HCR northern blot protocol

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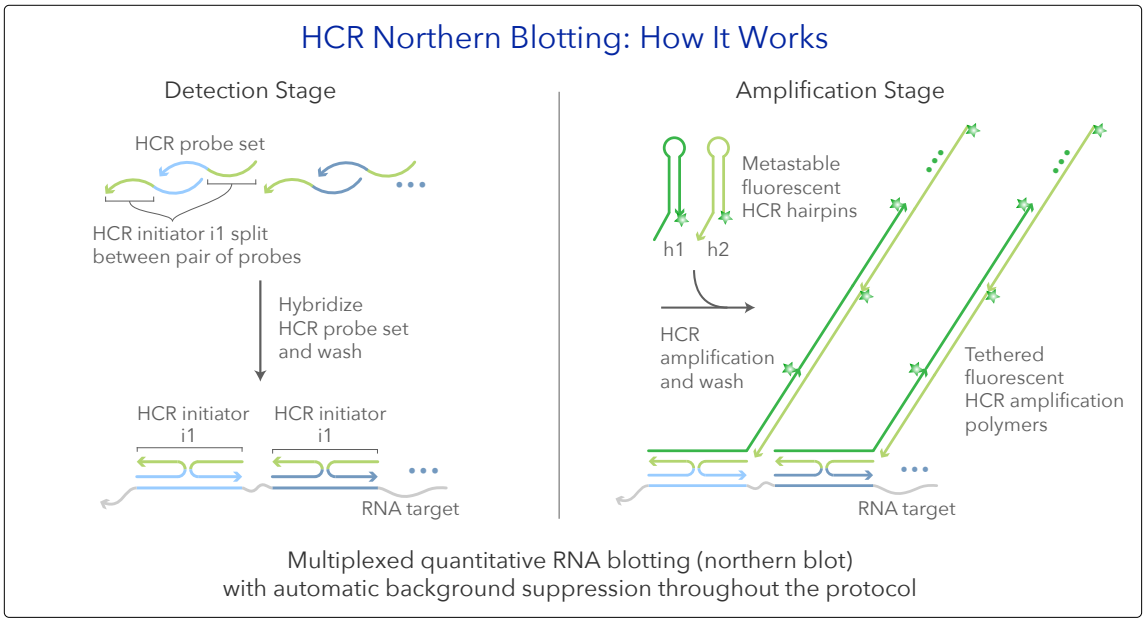

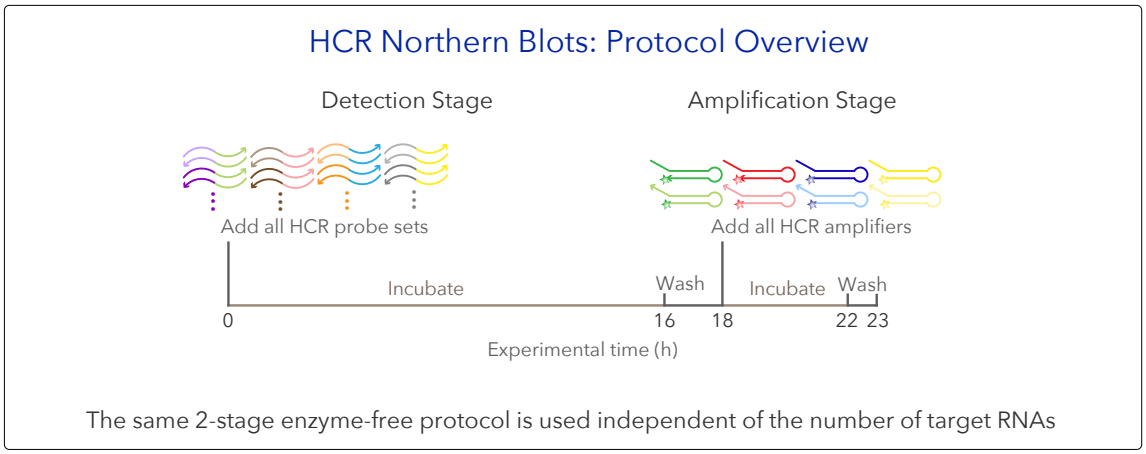

HCR Northern Blots

Multiplexed quantitative RNA blotting

Multiplexed Experiment

- Order one HCR RNA-FISH bundle per target RNA

Example 2-Plex Experiment

- HCR bundle for target mRNA1
  - HCR split-initiator probe set: target mRNA1 for use with amplifier B1
  - HCR amplifier: B1-647
  - HCR RNA-FISH buffers: probe hybridization buffer, probe wash buffer, amplification buffer (for use with all bundles)
- HCR bundle for target mRNA2
  - HCR split-initiator probe set: target mRNA2 for use with amplifier B2
  - HCR amplifier: B2-488

Storage conditions

- Store HCR probe sets, HCR amplifiers, HCR probe hybridization buffer, and HCR probe wash buffer at -20 °C.
- Store HCR amplification buffer at 4 °C.
- On the bench top, keep stock solutions on ice.
- Make sure all solutions are well mixed before use.

Denaturing agarose gel electrophoresis

1. Prepare a 1% denaturing agarose gel.
   NOTE: *The gel should be ≤6 mm for efficient RNA transfer.*
   NOTE: *We recommend using NorthernMax™ denaturing gel buffer for preparing denaturing agarose gels.*

2. Mix RNA samples in a 1:1 ratio with formamide and heat to 65 °C for 15 min prior to gel loading.
   CAUTION: *formamide is a hazardous material.*

3. Run RNA samples (typically 1–20 μg) at 55 V in 1× NorthernMax™ running buffer until your targets of interest are well-resolved.
   NOTE: *For targets with low or unknown expression levels we recommend starting with 10–20 μg of total RNA.*

RNA transfer and crosslinking

1. Wash the gel 4 × 5 min, in ultrapure H_2O.

2. Wet membrane in ultrapure H_2O and equilibrate for 5 min in 20× SSC.
   NOTE: *A positively charged nylon membrane is recommended.*

3. Perform a capillary transfer of RNA onto the membrane in 20× SSC.
   NOTE: *We recommend using the TurboBlotter Rapid Downward Transfer System. Alternative transfer methods may be used.*

4. Wash the membrane for 5 min in 2× SSC.

5. Crosslink the RNA to the membrane by incubating at 80 °C for 2 h.
   NOTE: *Alternative RNA crosslinking methods may be used.*

Multiplexed HCR northern blot protocol

Detection stage

1. Let V denote the volume of buffer to be used for blots, calculated as:
   (a) 1 mL per 10 cm^2 of membrane
   (b) rounded up to the nearest 0.5 mL
   (c) no less than 1.5 mL

   For example, $V = 3.5$ mL for a membrane that is 32 cm^2 and $V = 1.5$ mL for a membrane that is 9 cm^2.
2. Pre-heat HCR probe hybridization buffer to 60–68 °C for 1 h and maintain at 37 °C until use.
   CAUTION: *HCR probe hybridization buffer contains formamide, a hazardous material.*
3. Pre-hybridize blot in $(V - 0.5$ mL$)$ of HCR probe hybridization buffer in a hybridization bottle for 30–60 min at 37 °C in a rolling hybridization incubator.
4. Prepare probe solution by adding each probe set into a total volume of 0.5 mL of HCR probe hybridization buffer at 37 °C such that each probe set will be at a final concentration of 5 nM in volume V.
5. Add the probe solution to the pre-hybridization solution and incubate blot overnight at 37 °C in a rolling hybridization incubator.
6. Remove excess probes by washing four times using pre-heated 37 °C wash solutions (volume $2V$ per wash) :
   (a) two low-stringency washes (2× SSC, 0.1% SDS; 5 min at 37 °C)
   (b) two high-stringency washes (0.2× SSC, 0.1% SDS; 15 min at 37 °C)

Amplification stage

1. Pre-heat HCR amplification buffer to 37 °C.
2. Pre-amplify blot in $(V - 0.5$ mL$)$ of HCR amplification buffer in a hybridization bottle for 30–60 min at 37 °C in a rolling hybridization incubator.
3. Separately prepare hairpin h1 and hairpin h2 by snap cooling (heat at 95 °C for 90 seconds and cool to room temperature in a dark drawer for 30 min).
   NOTE: *HCR hairpins h1 and h2 are provided in hairpin storage buffer ready for snap cooling. Snap cool an amount of each hairpin corresponding to 30 nM final concentration in a final volume V. h1 and h2 should be snap cooled in separate tubes.*
4. Prepare hairpin solution by adding all snap-cooled hairpins into a final volume of 0.5 mL HCR amplification buffer at 37 °C.
5. Add the hairpin solution to the pre-amplification solution and incubate blot for 4 h at 37 °C in the dark in a rolling hybridization incubator.
   NOTE: *Amplification time can be increased beyond 4 h if desired.*
   NOTE: *HCR amplification may alternatively be carried out at room temperature.*
6. Remove excess hairpins by washing in pre-heated 5× SSCT (volume $2V$ per wash): 2 × 15 min at 37 °C in the dark.
   NOTE: *If HCR amplification is performed at room temperature, hairpin washes should also be performed at room temperature.*

Buffer recipes for sample preparation

10% SDS
10% SDS

For 100 mL of solution
10 g of SDS powder
Fill up to 100 mL with ultrapure H_2O
Heat solution to 68 °C to dissolve powder if necessary.

2× SSC, 0.1% SDS
2× sodium chloride sodium citrate (SSC)
0.1% SDS

For 100 mL of solution
10 mL of 20× SSC
1 mL of 10% SDS
Fill up to 100 mL with ultrapure H_2O

0.2× SSC, 0.1% SDS
0.2× sodium chloride sodium citrate (SSC)
0.1% SDS

For 100 mL of solution
1 mL of 20× SSC
1 mL of 10% SDS
Fill up to 100 mL with ultrapure H_2O

5× SSCT
5× sodium chloride sodium citrate (SSC)
0.1% Tween 20

For 40 mL of solution
10 mL of 20× SSC
400 μL of 10% Tween 20
Fill up to 40 mL with ultrapure H_2O

Reagents and supplies

NorthernMax™ denaturing gel buffer (10X) (ThermoFisher Scientific, Cat. # AM8676)
NorthernMax™ (10X) running buffer (ThermoFisher Scientific, Cat. # AM8671)
Nylon membrane, positively-charged (Roche, Cat. # 11209272001)
3 mm Whatman chromatography paper (GE Healthcare Life Sciences, Cat. # 3030-6188)
Whatman TurboBlotter (Fisher Scientific, Cat. # 09-301-184)
Whatman gel blotting paper (GE Healthcare Life Sciences, Cat. # 10427805)
Whatman GB003 filter paper (GE Healthcare Life Sciences, Cat. # 10427812)
Hybridization bottle (Wheaton, Cat. # 805000 or 805021)
Rolling hybridization incubator (SciGene, Cat. # 1040-50-1)

HCR Technology Citation Notes

For citation, please select from the list below as appropriate for your application:

- **HCR IHC + HCR RNA-FISH**
  HCR IHC + HCR RNA-FISH enables a unified approach to multiplexed, quantitative, high-resolution protein immunohistochemistry (IHC) and RNA fluorescence in situ hybridization (RNA-FISH), with quantitative 1-step enzyme-free HCR signal amplification performed for all protein and RNA targets simultaneously (Schwarzkopf et al., 2021).

- **HCR IHC**
  HCR IHC enables multiplexed, quantitative, high-resolution protein immunohistochemistry (IHC) in highly autofluorescent samples (e.g., FFPE brain tissue sections) (Schwarzkopf et al., 2021).

- **HCR RNA-FISH (v3.0)**
  Third-generation HCR RNA-FISH (v3.0) enables multiplexed, quantitative, high-resolution RNA fluorescence in situ hybridization (RNA-FISH) with automatic background suppression *throughout the protocol* for dramatically enhanced performance (signal-to-background, qHCR precision, dHCR fidelity) and ease-of-use (no probe set optimization for new targets and organisms) (Choi et al., 2018). Quantitative analysis modes:

  - qHCR RNA imaging: analog mRNA relative quantitation with subcellular resolution in the anatomical context of thick autofluorescent samples.
  - dHCR RNA imaging: digital mRNA absolute quantitation with single-molecule resolution in the anatomical context of thick autofluorescent samples.
  - qHCR RNA flow cytometry: analog mRNA relative quantitation for high-throughput expression profiling of mammalian cells and bacteria.

  Protocols for HCR RNA-FISH (v3.0) in diverse organisms are adapted from the Zoo paper.

- **qHCR RNA imaging**
  qHCR RNA imaging enables mRNA relative quantitation with subcellular resolution in the anatomical context of thick autofluorescent samples (e.g., whole-mount vertebrate embryos). The read-out/read-in analysis framework enables bidirectional quantitative discovery in an anatomical context (Trivedi et al., 2018).

- **Zoo paper**
  Protocols for multiplexed mRNA imaging in diverse sample types (Choi et al., 2016):
  - bacteria in suspension
  - FFPE human tissue sections
  - generic sample in solution
  - generic sample on a slide
  - mammalian cells on a slide
  - mammalian cells in suspension
  - whole-mount chicken embryos
  - whole-mount fruit fly embryos
  - whole-mount mouse embryos
  - whole-mount nematode larvae
  - whole-mount sea urchin embryos
  - whole-mount zebrafish embryos and larvae

- **dHCR imaging**
  dHCR RNA imaging enables RNA absolute quantitation with single-molecule resolution in the anatomical context of thick autofluorescent samples (e.g., 0.5 mm adult mouse brain sections) (Shah et al., 2016).

- **qHCR northern blots**
  qHCR northern blots enable multiplexed quantification of RNA target size and abundance for up to 5 target RNAs (Schwarzkopf & Pierce, 2016).

- **HCR RNA-FISH (v2.0)**
  Second-generation in situ HCR RNA-FISH technology (v2.0) using DNA HCR probes and DNA HCR probes and DNA HCR amplifiers: 10× increase in signal, 10× reduction in cost, dramatic increase in reagent durability (Choi et al., 2014).

- **HCR RNA-FISH (v1.0)**
  First-generation HCR RNA-FISH technology (v1.0) using RNA HCR probes and RNA HCR amplifiers: multiplexed mRNA imaging in whole-mount vertebrate embryos with simultaneous signal amplification for up to 5 target mRNAs (Choi et al., 2010).

- **HCR mechanism**
  The hybridization chain reaction (HCR) mechanism enables multiplexed, quantitative, 1-step, isothermal, enzyme-free signal amplification in diverse technological settings (Dirks & Pierce, 2004).

HCR Technology References

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