Transfer GEMs

- a. Place a tube strip on ice.
- b. Press the eject button of the Chromium X series instrument and remove the chip.
- c. Discard the gasket. Open the chip holder. Fold the lid back until it clicks to expose the wells at 45 degrees.
-  d. Visually compare the remaining volume in rows labeled 1-2. Abnormally high volume in one well relative to other wells may indicate a clog.
- e. Slowly aspirate **100 µl** GEMs from the lowest points of the recovery wells in the top NO FILL row without creating a seal between the tips and the bottom of the wells.
- f. Withdraw pipette tips from the wells. GEMs should appear opaque and uniform across all channels. Excess Partitioning Oil (clear) in the pipette tips indicates a potential clog.
-  g. Over the course of **~20 sec**, dispense GEMs into the tube strip on ice with the pipette tips against the sidewalls of the tubes.
- h. It is recommended to start GEM incubation within **5 min**. If multiple chips are run back-to-back, place the GEMs from the subsequent chips in separate thermal cyclers.



1.5 GEM-RT Incubation

Use a thermal cycler that can accommodate at least 100 μl volume. A volume corresponding to the maximum allowable amount, for a given supported thermal cycler, is the preferred setting. For example a volume of 125 μl is the preferred setting on Bio-Rad C1000 Touch. In alternate thermal cyclers, use highest reaction volume setting.

- a. Incubate in a thermal cycler with the following protocol.

	Lid Temperature	Reaction Volume	Run Time
	48°C	125 μl	~55 min
	Step	Temperature	Time hh:mm:ss
	1	48°C	00:45:00
	2	85°C	00:05:00
	3	4°C	Hold



- b. Store at 4°C for up to 72 h or at -20°C for up to a week, or proceed to the next step.

Step 2:

Post GEM-RT Cleanup & cDNA Amplification

2.0 Get Started	45
2.1 Post GEM-RT Cleanup – Dynabeads	47
2.2 cDNA Amplification	50
Step Overview (steps 2.2 & 2.3)	51
2.3 cDNA Cleanup – SPRIselect	52
2.3A Pellet Cleanup for 3' Gene Expression Library	53
2.3B Transferred Supernatant Cleanup for Cell Surface Protein	54
2.4 Post cDNA Amplification QC & Quantification	55

2.0 Get Started

Item	10x PN	Preparation & Handling	Storage
Equilibrate to Room Temperature			
<input type="checkbox"/> ○	Reducing Agent B 2000087	Thaw, vortex, verify no precipitate, centrifuge briefly.	-20°C
<input type="checkbox"/> ● ⚠	Feature cDNA Primers 2 <i>Verify name & PN</i> 2000097	Thaw, vortex, centrifuge briefly.	-20°C
<input type="checkbox"/>	Dynabeads MyOne SILANE 2000048	Vortex thoroughly (≥30 sec) immediately before adding to the mix. If still clumpy, pipette mix to resuspend completely. DO NOT centrifuge before use.	4°C
<input type="checkbox"/>	Beckman Coulter SPRIselect Reagent —	Manufacturer's recommendations.	—
<input type="checkbox"/>	Agilent Bioanalyzer High Sensitivity Kit <i>If used for QC & quantification</i> —	Manufacturer's recommendations.	—
<input type="checkbox"/>	DNA High Sensitivity Reagent Kit <i>If LabChip used for QC & quantification</i> —	Manufacturer's recommendations.	—
<input type="checkbox"/>	Agilent TapeStation ScreenTape & Reagents <i>If used for QC & quantification</i> —	Manufacturer's recommendations.	—
Place on Ice			
<input type="checkbox"/> ○ ⚠	Amp Mix <i>DO NOT use the Library Amp Mix PN-2000531 (if provided) at this step to avoid a significant decrease in assay performance</i> 2000047 /2000103	Vortex, centrifuge briefly.	-20°C
Thaw at 65°C			
<input type="checkbox"/> ●	Cleanup Buffer 2000088	Thaw for 10 min at 65°C at max speed on a thermomixer. Verify no visible crystals. Cool to room temperature.	-20°C
Obtain			
<input type="checkbox"/> ○	Recovery Agent 220016	—	Ambient
<input type="checkbox"/>	10x Magnetic Separator B 2001212	—	Ambient
<input type="checkbox"/>	Qiagen Buffer EB —	Manufacturer's recommendations.	—

Item		10x PN	Preparation & Handling	Storage
<input type="checkbox"/>	Bio-Rad 10% Tween 20	—	Manufacturer's recommendations.	—
<input type="checkbox"/>	Prepare 80% Ethanol <i>Prepare 15 ml for 8 reactions.</i>	—	Prepare fresh.	Ambient

2.1 Post GEM-RT Cleanup – Dynabeads

- a. Add **125 μ l** Recovery Agent to each sample (Post GEM-RT) at room temperature. *If using sample stored at -20°C , equilibrate to room temperature before adding the Recovery Agent.* DO NOT pipette mix or vortex the biphasic mixture. Wait **2 min.**

The resulting biphasic mixture contains Recovery Agent/Partitioning Oil (pink) and aqueous phase (clear), with no persisting emulsion (opaque).

If biphasic separation is incomplete:

- Firmly secure the cap on the tube strip, ensuring that no liquid is trapped between the cap and the tube rim.
- Mix by inverting the capped tube strip 5x, centrifuge briefly, and proceed to step b. DO NOT invert without firmly securing the caps.



A smaller aqueous phase volume indicates a clog during GEM generation.

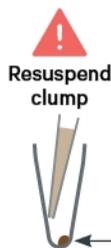


- b. Slowly remove and discard **125 μ l** Recovery Agent/Partitioning Oil (pink) from the bottom of the tube. DO NOT aspirate any aqueous sample.



- c. Prepare Dynabeads Cleanup Mix.

Before using Dynabeads MyOne SILANE to prepare the Dynabeads Cleanup Mix:



Vortex the Dynabeads thoroughly (≥ 30 sec) **immediately** before adding to the mix.

- Aspirate full liquid volume in the Dynabead tube with a pipette tip to verify that beads have not settled in the bottom of the tube. If clumps are present, pipette mix to resuspend completely. DO NOT centrifuge before adding to the mix.

Dynabeads Cleanup Mix <i>Add reagents in the order listed</i>		PN	1X (μ l)	4X + 10% (μ l)	8X + 10% (μ l)
●	Cleanup Buffer	2000088	182	801	1602
	Dynabeads MyOne SILANE	2000048	8	35	70
○	Reducing Agent B	2000087	5	22	44
	Nuclease-free Water	—	5	22	44
Total			200	880	1760

- d. Vortex and add **200 μ l** to each tube. Pipette mix 10x (pipette set to 200 μ l). Before adding ensure that there are no clumps.



- e. Incubate **10 min** at **room temperature** (keep caps open). Pipette mix again at ~5 min after start of incubation to resuspend settled beads.
- f. Prepare Elution Solution I. Vortex and centrifuge briefly.

Elution Solution I <i>Add reagents in the order listed</i>		PN	1X (μ l)	10X (μ l)
	Buffer EB	—	98	980
	10% Tween 20	—	1	10
○	Reducing Agent B	2000087	1	10
Total			100	1000



- g. At the end of **10 min** incubation, place on a 10x Magnetic Separator•**High** position (magnet•**High**) until the solution clears.
A white interface between the aqueous phase and Recovery Agent is normal.
- h. Remove the supernatant.
- i. Add **300 μ l** 80% ethanol to the pellet while on the magnet. Wait **30 sec**.
- j. Remove the ethanol.
- k. Add **200 μ l** 80% ethanol to pellet. Wait **30 sec**.
- l. Remove the ethanol.

- m.** Centrifuge briefly. Place on the 10x Magnetic Separator **Low** position (magnet **Low**).
- n.** Remove remaining ethanol. Air dry for **1 min**.
- o.** Remove from the magnet. Immediately add **35.5 µl** Elution Solution I.
- p.** Pipette mix (pipette set to 30 µl) without introducing bubbles. Pipette mix 15x. If beads still appear clumpy, continue pipette mixing until fully resuspended.
- q.** Incubate **1 min** at **room temperature**.
- r.** Place on the magnet **Low** until the solution clears.
- s.** Transfer **35 µl** sample to a new tube strip.

2.2 cDNA Amplification

- a. Prepare cDNA Amplification Mix on ice. Vortex and centrifuge briefly.

cDNA Amplification Mix		PN	1X (μ l)	4X + 10% (μ l)	8X + 10% (μ l)
Add reagents in the order listed					
	Amp Mix DO NOT use the Library Amp Mix PN-2000531 (if provided)	2000047/ 2000103	50	220	440
	Feature cDNA Primers 2 Verify name & PN	2000097	15	66	132
					
Total			65	286	572

- b. Add **65 μ l** cDNA Amplification Reaction Mix to **35 μ l** sample (Post-GEM-RT Cleanup, step 2.1s).

- c. Pipette mix 15x (pipette set to 90 μ l). Centrifuge briefly.

- d. Incubate in a thermal cycler with the following protocol.



Lid Temperature	Reaction Volume	Run Time
105°C	100 μ l	~25-50 min
Step	Temperature	Time hh:mm:ss
1	98°C	00:00:45
2	98°C	00:00:20
3	63°C	00:00:30
4	72°C	00:01:00
5	Go to Step 2, see table below for total # of cycles	
6	72°C	00:01:00
7	4°C	Hold



Recommended starting point for cycle number optimization. The optimal cycle number is a trade-off between generating sufficient final mass for libraries & minimizing PCR amplification artifacts.

Targeted Cell Recovery	Total Cycles
<500	13
501-6,000	12
>6,000	11



- e. Store at **4°C** for up to **72 h** or **-20°C** for **≤1 week**, or proceed to the next step.

Step Overview (steps 2.2 & 2.3)

Amplification Products Generated in Step 2.2 – cDNA Amplification

Post GEM-RT Cleanup Products

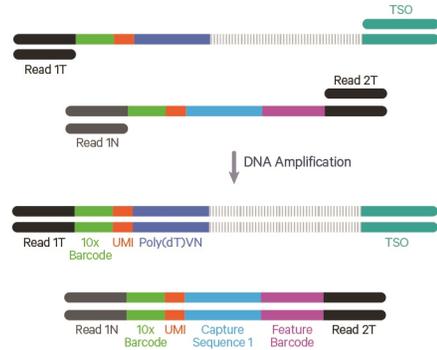
+

Feature cDNA Primers 2
PN-2000097

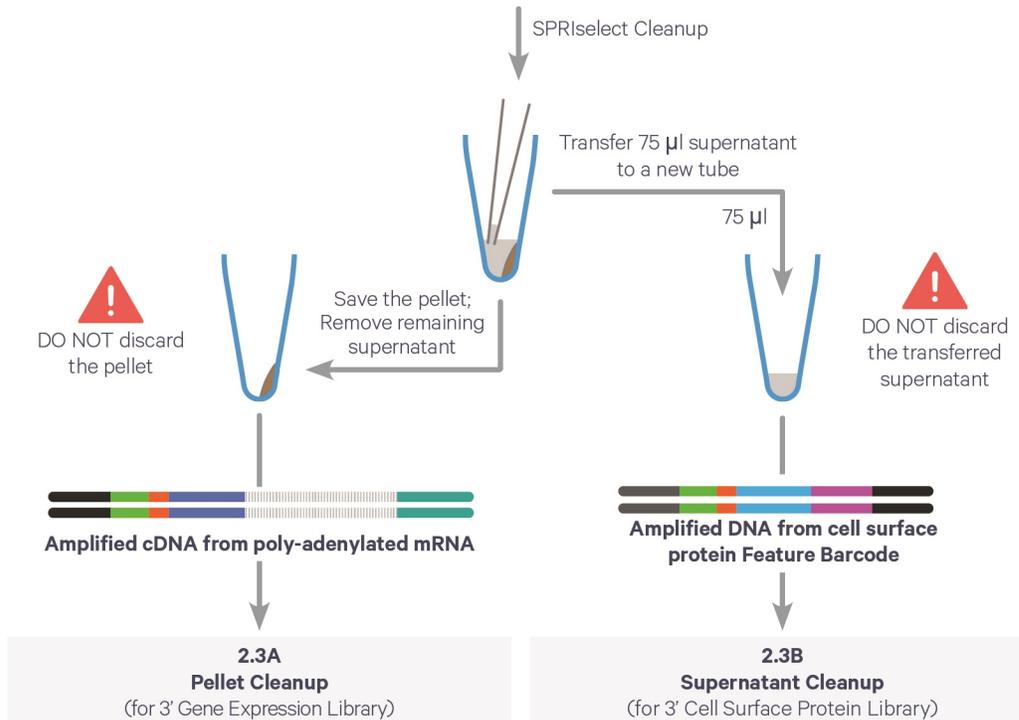
Amplification Products

cDNA from poly-adenylated mRNA

DNA from cell surface protein Feature Barcode



Step 2.3 – cDNA Cleanup – SPRIselect Overview



2.3 cDNA Cleanup – SPRIselect

- a. Vortex to resuspend the SPRIselect reagent. Add **60 µl** SPRIselect reagent (**0.6X**) to each sample and pipette mix 15x (pipette set to 150 µl).
- b. Incubate **5 min** at **room temperature**.
- c. Place on the magnet **High** until the solution clears.
-  d. Transfer and save **75 µl** supernatant in a new tube strip without disturbing the pellet. Maintain at **room temperature**. DO NOT discard the transferred supernatant (cleanup for Cell Surface Protein library construction step 2.3B).
- e. Remove the remaining supernatant from the pellet without disturbing the pellet. DO NOT discard the pellet (cleanup for 3' Gene Expression library construction). **Immediately** proceed to Pellet Cleanup (step 2.3A).

2.3A Pellet Cleanup for 3' Gene Expression Library

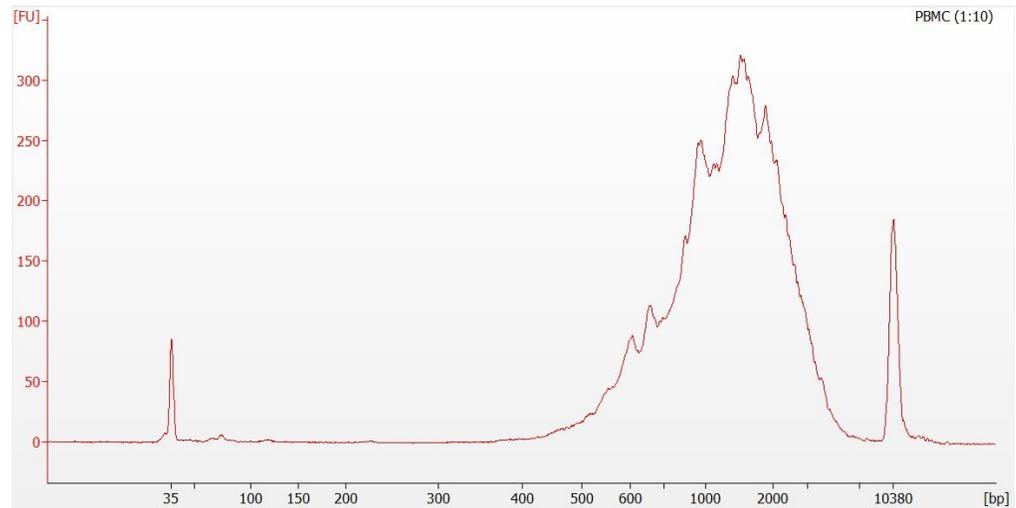
- a. Add **200 μ l** 80% ethanol to the pellet while still on the magnet•**High**. Wait **30 sec**.
- b. Remove the ethanol.
- c. **Repeat** steps a and b for a total of 2 washes.
- d. Centrifuge briefly and place on the magnet•**Low**.
- e. Remove any remaining ethanol. Air dry for **2 min**. DO NOT exceed **2 min** as this will decrease elution efficiency.
- f. Remove from the magnet. Add **40.5 μ l** Buffer EB. Pipette mix 15x.
- g. Incubate **2 min** at **room temperature**.
- h. Place the tube strip on the magnet•**High** until the solution clears.
- i. Transfer **40 μ l** sample to a new tube strip.
-  j. Store at **4°C** for up to **72 h** or at **-20°C** for up to **4 weeks**, or proceed to step 2.4 followed by step 3 for 3' Gene Expression Library Construction.

2.3B Transferred Supernatant Cleanup for Cell Surface Protein

- a. Vortex to resuspend the SPRIselect reagent. Add **70 μ l** SPRIselect reagent (**2.0X**) to 75 μ l of the transferred supernatant and pipette mix 15x (pipette set to 140 μ l).
- b. Incubate for **5 min** at **room temperature**.
- c. Place on the magnet•**High** until the solution clears.
- d. Remove supernatant.
- e. Add **200 μ l** 80% ethanol to the pellet. Wait **30 sec**.
- f. Remove the ethanol.
- g. **Repeat** steps e and f for a total of 2 washes.
- h. Centrifuge briefly and place on the magnet•**Low**.
- i. Remove any remaining ethanol. Air dry for **2 min**. DO NOT exceed **2 min** as this will decrease elution efficiency.
- j. Remove from the magnet. Add **40.5 μ l** Buffer EB. Pipette mix 15x.
- k. Incubate **2 min** at **room temperature**.
- l. Place the tube strip on the magnet•**High** until the solution clears.
- m. Transfer **40 μ l** sample to a new tube strip.
-  n. Store at **4°C** for up to **72 h** or at **-20°C** for up to **4 weeks**, or proceed directly to step 4 for Cell Surface Protein Library Construction.

2.4 Post cDNA Amplification QC & Quantification

- a. Run 1 μl (see dilutions below) product from step 2.3A on an Agilent Bioanalyzer High Sensitivity chip.
 - Low RNA content cells (<1 pg total RNA/cell) should be run undiluted
 - High RNA content cells should be run at 1:5 or 1:10 dilutionDO NOT run sample from 2.3B Transferred Supernatant Cleanup step.



- b. See example calculation in the following page.

Alternate Quantification Methods

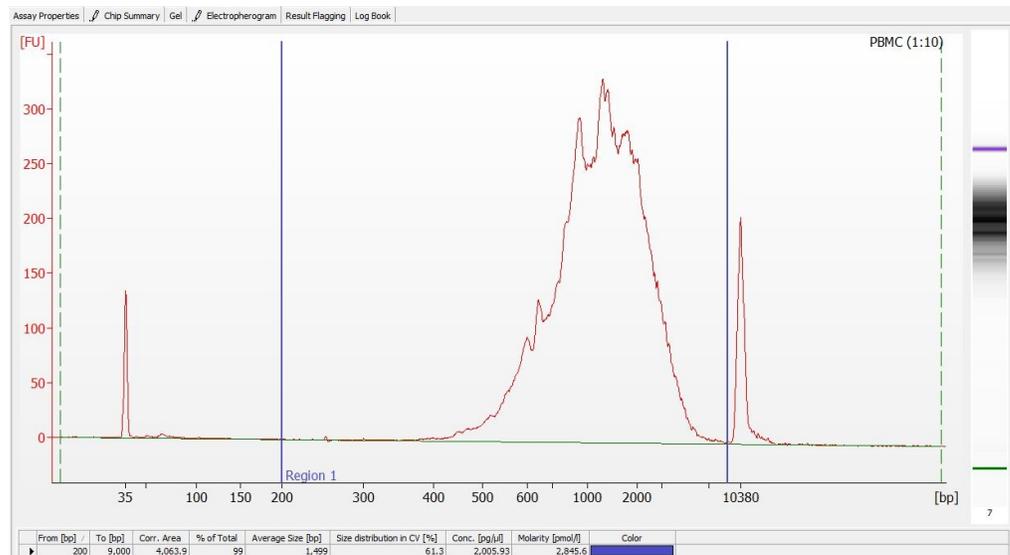
Agilent TapeStation

LabChip

See [Appendix on page 86](#) for representative traces.

Example Calculation

- i. Select Region: Under the “Electropherogram” view, choose the “Region Table.” Manually select the region of ~200 – ~9000 bp.
- ii. Note Concentration [pg/ μl]



- iii. Calculate: Multiply the diluted sample concentration [pg/μl] reported via Agilent 2100 Expert Software by the dilution factor and divide by 1000 to obtain the total cDNA yield in ng/μl.

Carry forward ONLY 25% of total cDNA yield into Gene Expression Library Construction.

Example Calculation of cDNA Yield

Concentration: **2005.93 pg/μl** Elution volume: 40 μl; Dilution Factor: 10

Total Yield

$$\begin{aligned}
 &= \frac{\text{Conc'n (pg/}\mu\text{l)} \times \text{Elution Vol. (}\mu\text{l)} \times \text{Dilution Factor}}{1000 \text{ (pg/ng)}} \\
 &= \frac{2005.93 \times 40 \times 10}{1000 \text{ (pg/ng)}} \\
 &= 802.37 \text{ ng}
 \end{aligned}$$

Carrying Forward ONLY 25% of total cDNA yield for GEX Library

$$= \text{Total cDNA} \times 0.25 = 802.37 \text{ ng} \times 0.25 = \mathbf{200.59 \text{ ng}}$$

Refer to step 3.5 for appropriate number of Sample Index PCR cycles based on carry forward cDNA product yield.

Step 3:

3' Gene Expression Library Construction

3.0 Get Started	58
Step Overview (Step 3.1d)	59
3.1 GEX Fragmentation, End Repair & A-tailing	60
3.2 GEX Post Fragmentation, End Repair & A-tailing Double Sided – SPRIselect	62
3.3 GEX Adaptor Ligation	63
3.4 GEX Post Ligation Cleanup – SPRIselect	64
3.5 GEX Sample Index PCR	65
3.6 Post Sample Index PCR Double Sided Size Selection – SPRIselect	66
3.7 Post Library Construction QC	67

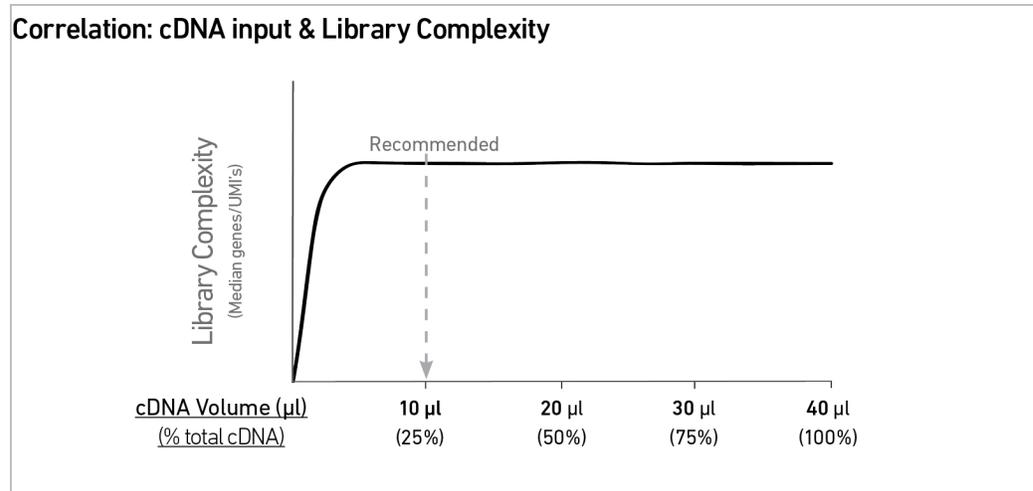
3.0 Get Started

Item	10x PN	Preparation & Handling	Storage
Equilibrate to Room Temperature			
<input type="checkbox"/> 	Fragmentation Buffer 2000091	Thaw, vortex, verify no precipitate, centrifuge.	-20°C
<input type="checkbox"/> 	Ligation Mix 2001109	Thaw, vortex, verify no precipitate, centrifuge.	-20°C
<input type="checkbox"/> 	Dual Index Plate TT Set A <i>Verify name & PN. Use indicated plate only</i>	—	-20°C
<input type="checkbox"/>	Beckman Coulter SPRIselect Reagent —	Manufacturer's recommendations.	—
<input type="checkbox"/>	Agilent Bioanalyzer High Sensitivity Kit <i>If used for QC</i>	Manufacturer's recommendations.	—
<input type="checkbox"/>	DNA High Sensitivity Reagent Kit <i>If LabChip used for QC</i>	Manufacturer's recommendations.	—
<input type="checkbox"/>	Agilent TapeStation ScreenTape & Reagents <i>If used for QC</i>	Manufacturer's recommendations.	—
Place on Ice			
<input type="checkbox"/> 	Fragmentation Enzyme <i>Ensure that Fragmentation Buffer and Fragmentation Enzyme from the same kit are used together. Lots are matched for optimal performance</i>	2000090 /2000104	Centrifuge briefly. -20°C
<input type="checkbox"/> 	DNA Ligase 220110/220131	Centrifuge briefly.	-20°C
<input type="checkbox"/> 	Library Amp Mix or Amp Mix 2000531 or 2000047/2000103	Vortex, centrifuge briefly.	-20°C
<input type="checkbox"/>	KAPA Library Quantification Kit for Illumina Platforms —	Manufacturer's recommendations.	—
Obtain			
<input type="checkbox"/>	10x Magnetic Separator B 2001212	See Tips & Best Practices.	Ambient
<input type="checkbox"/>	Qiagen Buffer EB —	Manufacturer's recommendations.	Ambient
<input type="checkbox"/>	Prepare 80% Ethanol <i>Prepare 15 ml for 8 reactions.</i>	Prepare fresh.	Ambient

Step Overview (Step 3.1d)

Correlation between input & library complexity

A Single Cell Gene Expression library is generated using a fixed proportion (10 μ l, 25%) of the total cDNA (40 μ l) obtained at step 2.3A. The complexity of this library will be comparable to one generated using a higher proportion (>25%) of the cDNA. The remaining proportion (30 μ l, 75%) of the cDNA may be stored at 4°C for up to 72 h or at -20°C for long-term storage (up to 4 weeks).



Note that irrespective of the total cDNA yield (ng), which may vary based on cell type, targeted cell recovery etc., this protocol has been optimized for a broad range of input mass (ng), as shown in the example below. The total number of SI PCR cycles (step 3.5d) should be optimized based on carrying forward a fixed proportion (10 μ l, 25%) of the total cDNA yield calculated during Post cDNA Amplification QC & Quantification (step 2.4).

Example: Library Construction Input Mass & SI PCR Cycles

Cell	Targeted Cell Recovery	Total cDNA Yield (ng)	cDNA Input into Fragmentation		SI PCR Cycle Number
			Volume (μ l)	Mass (ng)	
High RNA Content	Low 	500 ng	10 μ l	125 ng	13
	High 	3800 ng	10 μ l	950 ng	10

Example: Library Construction Input Mass & SI PCR Cycles (continued)

Cell	Targeted Cell Recovery	Total cDNA Yield (ng)	cDNA Input into Fragmentation		SI PCR Cycle Number
			Volume (μl)	Mass (ng)	
Low RNA Content	Low 	2 ng	10 μl	0.5 ng	16
	High 	400 ng	10 μl	100 ng	12

3.1 GEX Fragmentation, End Repair & A-tailing

- a. Prepare a thermal cycler with the following incubation protocol.

Lid Temperature	Reaction Volume	Run Time
65°C	50 μl	~35 min
Step	Temperature	Time hh:mm:ss
 Pre-cool block <i>Pre-cool block prior to preparing the Fragmentation Mix</i>	4°C	Hold
Fragmentation	32°C	00:05:00
End Repair & A-Tailing	65°C	00:30:00
Hold	4°C	Hold

- b. Vortex Fragmentation Buffer. Verify there is no precipitate.
- c. Prepare Fragmentation Mix on ice. Add reagents in the order listed. Pipette mix and centrifuge briefly.

Fragmentation Mix <i>Add reagents in the order listed</i>	PN	1X (μl)	4X + 10% (μl)	8X + 10% (μl)
Buffer EB	-	25	110	220
 Fragmentation Buffer	2000091	5	22	44
 Fragmentation Enzyme	2000090/ 2000104	10	44	88
Total		40	176	352

- d. Transfer **ONLY 10 μl** purified cDNA sample from Cleanup (step 2.3A) to a tube strip. Note that only 10 μl (25%) cDNA sample is sufficient for generating Gene Expression library. The remaining cDNA sample can be

stored at **4°C** for up to **72 h** or at **-20°C** for up to **4 weeks** for generating additional Gene Expression libraries.

- e.** Add **40 µl** Fragmentation Mix to each **10 µl** sample.
- f.** Pipette mix 15x (pipette set to 30 µl) on ice. Centrifuge briefly.
- g.** Transfer into the pre-cooled thermal cycler (**4°C**) and press “SKIP” to initiate the protocol.

3.2 GEX Post Fragmentation, End Repair & A-tailing Double Sided – SPRIselect

- a. Vortex to resuspend SPRIselect reagent. Add **30 µl** SPRIselect reagent(**0.6X**) to each sample. Pipette mix 15x (pipette set to 75 µl).
- b. Incubate **5 min** at **room temperature**.
- c. Place on the magnet•**High** until the solution clears. DO NOT discard supernatant.
- d. Transfer **75 µl** supernatant to a new tube strip.
- e. Vortex to resuspend SPRIselect reagent. Add **10 µl** SPRIselect reagent (**0.8X**) to each sample. Pipette mix 15x (pipette set to 80 µl).
- f. Incubate **5 min** at **room temperature**.
- g. Place on the magnet•**High** until the solution clears.
- h. Remove **80 µl** supernatant. DO NOT discard any beads.
- i. With the tube strip still on the magnet, add **125 µl** 80% ethanol to the pellet. Wait **30 sec**.
- j. Remove the ethanol.
- k. **Repeat** steps i and j for a total of 2 washes.
- l. Centrifuge briefly. Place on the magnet•**Low** until the solution clears.
- m. Remove remaining ethanol. DO NOT over dry to ensure maximum elution efficiency.
- n. Remove from the magnet. Add **50.5 µl** Buffer EB to each sample. Pipette mix 15x (pipette set to 45 µl).
- o. Incubate **2 min** at **room temperature**.
- p. Place on the magnet•**High** until the solution clears.
- q. Transfer **50 µl** sample to a new tube strip.

3.3 GEX Adaptor Ligation

- a. Prepare Adaptor Ligation Mix. Pipette mix and centrifuge briefly.

Adaptor Ligation Mix <i>Add reagents in the order listed</i>	PN	1X (μ l)	4X + 10% (μ l)	8X + 10% (μ l)
● Ligation Mix	2001109	40	176	352
● DNA Ligase	220110/220131	10	44	88
Total		50	220	440

- b. Add **50 μ l** Adaptor Ligation Mix to **50 μ l** sample. Pipette mix 15x (pipette set to 90 μ l). Centrifuge briefly.
- c. Incubate in a thermal cycler with the following protocol.

Lid Temperature	Reaction Volume	Run Time
30°C	100 μ l	15 min
(lid may be turned off if the instrument does not enable 30°C)		
Step	Temperature	Time hh:mm:ss
1	20°C	00:15:00
2	4°C	Hold

3.4 GEX Post Ligation Cleanup – SPRIselect

- a. Vortex to resuspend SPRIselect Reagent. Add **80 µl** SPRIselect Reagent (**0.8X**) to each sample. Pipette mix 15x (pipette set to 150 µl).
- b. Incubate **5 min** at **room temperature**.
- c. Place on the magnet•**High** until the solution clears.
- d. Remove the supernatant.
- e. Add **200 µl** 80% ethanol to the pellet. Wait **30 sec**.
- f. Remove the ethanol.
- g. **Repeat** steps e and f for a total of 2 washes.
- h. Centrifuge briefly. Place on the magnet•**Low**.
- i. Remove any remaining ethanol. Air dry for **2 min**. DO NOT exceed 2 min as this will decrease elution efficiency.
- j. Remove from the magnet. Add **30.5 µl** Buffer EB. Pipette mix 15x.
- k. Incubate **2 min** at **room temperature**.
- l. Place on the magnet•**Low** until the solution clears.
- m. Transfer **30 µl** sample to a new tube strip.

3.5 GEX Sample Index PCR



- a. Choose the appropriate sample index sets to ensure that no sample indices overlap in a multiplexed sequencing run. Record the 10x sample index name (PN-3000431 Dual Index Plate TT Set A well ID) used.
- b. Add **50 µl** Library Amp Mix (PN-2000531) or Amp Mix (PN-2000047/2000103) to **30 µl** sample.
- c. Add **20 µl** of an individual Dual Index TT Set A to each sample and record the well ID used. Pipette mix 5x (pipette set to 90 µl). Centrifuge briefly.
- d. Incubate in a thermal cycler with the following protocol.

Lid Temperature	Reaction Volume	Run Time
105°C	100 µl	~30 min
Step	Temperature	Time hh:mm:ss
1	98°C	00:00:45
2	98°C	00:00:20
3	54°C	00:00:30
4	72°C	00:00:20
5	Go to step 2, see below for # of cycles	
6	72°C	00:01:00
7	4°C	Hold



The table recommends a starting point for optimization. The total cycles should be optimized based on 25% carry forward cDNA yield/input calculated during cDNA QC & Quantification (step 2.4).

Recommended Cycle Numbers

cDNA Input	Total Cycles
0.25-50 ng	14-16
50-250 ng	12-14
250-600 ng	10-12
600-1,100 ng	8-10
1,100-1,500 ng	6-8
>1,500 ng	5



- e. Store at **4°C** for up to **72 h** or proceed to the next step.

3.6 Post Sample Index PCR Double Sided Size Selection – SPRIselect

- a. Vortex to resuspend the SPRIselect reagent. Add **60 µl** SPRIselect Reagent (**0.6X**) to each sample. Pipette mix 15x (pipette set to 150 µl).
- b. Incubate **5 min** at **room temperature**.
- c. Place the magnet **High** until the solution clears. DO NOT discard supernatant.
- d. Transfer **150 µl** supernatant to a new tube strip.
- e. Vortex to resuspend the SPRIselect reagent. Add **20 µl** SPRIselect Reagent (**0.8X**) to each transferred supernatant. Pipette mix 15x (pipette set to 150 µl).
- f. Incubate **5 min** at **room temperature**.
- g. Place the magnet **High** until the solution clears.
- h. Remove **165 µl** supernatant. DO NOT discard any beads.
- i. With the tube still in the magnet, add **200 µl** 80% ethanol to the pellet. Wait **30 sec**.
- j. Remove the ethanol.
- k. **Repeat** steps i and j for a total of 2 washes.
- l. Centrifuge briefly. Place on the magnet **Low**.
- m. Remove remaining ethanol. DO NOT over dry beads to ensure maximum elution efficiency.
- n. Remove from the magnet. Add **35.5 µl** Buffer EB. Pipette mix 15x (pipette set to 35 µl).
- o. Incubate **2 min** at **room temperature**.
- p. Place on the magnet **Low** until the solution clears.
- q. Transfer **35 µl** to a new tube strip.
- r. Store at **4°C** for up to **72 h** or at **-20°C** for **long-term** storage.



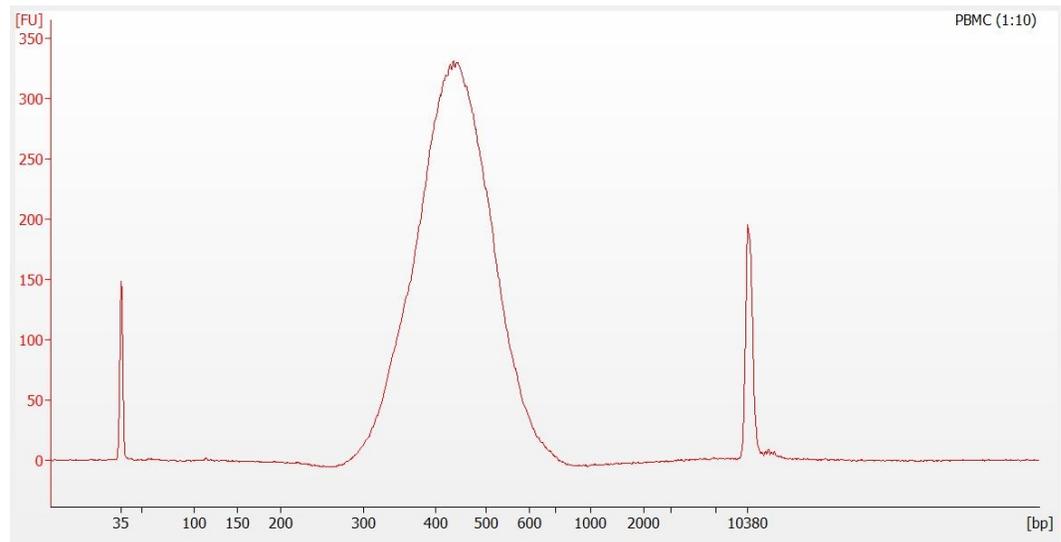
3.7 Post Library Construction QC

Library QC

Use Agilent Bioanalyzer, Perkin Elmer LabChip, or Agilent Tapestation for QC.

- a. Run **1 µl** sample at **1:10** dilution on an Agilent Bioanalyzer High Sensitivity chip.
- a. Select the region between 200-2,000 bp to determine average size of the library. This will be used as the insert size for library quantification.

Representative Trace



If additional peaks below 200 bp are observed, repeat step 3.6 Post Sample Index PCR Double Sided Size Selection - SPRIselect. Add nuclease-free water to bring the library volume to 100 µl before performing step 3.6a. Note that ~40% of material may be lost when repeating step 3.6. Alternatively, libraries that will be sequenced together can first be pooled and then used as input into step 3.6.

See [Appendix on page 86](#) for representative traces

Quantification

Library quantification should be performed prior to sequencing. For the most accurate quantitative assessment of libraries, a qPCR-based method should be used to ensure that the sequencing flowcell is loaded properly.

See [Post Library Construction Quantification using KAPA qPCR on page 88](#)

Step 4:

Cell Surface Protein Library Construction

4.0 Get Started	69
4.1 Sample Index PCR	70
4.2 Post Sample Index PCR Size Selection – SPRIselect	72
4.3 Post Library Construction QC	73

4.0 Get Started

Item	10x PN	Preparation & Handling	Storage	
Equilibrate to Room Temperature				
<input type="checkbox"/>	 Dual Index Plate NT Set A <i>Verify name & PN. Use indicated plate only</i>	3000483	—	—20°C
<input type="checkbox"/>	Beckman Coulter SPRIselect Reagent	—	Manufacturer's recommendations.	—
<input type="checkbox"/>	Agilent Bioanalyzer High Sensitivity Kit <i>If used for QC</i>	—	Manufacturer's recommendations.	—
<input type="checkbox"/>	DNA High Sensitivity Reagent Kit <i>If LabChip used for QC</i>	—	Manufacturer's recommendations.	—
<input type="checkbox"/>	Agilent TapeStation ScreenTape & Reagents <i>If used for QC</i>	—	Manufacturer's recommendations.	—
Place on Ice				
<input type="checkbox"/>	 Amp Mix <i>Retrieve from Chromium GEM-X Single Cell 3' Feature Barcode Kit</i>	2000047	Centrifuge briefly.	—20°C
<input type="checkbox"/>	KAPA Library Quantification Kit for Illumina Platforms	—	Manufacturer's recommendations.	—
Obtain				
<input type="checkbox"/>	10x Magnetic Separator B	2001212	See Tips & Best Practices.	Ambient
<input type="checkbox"/>	Qiagen Buffer EB	—	Manufacturer's recommendations.	Ambient
<input type="checkbox"/>	Prepare 80% Ethanol <i>Prepare 20 ml for 8 reactions.</i>	—	Prepare fresh.	Ambient

4.1 Sample Index PCR



a. Choose the appropriate sample index sets to ensure that no sample indices overlap in a multiplexed sequencing run. Record the 10x sample index name (PN-3000483 Dual Index Plate NT Set A well ID) used.

b. Prepare Sample Index PCR Mix. Add reagents in the order listed.

Sample Index PCR Mix	PN	1X (μ l)	4X + 10% (μ l)	8X + 10% (μ l)
○ Amp Mix <i>Retrieve from Chromium GEM-X Single Cell 3' Feature Barcode Kit</i>	2000047	50	220	440
Buffer EB	—	25	110	220
Total		75	330	660

c. Transfer **ONLY 5 μ l** from the Transferred Supernatant Cleanup (step 2.3B) to a new tube strip.

- Note that only **5 μ l** sample transfer is sufficient for generating Cell Surface Protein library.
- The remaining sample can be stored at **4°C** for up to **72 h** or at **-20°C** for up to **4 weeks**, for generating additional libraries.

d. Add **75 μ l** Sample Index PCR Mix to **5 μ l** Transferred Supernatant Cleanup sample.

e. Add **20 μ l** of an individual Dual Index NT Set A to each sample and record the well ID used. Pipette mix 5x (pipette set to 90 μ l). Centrifuge briefly.

f. Incubate in a thermal cycler with the following protocol.

Lid Temperature	Reaction Volume	Run Time
105°C	100 µl	~35 min
Step	Temperature	Time hh:mm:ss
1	98°C	00:00:45
2	98°C	00:00:20
3	54°C	00:00:30
4	72°C	00:00:20
5	Go to step 2, repeat 9X for a total of 10 cycles*	
6	72°C	00:01:00
7	4°C	Hold

**Optimization of cycle number may be needed based on target protein expression levels and number of antibodies used for labeling.*

4.2 Post Sample Index PCR Size Selection – SPRIselect

- a. Vortex to resuspend the SPRIselect reagent. Add **120 µl** SPRIselect Reagent (**1.2X**) to each sample. Pipette mix 15x (pipette set to 150 µl).
- b. Incubate **5 min** at **room temperature**.
- c. Place on the magnet•**High** until the solution clears. Remove the supernatant.
- d. Add **300 µl** 80% ethanol to the pellet. Wait 30 sec.
- e. Remove the ethanol.
- f. Add **200 µl** 80% ethanol to the pellet. Wait **30 sec**.
- g. Remove the ethanol.
- h. Centrifuge briefly. Place on the magnet•**Low**. Remove remaining ethanol.
- i. Remove from the magnet. Add **35.5 µl** Buffer EB. Pipette mix 15x.
- j. Incubate **2 min** at **room temperature**.
- k. Place on the magnet•**Low** until the solution clears.
- l. Transfer **35 µl** to a new tube strip.
-  m. Store at **4°C** for up to **72 h** or at **-20°C** for **long-term** storage.

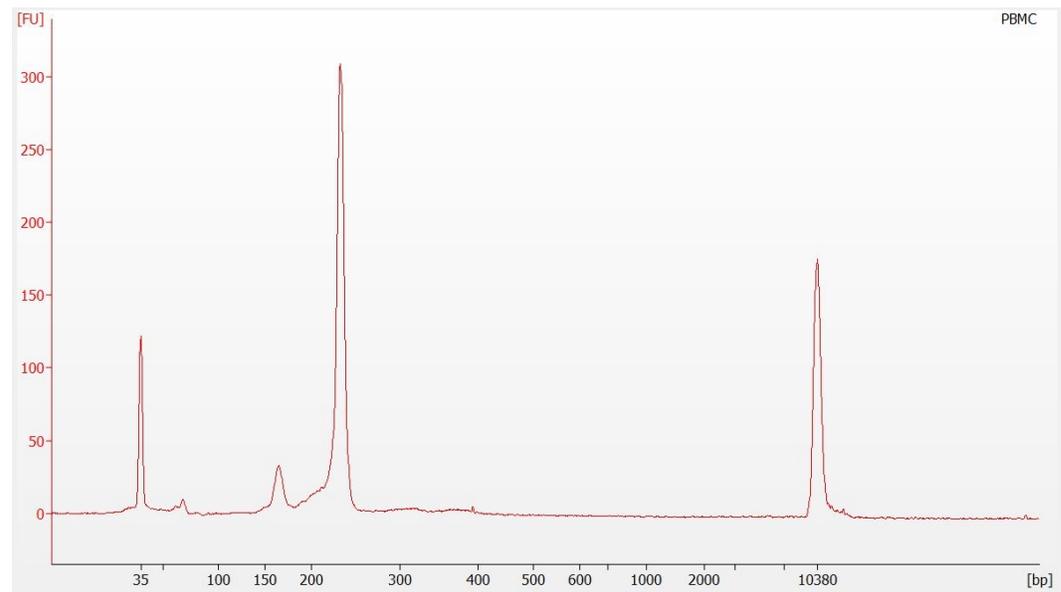
4.3 Post Library Construction QC

Library QC

Use Agilent Bioanalyzer, Perkin Elmer LabChip, or Agilent Tapestation for QC.

- Run **1 μ l** sample at 1:10 dilution on an Agilent Bioanalyzer High Sensitivity chip.
- Select the region between 150-300 bp to determine average size of the library. This will be used as the insert size for library quantification.

Representative Trace



See [Appendix on page 86](#) for representative traces

Quantification

Library quantification should be performed prior to sequencing. For the most accurate quantitative assessment of libraries, a qPCR-based method should be used to ensure that the sequencing flowcell is loaded properly.

See [Post Library Construction Quantification using KAPA qPCR on page 88](#)

Step 5:

Sequencing

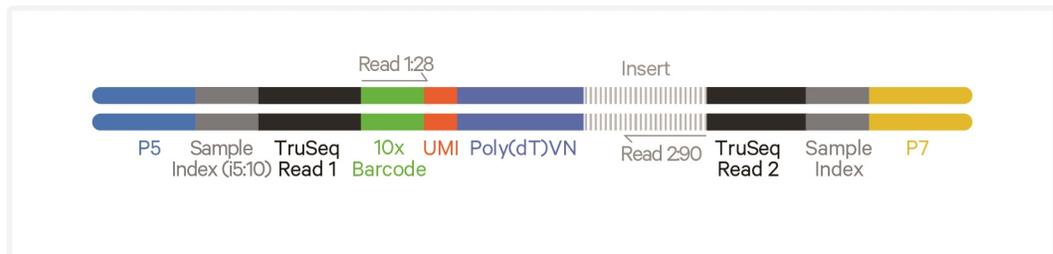
Sequencing Libraries	75
Illumina Sequencer Compatibility	75
Sample Indices	76
Library Sequencing Depth & Run Parameters	76
Library Loading	77
Library Pooling	77
Data Analysis and Visualization	79

Sequencing Libraries

Chromium Single Cell Gene Expression Libraries

Chromium Single Cell 3' Gene Expression Dual Index libraries comprise standard Illumina paired-end constructs which begin with P5 and end with P7. These libraries include 16 bp 10x Barcodes at the start of TruSeq Read 1 while i7 and i5 sample index sequences are incorporated as the sample index read. TruSeq Read 1 and TruSeq Read 2 are standard Illumina sequencing primer sites used in paired-end sequencing of Single Cell Gene Expression libraries.

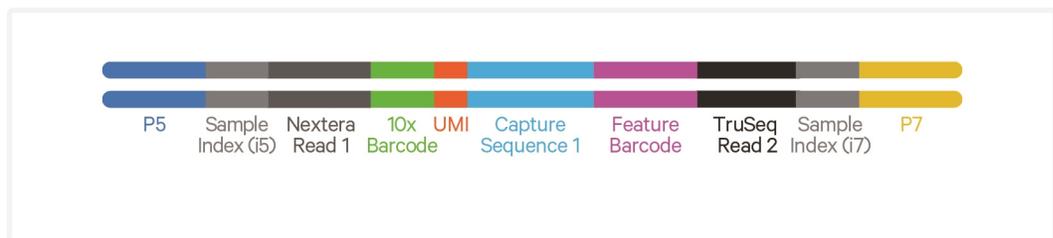
Chromium Single Cell 3' Gene Expression Library



Chromium Single Cell 3' Cell Surface Protein Libraries

Chromium Single Cell 3' Cell Surface Protein Dual Index libraries comprise standard Illumina paired-end constructs which begin with P5 and end with P7. These libraries include 16 bp 10x Barcodes at the start of Nextera Read 1 (Read 1N) while i7 and i5 sample index sequences are incorporated as the sample index read. Nextera Read 1 (Read 1N) and TruSeq Read 2 are standard Illumina sequencing primer sites used in paired-end sequencing of Cell Surface Protein libraries.

Chromium Single Cell 3' Cell Surface Protein Library



Sequencing these libraries produces a standard Illumina BCL data output folder.

Illumina Sequencer Compatibility

The compatibility of the listed sequencers has been verified by 10x Genomics. Some variation in assay performance is expected based on sequencer choice.

For more information about performance variation, visit the 10x Genomics Support website.

- MiSeq
- NextSeq 500/550/2000
- HiSeq 2500 (Rapid Run)
- HiSeq 3000/4000
- NovaSeq 6000

Sample Indices

Each sample index in the relevant Dual Index Kit contains a mix of one unique i7 and one unique i5 sample index. If multiple samples are pooled in a sequence lane, the sample index name (i.e. the Dual Index plate well ID) is needed in the sample sheet used for generating FASTQs with "cellranger mkfastq". If multiple libraries are pooled in a sequence lane, a separate sample index is needed with each library (see [Sample Indices in Sample Index PCR on page 30](#)).

Library Sequencing Depth & Run Parameters

3' Gene Expression Library

Parameter	Description
Sequencing Depth	Minimum 20,000 read pairs per cell
Sequencing Type	Paired-end, dual indexing
Sequencing Read	Recommended Number of Cycles
Read 1	28 cycles
i7 Index	10 cycles
i5 Index	10 cycles
Read 2	90 cycles

Cell Surface Protein Library

Pooling Single Cell 3' Gene Expression & Cell Surface Protein libraries is recommended for sequencing to maintain nucleotide diversity.

Parameter	Description
Sequencing Depth	Minimum 5,000 read pairs per cell
Sequencing Type	Paired-end, dual indexing
Sequencing Read	Recommended Number of Cycles
Read 1	28 cycles
i7 Index	10 cycles
i5 Index	10 cycles
Read 2	90 cycles
	<i>(Minimum required Read 2 length for Cell Surface Protein Libraries is 25 bp)</i>

Library Loading

Once quantified and normalized, libraries should be denatured and diluted as recommended for Illumina sequencing platforms. Refer to Illumina documentation for denaturing and diluting libraries. Refer to the 10x Genomics Support website for more information.

3' Gene Expression libraries alone or in combination with Cell Surface Protein libraries



Library Loading

Instrument	Loading Concentration (pM)*	PhiX (%)
MiSeq	12	1
NextSeq 500/550	1.6	1
NextSeq 1000/2000	650	1
HiSeq 2500 (RR)	12	1
HiSeq 4000	240	1
NovaSeq 6000 Standard & Xp workflow	150	1

**Minor updates to the loading concentrations*

Library Pooling

Different libraries maybe pooled for sequencing, taking into account the differences in cell number and per-cell read depth requirements between each library. Samples utilizing the same sample index should not be pooled together or run on the same flow cell lane, as this would not enable correct sample demultiplexing.

Library Pooling Example

Libraries	Sequencing Depth (read pairs per cell)	Library Pooling Ratio
3' Gene Expression library	20,000	4
Cell Surface Protein library	5,000	1

Data Analysis and Visualization

Sequencing data may be analyzed using Cell Ranger and visualized using Loupe Browser. Key features for these tools are listed below. For detailed product-specific information, visit the 10x Genomics Support website.

Cell Ranger

Cell Ranger is a set of analysis pipelines that processes Chromium Single Gene Expression data to align reads, generate Feature Barcode matrices and perform clustering and gene expression analysis.

- Input: Binary base call (BCL) and FASTQ
- Output: BAM, MEX, CSV, HDF5, Web Summary, .cloupe/.loupe
- Operating System: Linux

Cloud Analysis

Cloud Analysis is currently only available for US & Canada customers.

Cloud Analysis allows users to run Cell Ranger analysis pipelines from a web browser while computation is handled in the cloud.

- Key features: scalable, highly secure, simple to set up and run
- Input: FASTQ
- Output: BAM, MEX, CSV, HDF5, Web Summary, .cloupe/.loupe

Loupe Browser

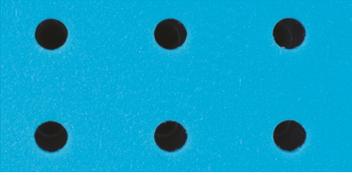
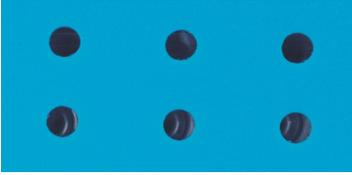
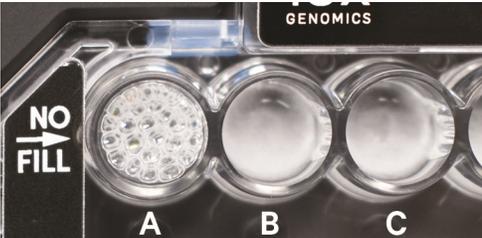
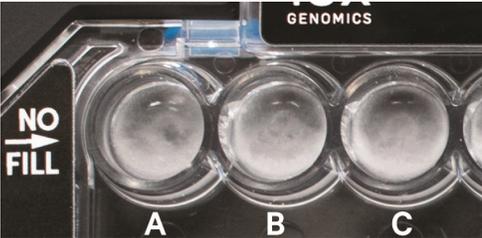
Loupe Browser is an interactive data visualization application that requires no prior programming knowledge.

- Input: .cloupe, .loupe
- Output: Data visualization, including t-SNE and UMAP projections, custom clusters, differentially expressed genes
- Operating System: MacOS, Windows

Troubleshooting

GEM Generation & Barcoding	81
Chromium X Series Errors	85

GEM Generation & Barcoding

STEP	Normal	Impacted
<p>1.2</p> <p>Load Chromium GEM-X Chip</p>		
	<p>Gasket holes are aligned with the sample and gel bead wells.</p>	<p>Gasket holes are misaligned with the gel bead wells. Open and close the chip holder slowly once. <i>One of the rows of Chromium X/iX gasket will not align with the GEM-X chip. This is normal and will not impact the assay.</i></p>
<p>1.4d</p> <p>After Chip is removed from the instrument and the wells are exposed.</p>		
	<p>All recovery wells are similar in volume and opacity.</p>	<p>Recovery well A indicates a wetting failure. Not all wetting failures may present themselves with excess bubbles (foam).</p>
		 <p>Recovery wells A-C show normal emulsions. Not all normal emulsions may have small (in size and number) bubbles in the recovery wells.</p> <p>Inspecting emulsions in pipette tips is recommended for diagnosing emulsion failures.</p>

STEP	Normal	Impacted
------	--------	----------

1.4e
Transfer GEMs from Chip

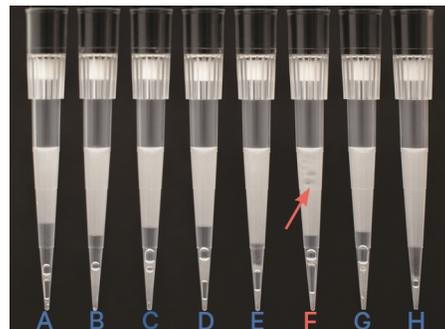


All liquid levels are similar in volume and opacity without air trapped in the pipette tips.



● Wetting failure
○ Normal emulsion

Pipette tip A shows wetting failure. Pipette tips B-C show uniform emulsions & slightly low volumes. (~95 µl)
Most wetting failures will not impact emulsion volumes of other sample run on the chip.
Occasionally, wetting failures may impact the emulsion volumes recovered from other lanes. This is expected and does not indicate an emulsion failure if the samples are uniform in volume and opacity (B-C).

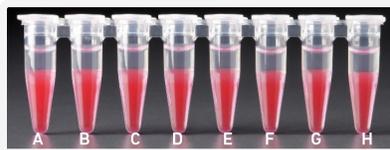


In pipette tips A-E & G-H, a portion of the emulsion displays separate layers of oil, which indicates clog.
Pipette tip F indicates a clog (separate oil layers) and wetting failure (non-uniform emulsion).

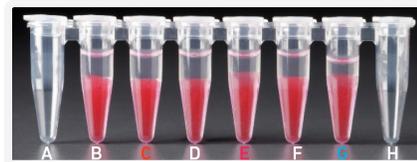
Emulsion failures are not expected to be observed across the entire chip. The above images are for illustrative purposes to show a range in emulsion failures. A clog is not expected to impact other lanes on the chip.

2.1a

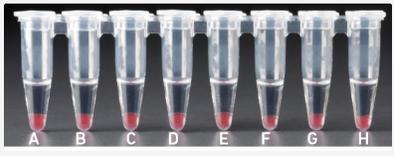
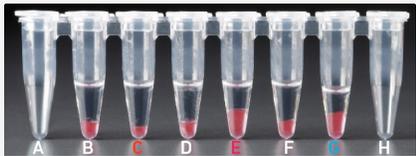
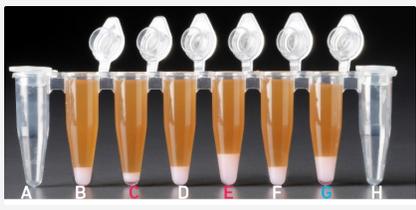
After transfer of the GEMs + Recovery Agent



All liquid levels are similar in the aqueous sample volume (clear) and Recovery Agent/ Partitioning Oil (pink).



Tube G indicates a reagent clog has occurred. There is a decreased volume of aqueous layer (clear).
Tube C and E indicate a wetting failure has occurred. There is an abnormal volume of Recovery Agent/Partitioning Oil (pink).

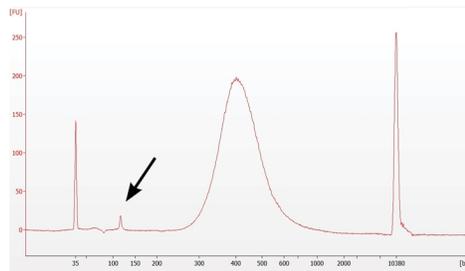
STEP	Normal	Impacted
<p>2.1b After aspiration of Recovery Agent/ Partitioning Oil</p>	 <p>All liquid volumes are similar in the aqueous sample volume (clear) and residual Recovery Agent/Partitioning Oil (pink).</p>	 <p>Tube G indicates a reagent clog has occurred. There is a decreased volume of aqueous layer (clear). There is also a greater residual volume of Recovery Agent/Partitioning Oil (pink).</p> <p>Tube C and E indicate a wetting failure has occurred. There is an abnormal residual volume of Recovery Agent/Partitioning Oil (pink).</p>
<p>2.1d After addition of Dynabeads Cleanup Mix</p>	 <p>All liquid volumes are similar after addition of the Dynabeads Cleanup Mix.</p>	 <p>Tube G indicates a reagent clog has occurred. There is an abnormal ratio of Dynabeads Cleanup Mix (brown) to Recovery Agent/Partitioning Oil (appears white). Tube C and E indicate a wetting failure has occurred. There is an abnormal ratio of Dynabeads Cleanup Mix (brown) to Recovery Agent/Partitioning Oil (appears white).</p>



If a channel clogs or wetting failure occurs during GEM generation, it is recommended that the sample be remade. If any of the listed issues occur, take a picture and send it to support@10xgenomics.com for further assistance. Replacement reagents and chips may be provided for properly documented clogs or wetting failures if they are associated with runs of unexpired reagents and chips, and are reported within 30 days of the expiration date.

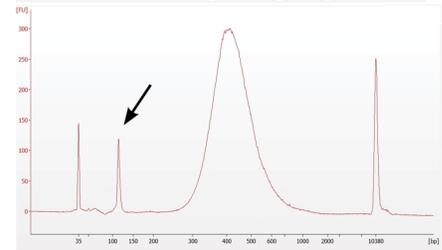
Step	Normal	Prominent Adaptor Dimer Peaks
------	--------	-------------------------------

**3.7 Post Library Construction QC
(Gene Expression)**

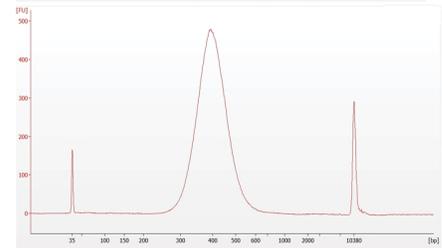


Minor peaks below 200 bp may be observed.

Libraries before repeating step 3.6



Libraries after repeating step 3.6



If peaks below 200 bp are more prominent, repeat step 3.6 Post Sample Index PCR Double Sided Size Selection - SPRIselect.

Chromium X Series Errors

The Chromium X touchscreen will guide the user through recoverable errors. If the error continues, or if the instrument has seen critical or intermediate errors, email support@10xgenomics.com with the displayed error code. Support will request a troubleshooting package. Upload pertinent logs to 10x Genomics by navigating to the Logs menu option on screen.

There are two types of errors:

Critical Errors – When the instrument has seen a critical error, the run will immediately abort. Do not proceed with any further runs. Contact support@10xgenomics.com with the error code.

- a. System Error
- b. Pressure Error
- c. Chip Error
- d. Run Error
- e. Temperature Error
- f. Software Error

User Recoverable Errors – Follow error handling instructions through the touchscreen and continue the run.

- a. Gasket Error
- b. Tray Error
- c. Chip Error
- d. Unsupported Chip Error
- e. Network Error
- f. Update Error



Consult the Chromium X Series Instrument User Guide with Readiness Test (CG000396) for additional information and follow the instrument touchscreen prompts for execution. The instrument touchscreen will guide the user through recoverable errors.

Appendix

GEM-X Chip Loading Overview	87
Post Library Construction Quantification using KAPA qPCR	88
LabChip Traces	89
Oligonucleotide Sequences	90

GEM-X Chip Loading Overview

This section provides a quick overview to the GEM-X chip loading and does not include detailed instructions. Refer to [Load GEM-X Chip on page 39](#) for details. The Chromium X/iX Chip Holder and X/iX Chip Gasket images shown here are representative. Refer to [Assemble GEM-X Chip on page 35](#) for details.

Steps

Open the lid (gasket attached) of the assembled chip and lay flat for loading.

Color Legend

- 2: Gel beads
- 1: Sample
- 3: Oil

a. Add 50% glycerol solution to each unused well

- Load 60 μ l to row labeled 1
- Load 60 μ l to row labeled 2
- Load 250 μ l to row labeled 3

b. Prepare Gel Beads

- Vortex for 30 sec
- Centrifuge for 5 sec

c. Prepare GEM Master Mix + Sample

d. Load Row Labeled 1

- Mix GEM Master Mix + Sample
- Load 60 μ l to row labeled 1
- Wait 30 sec

e. Load Row Labeled 2

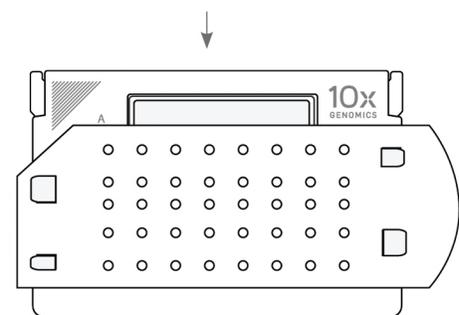
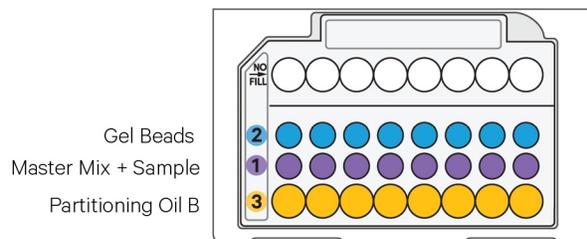
- Aspirate Gel Beads
- Load 60 μ l to row labeled 2
- Wait 30 sec

f. Load Row Labeled 3

- Load 250 μ l Partitioning Oil B to row labeled 3 by pipetting two aliquots of 125 μ l from a reagent reservoir.

g. Close the lid and prepare for run.

Representative Images



*Representative Images.
Chip holder and gasket should be black and blue in color, respectively.*

Post Library Construction Quantification using KAPA qPCR

- a. Thaw KAPA Library Quantification Kit for Illumina Platforms.
- b. Dilute **2 µl** sample with deionized water to appropriate dilutions that fall within the linear detection range of the KAPA Library Quantification Kit for Illumina Platforms. (For more accurate quantification, make the dilution(s) in duplicate).
- c. Make enough Quantification Master Mix for the DNA dilutions per sample and the DNA Standards (plus 10% excess) using the guidance for 1 reaction volume below.

Quantification Master Mix	1X (µl)
SYBR Fast Master Mix + Primer	12
Water	4
Total	16

- d. Dispense **16 µl** Quantification Master Mix for sample dilutions and DNA Standards into a 96 well PCR plate.
- e. Add **4 µl** sample dilutions and **4 µl** DNA Standards to appropriate wells. Centrifuge briefly.
- f. Incubate in a thermal cycler with the following protocol.

Step	Temperature	Run Time
1	95°C	00:03:00
2	95°C	00:00:05
3	67°C Read Signal	00:00:30
4	Go to Step 2, 29X (Total 30 cycles)	

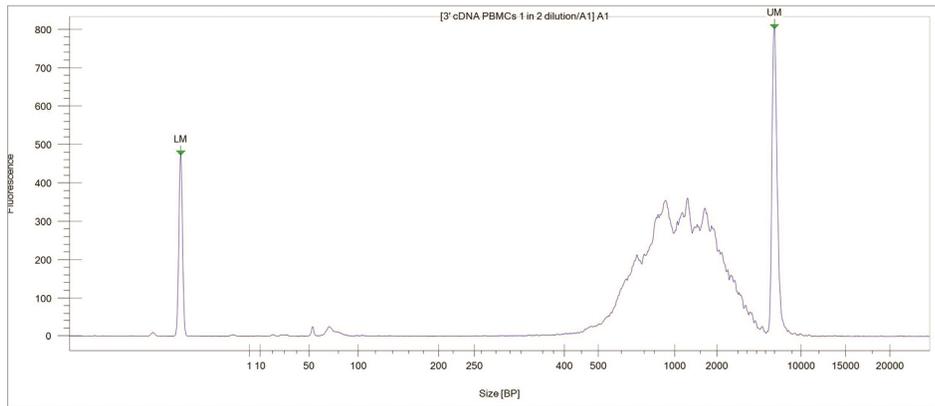
- g. Follow the manufacturer's recommendations for qPCR-based quantification. For library quantification for sequencer clustering, determine the concentration based on insert size derived from the Bioanalyzer/TapeStation trace.

LabChip Traces

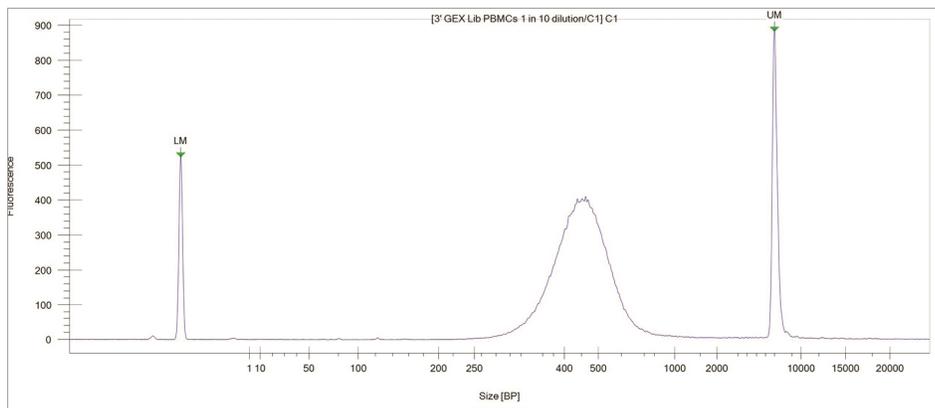
LabChip Traces

DNA High Sensitivity Reagent Kit was used.

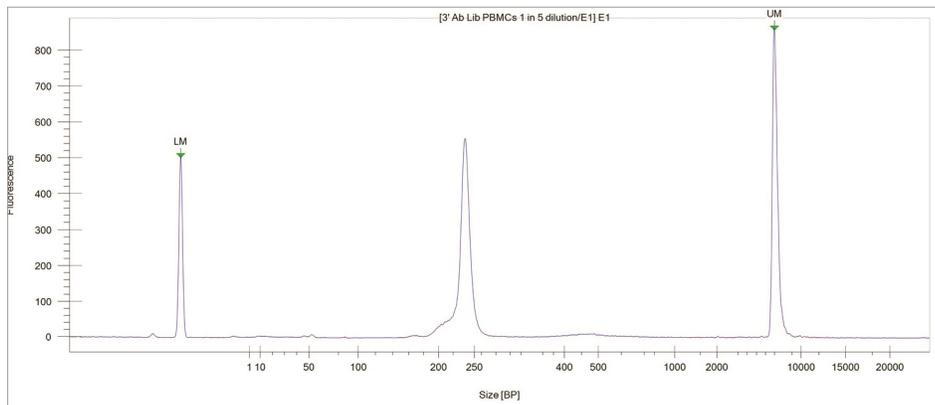
Post cDNA Amplification QC & Quantification



GEX- Post Library Construction QC

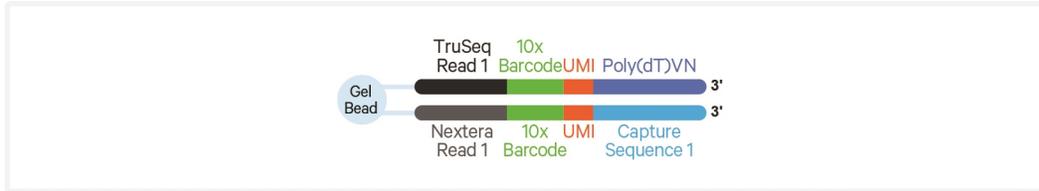


Cell Surface Protein - Post Library Construction QC



Oligonucleotide Sequences

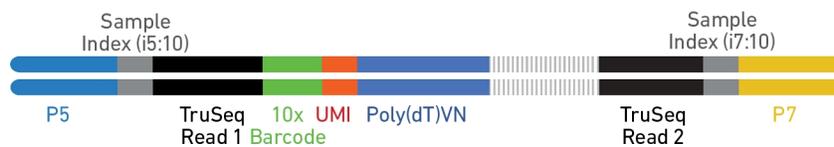
Gel Bead Primers



5'-CTACACGACGCTCTCCGATCT-N16-N12-TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT-VN-3'
 5'-GTCAGATGTGTATAAGAGACAG-N16-N12-TTGCTAGGACCGGCCTTAAAGC-3'

Gene Expression Library

Sample Index PCR Product



5'-AATGATACGGCGACCACCGAGATCTACAC-N10-ACACTCTTTCCCTACACGACGCTCTTCCGATCT-N16-N12-T30-VN-cDNA_Insert-AGATCGGAAGAGCACACGTCTGAACTCCAGTCAC-N10-ATCTCGTATGCCGCTTCTGCTTG-3'

3'-TTACTATGCCGCTGGTGGCTCTAGATGTG-N10-TGTGAGAAAGGGATGTGCTGCGAGAAGGCTAGA-N16-N12-A30-BN-cDNA_Insert-TCTAGCCTTCTCGTGTGCAGACTTGAGGTCAGTG-N10-TAGAGCATACGGCAGAAGACGAAC-5'

Cell Surface Protein Library

Sample Index PCR Product



5'-AATGATACGGCGACCACCGAGATCTACAC-N10-TCGTCGGCAGCGTCAGATGTGTATAAGAGACAG-N16-N12-TTGCTAGGACCGGCCTTAAAGC-N9-N15-N10-AGATCGGAAGAGCACACGTCTGAACTCCAGTCAC-N10-ATCTCGTATGCCGCTTCTGCTTG-3'

3'-TTACTATGCCGCTGGTGGCTCTAGATGTG-N10-AGCAGCCGTCGCAGTCTACACATATTCTCTGTC-N16-N12-AACGATCCTGGCCGAATTCG-N9-N15-N10-TCTAGCCTTCTCGTGTGCAGACTTGAGGTCAGTG-N10-TAGAGCATACGGCAGAAGACGAAC-5'