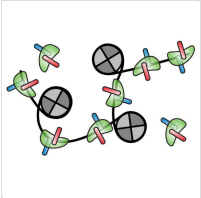

Jun 08, 2022

Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays

Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays

Ryan Corces[1], William J. Greenleaf[2], Howard Y. Chang[2]

[1]Gladstone Institutes; [2]Stanford University

dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

杰李

This protocol enables the isolation of nuclei from frozen tissues. These nuclei are suitable for use in ATAC-seq, single-cell ATAC-seq, ChIP-seq, HiC/3C, and many other assays.

DOI

dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

https://www.ncbi.nlm.nih.gov/pubmed/28846090

Ryan Corces, William J. Greenleaf, Howard Y. Chang 2022. Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays. **protocols.io** https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

protocol

Corces MR, Trevino AE, Hamilton EG, Greenside PG, Sinnott-Armstrong NA, Vesuna S, Satpathy AT, Rubin AJ, Montine KS, Wu B, Kathiria A, Cho SW, Mumbach MR, Carter AC, Kasowski M, Orloff LA, Risca VI, Kundaje A, Khavari PA, Montine TJ, Greenleaf WJ†, Chang HY†. An improved ATAC-seq protocol reduces background and enables interrogation of frozen tissues. 2017. Nature Methods. (PMID: 28846090).

Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays, Ryan Corces

ATAC-seq, Nuclei Isolation, Frozen Tissue Homogenization

protocol ,

Jun 08, 2022

Jun 08, 2022

64169

The quality of the tissue at the time of freezing is a major factor in the quality of data downstream. If freezing tissue for use later, you may want to consider cryopreserving 50 mg tissue chunks in BAM Banker cryopreservative. If using previously frozen tissue, the ischemic time or post mortem interval should be kept as short as possible.

Nuclei can be cryopreserved in BAM Banker. In our experience, freeze-thaw cycles do not adversely affect data quality as long as thawing is carried out on ice and freezing is performed using a slow-freeze freezing container. We have had success isolating nuclei from every tissue we have tried including difficult to work with tissues such as heart.

STOCK BUFFERS

All stock solutions should be filtered using a 0.22 um PVDF filter system. All solutions except for the 50% Iodixanol solution are stable at 4°C for at least 6 months.

1.034x Homogenization Buffer Stable Solution - 200 ml

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Total Vol. (ul)*
1	M Sucrose	0.26	3.87	51706.50
2	M KCl	0.03	77.36	2585.33
1	M MgCl2	0.01	193.40	1034.13
0.75	M Tricine-KOH pH 7.8	0.02	36.26	5515.36
-	Water	-	-	139158.69

Diluent Buffer - 100 ml

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Total Vol. (ul)*
2	M KCl	0.15	13.33	7500.00
1	M MgCl2	0.03	33.33	3000.00
0.75	M Tricine-KOH, pH 7.8	0.12	6.25	16000.00
-	Water	-	-	73500.00

50% Iodixanol Solution - 50 ml (Remake monthly for stability)

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Total Vol. (ul)*
-	Diluent Buffer	1	-	8333.33
60	% Iodixanol	50	1.20	41666.67

ATAC-RSB Buffer - 500 ml

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Total Vol. (ul)*
1	M Tris-HCl pH 7.5	0.01	100.00	5000.00
5	M NaCl	0.01	500.00	1000.00
1	M MgCl2	0.003	333.33	1500.00
-	Water	-	-	492500.00

SAME DAY BUFFERS

1x Homogenization Buffer Unstable Solution

**Note – cOmplete Protease Inhibitors come as tablets. It is difficult to use less than 1/2 tablet so we prepare the 1x Homogenization Buffer Unstable Solution in batches of 12 as outlined below.

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Vol per 12 samp. (ul)*
1.0341	x HB Stable Solution	1	1.03	24175.00
1	M DTT	0.001	1000.00	25.00
500	mM Spermidine	0.5	1000.00	25.00
150	mM Spermine	0.15	1000.00	25.00
10	% NP40	0.3	33.33	750.00
-	cOmplete Protease Inhibitor	-	-	0.50 Tablets

30% Iodixanol Solution

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Vol per sample (ul)*
-	1x Homog. Buffer Unstable	-	-	240.00
50	% Iodixanol Solution	30	1.67	360.00

40% Iodixanol Solution

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Vol per sample (ul)*
-	1x Homog. Buffer Unstable	-	-	120.00
50	% Iodixanol Solution	40	1.25	480.00

ATAC-RSB-Tween Buffer

Stock	*Name*	*Final Conc.*	*Fold Dilution (x)*	*Vol per sample (ul)*
-	ATAC-RSB	-	-	2970.00
10	% Tween-20	0.1	100.00	30.00

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

ATAC-seq Reaction Mix

Reagent	*Vol per sample (ul)*
H2O	5
PBS	16.5
2x TD Buffer	25
1% Digitonin	0.5
10% Tween-20	0.5
Tn5 Transposase	2.5

Reagents used in this protocol

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

Item	Supplier	Cat Number
Eppendorf 2 ml Lo-Bind tubes	Sigma	Z666556-250EA
Eppendorf 1.5 ml Lo-Bind tubes	Sigma	Z666548-250EA
Nunc cryovials	Thermo	375418PK
Iodixanol (comes at 60%)	Sigma	D1556-250ML
Sucrose	Sigma	S7903-250G
NP40	Roche (Sigma)	11332473001
Tricine	Sigma	T0377-25G
Potassium Hydroxide (KOH)	Sigma	P5958-250G
cOmplete Protease Inhibitors	Roche	11697498001
MgCl2	Ambion (Thermo)	AM9530G
KCl	Ambion (Thermo)	AM9640G
DTT	Thermo	R0861
Spermidine	Sigma	S2501
Spermine	Sigma	S3256-1G
70 um Flowmi cell strainers	Fisher	03-421-228
70 um bucket-style cell strainers	BD Falcon	352350
Tris-HCl pH 7.5	Invitrogen	15567-027
NaCl	Ambion (Thermo)	AM9759
Tween 20	Roche (Sigma)	11332465001
H2O	Invitrogen	10977-015
Dounce Tissue Grinder Set	Sigma	D8938-1SET
INCYTO Disposable hemocytometers	Fisher	22-600-100
BAM Banker	Wako Chemicals	302-14681
RiboLock	Thermo	EO0384
0.22 um PVDF Filter Units (500 ml)	Millipore	SCGVU05RE
0.22 um PVDF Filter Units (50 ml)	Millipore	SE1M179M6
Tn5 Transposase (TDE1)	Illumina	15027865
2x TD Tagment DNA Buffer	Illumina	15027866

Before you start the protocol:

1 All steps should be performed on ice or at **4 °C** . Pre-chill a swinging bucket centrifuge and a fixed angle centrifuge to 4°C.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

2 Pre-chill all Dounces and pestles to 4 °C in a fridge.

3 Pre-chill all tubes. For each sample you are processing, you will need: (i) One 2 ml round-bottom LoBind tube for gradient separation (ii) One 1.5 ml LoBind tube for RNA homogenate (iii) One 2 ml Nunc Cryotube for extra nuclei (iv) One 50 ml conical for filtration step (often optional)

4 Prepare all buffers. For faster dissolution, crush protease inhibitor tablets prior to addition to 1x Homogenization Buffer Unstable Solution. DTT, Spermidine, Spermine, and digitonin are stored at -20°C. All other detergents, ATAC-RSB, and other buffers are stored at 4 °C . Do not prepare transposition mix ahead of time. a. Remember that the catalog number provided for iodixanol from Sigma comes as a 60% solution (not 100%).

5 Fill up a 2 L beaker with 500 ml sterile water to soak the used Dounces and pestles.

Isolation of Nuclei via Dounce Homogenization and Density Gradient Centrifugation

6 Remove samples from liquid nitrogen storage and keep on dry ice until use.

6.1 If the tissue you are using is difficult to homogenize (for example heart, muscle, etc) then you may want to consider pre-crushing the tissue prior to Dounce homogenization. To do this, pre-chill a mortar and pestle and use the pestle to break the tissue chunk into smaller pieces by repeatedly hitting the tissue. We dont recommend pulverizing the tissue into a powder - it should remain as small chunks.These small chunks may make it so that the Dounce gets stuck more frequently, but in our experience this pre-crushing can help liberate more nuclei from difficult tissues.

7 Place 20 mg frozen tissue into a pre-chilled 2 ml Dounce containing 1 ml cold 1x HB and let thaw for 00:05:00 . For >30 mg tissue, use 2 ml 1x HB. For 10-20 mg tissue, use 1 ml 1x HB. For 50 um tissue sections, use 0.5 ml 1x HB.

8 If you would like to collect RNA from the same sample, add 10 ul RiboLock per ml of 1x HB and mix well.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

9 Dounce with “A” loose pestle until resistance goes away (~10 strokes).

10 Place “A” pestle into beaker with sterile water to soak for cleaning later.

10.1 Optional – If residual un-homogenized tissue makes it difficult to Dounce, filter homogenate through a 70 um bucket-style cell strainer filter into a pre-chilled 50 ml conical prior to using tight pestle “B”.

11 Dounce with “B” tight pestle for 20 strokes.

12 Place “B” pestle into beaker with sterile water to soak for cleaning later.

13 Filter during transfer using a 70 um Flowmi strainer and transfer homogenate to a pre-chilled 2 ml LoBind tube.

14 Place Dounce into beaker with sterile water to soak for cleaning later.

15 Pellet nuclei by spinning **00:05:00** at **4 °C** at 350 RCF in a fixed angle centrifuge.

16 Remove all but 50 ul of supernatant (containing cytoplasmic RNAs) and transfer to a pre-chilled 1.5 ml LoBind tube. If the pellet is not clearly visible, you can leave more supernatant in the tube, up to 400 ul and add less of the 1x HB buffer in the next step.

17 Gently resuspend nuclei in a total volume of 400 ul 1x HB. If you only left 50 ul in the tube in the previous step, this means you should add 350 ul 1x HB. Make sure nuclei are fully resuspended without clumps.

18 Add 1 volume (400 ul) of 50% Iodixanol Solution and mix well by pipetting

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

19 Slowly layer 600 ul of 30% Iodixanol solution under the 25% mixture. To avoid mixing of layers, wipe the side of the pipette tip with a Kimwipe to remove excess Iodixanol solution from the external surfaces of the pipette tip.

20 Layer 600 ul of 40% Iodixanol solution under the 30% mixture. To avoid mixing of layers, wipe the side of the pipette tip with a Kimwipe to remove excess Iodixanol solution from the external surfaces of the pipette tip.

20.1 During this step, you will need to gradually draw your pipette tip up to avoid overflowing the tube. However, the tip of your pipette must stay below the 30%-40% interface at all times.

21 In a pre-chilled swinging bucket centrifuge, spin for **00:20:00** at **4 °C** at 3,000 RCF with the brake off. Handle tubes gently so as to not disturb the gradient.

21.1 Iodixanol is meant to be used at higher speeds (10,000 RCF) but high-speed swinging bucket centrifuges are not always readily available so we perform this step at 3,000 g and have not had any issues.

22 Using a vacuum, aspirate the top layers down to within 200-300 ul of the nuclei band at the 30%-40% interface. Be careful not to get too close as you will disrupt the nuclei band.

23 Using a 200 ul volume, collect the nuclei band and transfer to a fresh tube. Do not aspirate more than 200 ul at this step as this can cause you to take too much of the 40% layer which sometimes contains debris.

24 Dilute nuclei by adding some volume of ATAC-RSB-Tween Buffer. Mix gently by pipetting. The precise volume of ATAC-RSB-Tween to add will depend on how many nuclei you have. If you don't dilute enough, it will be hard to get an accurate count. If you dilute too much, it will be similarly hard to get an accurate count. You should minimally add 200 ul of ATAC-RSB-Tween buffer to dilute the iodixanol as high concentrations of iodixanol can be too viscous for hemocytometers.

Transposition of Nuclei

25 Count nuclei using Trypan blue staining (1:1 ratio of Trypan to sample) and a manual hemocytometer. We recommend using disposable hemocytometers for consistency but do not recommend automated cell counters.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

26 We normally perform two technical replicates per sample. Each technical replicate should ideally have 50,000 nuclei, requiring 100,000 nuclei total. If you don't have at least 100,000 nuclei, follow this convention: (A) More than 50,000 nuclei, still do 2 technical replicates using half of the volume for each replicate but reduce the volume of Tn5 transposase proportionately to the number of nuclei. Maintain all other transposition reaction volumes. For example, for 25,000 cells, use 1.25 ul of Tn5 transposase in a 50 ul total reaction volume. Replace omitted Tn5 volume with water. (B) Fewer than 50,000 nuclei, only do 1 technical replicate and reduce the volume of Tn5 transposase proportionately to the number of nuclei. Maintain all other transposition reaction volumes. For example, for 25,000 cells, use 1.25 ul of Tn5 transposase in a 50 ul total reaction volume. Replace omitted Tn5 volume with water.

27 Label and chill 1.5 ml LoBind tubes according to how many tubes will be needed for transpositions.

28 Transfer 50,000 nuclei into a 1.5 ml LoBind tube containing 1000 ul of ATAC-RSB-Tween Buffer. If the total volume won't fit in a 1.5 ml tube, just reduce the amount of ATAC-RSB-Tween that you add to the tube to start.

29 Centrifuge nuclei for **00:10:00** at 500 RCF at **4 °C** in a fixed angle centrifuge. At this point, the pellet should be clearly visible if 50,000 nuclei were used. Pellets of as few as 10,000 nuclei should be visible.

30 ⚠

Using a p1000 pipette, remove all but the last 100 ul of supernatant. Remove last 100 ul with p200 pipette set to 200 ul using a single fluid pipetting motion. Place the tip of your pipette on the opposite side of the tube to where the nuclei pellet is located during this final aspiration step.

31 Add 50 ul ATAC-seq Reaction Mix to each tube and pipette up and down 6 times to resuspend nuclei pellet.

31.1 Unlike the published ATAC-seq protocols, you do not need to do an individual lysis step in this protocol because the nuclei are exposed to NP40 throughout the Douncing portion of the protocol.

32 Incubate reactions at **37 °C** for **00:30:00** in a thermoshaker with 1000 RPM constant shaking.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

33 After incubation, add 250 ul (5 volumes) of Binding Buffer from the Zymo DNA Clean and Concentrator 5 kit. Mix well by vortexing and inverting to collect any condensate from the lid.

34 Pulse centrifuge to collect volume in the bottom of the tube.

35 Either finish the cleanup protocol using the Zymo DNA Clean and Concentrator 5 kit or transfer the binding buffer transposition mix to **-20 °C** for short term storage for up to 2 weeks.

35.1 If you store the binding buffer transposition mix at **-20 °C**, allow it to equilibrate to room temperature and mix well before proceeding with the Zymo DNA Clean and Concentrator clean up protocol. This will dissolve any precipitate that has formed and allow optimal binding to the column membrane.

Cleanup and Freezing Down of Nuclei and Homogenate

36 If you would like to save extra nuclei for other assays or to potentially use in additional ATAC-seq experiments downstream:

36.1 Pellet remaining nuclei by centrifugation for **00:10:00** at 500 RCF at **4 °C**.

36.2 Carefully aspirate supernatant using two pipetting steps (p1000 then p200) as above.

36.3 Gently resuspend nuclei pellet in 100 ul of cold BAM Banker media and transfer to a pre-chilled 2 ml Nunc cryovial.

36.4 Slow-freeze nuclei in a freezing container and move to **-80 °C** or liquid nitrogen storage the next day.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

37 If you would like to keep homogenate for making RNA (or potentially protein) downstream, store homogenate at **-80 °C** .

38 Cleaning Dounces and pestles: Rinse all Dounces and pestles thoroughly with sterile water (2x) followed by 70% ethanol (2x). Let Dounces and pestles dry on a kimwipe or paper towel for a few hours to overnight.

Processing Homogenate to Make RNA (optional)

39 Pre-chill a fixed-angle centrifuge to **4 °C** .

40 Thaw homogenate on ice.

41 Transfer 150 ul to a 2 ml LoBind tube containing 1500 ul Trizol and mix.

42 Add 400 ul chloroform to the Trizol and mix by vortexing for **00:00:15** .

43 Immediately spin in a pre-chilled fixed-angle centrifuge at

21,000 RCF for **00:15:00** at **4 °C** .

44 Pipette clear aqueous layer (~650 ul) into a clean 1.5 ml LoBind tube.

45 Add an equal volume (650 ul) of 100% ethanol and mix well.

46 Pass all volume through a QIAgen RNeasy column using two centrifugation steps.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

47 Follow the QIAgen RNeasy protocol and elute in 27 ul of elution buffer

48 Add 3 ul of 10x Turbo DNase Buffer and 1 ul of Turbo DNase enzyme.

49 Incubate at **37 °C** for **00:30:00** .

50 Add 70 ul of RNase free water and 350 ul of QIAgen RLT Buffer and mix well.

51 Add 250 ul 100% ethanol and mix well.

52 Apply to column. Wash 2x with RPE. Elute in 20 ul RNase-free water.

Using Nuclei for Single-Nuclei ATAC-seq with 10x Genomics

53 Thaw nuclei on ice or use directly after isolation.

54 Aliquot desired number of nuclei into 1 ml RSB-T (RSB buffer - 10 mM Tris-HCl pH 7.5, 10 mM NaCl, 3 mM MgCl2 - containing 0.1% Tween). We have had success using 65,000 nuclei but this is far more than recommended by 10x. The number of nuclei you use will affect the doublet rate of your single cell data.

55 Pellet at 500 RCF at **4 °C** for **00:05:00** in a fixed-angle rotor. You should be able to see a small pellet if you used more than 25,000 nuclei.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1

56 Aspirate supernatant using 2 pipetting steps as above (p1000 then p200).

57 Add 12 ul of 1x Nuclei buffer (The 10x kit provides a 20x stock and you dilute it in water to make 1x buffer).

57.1 After this step, you will use 5 ul in the transposition reaction. If you used 65,000 nuclei initially, then 5 ul will contain approximately 27,000 nuclei. Again, this is more than recommended by 10x.

58 Transfer 5 ul of nuclei suspension containing nuclei into 10 ul of transposition mix from the 10x protocol.

59 Mix by pipetting, do not centrifuge or vortex and avoid introducing bubbles. Proceed to transposition incubation as indicated in the part of the 10x protocol.

Citation: Ryan Corces, William J. Greenleaf, Howard Y. Chang Isolation of nuclei from frozen tissue for ATAC-seq and other epigenomic assays https://dx.doi.org/10.17504/protocols.io.ewov1nm2kgr2/v1